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Food consumption disparities, public health and sustainability in latin america and the caribbean

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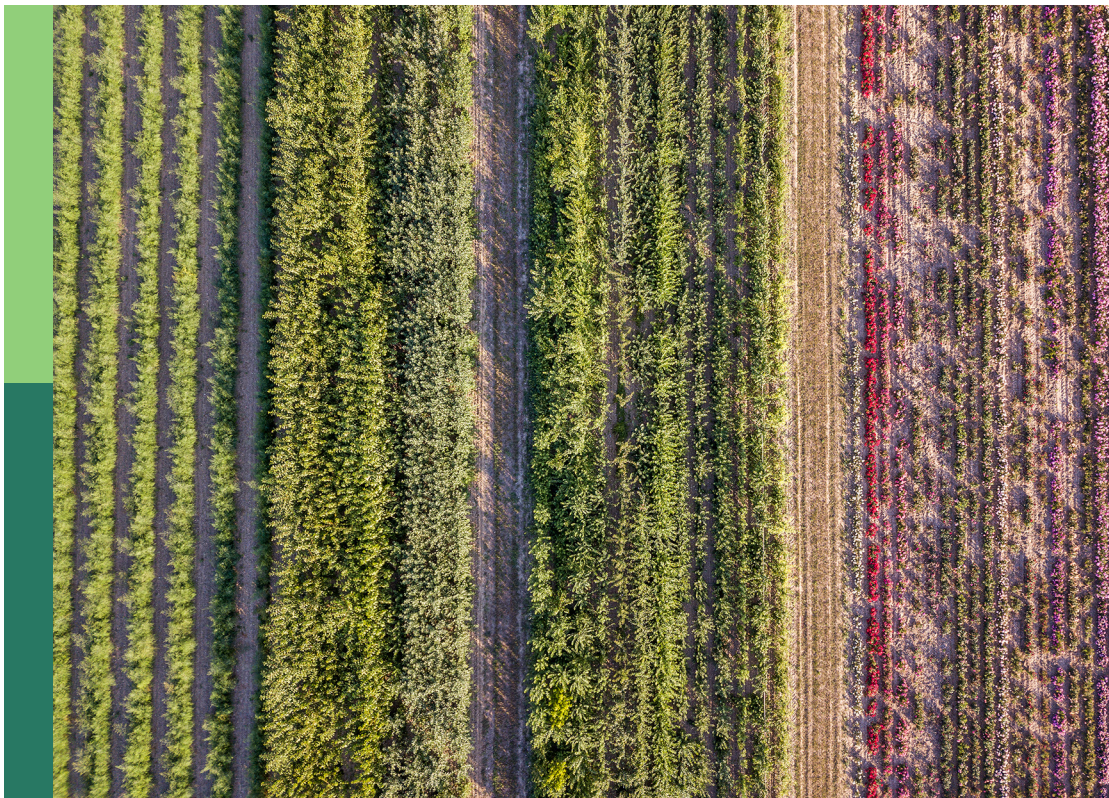

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Food consumption disparities, public health and sustainability in latin america and the caribbean

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Table of contents

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Editorial: Food consumption disparities, public health and sustainability in Latin America and the Caribbean

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Editorial on the Research Topic
Food consumption disparities, public health and sustainability in Latin America and the Caribbean

One of the central challenges of the world and, particularly for Latin America, has been the production, distribution, and equitable consumption of food. This challenge has become more complex, for a series of changes at the societal level such as urbanization, changes in the patterns of organization of domestic and unpaid work and increased income. These changes, among other issues, have been associated with increased consumption of ultra-processed foods of low nutritional value such as sugary drinks. On the contrary, adequate consumption of foods, such as fruit and vegetables, is linked with a lower risk of cardiovascular diseases and stroke, decreased risk of depression, and increased natural immunity, among other important health- and wellbeing-related aspects. Accordingly, public authorities have been historically interested in identifying policies that can increase healthy and sustainable food consumption. Knowing social determinants of dietary decisions can be a contribution for designing food policies oriented to increase healthy food intake and reduce nutrition and health disparities, while promoting sustainable production and consumption.

This Research Topic entitled "*Food consumption disparities, public health and sustainability in Latin America and the Caribbean*" aims at contributing to the understanding of dynamics associated with food production, the consumption of healthy diets and the sustainability of food systems in the region. To that end, it presents a broad array of topics, methodological approaches and analyses in different countries of Latin America and the Caribbean: Using data from Costa Rica, Dal et al. use a QUAIDS model to estimate food elasticities and provide results that encourage the generation of policies oriented to a significant price reduction in order to promote fruit and vegetable consumption. By contrast, Silva et al. use data from Colombia, Chile, Ecuador and Mexico, and take a more skeptical point of view regarding price policies. The authors argue that it is necessary to add the mental access dimension to the fruit and vegetable promotion discussion, as they found that consumers seemed satisfied with their fruit and vegetable intake, despite not consuming the quantities needed for a healthy diet. Within the same topic, Pinheiro et al. found that, whereas this is a national and a regional health issue, food insecurity is highly concentrated among poorer individuals, as prevalence is near twice in low-income population compared to national means in Chile.

From a food production point of view, sustainability in fruit and vegetable production means considering its economic, social and environmental impacts. The lack of sustainable production may also lead to relevant health disparities. The manuscript by Castillo et al. analyses the main impacts of the Productive Alliance Programme (PAP) in Chile, a government-mediated partnership between large agricultural companies and small farmers. The authors found that small farmers participating in the programme improve their managerial skills, increase their production, and reduce uncertainty, by simultaneously increasing food production sustainability. This last aspect is relevant as a significant proportion of the food produced globally is wasted or lost at some point during the food supply chain. By interviewing small farmers, Herrera-Quinteros and Jara-Rojas, show that a relevant part of the food produced is lost mostly during harvest, partially due to the way in which the commercialization process occurs, but also in response to what they refer to as cosmetic standards.

From the consumer side and considering both food quality and sustainability, Curi-Quinto et al. study the factors leading to a consumption of sustainable food diets among the Mexican population. The authors found that healthier and sustainable diets are consumed relatively more by rural inhabitants and disadvantaged households. However, the consumption of healthy and sustainable diets is still low across all population groups and areas of the country. Perhaps a solution to the access to more sustainable and healthy diets is presented in the work of Biskupovic et al., which compares the experiences of France and Chile with respect to the creation of community gardens and their impacts in food consumption, diets, and other outcomes related to the creation of social values. The authors found that community gardens promote ecological citizenship.

Finally, the COVID-19 pandemic has also produced several impacts. Using data from ten Latin American countries, Murillo et al., found that, despite college students having unhealthy dietary habits, among them there are important differences: after the COVID-19 pandemic, the ones who follow a plant-based diet, such as vegetarians and vegans, exhibit better scores and healthier dietary conducts. To that end, work environments could be an important aspect for the consumption of healthier diets. Using adult worker data from Chile, Tiboni-Oschilewski et al., found that people working from home perceive themselves as eating healthier, however, contrary to what one would have expected, they do not report they have been able to lose weight. In what regards to methods, the COVID-19 pandemic required the use of several online ways of collecting data. However, the validity of the data collected online, as used by several of the studies mentioned here, had not been studied. This is something Vega-Salas et al. did in the case of Peru. Their relevant methodological contribution shows that the use of an online food frequency questionnaire proves to provide consistent results.

We believe the manuscripts presented in this Research Topic make an contribution to advance the knowledge around food production and consumption, as well as the sustainability along the food supply chain, with an especial focus in Latin America. However, the results presented in these manuscripts are not only relevant to the Latin American context, but to other contexts, especially in developing regions of the world. The broad array of methods, from qualitative to quantitative and mixed approaches, and disciplines brought to this Research Topic, from health experts, sociologists, and economists, are also an contribution to science in general, as they emphasize how solutions cannot be thought as one-dimensional. We expect this Research Topic can not only contribute to science, but more importantly to the political discussion around food production, consumption, and the promotion of healthy diets in Latin America and the Caribbean.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Fiscal Reform in Costa Rica: Price Elasticities of Major Food Categories to Inform Decision-Making

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In the context of fiscal reform in Costa Rica (value added tax revision), the definition of a new basic tax basket, "*canasta básica tributaria*" (CBT) in Spanish, incorporating nutritional criteria is underway in the country. In this study, price elasticities of major food categories were analyzed using a Quadratic Almost Ideal Demand System (QUAIDS) model. Data from the 2018 National Survey of Household Income and Expenditures was used. Measuring price elasticities is essential because it allows: knowing the extent to which food demand reacts to price changes, anticipating changes in the quantities demanded as a result of fiscal policy changes, measuring potential substitution and complementary effects between food groups, and potential nutritional effects of fiscal policies. As a result, it helps providing recommendations on the content of a CBT with nutritional criteria. Results show that the food categories with the most elastic demand are "Bread and cereals," soft drinks and "Milk, cheese and eggs." Substitution effects exist between the following groups: "Fruits" and "Oils and fats," "Fruits" and "Bread and cereals," and between "Milk, cheese and eggs" and "Oils and fats." For this last food category and for the one which includes sweets and chocolates, the consumption decreases when the price of "Bread and cereals" increases. They are complementary goods. These relations between food groups need to be taken into account when defining a national CBT with nutritional criteria and with the objective of promoting the consumption of healthier food groups while disincentivizing the consumption of the unhealthy ones. Lastly, it is important that the consumption of the healthiest foods within each food group be fiscally promoted.

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INTRODUCTION

Costa Rica does not escape the double burden of hunger and malnutrition (overweight and obesity) in Latin America. Although the country has been successful in the fight against malnutrition, 5.4% of the population remains food insecure (1). Extreme poverty is stagnant at 5.8% of the population, and poverty at 21% for more than 15 years (2). At the same time, according to the 2009 National Nutrition Survey, 64.5% of the adult population is overweight or obese; 66.6% among women and 62.4% among men. Another affected group is childhood and adolescence: according to the 2016 School Census, overweight and obesity affect about 34% of the school population (3).

The country is in the process of implementing a tax reform that includes the review and modification of the value added tax (VAT). With the approval of the "*Ley de Fortalecimiento de las Finanzas Públicas*" (No. 9635) by the Legislative Branch in December 2018, different criteria have been established to tax foods in a differentiated manner. Products listed in the basic tax basket (*canasta básica tributaria* [CBT]) would be taxed at 1% VAT, while the rest of the products would be taxed at 13%. The products included in the CBT are defined by Presidential Decree and referred to the food products most consumed by the first quintile of the population according to the 2013 National Survey of Household Income and Expenditures (4). Subsequently, on 4 December 2020, Law No. 9914 called *"Definición de la Canasta Básica por el Bienestar Integral de las Familias"* was approved (5). The law establishes that the CBT will be constituted considering the products most consumed by the 30% of households with the lowest income, and "will value the inclusion of foods of high nutritional value, based on criteria such as the implementation of a balanced and diverse diet that meets the nutritional needs, culturally relevant and derived from the epidemiological profile of the population."

This last point is fundamental given that international evidence indicates that lower-income households tend to opt for foods whose cost per calorie provided is lower, such as foods high in sugars, fats and sodium, and consume relatively fewer foods whose cost per calorie provided is higher, such as fruits and vegetables (6). As a consequence, the introduction of VAT and the definition of a CBT without nutritional criteria may widen the gap between the costs of foods of low nutritional value and foods of high nutritional value, negatively impacting access to nutritionally desirable foods for the entire population and, particularly, for the lower-income population.

This can have socially undesirable consequences. On the one hand, it can create a vicious circle of poor nutrition by reinforcing low-quality diets, especially among the most socially vulnerable population. On the other hand, it can generate changes in poverty profiles if the composition of the CBT is not taken into account. Finally, indirectly incentivizing unhealthy diets can increase the development of non-communicable diseases in the medium and long term (7–10, 12, 14). Then, it is necessary to elaborate basic tax baskets with nutritional criteria and reject the logic of elaborating baskets whose composition barely covers the nutritional minimums without considering the other components of the right to food. According to the recommendations of the Institute of Nutrition of Central America and Panama (INCAP) for the elaboration of basic food baskets, it is necessary to include locally produced foods with high nutritional content and reject the inclusion of industrialized foods with low nutritional content and high caloric content. In this context, the CBT should not be far from this reality.

In the case of Costa Rica, a 2015 study by Vargas and Elizondo analyzed the price elasticity[1] of food demand, identifying two groups of foods: those whose demand is inelastic (quantity demanded reacts less than proportionally to price changes) and those whose demand is elastic (quantity demanded reacts more than proportionally to price changes). The findings suggest that the introduction of taxes on high-calorie, low-nutrient products, such as soft drinks and cookies, could significantly reduce the consumption of these foods.

Knowing the extent to which food demand reacts to price changes makes it possible to anticipate changes in the quantities demanded as a result of fiscal policy changes (e.g., introduction of excise taxes or changes in VAT). It also allows measuring potential substitution and complementary effects between food groups, and the nutritional effects of fiscal policies. It is particularly relevant for the case of Costa Rica, since the content of the CBT is currently under discussion, and would incorporate a nutritional component for the selection of food products.

In this study, we estimate income[2] and price elasticities (uncompensated)[3] of different food groups for Costa Rican households using the *Encuesta Nacional de Ingresos y Gastos de los Hogares 2018* (15) and using a Quadratic Almost Ideal Demand System (QUAIDS) model. Price elasticities estimated from demand system models such as QUAIDS are key elements to measure the impact of fiscal policies on household spending for specific food groups. The objective of this work is to generate technical and reliable information for fiscal policy decision making to promote actions to facilitate the consumption of healthier foods, especially in population with social vulnerability, and under the progressive approach of the current government. The results of this study could be used to redesign or evaluate current fiscal policies related to food and beverage consumption.

METHODOLOGY

Data Sources

The *Encuesta Nacional de Ingresos y Gastos de los Hogares 2018* (15) conducted by the National Institute of Statistics and Census (INEC) was used to estimate the model and the elasticity calculations. The cross-sectional survey collects household-level information on spending on different goods and services (expenditures and quantities), as well as socioeconomic and demographic information on 7,046 households. It is used to elaborate the Consumer Price Index, basic food baskets, to define poverty and perform other consumption/socioeconomic analyses. The survey is representative for 6 different regions covering Costa Rica. The information was collected between February 2018 and March 2019 for 36 weeks and over 10-day periods. For the purpose of this study, all food and beverage product records are taken into account with the exception of donations, obtaining a final sample of 6,972 households. Donations have been eliminated because they do not represent any purchase decision by the individual based on a certain price.

Variables

Eleven food and beverage groups were used for this study. The food and beverage groups used in this study are based

[1]The price elasticity of demand reveals how much the quantity demanded for a good or food (or category of food) varies with changes in its price.

[2]Income elasticity of demand reveals how much the quantity demanded for a good or food (or food category) varies with changes in consumers' income levels.

[3]Uncompensated price elasticity takes into account the influence of prices and income on utility maximization, compensated price elasticity only prices.

on the *Clasificación del Consumo Individual por Finalidades* (CCIF classification), because they correspond to large food categories that we are interested in analyzing. The CCIF is a classification of household consumption expenditures that national statistical offices have developed on their own, and have used in various analytical applications (1, 11). They are sufficiently large categories to obtain reliable price and income elasticities, and sufficiently disaggregated to observe complementarities and substitutions between groups according to potential price and/or income changes. CCIF groups are used rather than nutritional groups in order to give an economic balance representing an individual's consumption. Foods are already classified according to the CCIF classification in the ENIGH 2018 (15). **Table 1** shows the list of categories with the respective codes.

Food expenditure percentages were calculated for each household by summing the expenditures within each group and then dividing by the total expenditure for the twelve categories. Unit price values were calculated for each household as the ratio of expenditure to quantity for each group.

Demand Analysis: QUAIDS and Elasticity Calculations

The objective of the study is to understand the sensitivity of consumers with different economic situations to price changes, producing elasticities that report this sensitivity. To do so, we estimate a Quadratic Almost Ideal Demand System (QUAIDS) using Stata v.16.1. This model allows us to assess the extent to which demand reacts to price and income variations, hence allowing to anticipate variations in quantities demanded as a result of potential changes (e.g., the introduction of taxes or changes in the VAT rate). More details about the model can be found in **Annex 1**.

Endogeneity and Missing Values

A proportion of households do not report purchases of the food and beverage categories we considered. This may be due to different reasons such as: the household does not consume these types of products or simply did not do so in that reference period of the survey. In fact, the ENIGH was not conducted for the purpose of this analysis in particular. It is used to elaborate the Consumer Price Index, basic food baskets, to define the poverty line as well as other consumption/socioeconomic analyses. For this reason, depending on the decade considered, some households report consuming the different food categories and some others do not, but it is still useful because the reports balance each other out, and allow the aforementioned studies to be carried out.

Nevertheless, the ENIGH is the only source of information in Costa Rica with timely and current data on food quantities and expenditures. It has been proven that income and expenditure surveys are a tangible and reliable option to develop this type of analysis if the data is analyzed cautiously.

It is possible to implement a specific methodology to take into account this issue of missing values (biased parameter estimates). Cohorts can be created to group households and have complete information for a certain defined number of groups. This methodology has been used by Mendoza-Velázquez (13, 16). In our case, 200 groups were created from the income variable (net, current, per capita and without rental value) of the database. This method reduces data variability, but it gives elasticities that represent better the totality of households, and not only the households that report consuming more food categories, who in general have similar socio-demographic characteristics.

This aggregation of hlds also mitigates the endogeneity problems that naturally exist in these demand systems: the unit values are calculated using other variables of the system (expenditures and quantities per food category); hence they are endogenous. The consequence is that the obtained expenditure percentages may depend on other factors. The creation of 200 income groups should generate reliable average unit values for each group, smoothing out the variations that may exist in food quality as well.

RESULTS

Table 1 presents general sociodemographic descriptive data. Results will also be presented by deciles of net current income per capita (without rental value) for the first two deciles and first three deciles of the population. Results are presented in this way because the basic food basket in Costa Rica is usually based on the consumption patterns from the first two deciles of the population in terms of income.

Tables 1–3 show the percentage of households reporting consumption in each category, the average expenditure per food group and the average unit values in the different decile groups. The percentage of households reporting expenditure greater than zero allows us to identify the food categories most consumed by households, and to evaluate the problem of missing values.

The category "Fish" has the lowest percentage of households reporting purchases, followed by "Coffee, tea and cocoa." On the contrary, 93.2% of households report buying "Bread and cereals," and 83.2% "Milk, cheese and eggs." There is a pronounced difference in fruit consumption between the first two deciles of the population (35.5%) and the last seven (57.2%). "Fish" is the group with the highest average unit value per gram, followed by: "Coffee, tea and cocoa"; "Condiments"; "Sugar, jam, honey, chocolate and sweets" and "Meat."

Table 4 is a summary of the key values, highlighting the problem of missing values with the column "Proportion of households with no consumption (percentage)," which is the percentage of households out of the total sample that do not report consuming a certain food category. For example, 59% of the total sample (4,113 households) do not report consuming fish and 6.71% (468 households) do not report consuming bread and cereals (see **Table 1**, households reporting expenditure > 0).

Tables 5, **6** present the income and uncompensated price elasticities (own and cross-price elasticities) of the QUAIDS model. To facilitate the interpretation of the following tables, the different types of elasticities obtained are defined and explained:

- **Income elasticity:** reveals how much the quantity demanded for a good or food (or food category) varies as a percentage against percentage changes in consumers' income levels.
- **Price elasticity:** reveals how much the quantity demanded for a good or food (or food category) varies as a percentage

TABLE 1 | Descriptive statistics of consumption by CCIF category: households reporting expenditure>0 (6,972 households).

Deciles		2 first deciles (1,661 obs.)	3 first deciles (2,433 obs.)	7 other deciles (4,539 obs.)	Total sample (6,972 obs.)
Number of households		1,661	2,433	4,539	6,972
Average monthly expenditure		1.99×10^7	2.14×10^7	3.49×10^7	3.02×10^7
CCIF category	**CCIF code**	**Households reporting expenditure > 0**			
Bread and cereals	0111	1,562	2,288	4,216	6,504
Meat	0112	1,175	1,730	3,252	4,982
Fish	0113	659	965	1,894	2,859
Milk, cheese, and eggs	0114	1,351	1,979	3,831	5,810
Oils and fats	0115	965	1,385	2,091	3,476
Fruits	0116	589	943	2,596	3,539
Pulses and vegetables	0117	1,351	1,986	3,665	5,651
Sugar, jam, honey, chocolate, and sweets	0118	1,192	1,700	2,779	4,479
Condiments	0119	1,016	1,443	2,437	3,880
Coffee, tea, and cocoa	0121	953	1,365	1,951	3,316
Mineral waters, soft drinks, fruit, and vegetable juices	0122	842	1,268	2,581	3,849

Average expenditure per month is expressed in 2020 CRC (CRC 615.2 = EUR 1).
Source: Own elaboration with data from INEC (15). Weighted values.

TABLE 2 | Descriptive statistics of consumption by CCIF category: average expenditure (6,972 households).

Deciles	2 first deciles (1,661 obs.)	3 first deciles (2,433 obs.)	7 other deciles (4,539 obs.)	Total sample (6,972 obs.)
CCIF category	**Average expenditure (% of total food expenditure)**			
Bread and cereals	24.88%	24.42%	20.38%	21.37%
Meat	16.76%	17.06%	17.80%	17.63%
Fish	4.06%	3.98%	4.76%	4.57%
Milk, cheese, and eggs	13.73%	14.0%	14.97%	14.69%
Oils and fats	4.12%	3.87%	2.75%	3.03%
Fruits	3.27%	3.81%	7.61%	6.68%
Pulses and vegetables	12.27%	12.54%	13.08%	12.99%
Sugar, jam, honey, chocolate, and sweets	6.73%	6.38%	4.85%	5.21%
Condiments	5.21%	4.98%	5.38%	5.26%
Coffee, tea, cocoa	4.85%	4.73%	3.26%	3.63%
Mineral waters, soft drinks, fruit, and vegetable juices	4.21%	4.21%	4.86%	4.70%

Average expenditure per month is expressed in 2020 CRC (CRC 615.2 = EUR 1).
Source: Own elaboration with data from INEC (15). Weighted values.

against percentage changes in its price. There are two types of price elasticities:

- **Uncompensated (own) price elasticity:** takes into account the influence of prices and income on utility maximization.
- **Uncompensated (cross-price) price elasticity:** reveals the change in the quantity demanded for a good or food (or food category) when the price of another good, product or food category changes. This elasticity reveals whether two goods or groups of goods are complementary or substitutes.

Uncompensated elasticities were chosen because they take into account the influence of prices and income in the maximization of utility, the compensated ones only prices. **Annex 2** presents the uncompensated price elasticities. The main observations on **Table 5** and **Annex 2** are the following:

Income Elasticities (Table 5)

All elasticities have positive values, and most of them are very close to one (**Table 5**). It means that the food categories correspond to foods that are normal goods (elasticities between

TABLE 3 | Descriptive statistics of consumption by CCIF category: unit values (6,972 households).

Deciles	2 first deciles (1,661 obs.)	3 first deciles (2,433 obs.)	7 other deciles (4,539 obs.)	Total sample (6,972 obs.)
CCIF category	**Average unit values for 100 grams**			
Bread and cereals	157	161	223	201
Meat	295	298	367	343
Fish	547	556	618	597
Milk, cheese, and eggs	202	201	214	210
Oils and fats	147	152	206	184
Fruits	139	142	161	156
Pulses and vegetables	124	122	131	128
Sugar, jam, honey, chocolate, and sweets	230	242	421	353
Condiments	429	426	471	454
Coffee, tea, cocoa	458	472	654	579
Mineral waters, soft drinks, fruit, and vegetable juices	87	90	96	94

Average expenditure per month is expressed in 2020 CRC (CRC 615.2 = EUR 1).
Source: Own elaboration with data from INEC (15). Weighted values.

TABLE 4 | Summary of descriptive statistics of consumption by CCIF category (6,972 households).

CCIF category	Average expenditure (% of total food expenditure)	Average unit values for 100 grams	Proportion of households without consumption (%)	Number of missing values
Bread and cereals	21.37%	201	6.71%	468
Meat	17.63%	343	28.54%	1,990
Fish	4.57%	597	59%	4,113
Milk, cheese, and eggs	14.69%	210	16.67%	1,162
Oils and fats	3.03%	184	50.21%	3,496
Fruits	6.68%	156	50.14%	3,443
Pulses and vegetables	12.99%	128	18.95%	1,321
Sugar, jam, honey, chocolate, and sweets	5.21%	353	35.76%	2,493
Condiments	5.26%	454	44.35%	3,092
Coffee, tea, cocoa	3.63%	579	52.44%	3,56
Mineral waters, soft drinks, fruit, and vegetable juices	4.70%	94	44.79%	3,123

Average expenditure per month is expressed in 2020 CRC (CRC 615.2 = EUR 1).
Source: Own elaboration with data from INEC (15). Weighted values.

zero and one). When income increases, consumption of normal goods increases almost proportionally to the increase in income. For two categories, the elasticities are slightly higher than one: "Fruits" (1.09) and "Mineral waters, soft drinks and juices" (1.07). For interpretation purposes, income elasticities higher than one correspond to "luxury" categories/foods. It means that when income increases, consumption increases more than the increase in income. For the category "Fruits," it means that when income increases by 10 percent, consumption increases by 10.9 percent. This is the case when there is perfect price transmission. In reality, it is rarely verified since market structure, education, households culinary skills or even time use for example, also play an important but often unobservable role in consumption patterns. Normally, meat, fish and sugary products are expected to be "luxury" categories.

Income elasticities provide information on the importance of income in consumption patterns according to food categories. In this case, no essential differences are observed between food categories. It is essential to take this result into account when we want to measure the potential effect of fiscal policy changes. This is also why uncompensated price elasticities are more suitable for drawing conclusions. They allow us to take into account the influence of prices and income on the maximization of utility, while the compensated ones only take prices into account.

Own Price Elasticities (Annex 2)

The values on the diagonal of **Annex 2** represent the own uncompensated price elasticities, while the values not on the diagonal represent the cross uncompensated price elasticities (see next section).

All elasticities are negative. A negative price elasticity means that when the price goes up, consumption decreases, i.e., there is an inverse price-quantity relationship. The most elastic categories (elasticities far from zero) are the following: "Bread and cereals" (−1.19); "Mineral waters, soft drinks and fruit and vegetable juices" (−1.14); "Milk, cheese and eggs" (−1.03); "Pulses and vegetables" (−1.00) and "Meat" (−1.00). In theory, an elastic food is a food whose variation in consumption is higher than the observed price variation, i.e., the quantity demanded reacts more than proportionally to price changes. This is the case for the category "Mineral waters, soft drinks and fruit and vegetable juices." The result means that when the price of the category rises by 10%, consumption decreases by 11.4%. A VAT of 13% on this food category gives for example a reduction in consumption of 14.8%. If the elasticities are equal to one, it means that the quantity demanded reacts proportionally to price changes, this is the case for the mentioned categories ("Meat" and "Vegetables"). For the rest of the categories, the elasticities are inelastic, especially for the following categories: "Coffee, tea and cocoa" (−0.39); "Condiments" (−0.41), and in a second tier "Oils and fats" (−0.70).

Table 6 summarizes the main results of the study (**Tables 4–6**).

TABLE 5 | Income elasticities from QUAIDS model (6,972 households).

CCIF category	Mean	Standard deviation	Min	Max
Bread and cereals	0.99	0.002	0.98	0.99
Meat	1.00	0.001	1.00	1.00
Fish	0.97	0.012	0.91	0.99
Milk, cheese, and eggs	1.01	0.002	1.01	1.02
Oils and fats	1.01	0.005	1.00	1.06
Fruits	1.09	0.063	1.02	1.59
Pulses and vegetables	1.01	0.002	1.01	1.02
Sugar, jam, honey, chocolate, and sweets	0.96	0.011	0.92	0.98
Condiments	0.96	0.017	0.86	0.99
Coffee, tea, cocoa	0.92	0.033	0.73	0.97
Mineral waters, soft drinks, fruit and vegetable juices	1.07	0.021	1.03	1.16

Own elaboration with data from INEC (15). Weighted values.

Cross Price Elasticities

Cross-price elasticities allow to identify complementarities and substitutions between groups. **Table 7** shows the foods with the highest substitution ratio, i.e., substitute groups (elasticities>0). A substitute good is a good capable of satisfying the same need as another good. When the price of such a good increases, the demand for one of its substitutes increases. A complementary good is a good which consumption level is linked to the price of another good. When the price of such a good increases, the demand for one of its complements decreases.

The results show that an increase in the price of bread and cereals contributes to an increase in fruit consumption. Similarly, an increase in the price of fruits contributes to an increase in the consumption of oils and fats; and of milk, cheese and dairy products to an increase in the consumption of oils and fats. Also, an increase in the price of meat contributes to an increase in fish consumption. In these cases, the increase in consumption is quite small (<10%). For instance, a 10% price increase of the category "Bread and cereals" would lead to an increase in the fruits quantities consumed by 4.7%. It is important to take

TABLE 6 | Average expenditures, unit values, share of zero consumption and elasticities.

CCIF category	Average expenditure (% of total food expenditure)	Average unit values for 100 grams	Proportion of households without consumption (%)	Income elasticities	Uncompensated own price elasticities
Bread and cereals	21.37%	201	6.71%	0.99	−1.19
Meat	17.63%	343	28.54%	1.00	−1.00
Fish	4.57%	597	59%	0.97	−0.96
Milk, cheese and eggs	14.69%	210	16.67%	1.01	−1.03
Oils and fats	3.03%	184	50.21%	1.01	−0.70
Fruits	6.68%	156	50.14%	1.09	−0.99
Pulses and vegetables	12.99%	128	18.95%	1.01	−1.00
Sugar, jam, honey, chocolate, and sweets	5.21%	353	35.76%	0.96	−0.89
Condiments	5.26%	454	44.35%	0.96	−0.41
Coffee, tea, cocoa	3.63%	579	52.44%	0.92	−0.39
Mineral waters, soft drinks, fruit, and vegetable juices	4.70%	94	44.79%	1.07	−1.14

Average expenditure per month is expressed in 2020 CRC (CRC 615.2 = EUR 1).
Source: Own elaboration with data from INEC (15). Weighted values.

these substitutions into account because these results show that changing the price of one food category changes the consumption of others.

With respect to the complementary goods, if the prices of the "Bread and cereals" group rise, there is on the one hand a reduction in its consumption (−1.19), and on the other hand to reduce the consumption of other food groups such as "Oils and fats" (−0.69) and "Sugar, jam, honey, chocolates and sugar confectionery" (−0.29). Indeed, the consumption of bread is usually associated to some products of these two categories. On the other hand, the consumption of fruits (0.47), fish (0.23) and milk, cheese and eggs (0.21) would increase. In general terms, these would appear to be nutritionally healthy variations. It is worth noticing that, in the event of a rise in the price of fruit, there will be a drop in its consumption (−0.99), but consumption of pulses and vegetables (−0.15) and fish (−0.32) would also slightly drop, while consumption of sugar (0.13) and oils and fats (0.32) would slightly rise. All these variations would not be very healthy in the evolution of the diet.

The price increase in the sugar group, in addition to reducing the consumption of these products, would contribute to a decrease in the consumption of oils and fats and an increase in the consumption of fruits. Finally, it is important to mention that a rise in the price of meat would lead to an increase in fish consumption by substitution (0.26). Therefore, if greater fish consumption were to be encouraged, the inclusion of a smaller number of meat products in the CBT could be an alternative to be considered. The increase in the price of meat would also lead to a reduction in the consumption of soft drinks and juices (−0.27).

TABLE 7 | Main substitutions between groups.

Change in price/change in quantity	Uncompensated cross price elasticities
Bread and cereals/fruits	0.47
Fruits/oils and fats	0.36
Milk, cheese and eggs/oils and fats	0.31
Meat/fish	0.26

Other groups are substitutes but the table presents the strongest relationships.
Source: Own elaboration with data from INEC (15).

DISCUSSION

The results are consistent with the results found by other studies in Latin America, especially for the following categories: "Mineral waters, soft drinks, fruit and vegetable juices"; "Fruits"; "Milk, cheese and eggs"; "Meat"; "Sugar, jam, honey, chocolate and sweets" and "Fish." For the category "Bread and cereals," we found a more elastic result than the literature. Variations in the estimates may be given by the specifications of the models (AIDS or QUAIDS), the food groups elected and/or by the data used (sample size, chosen demographic variables).

Comparing the results with the Vargas and Elizondo (17) study in particular, we have similar results except for the categories "Meat" and "Fish." In their study, the results are less elastic. The Vargas and Elizondo study also calculates elasticities based on the ENIGH in Costa Rica, but does not use a QUAIDS model and presents different food groups than those presented in this study. This may explain the differences obtained. Meat and fish are comparatively expensive foods, and this is why we find more elastic price elasticities. Similarly, the categories "Milk, cheese and eggs" and "Vegetables" are more elastic in our study. It means that the consumption of vegetables can be encouraged with a decrease in their price. On the contrary, the category "Sugar, jam, honey, chocolate and sweets" is less elastic in this study. This information confirms that in order

TABLE 8 | Uncompensated price elasticities.

CCIF category	Present study (2020)	Vargas and Elizondo (17)	Caro et al. (18)	Nimanthika Lokuge et al. (19)	Mendoza-Velázquez (16)	Caro et al. (20)
Country	**Costa Rica**	**Costa Rica**	**Colombia**	**Sri Lanka**	**Mexico**	**Chile**
Bread and cereals	−1.19	−1.00	−0.85	−0.67	−0.46	−0.67
Meat	−1.00	−0.65	−0.84	−1.30	−0.49	−1.13
Fish	−0.96	−0.30		−0.98		−1.10
Milk, cheese and eggs	−1.03	−0.85	−0.94	−0.98		
Oils and fats	−0.70	−0.95			−0.58	
Fruits	−0.99	−0.80	−0.96	−0.80		
Pulses and vegetables	−1.00	−0.70	−0.96	−0.80	−0.7	
Sugar, jam, honey, chocolate and sweets	−0.89	−1.00	−0.80			−0.80
Condiments	−0.41		−1.01			
Coffee, tea, cocoa	−0.39	−0.50	−1.35			−1.37
Mineral waters, soft drinks, fruit and vegetable juices	−1.14	−0.10	−1.62			−1.00

Elasticities are significant at $p < 0.05$.
Source: Own elaboration with data from INEC (15).

to discourage the consumption of this type of food, a more complete nutritional strategy should be articulated, including public campaigns, advertising bans, education, among others. Besides, an additional increase in the taxation of unhealthy products such as soft drinks would reduce the current high consumption rates. In this study and others, soft drinks have an elasticity greater than one, which means the effect of an increase in price on consumption would be significant. The more price-elastic a food is, the more efficient it is, for the reduction of its consumption, to increase its price (taxes, VAT increase, etc).

Table 8 presents the results obtained in similar studies. When the categories were different, the results of the studies were averaged to correspond to the groups used in this study. Not all studies look at all the categories incorporated in this paper.

We identified that there was substitution between the "Fruits" category and two other categories: "Oils and fats" and "Bread and cereals." For example, if one wants to increase the consumption of fruits, one should keep their price low so as not to direct consumption toward more foods of the "Oils and fats" category, as well as raise the price of bread and cereals. This result makes sense because the unit values of fruits and oils and fats are quite similar, also with the unit value of pulses and vegetables. Nevertheless, it can be intuited that consumption is shifted toward more oils and fats because they are more convenient foods to eat and cook with (current lifestyles). There is also a preference to consume foods from the category "Bread and cereals" when the price of fruits goes up because these foods are preferred and consumed a lot in Costa Rica. There is also substitution between the "Milk, cheese and eggs" category and the "Oils and fats" category. For example, if we wanted to increase the consumption of milk, cheese and eggs, we would have to keep their prices sufficiently low. The tendency is to substitute these more expensive fats with cheaper fats of the "Oils and fats" category.

Substitution effects between food categories are important elements when constructing a CBT with nutritional criteria, as they determine whether the CBT can ultimately have positive effects on health. For the CBT it would mean, for instance, that to promote fruit consumption and avoid shifting consumption to more oils and fats, limiting the inclusion of products from the categories "Bread and cereals" in the basket may be an option. It is necessary to choose carefully the products from this category that will be part of the basket, based on nutritional and/or food security criteria. On the contrary, more fruits should be included in the CBT for positive health effects. As suggested by the analysis, a rise in the price of "Bread and cereals" also leads to a decrease in oils, fats and sweets consumption, which induces a general positive impact on health.

CONCLUSION

Nutritional visions in the definition of any fiscal measure involving food products is vital, due to the proven impact that the variation of their price has on food choices and therefore on the health of the population. The inclusion or removal of products from the CBT has nutritional and public health effects, and it is essential that these are taken into consideration when selecting the CBT. It is important to encourage the consumption of particularly healthy food groups such as fruits, pluses and vegetables to promote healthier diets. The consumption of fruits, pulses and vegetables can be significantly encouraged through price reductions and, for example, reduced VAT. A greater number of these types of products in the CBT will be an indicator of its healthy character. It is important at the same time to discourage the consumption of particularly unhealthy food groups such as sugar-sweetened beverages and the group of sugar, jam, honey, chocolate and sweets with fiscal measures (VAT increase and/or excise taxes), but also with other complementary measures (public campaigns, banning of advertisements, education, among others), since we observed the consumption of some of these products was not strongly elastic to price changes.

Finally, it is important that in each food group, the consumption of the healthiest foods within each group be fiscally promoted. Being more nutritionally selective when choosing products to be included in the basic food basket is essential due to the negative impact some food products can have on the overall diet. In this regard, effects of substitution and complementarity between food groups must be taken into account. Substitutions and complementarity with the food group "Bread and cereals" is a case in point in this study.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary materials, further inquiries can be directed to the corresponding author.

AUTHOR CONTRIBUTIONS

RR and CM: conceptualization, validation, supervision, and project administration. RR, CM, and ED: methodology. ED, RR, and MM: software and data curation. ED and RR: formal analysis and investigation. CM: resources and funding acquisition. ED: writing–original draft and visualization. ED, CM, and RR: writing—review and editing. All authors contributed to the article and approved the submitted version.

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Sustainability of Diets in Mexico: Diet Quality, Environmental Footprint, Diet Cost, and Sociodemographic Factors

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Background: Little is known about the current intake of sustainable diets globally and specifically in middle-income countries, considering nutritional, environmental and economic factors.

Objective: To assess and characterize the sustainability of Mexican diets and their association with sociodemographic factors.

Design: Dietary data of 2,438 adults within the National Health and Nutrition Survey 2012 by integrating diet quality measured by the Healthy Eating Index (HEI-2015), diet cost, and four environmental indicators were analyzed: land use (LU), biodiversity loss (BDL), carbon footprint (CFP), and blue water footprint (BWFP). We defined healthier more sustainable diets (MSD) as those with HEI-2015 above the overall median, and diet cost and environmental indicators below the median. Logistic regression was used to evaluate the association of sociodemographic factors with MSD.

Results: MSD were consumed by 10.2% of adults (4% of urban and 22% of rural), who had lower intake of animal-source foods, unhealthy foods (refined grains, added sugar and fats, mixed processed dishes and sweetened beverages), fruits, and vegetables, and higher intake of whole grains than non-MSD subjects. Characteristics of MSD vs. non-MSD (urban; rural) were: HEI-2015 (62.6 vs. 51.9; 66.8 vs. 57.6), diet-cost (1.9 vs. 2.8; 1.9 vs. 2.5 USD), LU (3.3 vs. 6.6; 3.2 vs. 5.9 m^2), BDL (105 vs. 780; 87 vs. 586 species $\times$ 10^{-10}), BWFP (244 vs. 403; 244 vs. 391 L), and CFP (1.6 vs. 4.4; 1.6 vs. 3.7 kg CO_2eq). Adults from rural vs. urban (OR 2.7; 95% CI: 1.7, 4.1), or from the South (OR 2.1; 95% CI: 1.1, 3.9), Center (OR 2.3; 95% CI: 1.3, 4.4) vs. the North were more likely to consume MSD, while adults with high vs. low socioeconomic status were less likely (OR 0.17; 95% CI: 0.09, 0.3).

Conclusions: The MSD is a realistic diet pattern mainly found in disadvantaged populations, but diet quality is still sub-optimal. Increased consumption of legumes, fruits, and vegetables, and a reduction in unhealthy foods, is required to improve nutritional quality of diets while ensuring their environmental sustainability.

Keywords: sustainable diet, Mexico, diet cost, environmental footprint, carbon footprint, land use, water footprint

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INTRODUCTION

Globally, there is a growing need to promote not only healthy and affordable diets, but also more environmentally sustainable diets (1–3). Food systems currently contributes one-third of global greenhouse gas emissions (GHGE) (2), uses 50% of available land, and is responsible for up to 70% of freshwater use (1, 2, 4).

In Mexico, food production is a major user of freshwater resources and land, with land use for agriculture being the main driver of deforestation and biodiversity loss (5, 6). The Mexican food system contributes one-third of national GHGE (7). In the past 20 years, consumption of animal-source foods and processed foods high in energy, sodium, added sugar, and saturated fats and low in nutrients, e.g., sweetened beverages and sweet and salty snacks (8), has increased and consumption of whole grain and legumes has decreased. Consistent with economic theory (9), the proportion of spending on food decreased as income increased (Engel's law). Specifically, the share for basic foods such as legumes and some cereals decreased (Bennet's law), while the share on animal source food, fruits and vegetables and non-basic products increased in the wealthier households (10). This is contributing to an epidemic of obesity and non-communicable chronic diseases, coexisting with nutritional deficiencies (11). Thus, there is a growing need to transform Mexico's food system and promote healthy and sustainable diets.

Sustainable diets, defined by the Food and Agriculture Organization (FAO) as those that "*are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy; while optimizing natural and human resources*" (12), comprise different dimensions (nutritional, economic, environmental, cultural), and there is no standardized way to analyze the sustainability of diets (13, 14). Most studies on sustainable diets derive from high-income settings, and most limit their analysis and interpretation to the nutritional dimension and one or a few environmental indicators (mainly GHGE) (15–19). Few studies have analyzed the sociodemographic factors associated with sustainable diets (20–23), which are important when tailoring policy recommendations to a local context.

Sustainable diets have different environmental footprints and costs in low- and middle-income countries compared with high-income countries (24–27). Studies to date show that diets with lower consumption of animal-source foods generally reduce the carbon footprint and land use (1, 28–31). However, some diets high in fruit and vegetables have a relatively high water footprint (32). More sustainable and healthier diets can be more expensive in lower-income compared with higher-income countries (25, 27), but a modeling study in Mexico, which is considered an upper-middle income country by the World Bank, showed that sustainable diets could be achieved at a lower cost than the average diet (33). Dietary patterns in Mexico also differ with sociodemographic characteristics (34–36). This variability, and the current lack of data on the environmental footprint of Mexican diets, emphasize the need to assess the sustainability of Mexican adult diets and their association with sociodemographic factors. Therefore, the aim of this study is to assess and characterize the sustainability of Mexican diets, using indicators of diet quality, diet cost, and environmental footprints; and to analyze the association between the consumption of relatively more sustainable diets with sociodemographic factors. To our knowledge, this is the first study to integrate all these aspects when analyzing the Mexican diet.

Abbreviations: BDL, Biodiversity loss; CFP, Carbon footprint; DGA, Dietary Guidelines for Americans; EAT-HRD, EAT-Lancet Healthy Diet Recommendation; ENIGH, National Household Income and Expenditure Survey; ENSANUT, National Health and Nutrition Survey; FAO, Food and Agriculture Organization; GLEAM, Global Livestock Environmental Assessment Model; GHGE, Greenhouse gas emissions; HEI-2015, Healthy Eating Index 2015; INSP, National Institute of Public Health in Mexico; INEGI, National Institute of Statistic, Geography, and Informatics; LU, Land use; LCA, Life cycle assessment; MSD, Healthier and more sustainable diets; MXN, Mexican pesos; SFFQ, Semi-quantitative food frequency questionnaire; BWFP, Blue water footprint.

METHODS

Study Design and Population

The study sample was obtained from the National Health and Nutrition Survey (ENSANUT-2012), a stratified and multi-stage random dietary survey conducted between October 2011 and May 2012 with representativeness at national, state, and rural/urban level (37). Although the ENSANUT-2012 is not representative at the municipal level, it has information on the municipality and locality in which each individual interviewed lives, which allows food price data to be linked at the municipal level from other income and expenditure survey, as explained in the diet cost assessment.

From an initial sample of 2,792 adults (18- to 59-year-olds), we excluded 147 pregnant or lactating women and 207 adults with implausible nutrient intake. Therefore, our analytical sample was 2,438 adults with complete dietary and sociodemographic data (see the flow chart in **Supplementary Figure 1**). The dietary data derived from responses to a semi-quantitative 7-day food frequency questionnaire (SFFQ), collected by trained interviewers using standardized methodology (37). The SFFQ was validated with a 24-h recall and included 140 foods items classified into 14 groups that contributed more than 90% of total energy and nutrient intake (38). The study protocol for the survey was approved by the Ethics Committee of the National Institute of Public Health in Mexico (INSP).

Overview of the Diet Sustainability Assessment

Based on FAO definition of sustainable diets (12) and the methodological approach used by Masset et al. (20), we assessed the sustainability of the diets by integrating the nutritional, environmental and economic components using indicators of diet quality (using the HEI-2015), diet cost, and four environmental impact indicators (land use, biodiversity loss, water and carbon footprint). We used the median values of each indicator for the overall population as cutoff points to identify adults consuming a healthier and more sustainable diet (MSD). We defined the MSD as having higher diet quality (HEI-2015 above the overall median value), lower diet cost, and

lower environmental footprint (below the overall median value). We established a comparison group considering those adults whose diet did not meet these three conditions (non-MSD). We compared the dietary characteristics of adults consuming a MSD with those who do not have a more sustainable diet (non-MSD), and we assessed the association between the consumption of MSD with sociodemographic factors. As part of the description, we also presented the characteristics of the average diet (corresponding to the overall study sample), and diets with high-quality (above the median), low cost and low-environmental impact (below the median). The schematic overview of the diet sustainability assessment is presented in **Supplementary Figure 2**.

Assessment of Indicators of Diet Sustainability

Diet Quality Assessment

Diet quality was assessed using the Healthy Eating Index (HEI-2015), a validated method for assessing overall diet quality in adults according to the American Dietary Guidelines (39). HEI-2015 is based on analysis of food groups and nutrients grouped into nine adequacy components (recommended for a healthy diet): total fruits, whole fruits, total vegetables, greens and beans, whole grains, dairy, total protein foods, seafood and plant proteins, and fatty acids (ratio of poly- and mono-unsaturated to saturated fatty acids); and four moderation components (to be limited in a healthy diet): refined grains, sodium, added sugars, and saturated fats. Each component can contribute from 0 to 5 or 0 to 10 points, so the total score ranges from 0 to 100. To calculate the HEI-2015 for individuals, we followed the procedures described in detail on the National Cancer Institute website (40). In the case of added sugar, we followed the methodology of Louie et al. (41). We adapted the original food grouping to avoid double counting in the diet cost and environmental footprint analyses. For the "greens and beans" component, we included only beans and other legumes, for "total protein foods" we included only animal-food protein (no seafood), and for "seafood and plant proteins" we included seafood, seeds, and nuts (see food groups and scoring in **Supplementary Table 1**).

Diet Cost Assessment

Daily diet cost per person was estimated by adding up the product of the quantity consumed for each food (as reported in the SFFQ) and its average unit price at the municipality level as described below. To compare the dietary characteristics between individuals, the daily diet cost was adjusted to 2000 kcal, which is close to the average daily energy intake in adults (>19 years) in Mexico (1,958 kcal/day) as reported in a previous study based on SFFQ 2012 (42).

We obtained data on food prices at municipality level from the 2012 National Survey of Household Income and Expenditure (ENIGH), which applied a stratified probabilistic design with national representativeness for urban and rural areas (43). We estimated food prices by dividing the total monetary expenditure by the quantity purchased by households in the previous week and obtained median prices by municipality. For milk in the national program *"Liconsa"*, we used its subsidized price for 2012 (44). When prices at municipality level were missing, we used the median values of food prices at state level or in urban/rural areas. To reduce potential measurement error, we excluded food items with quantities and prices in the 1st or 99th percentile of the distribution. We replaced prices above two standard deviations with the average price for each food item plus two standard deviations (45). All prices were adjusted for inflation to the year 2018 using the National Consumer Price Index (46) and converted into dollars (USD) using the average exchange rate (19.23 Mexican pesos per USD) (47), the latter to allow comparability with international studies. We matched food prices to the SFFQ food items manually, and then linked them to each person in ENSANUT-2012 according to their geographical residence. For municipalities in ENSANUT-2012 for which prices were lacking in ENIGH, we assigned the prices in the nearest municipality based on geographical location coordinates provided by INEGI-2010, using the Stata module "*Geonear*" (48).

Environmental Footprint Assessment

The environmental footprint of diets was assessed using indicators for land use (LU), biodiversity loss (BDL), carbon footprint (CFP), and blue water footprint (BWFP). We estimated each indicator per kg of food item in the SFFQ (as described in detail below), then multiplied this by the amount of food consumed per person. Land use, BDL, and BWFP were estimated for primary production, while CFP was estimated from cradle to distribution center. We considered food losses during post-harvest, handling and storage, processing, distribution, and consumption as estimated by FAO (49).

The methodological scheme, a further explanation of the indicators used, and all detailed data used to estimate the environmental indicators of the food in the SFFQ are presented in **Supplementary Material** (Section Methods; **Supplementary Figures 3**, **4**; **Supplementary Tables 2**–**10**).

Land Use

Use of agricultural land, defined as the area of land needed to produce one kg food (m^2/kg), was estimated for plant-based foods by dividing the amount of the crop needed to obtain one kg of raw food by the average country-specific yield (kg/m^2) obtained in the period 2008–2012 according to the FAOSTAT database (50). We accounted for the contribution of land from imported foods by estimating the weighted average land use based on the contribution of the importing country to the total food supply in Mexico. We used data from National Mexican Agriculture Planning (2017–2030) (51) and the Statistical Yearbook of Foreign Trade of Mexico (2008–2012) (52) to identify imported foods, countries of origin, and their contribution. We estimated the land required to produce 1 kg of animal-source food based on animal feeding requirements. We followed the same steps as for plant-based food to estimate the land use for each component of the animal feed ration, then aggregated the values to obtain the land required per kg of food for animal feed. Since the feed ration composition differs with animal species and with production system, we accounted for the contribution of each system to the total production of each species. Considering these factors, we calculated the land use per

kg of final product from cattle, chicken, and pigs. For cattle, we included two product orientations (pure meat production and dairy systems) and two production systems (grazing and mixed). For chicken, we considered two orientations (pure meat broilers and eggs), and three production systems (meat broiler, egg backyard, and egg layer). For pigs, we included three production systems (backyard, intermediate, and industrial). Country-specific data on these orientation and production systems were taken from the Global Livestock Environmental Assessment Model (GLEAM) report issued by FAO. Data on feed ration composition by production system for Mexico were obtained from the interactive GLEAM-i tool, where estimates are made using a modeling framework based on life cycle assessment (LCA) that simulates the activities and processes involved in livestock production (53). GLEAM operates at (sub) national, regional, and global scale. Detailed data on the feed ration composition and the parameters for animal production are presented in **Supplementary Tables 4–10**.

Biodiversity Loss

Biodiversity loss, expressed as the average number of potential species lost $\times 10^{10}$ per kg of food, representing the biodiversity damage caused by land occupation for food production, was estimated using the methodology of Chaudhary et al. (54). In brief, we obtained characterization factors representing potential species loss for mammals, birds, amphibians, reptiles, and plants from food production occupying 1 m^2 of land, according to the type of land use (cropland for all plant-based foods, pasture for ryegrass and alfalfa) and production intensity based on land management intensity (low, light, or intense). We calculated the biodiversity loss for intense land use based on monoculture farming with no crop rotation, use of inorganic fertilizer, and use of an irrigation system (55). We multiplied the factor for the land needed to produce one kg of food by the amount of each food consumed according to the SFFQ.

Blue Water Footprint

Blue water footprint, expressed as L per kg of food, was calculated as the total amount of blue water (groundwater and surface water) needed to produce 1 kg of food, taken from Mekonnen and Hoekstra (56). The estimates obtained corresponded to the average water consumption 1996–2005 for different crops, livestock, and derived products for Mexico. In a similar manner as for the land use estimates, we accounted for the contribution of the BWFP of imported foods. This indicator measures consumptive water use, but does not capture the extent to which this water use is problematic in the region where the food is produced (57), which is a limitation. Lack of data on where within a country (primarily Mexico and the US in this case) the food commodities are grown prevented such an assessment (see Section Methods in **Supplementary Material** for more details).

Carbon Footprint

Carbon footprint was calculated as kg of carbon dioxide equivalents (kg CO_2e/kg) using the metric Global Warming Potential over 100 years (GWP_{100}) (58) (see **Supplementary Material** for more on this indicator and its limitations). Data on the CFP for plant-based food items were obtained from a systematic review of existing LCA studies by Clune et al. (59). Global averages were used, since CFP values specific for Mexico were not available. The CFP estimates for plant-based foods included the total GHGE from primary production to distribution center. In the case of animal-source food items, which have considerably higher CFP values, country-specific CFP values were obtained from the GLEAM-I estimates for Mexico (60).

Sociodemographic Variables

Sociodemographic variables considered were: sex (male/female), age, and socioeconomic status (SES) (all included in tertiles), education level, categorized as low (elementary school or no education), medium (high school), or high (university), ethnicity (indigenous and non-indigenous), and place of residence (area and region). We based SES on an index of household wellbeing constructed by ENSANUT using component analysis of household characteristics, goods, and services (61). We categorized ethnicity following ENSANUT's methodology as indigenous for an individual speaking any indigenous language, or otherwise non-indigenous. We defined area of residence as rural (locations with $<$2,500 inhabitants) or urban (locations with $\geq$2,500 inhabitants), and divided region of residence into North, Center, Mexico City, and South.

Statistical Analysis

We calculated the mean diet characteristics of the average diet, the individual components of diet sustainability (high-quality diet, low-cost diet, low environmental footprint diet), MSD and non-MSD by urban and rural, and determined the relative percentage difference of each type of diet in comparison with the average diet. We assessed differences between dietary characteristics and composition of diet by food groups for adults with MSD and non-MSD, using the *t*-test. We used multivariate logistic regression to evaluate the association between sociodemographic characteristics and consumption of MSD (yes/no). As part of the characterization of diet sustainability, we explored the association between each environmental indicator of the diet (LU, BDL, CFP, BWFP) and diet quality (HEI-2015 score), using the Spearman correlation coefficient (rho). We stratified all the analyses by urban and rural area, since descriptive analysis showed different patterns for all indicators. We performed sensitivity analysis on the definition of MSD by including only the nutritional and environmental dimensions, and excluding the diet cost. For the analyses, we used the Stata software version 14.0 and the complex survey module (SVY) to consider the probabilistic design of the survey and expansion factors, and considered a p-value < 0.05 to be statistically significant.

RESULTS

On average, the overall sample had daily energy intake of 1,898 kcal/day (95% CI: 1,854, 1,941), a HEI-2015 value of 54.1 points (95% CI: 53.5, 54.7), and a daily diet cost of 48.9 MXN (95% CI: 47.6, 50.2) or 2.5 USD (95% CI: 2.5, 2.6). The per capita daily

TABLE 1 | Characteristics of the average diet and of high-quality, low-cost, low-environmental footprint, and more sustainable diets (MSD), by area of residence in Mexico ($n = 2{,}438$).

	Average diet[a]	High-quality diet[b]	Low-cost diet[c]	Low-environmental footprint diet[d]	More sustainable diet (MSD)[e]	Non-sustainable diet (non-MSD)[f]	MSD vs. non-MSD
	Mean (95% CI)[g]	Mean (95% CI)[g]	Mean (95% CI)[g]	Mean (95% CI)[g]	Mean (95% CI)[g]	Mean (95% CI)[g]	*p*-value
Sample size							
Urban *n* (%)[f]	1,636 (77.0)	725 (41.0)	681 (43.8)	364 (21.8)	84 (4.1)	1,512 (93.4)	-
Rural*n* (%)[f]	802 (23.0)	494 (65.6)	538 (69.7)	300 (38.8)	165 (22.4)	637 (88.5)	-
Daily energy intake (kcal)							
Urban	1,926 (1,872, 1,981)	1,887 (1,809, 1,965)	1,951 (1,876, 2,027)	1,909 (1,802, 2,015)	1,963 (1,750, 2,177)	1,925 (1,869, 1,981)	0.215
Rural	1,804 (1,749, 1,859)*	1,787 (1,717, 1,857)	1,831 (1,764, 1,898)	1,861 (1,773, 1,949)	1,840 (1,731, 1,949)	1,793 (1,729, 1,858)	0.47
HEI-2015 score							
Urban	52.4 (51.7, 53.1)	62.1 (61.6, 62.7)	50.4 (49.3, 51.4)	49.4 (48.0, 50.7)	62.6 (60.9, 64.3)	51.9 (51.2, 52.7)	<0.001
Rural	59.7 (58.6, 60.8)*	66.7 (65.9, 67.6)	59.8 (58.4, 61.2)	59.3 (57.5, 61.1)	66.8 (65.5, 68.0)	57.6 (56.4, 58.9)	<0.001
Daily diet cost (MXN/2,000 kcal)							
Urban	54.0 (52.8, 55.2)	57.7 (56.1, 59.4)	41.9 (41.3, 42.6)	44.4 (42.6, 46.2)	36.1 (33.9, 38.2)	54.8 (53.6, 56.0)	<0.001
Rural	45.8 (44.3, 47.3)*	45.8 (44.0, 47.6)	38.9 (38.00, 39.78)	39.6 (37.6, 41.6)	35.7 (34.4, 37.1)	48.7 (47.0, 50.5)	<0.001
Daily diet cost (USD/2,000 kcal)							
Urban	2.8 (2.7, 2.9)	3.0 (2.9, 3.1)	2.2 (2.1, 2.2)	2.3 (2.2, 2.4)	1.9 (1.8, 2.0)	2.8 (2.8, 2.9)	<0.001
Rural	2.4 (2.3, 2.5)*	2.4 (2.3, 2.5)	2.0 (2.0, 2.1)	2.1 (1.95, 2.16)	1.9 (1.8, 1.9)	2.5 (2.4, 2.6)	<0.001
Land use (m^2/2,000 kcal)							
Urban	6.5 (6.2, 6.7)	6.6 (6.3, 6.9)	5.2 (5.0, 5.5)	3.5 (3.4, 3.6)	3.3 (3.1, 3.5)	6.6 (6.4, 6.8)	<0.001
Rural	5.3 (344, 376)*	5.2 (4.9, 5.5)	4.8 (4.5, 5.0)	3.3 (3.2, 3.5)	3.2(3.1, 3.4)	5.9 (5.6, 6.2)	<0.001
Blue water footprint L./2,000 kcal							
Urban	396 (384, 409)	458 (439, 477)	318 (305, 330)	256(247, 265)	244 (223, 265)	403 (390, 415)	<0.001
Rural	358 (342, 374)*	380 (359, 402)	309 (295, 323)	241 (230, 253)	244 (230, 258)	391 (372, 410)	<0.001
Carbon footprint kgCO2eq/2,000 kcal							
Urban	4.3 (4.1, 4.5)	4.3(4.1, 4.6)	3.3 (3.1, 3.5)	2.0 (1.9, 2.0)	1.6 (1.5, 1.8)	4.4 (4.3, 4.6)	<0.001
Rural	3.2 (3.0, 3.4)*	3.1 (2.8, 3.3)	2.8 (2.6, 3.1)	1.7 (1.59, 1.81)	1.6 (1.4, 1.7)	3.7 (3.5, 4.0)	<0.001
Potential species loss per/2,000 kcal							
Urban	752 (696.2, 807)	705 (636, 775)	529 (470, 588)	129 (111, 147)	105 (77.6, 133)	780 (722, 838)	<0.001
Rural	474 (414, 535)*	420 (352, 489)	395 (323, 468)	102 (80.1, 124.8)	87.4 (64.0, 110.8)	586 (511, 661)	<0.001

[a] *Overall mean.*
[b] *Diets with HEI-2015 above the overall median of the population (54.2).*
[c] *Diets with cost below the overall median (50.9 MXN ≈ 2.6 USD).*
[d] *Diets with environmental indicators below the overall median: land use (5.5 m^2), blue water footprint (361 L), carbon footprint (3.4 kgCO2eq), and biodiversity loss (423 potential species loss × 10^{-10}).*
[e] *Diets that combine the criteria for high-quality, low-cost and low-environmental-footprint diets. All the groups (2–5) are non-independent.*
[f] *Diets that do not meet the criteria for high-quality, low-cost and low-environmental-footprint diets.*
[g] *Percentage and mean values are adjusted by the probabilistic survey design.*
**Indicates significant difference compared with the average diet in urban area ($p < 0.05$).*

environmental footprint for LU, BDL, CFP, and BWFP was 5.8 m^2 (95% CI: 5.6, 6.0), 657 × 10^{-10} species potentially lost (95% CI: 610, 703); 3.8 kg CO_2e (95% CI: 3.7, 4.0), and 357 L (95% CI: 347, 367), respectively.

Table 1 displays the dietary characteristics of the average diet, diets with high quality, low cost, low environmental footprint, and MSD and non-MSD by area of residence. In comparison with the average urban diet, the average rural diet had significantly lower energy intake, lower cost, higher HEI-2015, and lower environmental footprint ($p < 0.05$ for all indicators). According to our definition of MSD, 10.2% of adults; 4.1% (95% CI: 3.1, 5.4%) of the urban population and 22.4% (95% CI: 18.7, 26.5%) of the rural population, consumed MSD. In terms of the relative difference (%) compared with the average diet, the high-quality diet had a higher cost in urban areas (+7%) with no extra cost in rural areas, and higher BWFP (+16% and +6%) and lower BDL (−6% and −11%) in urban and rural areas, respectively. The high-quality diet had lower CFP than the average diet (−5%) only in rural areas (**Figure 1**). The low-cost diet had lower diet quality in urban areas (−4%) and no quality difference in rural areas,

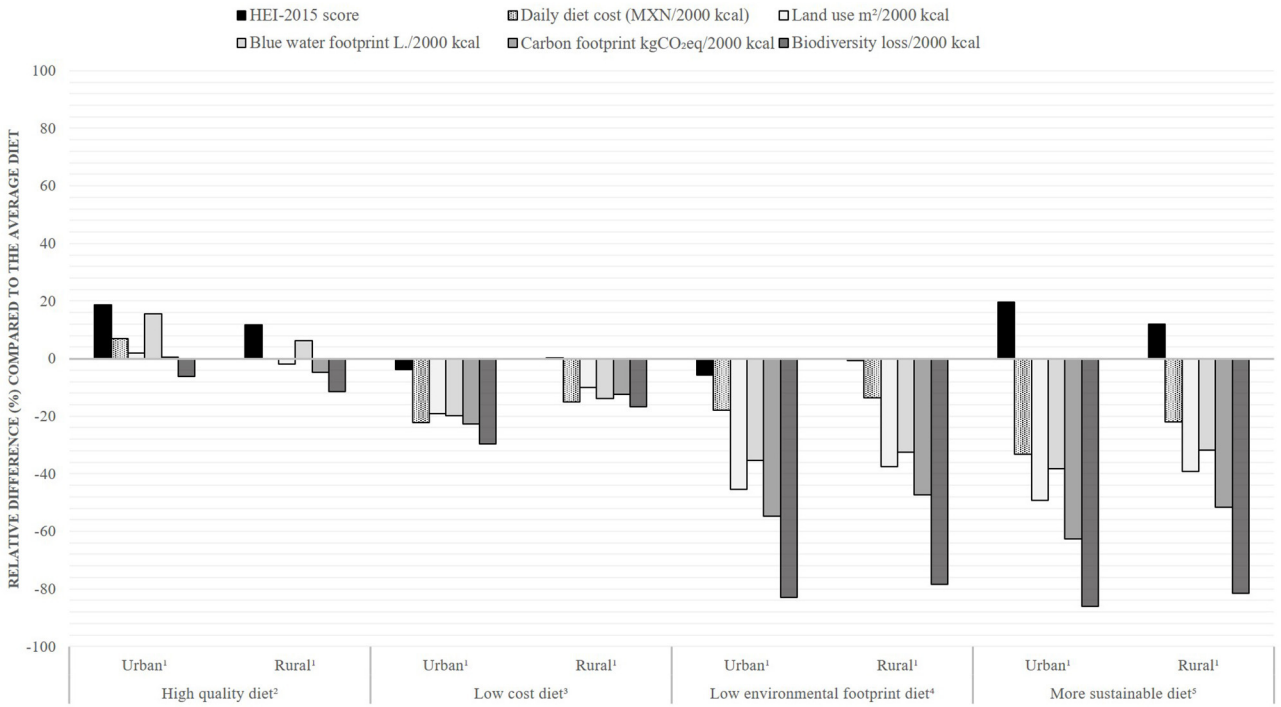

FIGURE 1 | Difference in dietary indicators of high-quality, low-cost, low-environmental footprint, and more sustainable diets relative to the average diet, by area of residence in Mexico. Values presented are the percentage difference in each dietary indicator (HEI-2015, cost and environmental footprint) relative to the average diet. [1]Urban: more than 2,500 inhab; Rural: less than 2,500 inhab. [2]Diets with HEI-2015 score above the overall median (54.2). [3]Diets with daily diet cost below the median (50.9 MXN ≈ 2.6 USD). [4]Diets with all environmental indicators below the median: land use (5.5 m^2), blue water footprint (361 L), carbon footprint (3.4 $kgCO_2eq$), and biodiversity loss (423 potential species loss × 10^{-10}). [5]Diets combining the criteria for high-quality, low-cost, and low-environmental-footprint diets. HEI-2015, Healthy Eating Index.

and had a lower environmental footprint (range −10 to −30%) than the average diet. The low-environmental footprint diet had a lower cost both in urban and rural areas (−18% and −14%) but also lower diet quality (−6% and −1%). As expected, MSD had a higher HEI-2015 value (+20% in urban and +12% in rural) and lower diet cost and environmental footprint than the average diet (**Figure 1**).

Comparison of the food group composition of diets revealed that both in urban and rural areas, adults following a MSD had higher intake of whole grains and lower intake of animal-source food (except eggs), added sugar, non-sweetened drinks, fruits, and vegetables than those not following a MSD. In urban areas only, intake of sweetened drinks and seafood & nuts was lower in MSD than non-MSD, while in rural areas intake of refined grains was lower in MSD than in non-MSD. We found no statistically significant differences in intake of legumes, eggs, added fats, and mixed processed dishes between MSD and non-MSD (**Table 2**).

The relative contribution of food groups to each environmental footprint indicator differed between adults according to type of diet (**Figure 2**). In both urban and rural areas, for those not following a MSD, beef, dairy, and pork were the major contributors to BDL, LU and CFP, while plant-based food groups (fruit and vegetables, legumes, whole grains) were the major contributor to BWFP. Refined grains and the group of added sugar and fats, sweetened drinks, and mixed processed dishes were the second largest contributors to CFP. For those following a MSD, the contribution of beef, dairy, and pork for all environmental footprint indicators was lower than for those not following a MSD, and the contribution of plant-based food groups, poultry and eggs was higher (**Figure 2**). For all diets in urban and rural areas, non-sweetened beverages and seafood and nuts made the lowest contributions to the environmental footprint indicators.

There were indications of an association between sociodemographic factors and MSD (**Table 3**). Adults from rural areas were 2.7 times more likely to follow a MSD than adults from urban areas, while adults from the South and the Center were more likely to consume a MSD than adults from the North (odds ratio (OR) 2.3 and 2.1, respectively). On the other hand, adults with medium and high SES were less likely to consume a MSD than adults with low SES (OR: 0.46 and 0.17, respectively). Age, sex, education, and ethnicity were not associated with consumption of a MSD (**Table 3**).

Regarding the association between diet quality and the environmental indicators, we found that HEI-2015 score had a positive association with BWFP (rho 0.3; $p < 0.001$), but an inverse association with CFP (rho −0.09; $p < 0.001$), and BDL (rho −0.14; $p < 0.001$) (**Supplementary Table 11**).

Sensitivity analysis using the definition of MSD excluding the diet cost showed similar, but slightly lower, values for

TABLE 2 | Comparison of intake of food groups among adults with and without more sustainable diets (MSD) in urban and rural areas of Mexico.

	URBAN			RURAL		
	Non-MSD[a] (n = 1,512)	MSD[b] (n = 84)	p-value*	Non- MSD[a] (n = 637)	MSD[b] (n = 165)	p-value*
Composition of diet by food groups (g)	**Mean (95% CI)**	**Mean (95% CI)**		**Mean (95% CI)**	**Mean (95% CI)**	
Whole fruits	209 (193, 226)	123 (103, 142)	<0.001	235 (211, 258)	124 (105.5, 142)	<0.001
Vegetables	197 (187, 207)	150 (123, 176)	0.001	190 (173, 207)	147 (130, 163)	<0.001
Legumes	18.6 (17.0, 20.2)	24 (17.4, 30.1)	0.088	28.5 (25.3, 31.8)	27.0 (22.2, 31.9)	0.61
Whole-grain foods	45.6 (40.6, 50.6)	251 (190, 312)	<0.001	132 (113, 150)	403 (358, 448)	<0.001
Seafood and nuts	8.9 (7.8, 9.9)	4.9 (2.2, 7.7)	0.008	6.5 (5.0, 8.1)	8.2 (4.9, 11.5)	0.351
Dairy	245 (229, 261)	124 (83.5, 164)	<0.001	215 (193, 237)	108 (78.3, 137)	<0.001
Beef	30.1 (27.6, 32.5)	2.7 (1.5, 3.8)	<0.001	22.4 (19.2, 25.6)	2.0 (1.0, 3.0)	<0.001
Poultry	21.6 (19.4, 23.7)	14.0 (7.6, 20.5)	0.021	19.6 (16.5, 22.7)	8.7 (6.28, 11.20)	<0.001
Eggs	33.8 (31.1, 36.6)	44.9 (33.6, 56.3)	0.087	36.5 (32.9, 40.2)	35.7 (28.9, 42.4)	0.827
Pork	34.0 (31.4, 36.6)	16.7 (12.1, 21.2)	0.001	26.4 (23.5, 29.2)	16.6 (11.29, 22.0)	<0.001
Refined-grain foods	245 (235, 255)	229 (175, 282)	0.567	195 (179, 210)	101.8 (77.7, 125.9)	<0.001
Added sugars	43.9 (40.9, 47.0)	20.3 (13.2, 27.4)	<0.001	40.6 (36.1, 45.0)	26.6 (21.6, 31.6)	<0.001
Added fats	11.6 (11.0, 12.3)	10.8 (7.8, 13.7)	0.573	11.6 (10.3, 12.8)	9.0 (6.53, 11.44)	0.06
Mixed processed dishes	52.1 (47.0, 57.1)	40.5 (28.2, 52.9)	0.098	50.7 (42.3, 59.0)	44.3 (27.0, 61.5)	0.514
Sweetened drinks	288 (265, 311)	183 (121, 244)	0.002	217 (190, 244)	184 (149.1, 220)	0.169
Non-sweetened drinks	154 (135, 173)	83.7 (36.8, 131)	0.004	136 (113, 159)	86.2 (57.4, 115)	0.009

[a]*Adults without MSD.*

[b]*Adults with MSD consisting of diets with HEI-2015 above the median, and diet cost and environmental indicators (land use, biodiversity loss, blue water and carbon footprint) below the median of the overall diet. The mean values presented were estimated considering the complex design of the Mexican National Health and Nutrition Survey (ENSANUT 2012).*

**The significance was assessed at $p < 0.05$ using a t-test for mean comparison with survey data. MSD, more sustainable diets; HEI-2015, Healthy Eating Index.*

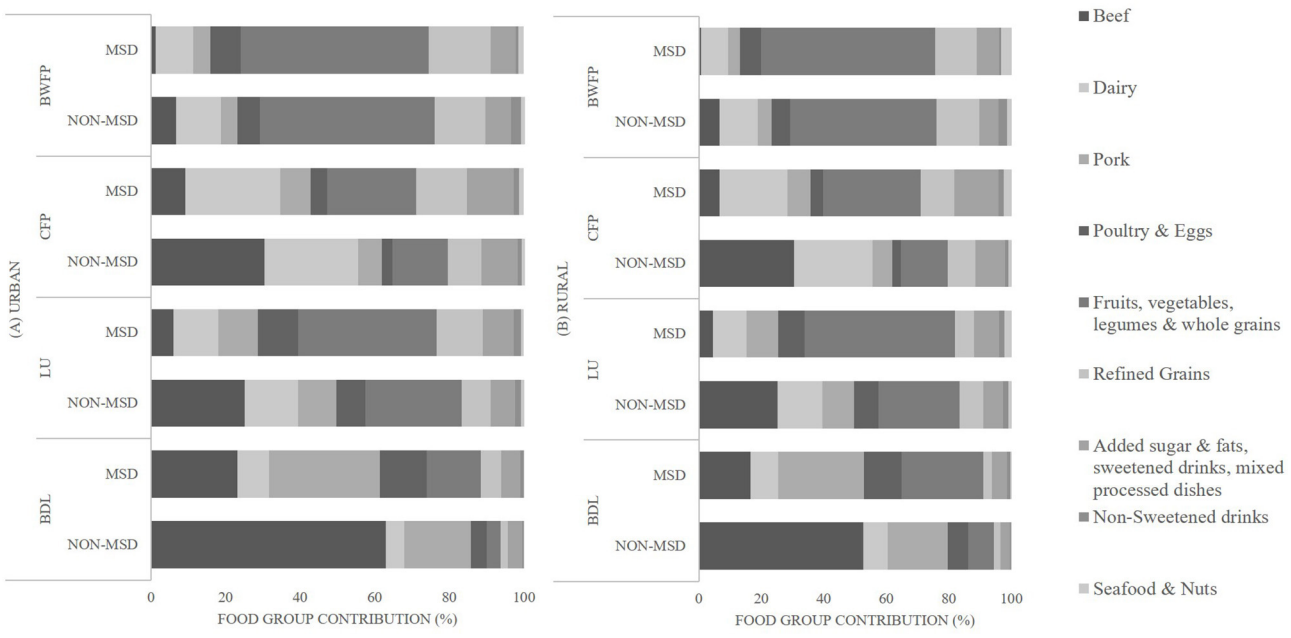

FIGURE 2 | Contribution (%) of food groups to the total environmental footprint indicators among adults with MSD and non-MSD in **(A)** urban and **(B)** rural areas of Mexico. BDL, Biodiversity loss (potential number of species lost/2,000 kcal $\times 10^{-10}$); LU, land use (m^2/2,000 kcal); CFP, carbon footprint ($kgCO_2eq$/2,000 kcal); BWFP, blue water footprint (L/2,000 kcal); MSD, more sustainable diet (diets with HEI-2015 above the median, diet cost and environmental indicators (land use, biodiversity loss, blue water and carbon footprint) below the median of the overall diet.

TABLE 3 | Sociodemographic characteristics associated with consumption of more sustainable diets (MSD) in Mexico.

More sustainable diet	OR[a] Adjusted (95% CI)	*p*-value
Age group (tertiles)		
18.0–<29.6	Reference	
29.6–<43.5	0.94 (0.58, 1.52)	0.801
43.5–59.0	0.88 (0.55, 1.40)	0.582
Gender		
Male	Reference	
Female	0.86 (0.59, 1.25)	0.418
Education level[b]		
Low	Reference	
Medium	1.54 (0.70, 3.36)	0.281
High	0.57 (0.22, 1.48)	0.249
Socioeconomic level[c]		
Low	Reference	
Medium	0.46 (0.29, 0.74)	0.001
High	0.17 (0.09, 0.32)	<0.001
Ethnicity[d]		
Indigenous	Reference	
Non-indigenous	0.96 (0.53, 1.72)	0.880
Area of residence (%)		
Urban	Reference	
Rural	2.67 (1.73, 4.13)	<0.001
Region of residence (%)		
North	Reference	
Center	2.12 (1.14, 3.94)	0.017
Mexico City	0.37 (0.08, 1.69)	0.198
South	2.34 (1.26, 4.37)	0.007

[a]*Estimated Odds Ratio coefficient from logistic regression model (n = 2,438) considering the complex design of the Mexican National Health and Nutrition Survey (ENSANUT 2012).*
[b]*Categorized as low (elementary school or no education), medium (high school), or high (university).*
[c]*Based on an index of household wellbeing constructed by ENSANUT using principal component analysis of household characteristics, goods, and services.*
[d]*Based on language spoken, categorized as indigenous (when the adult spoke any indigenous language) or non-indigenous.*

diet quality, mainly in urban areas, and similar values for the environmental footprint indicators, than the original definition (**Supplementary Figure 3**).

DISCUSSION

As far as we know, this is one of the first studies among middle-income countries and in the Latin American region to assess the environmental footprint of food and to link them with dietary data to characterize nutritional, economic, and environmental dimensions of diet sustainability using a National Survey with individual dietary data. We found that in Mexico, a small proportion of adults consume a healthier and more sustainable diet (10.2% nationally; 4% of urban and 22% of rural area). The MSD is a realistic diet pattern mainly found in disadvantaged populations but diet-quality is still sub-optimal and requires improvements.

Mexican adults following MSD had lower intake of animal-source food groups (mainly beef, dairy, pork), higher intake of plant-based food (mainly legumes and whole grains) (62, 63), lower intake of fruits and vegetables (undesirable), and lower intake of unhealthy food groups (refined grains, added sugar and fats, processed mixed dishes and sweetened beverages). This confirms that MSD can be achieved by increasing plant-based foods and decreasing animal-source and unhealthy foods, to improve diet quality while decreasing environmental footprint and diet costs (1, 23, 28). Consumption of fruits and vegetables in MSD should be promoted, while considering strategies to avoid increased diet costs.

Having lower SES and living in rural, South, or Central Mexico (which have the highest rates of poverty in Mexico) (64), were positively associated with having a healthier and more sustainable dietary pattern. A study on apparent food consumption (per-capita food availability) in Mexico showed that the richest consumed more animal-source foods, oils, and sugars, representing higher energy intake, with 60–80% higher land requirements than the diets of the poorest (58, 64). Other studies have found that adults with high SES in Mexico have less sustainable diets than indigenous or rural-dwelling adults (23). A recent study that analyzed the same survey showed that a higher SES was negatively associated with the quality of diet in urban and rural areas, and that a high-quality diet was more expensive in urban but not in rural areas at all SES levels (65). Nutrient-dense food such as fruits, animal and dairy products, but also some ultra-processed products are income elastic (66), which partly explains that lower-income groups have relatively more sustainable diets, since they consume less of these foods. This suggests that economic constraints as well as sociocultural and geographical factors are associated with MSD consumption, confirming previous findings of a negative relationship of SES with diet quality and a positive relationship with environmental footprint, due to higher consumption of animal-source and unhealthy products (34, 67, 68). In addition, the differences in food consumption patterns among place of residence are associated with a heterogeneous process of nutrition transition that was consistently found in previous reports in Mexico (33, 34, 63). Also, there are differences in food supply among areas and regions that determine food access and prices and quality (69), for instance, people from rural areas have more access to home produced food as these are the main places of food production in Mexico, while in the wealthier region of the North, supermarkets are the main supply of food and in the South and Center the open market is used more (11, 69, 70).

There is no standardized method for identification of MSD. Some define MSD using a theoretical reference diet, whereas we identified MSD relative to the average diet in the study population. Most studies define MSD with only indicators of nutritional adequacy and one environmental footprint indicator (22, 31, 63, 71), while we included diet quality, four environmental footprint indicators, and diet cost (13, 20, 57). The MSD characteristics identified were consistent with those found for other populations (31, 64, 71). Characteristics of MSD in the Mexican population were closer to the EAT Lancet Commission Healthy Reference Diet (EAT-HRD) (28) than the average diet

for added fats and sugars and whole grains (mainly in rural areas), while beef and pork intake was below/close to EAT-HRD. However, intake of legumes, fruits, vegetables, seafood, nuts, and dairy were below the EAT-HRD. Similarly, the environmental footprint of MSD was close to the absolute planetary boundaries for CFP and LU (1.9 kg CO_2e and 5.0 m^2 per capita and day, respectively) (72).

Sensitivity analysis of MSD excluding diet costs showed that high-quality diets with low environmental footprint cost less than the average diet, as found in a recent modeling study on food baskets in Mexico (33). Although healthy food costs more than non-healthy food in Mexico (73) and diet cost is positively associated with diet quality in urban areas, a higher-quality diet can be achieved at similar cost as a lower-quality diet, since cost distributions overlap (65). The lower cost of MSD compared with average diets in Mexico could be explained by reduced consumption of unhealthy products and animal-source food such as red meat, which cost more than whole grains and legumes present in higher amounts in MSD. We did not assess the affordability of MSD, due to lack of reliable information regarding income in ENSANUT, but we compared the average cost of MSD in our sample with the extreme poverty line in the country in 2018 (1.8 USD in rural areas, 2.5 USD in urban areas) (74). We found that MSD could be more affordable than the average diet, since in urban areas it cost 24% less than the extreme poverty line and in rural areas only 5% more, whereas the average diet cost exceeded the extreme poverty line by 12 and 25% in urban and rural areas, respectively.

Although MSD as defined had relatively better quality than the average diet, we highlight that it still had a sub-optimal diet quality score (62 and 69 points in urban and rural areas, respectively, compared with an optimum of >80 points) (36). This diet lacks sufficient fruits and vegetables, and still presents consumption of some unhealthy products such as sweetened beverages, processed dishes and ultra-processed products, confirming the need to improve the quality of the diet of Mexican adults (36) to meet their nutritional requirements in addition to being sustainable. This is relevant especially in rural areas, where the lower environmental footprint of MSD was associated with lower intake of animal-source foods, higher intake of whole grains and legumes, and lower intake of fruit and vegetables. This lower intake of certain food groups could reduce the diversity of their diets resulting in potential micronutrient deficiency (75). In a context of food insecurity, such as it happens in several communities in Mexico, consuming regional and seasonal fruits and vegetables can reduce problems of availability and high price of this food groups. Additionally, strategies for promoting sustainable diets among these vulnerable populations should support consumption of modest amounts of low environmental impact animal-source foods, such as poultry, eggs and pig, and increase access to fruits, vegetables, legumes and nuts. Furthermore, improvements in diet quality could be achieved without increasing its total cost by selecting healthy and sustainable food options (33, 65).

This study has some limitations. The CFP for plant-based food was derived from an international meta-analysis (59), which did not represent food production systems in Mexico or account for different levels of processing (76). For animal-source foods, CFP and LU were estimated using the GLEAM-I tool, which has major uncertainties in feed use especially for ruminants. Not accounting for different types of land (e.g., pasture vs. cropland) penalizes diets high in ruminant products, as ruminants can produce food on less productive land (see Section Methods in **Supplementary Material** for other details). Despite these uncertainties we have used the most systematized and update data to estimate the environmental footprint of Mexican diets, also as those errors are systematic, we do not expect any differential bias. Regarding health, the limited list of foods in the SFFQ could have underestimated food intake, as could underreporting (e.g., unhealthy foods) because of social desirability (77). However, SFFQ is a validated method and the foods contributed more than 90% of total energy and nutrient intake (38). The analyzed survey is 10 years old, but another study showed that HEI-2015 as diet quality indicator has not changed between ENSANUT 2006, 2012, and 2016 (35), and differences on dietary intake by place of residence are similar to those found in ENSANUT 2018-19 (78). Although HEI-2015 includes food groups and nutrients, processed foods had to be disaggregated into added sugar, sodium, fats, etc. to assess diet quality. Hence, HEI-2015 only captures the role of energy-dense and nutrient-poor foods in the diet through their ingredients. It can also generate errors in estimation of vitamin/mineral retention during cooking. However, HEI-2015 has been used for comparison between groups of people in relation to sustainability (79).

Among the strengths, this is the first study in Mexico and one of the first studies in middle-income countries and Latin America to assess the environmental footprint for +130 commonly consumed foods, based on a systematized dataset on primary production, which could be used by other similar countries in the region to link them with diet information or adapt the methodology to estimate its own environmental footprint indicators, instead of using information from high-income countries. We analyzed a representative national survey that used standardized methods to reduce potential selection bias and measurement errors, and we were the first to link indicators of diet quality, diet cost, and environmental footprint to measure diet sustainability considering nutritional, economic and environmental dimensions. This approach including the environmental impact of food production linked with food consumption opens a new line of analysis and platform of discussion in the field of public health and population nutrition. This may help to generate recommendations not only for healthy but also for more environmentally sustainable diets that are in line with the current sustainable development goals.

Our results highlight the urgent need to promote sustainable diets that incorporate high-quality diets at lower environmental footprints and accessible cost, considering the differences in food patterns by SES and area of residence. For this, our study provides methods and environmental footprint estimates of foods and diets for the formulation of sustainable food-based dietary guidelines for Mexico that are currently being updated and for the first time will consider an environmental approach, and our estimations of food environmental footprints could also be used by similar countries to include environmental sustainability indicators into their dietary guidelines. Also, further studies that complement our analysis of diet quality considering the

nutrients requirements for different age groups will be useful to promote a more sustainable and healthy diet for all of the population. We also highlight the need to improve/refine estimates of the environmental impact of processed foods, as limited data were found regarding their ingredients and methods of processing and packaging to estimate the carbon footprint of food production for Mexico. Also, data were not available for estimation of environmental impact indicators considering the different regional and local food production systems, for example, the comparison of more traditional vs. modern systems. Similarly, further analysis is needed of drivers of local food consumption and production systems by place of residence; this information can be useful for designing comprehensive policies to promote/maintain MSD considering socioeconomic, cultural, and geographical heterogeneities. This is particularly relevant for rural, South and Central regions of Mexico, which consistently showed better diets than average, but still not optimal diets.

In conclusion, this study provides estimation of the environmental footprint of most frequently consumed food in Mexico and a systematic methodology that could be used by other middle-income countries to assess diet sustainability considering nutritional, economic and environmental aspects. Among the sociodemographic factors associated to relatively MSD diets we found that compared with the average diet, a small proportion of Mexican adults in urban areas, and almost one-fifth in rural areas, had MSD characterized by lower intake of animal-source foods and unhealthy foods, and higher intake of whole grains, although intake of fruits and vegetables was low. Diets are relatively healthier and more sustainable among low vs. high income settings, but its nutritional quality is still suboptimal and there is need to further improve sustainable diets in Mexico through adding more legumes, fruits, and vegetables and reducing unhealthy products. Improving the economic conditions of the population will lead less sustainable diets, so promoting diets that are nutritionally adequate, affordable diets with a low environmental footprint is necessary to ensure the health of the planet and the population.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Material**, further inquiries can be directed to the corresponding author/s.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Ethics Committee of the National Institute of Public Health in Mexico (INSP). The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

KC-Q designed the study, conducted the data analysis, and wrote the manuscript. ER and MU-M assisted with the design, data analysis, interpretation, and drafting the manuscript. SR-R assisted with the data analysis and revision of the manuscript. JR, WW, and JF contributed to interpretation of the results and the discussion, and assisted in drafting the manuscript. KC-Q and MU-M had primary responsibility for the final content. All authors have read and approved the final manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fnut.2022.855793/full#supplementary-material

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Dietary Patterns and Dietary Recommendations Achievement From Latin American College Students During the COVID-19 Pandemic Lockdown

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This study aimed to compare the diet quality of different dietary patterns among college students from Latin American countries, including vegetarians, vegans, and omnivores during the COVID-19 pandemic. A cross-sectional, observational, multicenter study was conducted including a non- probabilistic sample of university students from 10 countries. University students were invited to participate in the study through social network platforms. Participants were self-reported to have followed a specific dietary pattern; either the Prudent diet, Western diet, Ovo-dairy-vegetarian diet, Fish-vegetarian diet, Strict vegetarian diet (vegan) or other. The last three patterns (vegetarians and vegans) were grouped as following a plant-based diet. A self-assessment survey was used to evaluate healthy eating habits using a questionnaire with values between 1 (do not consume) and 5 (consume) for a total of 9–45 points (higher values represent better eating habits). Unhealthy habits were assessed with nine questions. A total of 4,809 students filled out the questionnaire, and the majority of them were females (73.7%).

A high percentage have been in lockdown for more than 5 months and were in lockdown when the survey was released. 74.3% were self-reported to follow a prudent diet, while 11.4% reported following a western dietary pattern and 8.8% a plant-based diet. When compliance with healthy and unhealthy dietary habits was analyzed, although all groups had low compliance, the plant-based diet group (56.09 ± 6.11) performed better than the Western diet group (48.03 ± 5.99). The total diet quality score was significantly higher for plant-based diet followers, who also tended to better achieve the recommendations than omnivorous students, especially the ones following a western diet. These results present evidence that young adults such as college-aged students have unhealthy dietary habits. However, the ones who follow a plant-based diet such as vegetarians and vegans exhibit better scores and healthier dietary conducts.

Keywords: dietary patterns, vegetarians, vegans, omnivorous, COVID lockdown

INTRODUCTION

Latin America is one of the world's regions with a higher prevalence of risk factors of non-communicable diseases (NCDs) such as cardiovascular disease, cerebrovascular disease, type II diabetes (T2D) and hypertension (Anauati et al., 2015; Pan American Health Organization and World Health Organization, 2016). In addition to elevated morbidity, NCDs also exhibit a high mortality rate (Barquera et al., 2015; Kimokoti and Millen, 2016; Calazans and Queiroz, 2020; Lee et al., 2020).

Diet being a determinant factor of NCDs, the Latin American Study of Nutrition and Health (Estudio Latino Americano de Nutrición y Salud ELANS), a household-based cross-sectional survey conducted from March 2014 to December 2015, provided insight into different aspects of diet quality in adolescents and adults from eight Latin American countries (Fisberg et al., 2016), reporting that only 7.2% of the overall sample reached the World Health Organization's recommendations for fruits and vegetables consumption, and <3.5% met the optimal consumption level of vegetables, nuts, whole grains, fish and yogurt, highlighting the urgency of improving dietary habits in order to prevent NCDs and improve health (Kovalskys et al., 2019). This suboptimal intake of nutrient-dense food groups and healthy food groups was more frequently observed in younger rather than older adults (Kovalskys et al., 2019). Particularly, participants aged 20–34 years were more vulnerable to high total and added sugar intake than older age groups, with a mean of 20.1% of total energy intake from added sugar (Fisberg et al., 2018). This pre-pandemic data showed a huge gap between healthy food groups and micronutrients intake and recommendations that urged actions to improve diet quality in this population.

In terms of nutrition behavior, university students are a highly vulnerable population since they are still defining their dietary and lifestyle patterns. While some students show a tendency to adopt risky habits such as alcohol intake and tobacco use, snacking, skipping meals, physical inactivity, and inadequate sleep (Kimokoti and Millen, 2016; Sogari et al., 2018; Rodrigues et al., 2019), others gain interest in more nutrient-dense and environmental-conscious patterns such as vegetarianism and veganism. Although this trend includes different age groups, it is especially popular among younger populations such as college students and adolescents (Larsson and Johansson, 2002; Clarys et al., 2014; Segovia-Siapco et al., 2019; Sakkas et al., 2020).

Recent studies have shown that dietary patterns analysis is a cost-effective way to assess nutrient consumption. It has been shown that dietary patterns assessment is a good predictor of chronic disease risk, even more than individual nutrients or foods groups analysis, because it takes a look at a broader picture which is the individual's whole diet (Hu, 2002). Dietary pattern analysis provides comprehensive information about combined and synergistic relations between foods and nutrients consumed (Castro et al., 2015).

The western diet has been associated with an increased risk for NCDs, including the increasing prevalence of obesity (Kopp, 2019) in both developed and developing countries (Salameh et al., 2014). This pattern is characterized by its high caloric density that comes from ultra-processed foods, soft drinks, fast foods, alcohol and snacks (Cunnane, 2005; López-Taboada et al., 2020). People who follow this pattern have a high intake of trans, saturated and omega-6 polyunsaturated fatty acids, simple sugars and other high glycemic index carbohydrates, with little consumption of omega 3 fatty acids, dietary fiber, and some micronutrients and antioxidants. In general, it is the least nutrient-dense dietary pattern (Statovci et al., 2017; Kopp, 2019).

The prudent diet was proposed in the 1970's as a response to the increased prevalence in NCDs. In this diet, four principles are suggested: Avoid excessive caloric intake, increase dietary fiber, reduce total fat intake and increase polyunsaturated fatty acids in the diet (Mann, 1979).

Over the years, western societies including Latin American countries, have shown an increased interest in plant-based dietary patterns. For example, vegetarianism, which excludes certain food items such as meat, poultry, or fish; or veganism, which completely avoids all types of meat and animal products such as dairy and eggs (Tuso et al., 2013; Medawar et al., 2019). These increasingly popular diets focus on the consumption of fruits, vegetables, grains, nuts, seeds, mushrooms, and vegetable fats and oils (Sakkas et al., 2020).

There are many epidemiological studies that suggest that following a plant-based dietary pattern may be protective against many unhealthy outcomes related to western omnivore diets, such as obesity and chronic illness like T2D, hypertension, cardiovascular disease and, certain types of cancer (Craig, 2010; Tuso et al., 2013; Parker and Vadiveloo, 2019). This healthier status may respond to a lower intake of calories, saturated fat, and sodium as well as higher consumption of dietary fiber, polyphenols, carotenoids and, antioxidant vitamins (Sakkas et al., 2020). In addition, after shifting to a plant-based diet, many people have also adopted other healthy habits such as increased physical activity and abstinence from smoking and drinking alcohol (Cramer et al., 2017). On the other hand, there is also a strong body of evidence pointing out that the consumption of meat, seafood, eggs, and dairy products ensures meeting the dietary requirement for nutrients that are usually low or not as bioavailable in plant-based products, such as long-chain omega-3 fatty acids, vitamins D and B12, iron, iodine, calcium, and zinc (Craig, 2010; Clarys et al., 2014; Poinsot et al., 2020; Sakkas et al., 2020), which increases the need of nutrient supplementation and nutritional education to vegetarian and vegan individuals.

Since February of 2020, the COVID-19 pandemic forced countries in Latin America and the Caribbean to adopt several measures to control the virus outbreak and infection rate. These measures included social distancing, closing international borders, local public spaces and schools, instituting curfews, and quarantines (Garcia et al., 2020). Mandatory lockdown, in particular, has impacted people's lifestyles and habits. Some studies have shown that confined individuals reduced their physical activity and increased sedentary behavior (Dor-Haim et al., 2021; Sadarangani et al., 2021; Stockwell et al., 2021; Van Langen and Generali, 2021). It has also been documented that during quarantine, individuals changed some dietary habits. Some shifted toward unhealthy patterns by increasing sugar, alcohol, snacks and ultra-processed foods (UPFs) intake while decreasing the consumption of fresh products such as fruits and vegetables whereas some adopted better-eating behaviors and higher adherence to healthy dietary patterns (Bracale and Vaccaro, 2020; Celia et al., 2020; Di Renzo et al., 2020; Pellegrini et al., 2020; Bennett et al., 2021; Enriquez-Martinez et al., 2021; Pertuz-Cruz et al., 2021). It has been reported that no significant differences have been found regarding complete food group patterns, which means that vegetarians were not likely to become omnivorous, or western dieters did not turn vegan because of the COVID-19 lockdown (Husain and Ashkanani, 2020). However, there is data suggesting that individuals who followed a western-like dietary pattern did shift toward a more prudent diet, most likely to reinforce immune function (Madan et al., 2021; Navarro-Pérez et al., 2021).

Although several studies have characterized the university students' diet in the Latin American region, to our knowledge, this is the first in doing so comparing different dietary patterns. This study aimed to compare the diet quality of different dietary patterns among college students from Latin American countries, including vegetarians, vegans, and, omnivores during the COVID-19 pandemic lockdown in 2020.

METHODS

Study Design

A cross-sectional, observational, multicenter study was conducted using a non-probability sampling of uncontrolled distribution of instruments, a technique where participation is voluntary and self-selected (Schonlau et al., 2021), including university students from 10 Latin American Countries (Argentina, Chile, Colombia, Costa Rica, Ecuador, Guatemala, Mexico, Panama, Paraguay and Peru). Students actively enrolled in higher education institutes, 18 years of age or older, were eligible for inclusion. Those who did not complete the entire survey were excluded.

Data Collection

Participants were recruited from the 10 countries mentioned above by convenience sampling. University students were invited to participate in the study through social network platforms (Instagram, Facebook, and Twitter) or institutional emails. In order to participate, individuals have to be 18 years old or older and accept an online informed consent. A self-administrated digital questionnaire in Google Forms format was used to collect eating habits and physical activity information. Data was collected between November and December 2020. Sample size calculation determined a minimum of 1,194 participants. Sample size calculation was performed using G*Power (Erdfelder et al., 2009) (considering the performance of a logistic regression, a unilateral test, an Odds ratio = 1.3, Pr (Y = 1 |X = 1) H0 = 0.2, an α of 0.01 and a power (1-β) of 0.9.

Dietary Patterns

Participants self-reported to have followed a specific dietary pattern based on the following question, "Which of the following eating patterns best describes you?," and the following choices:

- Prudent diet: Characterized by a prudent and modest intake of all food groups, without excess or avoidance.
- Western diet: Characterized by a high intake of ultra-processed and fast foods such as pizza, burgers, fries, snacks, frozen, canned or fried foods. Also, a low intake of fruits, vegetables, legumes and whole-grain cereals.
- Ovo-dairy-vegetarian diet: A plant-based diet that includes dairy and eggs
- Fish-vegetarian diet: A plant-based diet that includes fish, dairy and eggs.
- Strict vegetarian diet (vegan): Characterized by the sole consumption of foods of vegetable origin.
- Other diet: For those who do not identify with any pattern stated before.

For the main analysis, people who answered Ovo-dairy-vegetarian diet, Fish-vegetarian diet or Strict vegetarian diet (vegan) were grouped as following a plant-based diet.

Eating Habits

Eating habits were assessed using a self-administered food habits survey, following a methodology proposed and adapted by Crovetto et al. (2018) according to the Chilean dietary

TABLE 1 | Sociodemographic characteristics by dietary pattern.

	General	Prudent diet	Western diet	Plant Based diet	Other diet
n (%)	4,859 (100)	3,610 (74.3)	554 (11.4)	428 (8.8)	267 (5.5)
Age	22.4 (4.34)	22.2 (4.24)	22.8 (4.33)	22.9 (4.71)	22.7 (4.96)
Sex					
Male	1,280 (26.3)	929 (25.7)	183 (33.0)	88 (20.6)	80 (30.0)
Female	3,579 (73.7)	2,681 (74.3)	371 (67.0)	340 (79.4)	187 (70.0)
Country					
Argentina	503 (10.4)	338 (9.4)	50 (9.0)	98 (22.9)	17 (6.4)
Colombia	273 (5.6)	217 (6.0)	27 (4.9)	19 (4.4)	10 (3.7)
Chile	376 (7.7)	261 (7.2)	24 (4.3)	72 (16.8)	19 (7.1)
Costa Rica	584 (12.0)	452 (12.5)	57 (10.3)	47 (11.0)	28 (10.5)
Ecuador	673 (13.9)	523 (14.5)	77 (13.9)	35 (8.2)	38 (14.2)
Guatemala	375 (7.7)	278 (7.7)	52 (9.4)	31 (7.2)	14 (5.2)
Mexico	1,242 (25.6)	926 (25.7)	142 (25.6)	93 (21.7)	81 (30.3)
Panama	293 (6.0)	221 (6.1)	48 (8.7)	10 (2.3)	14 (5.2)
Paraguay	257 (5.3)	177 (4.9)	53 (9.6)	7 (1.6)	20 (7.5)
Peru	283 (5.8)	217 (6.0)	24 (4.3)	16 (3.7)	26 (9.7)
Field of study					
Health sciences	3,093 (63.7)	2,368 (65.6)	304 (54.9)	269 (62.9)	152 (56.9)
Engineering and exact sciences	882 (18.2)	634 (17.6)	131 (23.6)	62 (14.5)	55 (20.6)
Education, social sciences and humanities	198 (4.1)	131 (3.6)	28 (5.1)	31 (7.2)	8 (3.0)
Arts, architecture and design	63 (1.3)	41 (1.1)	9 (1.6)	10 (2.3)	3 (1.1)
Management and economics sciences	156 (3.2)	114 (3.2)	25 (4.5)	11 (2.6)	6 (2.2)
Agricultural and biological sciences	207 (4.3)	147 (4.1)	16 (2.9)	30 (7.0)	14 (5.2)
Others	260 (5.4)	175 (4.8)	41 (7.4)	15 (3.5)	29 (10.9)
Year in course					
First year	953 (19.6)	677 (18.8)	110 (19.9)	108 (25.2)	58 (21.7)
Second year	1,217 (25.0)	894 (24.8)	150 (27.1)	109 (25.5)	64 (24.0)
Third year	961 (19.8)	723 (20.0)	94 (17.0)	80 (18.7)	64 (24.0)
Fourth year	766 (15.8)	579 (16.0)	85 (15.3)	67 (15.7)	35 (13.1)
Five or more years	962 (19.8)	737 (20.4)	115 (20.8)	64 (15.0)	46 (17.2)
Scholarity in household					
Primary school incomplete	325 (6.7)	219 (6.1)	54 (9.7)	25 (5.8)	27 (10.1)
Primary school	403 (8.3)	290 (8.0)	36 (6.5)	37 (8.6)	40 (15.0)
High school incomplete	396 (8.1)	282 (7.8)	51 (9.2)	37 (8.6)	26 (9.7)
Technical incomplete	1,046 (21.5)	790 (21.9)	118 (21.3)	84 (19.6)	54 (20.2)
Technical	816 (16.8)	607 (16.8)	88 (15.9)	80 (18.7)	41 (15.4)
University	1,248 (25.7)	955 (26.5)	138 (24.9)	110 (25.7)	45 (16.9)
Postgrads	625 (12.9)	467 (12.9)	69 (12.5)	55 (12.9)	34 (12.7)
Profession in household					
Medium executive	1,217 (25.0)	907 (25.1)	130 (23.5)	118 (27.6)	62 (23.2)
High executive	187 (3.8)	136 (3.8)	23 (4.2)	21 (4.9)	7 (2.6)
Workman	873 (18.0)	655 (18.1)	99 (17.9)	64 (15.0)	55 (20.6)
Administrative work	1,608 (33.1)	1,227 (34.0)	174 (31.4)	138 (32.2)	69 (25.8)
Trade job	696 (14.3)	499 (13.8)	77 (13.9)	63 (14.7)	57 (21.3)
Minor jobs	278 (5.7)	186 (5.2)	51 (9.2)	24 (5.6)	17 (6.4)

(Continued)

TABLE 1 | Continued

	General	Prudent diet	Western diet	Plant Based diet	Other diet
Time in lockdown					
None	210 (4.3)	152 (4.2)	37 (6.7)	12 (2.8)	9 (3.4)
< 1 month	119 (2.4)	90 (2.5)	9 (1.6)	14 (3.3)	6 (2.2)
1–2 months	303 (6.2)	218 (6.0)	34 (6.1)	30 (7.0)	21 (7.9)
3–5 months	853 (17.6)	642 (17.8)	93 (16.8)	79 (18.5)	39 (14.6)
More than 5 months	3,374 (69.4)	2,508 (69.5)	381 (68.8)	293 (68.5)	192 (71.9)
Currently in lockdown					
Yes	2,955 (60.8)	2,226 (61.7)	321 (57.9)	234 (54.7)	174 (65.2)
No	1,904 (39.2)	1,384 (38.3)	233 (42.1)	194 (45.3)	93 (34.8)
Type of lectures					
On Campus	29 (0.6)	19 (0.5)	3 (0.5)	6 (1.4)	1 (0.4)
Online/virtual	4,659 (95.9)	3,462 (95.9)	536 (96.8)	407 (95.1)	254 (95.1)
Mixed (on campus and virtual)	171 (3.5)	129 (3.6)	15 (2.7)	15 (3.5)	12 (4.5)

recommendations (Crovetto et al., 2018). The survey consisted of 15 items, which explore the consumption of different foods and food groups. The first nine items assessed the frequency of consumption of food groups recommended by the current Chilean dietary guidelines (dairy products, fruits, vegetables, legumes, fish, and whole grains) and the frequency of following healthy eating habits (consumption of breakfast, lunch, and dinner), ranging from no consumption (1 point), to the suggested daily/weekly portions (5 points). The suggested intake is as follows: dairy products 3 portions/d, fruits 3 units/d, vegetables ≥2 portions/d, legumes 2–3 times/w, fish ≥ 2 portion/w, whole grains ≥ 1 portion/d), obtaining a rating of the responses ranging from 9 to 45 points (higher value equivalent to better eating habits). The next six items referred to were unhealthy diet habits foods or food groups identified as promoters of NCD according to the recommendation of (≥1 portion/d of sugar sweetened beverages, ≥1 portion/d of alcohol, ≥1 portion/w of fried foods, ≥1 portion/d of fast food, ≥2 portion/d sweet snacks) and a negative food habit was added, such as adding salt to meals without tasting them; six of the questions have a score identical to the previous one (1 point, no consumption, to 5, more than three portions per day/week) and only one rated from 1 to 3 points (salt), reaching a value ranging from 7 to 33 points (higher value equivalent to worse eating habits). Both healthy and unhealthy scores were standardized on 100 points scale to facilitate comparison.

Statistical Analysis

Descriptive statistics were applied for data analysis. The quantitative data were expressed in mean and standard deviation, and qualitative data were expressed in number and percentage. Tests for trends across categories were assessed by chi-squared tests according to the distribution of the data. Analyses were conducted using R statistical software (version 4.0.3).

RESULTS

At the end of the data collection period, we ended with a database of 4,958 responses. Seventy eight students refused to participate and 71 were eliminated for incomplete data. Therefore, the present study evaluated 4,809 completed the survey correctly, which represents 96.9% of the total database.

Sociodemographic characteristics of the studied population are shown in **Table 1**. Briefly, the participants' mean age was 22.4 ± 4.3 years and were mainly females (73.7%) The percentage of men who follow a western diet pattern were slightly higher than others dietary patters. Most responses came from students in Mexico, Ecuador, and Costa Rica. The majority of the responses were obtained from health science students (63.7%). Most of them follow a prudent pattern and a lower percentage a western dietary pattern, while most of them lived with people with completed or uncompleted university or higher education. A high percentage have been in lockdown for more than 5 months and were in lockdown when the survey was released. 74.3% were self-reported to follow a prudent diet and 8.8% a plant-based diet. Among them, more than 50% were ovo-dairy-vegetarian. These were mostly from Argentina and Mexico (**Supplementary Table 1**).

A higher probability of following a prudent diet pattern was associated with living in Colombia, studying a health sciences career, being in the fifth or more years of career, and 3–5 months of time in lockdown (**Table 2**).

When analyzing the association between dietary patterns and the achievement of recommendations for healthy food groups, we found that students following a western diet had poor achievement in almost every healthy item. For instance, only 0.7% achieved the recommendation for fruits and vegetables. Meanwhile, this percentage was 15.7% for the self-reported vegetarians. Among this latter group, 75.5% achieved the legumes recommendation in comparison with 43.0% of people following a western diet. The probability of not meeting the recommendation

TABLE 2 | Association between following a prudent diet and socio-demographic characteristics.

Characteristic	OR (95% IC)
Country	
Argentina	Ref.
Chile	1.04 (0.78; 1.40)
Colombia	1.84 (1.29; 2.63)
Costa Rica	1.63 (1.24; 2.14)
Ecuador	1.50 (1.15; 1.97)
Guatemala	1.50 (1.11; 2.04)
Mexico	1.57 (1.23; 2.01)
Panama	1.64 (1.17; 2.29)
Paraguay	1.19 (0.85; 1.66)
Peru	1.65 (1.18; 2.32)
Age	0.97 (0.95; 0.98)
Field of study	
Arts, architecture and design	Ref.
Agricultural and biological sciences	1.20 (0.65; 2.19)
Health sciences	1.68 (0.98; 2.87)
Management and economics sciences	1.34 (0.71; 2.53)
Education, social sciences and humanities	1.06 (0.58; 1.94)
Engineering and exact sciences	1.28 (0.74; 2.21)
Other	1.05 (0.58; 1.90)
Year in course	
First year	Ref.
Second year	1.08 (0.89; 1.31)
Third year	1.25 (1.01; 1.55)
Fourth year	1.28 (1.01; 1.61)
Five or more years	1.45 (1.15; 1.83)
Sex	
Female	Ref.
Masculine	0.93 (0.79; 1.08)
Time in lockdown	
None	Ref
<1 month	1.19 (0.71; 2.02)
1–2 months	0.93 (0.62; 1.40)
3–5 months	1.04 (0.73; 1.47)
More than 5 months	0.98 (0.71; 1.36)

Multivariable logistic regression analyses. The dependent variable was a dummy variable indicating 1 = people with prudent diet vs. 0 = people with other diets (western, plan-based diet and other diets).

of healthy food groups was lower those following a western diet, except for dairy products (**Table 3**). In addition, students following a western diet were more likely to skip breakfast (50.4%) while more than 70% of people with a prudent and plant-based diet reported having this meal and showed a significantly lower probability of dinner and homemade meals consumption.

When plant-based dieters are further analyzed (**Supplementary Table 1**), among participants following a vegetarian diet 48.6 and 21% achieved the recommendations for vegetables and fruit intake, respectively, however, only 15.7% achieved the recommendation of 5 portions of fruits and vegetables altogether. Those students following a vegan diet

TABLE 3 | Achievement of healthy food group recommendations among dietary patterns.

	Fails the recommendation	Achieves the recommendation	OR (95% CI)
Fruits & vegetables			
Prudent diet	3,358 (93.0)	252 (7.0)	1.00 (Ref).
Western diet	550 (99.3)	4 (0.7)	0.10 (0.04; 0.27)
Plant-based diet	361 (84.3)	67 (15.7)	2.32 (1.71; 3.16)
Other diet	259 (97.0)	8 (3.0)	0.41 (0.20; 0.84)
Vegetables			
Prudent diet	2,489 (68.9)	1,121 (31.1)	1.00 (Ref).
Western diet	504 (91.0)	50 (9.0)	0.26 (0.21; 0.31)
Plant-based diet	220 (51.4)	208 (48.6)	1.76 (1.26; 2.46)
Other diet	211 (79.0)	56 (21.0)	0.38 (0.29; 0.50)
Fruits			
Prudent diet	3,214 (89.0)	396 (11.0)	1.00 (Ref).
Western diet	531 (95.8)	23 (4.2)	0.26 (0.21; 0.31)
Plant-based diet	337 (78.7)	91 (21.3)	1.59 (1.23; 2.06)
Other diet	241 (90.3)	26 (9.7)	0.52 (0.40; 0.67)
Dairy			
Prudent diet	2,545 (74.7)	860 (25.3)	1.00 (Ref).
Western diet	410 (78.7)	111 (21.3)	0.83 (0.65; 1.04)
Plant-based diet	310 (77.1)	92 (22.9)	0.72 (0.56; 0.94)
Other diet	204 (80.3)	50 (19.7)	0.76 (0.55; 1.06)
Legumes			
Prudent diet	1,527 (42.3)	2,083 (57.7)	1.00 (Ref).
Western diet	316 (57.0)	238 (43.0)	0.55 (0.45; 0.67)
Plant-based diet	105 (24.5)	323 (75.5)	3.16 (2.46; 4.05)
Other diet	141 (52.8)	126 (47.2)	0.67 (0.52; 0.88)
Fish			
Prudent diet	3,245 (89.9)	365 (10.1)	1.00 (Ref).
Western diet	526 (94.9)	28 (5.1)	0.53 (0.35; 0.79)
Plant-based diet	377 (88.1)	51 (11.9)	1.26 (0.91; 1.76)
Other diet	248 (92.9)	19 (7.1)	0.62 (0.38; 1.01)
Breakfast consumption			
Prudent diet	1,075 (29.8)	2,535 (70.2)	1.00 (Ref).
Western diet	279 (50.4)	275 (49.6)	0.41 (0.34; 0.50)
Plant-based diet	123 (28.7)	305 (71.3)	1.09 (0.86; 1.36)
Other diet	105 (39.3)	162 (60.7)	0.64 (0.50; 0.84)
Dinner consumption			
Prudent diet	2,243 (62.1)	1,367 (37.9)	1.00 (Ref).
Western diet	401 (72.4)	153 (27.6)	0.60 (0.49; 0.74)
Plant-based diet	262 (61.2)	166 (38.8)	1.00 (0.80; 1.24)
Other diet	187 (70.0)	80 (30.0)	0.73 (0.55; 0.97)
Homemade meals			
Prudent diet	966 (26.8)	2,644 (73.2)	1.00 (Ref).
Western diet	194 (35.0)	360 (65.0)	0.69 (0.57; 0.84)
Plant-based diet	149 (34.8)	279 (65.2)	0.69 (0.56; 0.87)
Other diet	83 (31.1)	184 (68.9)	0.86 (0.65; 1.14)
Oat and whole grain			
Prudent diet	1,682 (46.6)	1,928 (53.4)	1.00 (Ref).
Western diet	361 (65.2)	193 (34.8)	0.47 (0.39; 0.57)
Plant-based diet	172 (40.2)	256 (59.8)	1.37 (1.11; 1.69)
Other diet	151 (56.6)	116 (43.4)	0.64 (0.49; 0.83)

TABLE 4 | Achievement of unhealthy food groups recommendations and dietary patterns.

	Fails the recommendation	Achieves the recommendation	OR (95% CI)
Sugar-sweetened beverages			
Prudent diet	2,276 (63.0)	1,334 (37.0)	1.00 (Ref).
Western diet	458 (82.7)	96 (17.3)	0.39 (0.30; 0.49)
Plant-based diet	193 (45.1)	235 (54.9)	2.05 (1.65; 2.53)
Other diet	180 (67.4)	87 (32.6)	0.87 (0.66; 1.14)
Alcohol			
Prudent diet	1,483 (41.1)	2,127 (58.9)	1.00 (Ref).
Western diet	245 (44.2)	309 (55.8)	0.89 (0.74; 1.08)
Plant-based diet	180 (42.1)	248 (57.9)	1.19 (0.96; 1.48)
Other diet	102 (38.2)	165 (61.8)	1.08 (0.83; 1.41)
Added salt			
Prudent diet	3,133 (86.8)	477 (13.2)	1.00 (Ref).
Western diet	453 (81.8)	101 (18.2)	1.45 (1.14; 1.85)
Plant-based diet	360 (84.1)	68 (15.9)	1.26 (0.95; 1.68)
Other diet	220 (82.4)	47 (17.6)	1.31 (0.95; 1.81)
Fast food			
Prudent diet	3,061 (84.8)	549 (15.2)	1.00 (Ref).
Western diet	541 (97.7)	13 (2.3)	0.13 (0.08; 0.23)
Plant-based diet	284 (66.4)	144 (33.6)	2.88 (2.28; 3.63)
Other diet	214 (80.1)	53 (19.9)	1.31 (0.95; 1.81)
Snacks			
Prudent diet	2,871 (79.5)	739 (20.5)	1.00 (Ref).
Western diet	480 (86.6)	74 (13.4)	0.58 (0.45; 0.75)
Plant-based diet	321 (75.0)	107 (25.0)	1.19 (0.94; 1.52)
Other diet	200 (74.9)	67 (25.1)	1.26 (0.94; 1.69)
Fried food			
Prudent diet	2,871 (79.5)	739 (20.5)	1.00 (Ref).
Western diet	480 (86.6)	74 (13.4)	0.28 (0.18; 0.43)
Plant-based diet	321 (75.0)	107 (25.0)	1.99 (1.55; 2.57)
Other diet	200 (74.9)	67 (25.1)	1.12 (0.77; 1.62)

Multivariable logistic regression analyses. The dependent variable was a dummy variable indicating 1 = Achieves the recommendation vs. Fails the recommendation. The model was adjusted by age, gender, country, year in course, and period of lockdown.

were the ones who reached a higher percentage on these three guidelines, and therefore, achieved a higher dietary score.

When the analysis was done by unhealthy items (**Table 4**), most of the students failed to achieve the recommendations. But similar to healthy food groups recommendations, those who followed a Western diet had the lowest probability of achieving the recommendations. And people who follow a plant-based diet had higher proportion of people achieving the recommendations of sugar -sweetened beverages (54.9%), fast food (33.6%), and fried food (25.0%). No differences were found among plant-based diet subcategories (**Supplementary Table 2**).

Finally, When the diet quality was evaluated, the highest score was among vegetarian people (56.09 $\pm$ 6.11). Meanwhile, the lowest was for people who followed a western diet (48.03 $\pm$ 5.99). Indeed, most of the people with a western diet are in the lowest quartile of the diet quality score (**Table 5**).

DISCUSSION

This study aimed to evaluate and compare the diet quality of different dietary patterns in Latin-American college students during COVID lockdown between November and December 2020. In the current study, plant-based dieters, when compared to other students who reported following a prudent or western diets, are in the best diet quality quartiles and only 17% of them are found in the lowest quartile.

Lifestyle choices such as physical activity, smoking, alcohol consumption and dietary habits have been proven to play an important role in maintaining health and preventing diseases. Many health risk behaviors start in adolescence and young adulthood which make this population ideal to work within lifestyle interventions and prevention programs (Kimokoti and Millen, 2016; Sogari et al., 2018; Lanuza et al., 2020; Lee et al., 2020). In particular, college aged students face an important challenge: with increased independence, limited budget and spare time, healthful food choices are hard to make (Sogari et al., 2018; Sprake et al., 2018). College environment and lifestyle in Latin America include late snacking, skipping meals, fast food and alcohol intake during social events which explain why it has been repeatedly shown that there is an important weight gain during the first year of college, and this weight (which includes a fat percentage increase) is maintained throughout the whole university period (Huang et al., 2003; Lacaille et al., 2011; Santos et al., 2017). In fact, epidemiological studies have shown that the greatest weight and fat mass gain happen between 18 and 29 years of age, which include college years (Santos et al., 2017).

In this study, students were asked if they followed a prudent, western or vegetarian (which includes, for this analysis, Ovo-dairy-vegetarian, Fish-vegetarian and vegan) diet.

The results showed that the prudent diet was followed by 74.3% of the total students, and it was the most reported pattern in all the assessed countries. However, when analyzed by food group intake, most of these students fail the dietary recommendation for fruits and vegetables, dairy and fish (**Table 1**). It is important to note that the questionnaire for this study was released at a moment of lockdown due to the COVID-19 pandemic, which means that most students were having the majority of their meals at home. In fact, 73% of the individuals who self-reported a prudent diet achieved the recommendation of eating homemade meals. Similarly, Mueller et al. (2018) found that for college students, eating at home was associated with a higher adherence to this dietary pattern, and a lower prevalence of the western dietary pattern and alcohol consumption (Mueller et al., 2018). Having the opportunity or the need to eat outside their household can lead young adults to make poor health choices such as increasing their consumption of trans and saturated fats, added sugar and alcohol, habits that are more related to the western diet (Lacaille et al., 2011). However, it is important to note that during the COVID-19 emergency lockdown, several detrimental dietary changes have also been observed and reported, for example, the increase in comfort food intake such as sweets and fried foods and the increase of snacking due to anxiety (Di Renzo et al., 2020; Pellegrini et al., 2020; Bennett et al., 2021). This suggests that

TABLE 5 | Dietary score according to different dietary patterns.

	Overall	Prudent diet	Western diet	Plant-based diet	Other diet
N (%)	4,859 (100)	3,610 (74.3)	554 (11.4)	428 (8.8)	267 (5.5)
Total score mean (*SD*)	53.99 ± 6.06	54.81 ± 5.49	48.03 ± 5.99	56.09 ± 6.11	51.86 ± 5.70
Healthy dietary score by quartile *n* (%)					
Q1 Lowest	1,320 (27.2)	780 (21.6)	366 (66.1)	74 (17.3)	100 (37.5)
Q2 Medium Low	1,174 (24.2)	900 (24.9)	110 (19.9)	89 (20.8)	75 (28.1)
Q3 Medium high	1,238 (25.5)	1,018 (28.2)	57 (10.3)	98 (22.9)	65 (24.3)
Q4 Highest	1,127 (23.2)	912 (25.3)	21 (3.8)	167 (39.0)	27 (10.1)

SD, standard deviation.

during the period the survey was applied, eating at home not necessarily meant having a healthier diet.

In the present study, 11.4% of the students reported following this dietary western pattern and as expected, these failed to meet the recommendation for many healthy food groups including fruits and vegetables, dairy, fish and oats, and whole grains. In terms of unhealthy food groups, more than 80% of the western diet students failed to meet the recommendation for salt, sugar-sweetened beverages snacks, and more than 90% the ones for fast or fried foods (**Tables 3**, **4**). This trend is common in university students, for example in the study conducted by Yun et al. (2018) with college students in Brunei, most participants had the habit of snacking and consuming fried food frequently while having a low intake of fruits and vegetables (Yun et al., 2018). In Latin America, a study conducted in Chile reported that healthy foods consumption frequencies recommended by WHO and Chilean dietary guides were not achieved, and high consumption of sugar-sweetened soft drinks, alcohol, fried foods, fast food, and snacks consumption was also identified (Crovetto et al., 2018). Similar findings have also been reported in university students from Argentina (De Piero et al., 2015), Colombia (Vázquez et al., 2014), and Peru (Huamancayo-esp and Perez-c, 2019).

The third dietary pattern analyzed in this study, and reported by 8.8% of the participants was the plant-based diet, which includes ovo-dairy vegetarians, fish-vegetarians and, vegans. These dietary patterns have been receiving special interest recently, for instance, the sales of plant-based alternatives to meat and meat products grew by almost 40% between 2017 and 2019 (Davitt et al., 2021). The reasons and motivators to adopt this dietary pattern vary depending on age group, values and, beliefs; for instance, veganism and vegetarianism were usually adopted for religious reasons, however, nowadays the dietary shift also respond to ethical concerns such as animal rights and welfare, environmental impact, socioeconomic considerations, personal health and fitness concerns (Cramer et al., 2017; Clark et al., 2019; Sakkas et al., 2020; Davitt et al., 2021).

Plant-based diets aim to optimize nutrient-dense food items such as fruits, vegetables, legumes, seeds, and nuts while minimizing the consumption of calory-dense, processed foods, and animal products, although some may include dairy, eggs, and fish to some extent (Tuso et al., 2013; Miki et al., 2020). In the present study, the students who reported following a plant-based diet had the highest percentage of achievement of most of the healthy food group recommendations in comparison to the other dietary patterns (**Table 2**). This was observed for fruits and vegetables, vegetables, fruits, legumes, whole grain, and fish but not for dairy. However, among the same pattern, the recommendations were achieved by the majority of students only for the legumes and oat and whole gran categories, and vegan students were the closest to achieve the recommendations for fruits, vegetables, legumes and oats. This means that even the self-reported vegetarians or vegans failed the recommendation for many healthy food groups, such as fruits and vegetables. Although it is expected that plant-based dieters have a high intake of these food groups, it has been reported that in general, college students do not consume them as they should and in fact, the vast majority of college aged individuals fail to meet the 5 a day intake recommendation (Schroeter and House, 2015; Rodrigues et al., 2019). Alkazemi and Salmean (2021) state that this is due to taste, inconvenience and lack of knowledge on F/V intake recommendations and preparation methods (Alkazemi and Salmean, 2021) while Schroeter and House (2015) include a rising demand for fast, convenient foods and declining cooking skills to the list of intake barriers in this age group (Schroeter and House, 2015).

Regarding the unhealthy items, the plant-based diet group was the only one that achieved the recommendation for sugar sweetened drinks avoidance however, for the other categories such as fast foods, snacks and added salt, plant-based dieters did as poorly as the other groups (**Table 3**), This supports the idea that college aged individuals generally have risk related diet behaviors, independently of the dietary pattern they follow, and also, that some people choose to be vegetarian or vegan for environmental and animal welfare reasons and not always because they are concerned with their health (Vergeer et al., 2020; Davitt et al., 2021; Saintila et al., 2021).

There was a higher percentage of students achieving the recommendations for legumes and oats and whole grain among those following a vegan diet, but as expected, none of the participants following this pattern achieved the recommendations for dairy foods or fish consumption, which could lead to nutritional deficiencies such as calcium and omega-3 fatty acids, specifically eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) (Saunders et al., 2012; Bakaloudi et al., 2021). No differences on following recommendations for breakfast, dinner or homemade meals

consumption were observed when comparing the three plant-based dietary patterns. Regarding unhealthy items a higher percentage of strict-vegetarians achieved the recommendations for sugar-sweetened beverages, added salt, fast food and fried foods, while no differences were observed for alcohol and snacks consumption.

It is important to mention that there is a tendency to replace omnivorous products with plant-based substitutes that can be considered ultra-processed foods (UPFs) which are sources of sodium, saturated and trans fatty acids and refined sugar (Poti et al., 2015). Since vegetarianism and its derivatives imply just the avoidance of meat, dairy or other animal food sources, these UPFs can be highly consumed in plant-based diets, making these patterns not intrinsically healthier, as UPFs have shown to increase the risk of NCDs (Gehring et al., 2021; Jardim et al., 2021; Quinn et al., 2021).

A recent cross-sectional study conducted with French adults found that higher avoidance of animal-based foods was associated with a higher consumption of UPFs. In this study, UPFs contributed with more than 30% of the energy consumed by all participants, which is a reason for concern, however it was higher for self-reported vegans. This trend was also significantly correlated with age, meaning that the younger age commencing the plant-based pattern, the more likely it was for the participants to consume UPFs (Gehring et al., 2021). This could respond to the fact that not everyone who seeks for animal products avoidance gets proper nutritional counseling to do so, which could affect especially younger individuals such as college students, who, as mentioned before, tend to look for convenient, cheap and easy to prepare or even ready to eat goods (Mescoloto et al., 2017; Sogari et al., 2018). As Storz (2018) states, there could be also a lack of commitment in the health care community to engage patients, recommend and fully explain how to make the shift toward a plant-based diet, which usually takes time (Storz, 2018). This age association does not only apply for plant-based diets, as it has been also reported that younger individuals are more particularly associated with UPFs intake, independently of which dietary pattern they follow, as it has more to do with socioeconomic reasons (Julia et al., 2018).

Another reason why plant-based diets are recommended is sustainability. According to the EAT-Lancet Commission on healthy diets, the current dietary trends in combination with the estimated population growth not only implies a sanitary burden, but also a risk for our planet. Food production, transport, storage, cooking, and wastage contribute to greenhouse gas emissions, mineral pollution, and excessive water and land use. Therefore, a healthy diet should not only promote health to individuals but also should guarantee the conservation and rational use of natural resources, which can be obtained by shifting to a dietary pattern that includes most of its calories from plants and plant-based products (Scarborough et al., 2014; Willett et al., 2019). However, as UPFs of plant origin continue to grow, this has to be taken into consideration, as UPFs consumption is also detrimental to the environment. The production of these food items implies substantial use of natural and energetic resources, such as water and fossil fuel. One of the main purposes of UPFs is to create readily available and less perishable products, which means frozen, canned, or ready to eat goods. Under this perspective, although plant-based protein alternatives are less harmful than many meat products, as they produce fewer greenhouse gas emissions, for example (Rippin et al., 2021), this does not mean they are always sustainable. Experts suggest directing more efforts in the minimally processed vegetal choices that already exist, such as legumes, nuts, and seeds (MacDiarmid, 2021; Ohlau et al., 2022).

One of the reasons that health professionals recommend a shift to plant-based diets is the cardiovascular benefits associated with this dietary pattern. Studies have demonstrated that vegetarians have lower risk of cardiovascular disease and cardiovascular disease mortality (Kim et al., 2019; Wang et al., 2021) and show a healthier lipid profile (lower density lipoprotein and total cholesterol) when compared to omnivores (Wang et al., 2015; Rojas Allende et al., 2017; Vinay et al., 2020). However, some authors suggest that these health benefits are more influenced by the fact that usually vegetarians are more health conscious and consume more protective foods such and fruits, vegetables, fiber and antioxidants, rather than the exclusion of animal products like meat and dairy (Parker and Vadiveloo, 2019).

It is important to state that while plant-based diets have been extensively associated with favorable cardiovascular outcomes, it should be highlighted that some plant-derived foods such as refined grains, potatoes, fruit juices, and sugar-sweetened beverages have also been linked to a greater risk of cardiometabolic risk (Satija et al., 2016, 2017; Kim et al., 2021; Wang et al., 2021). In addition, even if these plant-based diets tend to include more healthy food groups, their basis is more about restricting animal products, so if it is not managed properly they can be deficient in energy, protein, omega 3 fatty acids, calcium, iron, and vitamin B-12 (Clarys et al., 2014; Blaurock et al., 2021) which can explain why it can alter some brain functions and be correlated with mental health, such as higher depression scores (Matta et al., 2018; Lee et al., 2021).

It has been shown that changes in dietary patterns can alter both the diversity and function of the gut microbiota, and the adoption of a plant-based diet is not an exception. Vegetarian diets seem to promote higher counts of certain Bacteroidetes compared with omnivores. Dietary fiber and polyphenols encourage the growth of short-chain fatty acids producer species, which improves immunity against pathogens, acts as energy fuel for intestinal cells and, promotes intestinal integrity (Tomova et al., 2019; Sakkas et al., 2020).

Despite the fact that most participants failed to meet most recommendations for both healthy and unhealthy items, when the analysis was performed according to diet score, most of the vegetarians fell in the highest quartile (39%), in comparison to 3.8% from the western diet and 25.3% from the prudent diet. Even though our study provided only a snapshot of dietary habits, our findings are in line with what has been observed in other studies with college students from not Latin American countries. In Germany, a study conducted with 61 female university students compared nutrient intake and nutritional quality between omnivores and vegetarians, reporting a higher score in those who followed a plant-based diet (Blaurock et al.,

2021). Clarys et al. (2014) used the Healthy Eating Index 2010 (HEI-2010) and the Mediterranean Diet Score (MDS) as indicators for diet quality when comparing different dietary patterns in university students from Belgium. The study reported that vegans had the lowest energy intake, better fat profile and, highest dietary fiber consumption than omnivorous and the highest HEI-2010 and MDS. Individuals who followed a non-vegan plant-based diet also obtained a better score than omnivorous students (Clarys et al., 2014). In the context of the pandemic, a French study assessed diet quality during COVID-19 lockdown compared to before, and observed a decreased in nutritional quality of diet due to modification in food choices (Marty et al., 2021). However, not all studies have found a decline in diet quality during the lockdown. Lamarche et al. (2021), reported a slight improvement in diet quality and a reduction of food insecurity in adults from Quebec during COVID-19-related early lock-down, and Di Renzo et al. (2020), reported that the population aged 18–30 years have higher adherence to the Mediterranean diet when compared with other age groups. This same study also observed that 15% of respondents turned to farmers or organic purchasing for fruit and vegetables (Di Renzo et al., 2020; Lamarche et al., 2021).

The major strength of this study is that involved a large population of university students from 10 different countries in Latin America, using the same methodology simultaneously, and provided a wide overview of their eating habits during the COVID-19 lockdown.

Given the nature of the data collection, this study is limited by the fact that a convenience sampling was used, therefore, the findings will not apply beyond the sample or could be extrapolated to other populations. Also, participants self-reported all the information which can lead to bias, misreporting, and misunderstanding of concepts. As a cross-sectional and observational study, it was not possible to assess the changes in dietary habits or patterns before and after the COVID-19 pandemic, which would help to further analyze how the lifestyle changes implied with the lockdown affected college students. More prospective studies of this kind are warranted to ensure proper nutritional handling of future public health emergencies.

CONCLUSION

This study demonstrated that in general, university students had low diet quality during the COVID-19 lockdown, which was reflected by more than 84% of the overall sample failing to meet the recommendations for fruits and vegetables, fish, added salt, fast food, and fried food.

Nevertheless, total diet quality score was significantly higher for plant-based diet followers, such as vegetarians and vegans, who also tended to better achieve the recommendations than omnivorous students, especially the ones following a western diet. These results add to the body of evidence that young adults, such as college aged students, have unhealthy dietary habits. However, the risk of short or long-term health problems may differ depending on the dietary pattern of each individual. Overall, the findings of this study support the need of developing policies, programs, and behavioral change interventions in order to improve their diet quality, nutritional status and to reduce the risk of health problems in late adulthood. It is also warranted that health professionals get updated on the latest trends regarding plant-based dietary patterns in order to give better nutritional recommendations about how to maintain a healthy but also sustainable diet. Nutritional Guides of different Latin American countries should also include adaptations for these particular populations, given the fact that they are increasing in number. This could guarantee that even young people, such as college students, regardless of what diet pattern they follow or how much time they have to prepare their meals, could make proper food choices, not only for their health and wellbeing, but also for the environment.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Scientific Ethics Committee of the University of the Americas (Chile) number 2020017. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

The data collection for each country was performed equally by each author. The statistical analysis was done by SP-S. The writing of the manuscript was done by AM and GG and was revised by SD-A and LL-D. All authors read and approved the final manuscript.

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SUPPLEMENTARY MATERIAL

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Development of an online food frequency questionnaire and estimation of misreporting of energy intake during the COVID-19 pandemic among young adults in Peru

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Background: The Young Lives longitudinal study switched to remote data collection methods including the adaptation of dietary intake assessment to online modes due to the physical contact restrictions imposed by the COVID-19 pandemic. This study aimed to describe the adaptation process and validation of an online quantitative food frequency questionnaire (FFQ) for Peruvian young adults.

Methods: A previously validated face-to-face FFQ for the adult Peruvian population was adapted to be administered through an online self-administered questionnaire using a multi-stage process. Questionnaire development was informed by experts' opinions and pilot surveys. FFQ validity was assessed by estimating misreporting of energy intake (EI) using the McCrory method, and the FFQ reliability with Cronbach alpha. Logistic regressions were used to examine associations of misreporting with sociodemographic, body mass index (BMI), and physical activity covariates.

Results: The FFQ was completed by 426 Peruvian young adults from urban and rural areas, among whom 31% were classified as misreporters, with most of them (16.2%) overreporting daily EI. Men had a lower risk of under-reporting and a higher risk of over-reporting (OR = 0.28 and 1.89). Participants without a higher education degree had a lower risk of under-reporting and a higher risk

of over-reporting (OR = 2.18 and 0.36, respectively). No major difference in misreporting was found across age groups, areas, studying as the main activity, being physically active or sedentary, or BMI. Results showed good internal reliability for the overall FFQ (Cronbach alpha = 0.82).

Conclusion: Misreporting of EI was mostly explained by education level and sex across participants. Other sociodemographic characteristics, physical activity, sedentary behavior, and BMI did not explain the differences in EI misreporting. The adapted online FFQ proved to be reliable and valid for assessing dietary intakes among Peruvian young adults during the COVID pandemic. Further studies should aim at using and validating innovative dietary intake data collection methods, such as those described, for informing public health policies targeting malnutrition in different contexts after the COVID-19 pandemic.

KEYWORDS

food frequency questionnaire, dietary intakes, questionnaire validation, reliability, young adults, Latin American

Introduction

An unhealthy diet is a major risk factor for non-communicable diseases (NCD), accounting for 11 million deaths (95% uncertainty interval [UI] 10–12) globally in 2017 (1). Measuring dietary intake is key for estimating the associations between diet and chronic diseases (2). There are several dietary assessment methods, including subjective reports and objective observation, open-ended surveys, such as dietary records, and closed-ended surveys, such as food frequency questionnaires (FFQs) (3). The latter is one of the most inexpensive and quickest methods for assessing usual food intakes over an extended period of time, and is extensively used by large-scale epidemiological studies (4). FFQs include a food list and a frequency response section, with the latter varying from open-or-closed-ended frequency responses, and optionally delimiting portion sizes (i.e., semiquantitative FFQ) (5). FFQs are appropriate when having limited resources for recording dietary intakes among a large number of participants (6), but they need to be developed and validated considering the different socioeconomic, cultural, and ethnic differences among the population targeted by the study (7). Even though an FFQ has been validated for the Peruvian population using face-to-face data collection methods (8), the FFQ used in our study has been further adapted to be administered as part of an online survey to estimate young people's dietary intakes in an effective and efficient way during the COVID-19 pandemic.

One of the most prominent errors in dietary assessment is misreporting, which leads to implausible values for energy intakes (EI), occurring in around 30% of the respondents, regardless of the nutritional assessment method (9). Under- and over-reporting can be challenging as it can affect the direction and strength of associations between dietary intakes and health outcomes (10). Misreporting bias can be related to difficulties in recalling and averaging intakes over the long term, social desirability (e.g., reporting healthier foods and excluding unhealthy foods), and social environments characterized by a widespread weight bias (11, 12). Participants' characteristics, including sex, age, and body weight, have also been associated with misreporting in studies conducted in different contexts (13–15). A study including Latin American countries (Argentina, Brazil, Chile, Colombia, Costa Rica, Ecuador, Peru, and Venezuela) identified sex, age, marital status, ethnicity, physical activity level (PAL), and Body Mass Index (BMI) nutritional status as key individual characteristics associated with misreporting of EI (16).

Peru is a middle-income country facing a double burden of malnutrition (DBM) characterized by the persistence of nutritional deficiencies, such as stunting and anemia, and a rapid increase in overweight and obesity rates among the adult population (37 and 21%, respectively) (17), but with dissimilar rates of under- and excess weight according to socioeconomic characteristics and geographical areas within the country (18, 19). During the COVID-19 pandemic, Peru became the country with the highest mortality rate worldwide by April 2022 (20). The lockdowns and reduced economic activity led to an increased food insecurity, especially among those from deprived backgrounds previous to the pandemic (21, 22). The rapid shifts in the DBM in Peru, with an increasingly overweight and obese adult population (23), makes it imperative to understand the dietary patterns of young adults by using a valid and reliable nutritional assessment method for this particular age group.

This study is a part of the Young Lives Study (YLS), known as "Niños del Milenio" in Peru, a longitudinal study tracking the livelihood of 12,000 children in four countries (Ethiopia, India (Andhra Pradesh and Telangana), Peru, and Vietnam) since 2002—a younger cohort born in 2001–2002, and an older cohort born in 1994–1995. In Peru, these cohorts were originally composed of 2,052 and 714 participants, respectively. In 2020, YLS planned to conduct the 6th visit to both cohorts when the subjects were aged 18–19 and 25–26 years (respectively). However, the COVID-19 pandemic imposed mobility restrictions and social distancing measures that made it impossible to collect data through face-to-face modes, and therefore, the YLS adapted its data collection mode to phone interviews and online self-administered questionnaires.

Hence, this study aims to describe the multi-stage process used to adapt a previously validated face-to-face FFQ of an online self-administered FFQ for young adults in Peru during the pandemic, including the selection of the food items, portion sizes, and food frequency response options. Furthermore, it aims at validating the FFQ by estimating the proportion and characteristics of misreporting of EI in this population and assessing the internal reliability of the online FFQ using Cronbach's alpha test. Findings from this study are expected to inform the measurement of usual dietary intake in the YLS cohort in Peru. In addition, the tool designed can be a good alternative to develop nutritional studies with large coverage at a low cost in the context of developing countries.

Materials and methods

Study participants

We analyzed data of 504 participants of the pilot study that was conducted in July 2021 to validate the online FFQ to be used as a dietary intake instrument for further YLS data collections. A convenience sample with similar characteristics as the ones from the YLS's younger cohort (including the region of residence, aged 18–27 years, and a balanced distribution of sex) was invited to participate in the pilot study. For practical reasons, only participants with access to the internet and a computer or smartphone were invited to participate. Pregnant or breastfeeding women were excluded. Of the total sample, we excluded 78 participants for not responding or providing incomplete data either in the online FFQ and/or for height/weight measures, resulting in 426 participants (**Figure 1**). As part of the pilot study, participants were interviewed by phone and asked to self-report their weight and height, sociodemographic characteristics, and physical activity. After that, they were invited to complete an online survey *via* which the FFQ was administered.

Development of the online food frequency questionnaire

As is shown in **Figure 2**, the online FFQ was developed following a multi-stage process that included:

Designing a face-to-face food frequency questionnaire

We adapted a previously validated semi-quantitative FFQ that was developed to measure the dietary intake in children and adolescents in Lima, Peru (8). Briefly, this instrument was validated using three 24-h dietary recalls. The age-adjusted correlation coefficient between the FFQ and the mean of the 24-h dietary recalls was 0.33, a value considered as an acceptable validity (0.20–0.60) (24). This original FFQ was adapted for young adults based on the expert opinion of the YLS health researchers, a process led by a nutritionist specialized in the measurement of dietary intake from the Research Institute of Nutrition in Peru (IIN by its initials in Spanish in *Peru)*. Considering the aim of the YLS to estimate dietary EI using a comprehensive list of foods in a time-restricted period of application including another set of questions that could prompt the participant's fatigue, the new adapted FFQ included the expert's recommendation resulting in: **(i)** a reduced number of food items from 127 to 95 food items where the food items that are not commonly consumed by young adults were excluded as well as the food items with multiple presentations such as different kinds or brands of milk; **(ii)** delimiting nine closed frequency options (never, < 1 per month, 1 per week, 2–4 per week, 5–6 per week, 1 per day, 2–3 per day, and 4–5 per day) over the last 12 months to four open frequency options; and (**iii**) the addition of the option "quantity" and the inclusion of portion size photos for guiding the participants, which allow us to have a better approximation of the portions consumed by the study population.

Piloting the new face-to-face food frequency questionnaire version

The newly adapted version was piloted in a convenience sample of 225 participants aged 14–19 from two sites located in the southern part of the region of Lima (urban neighborhoods in the Cañete district located in the coastal area, and rural towns in the Yauyos province located in the highlands area). The face-to-face pilot study was conducted in 2019 to evaluate the participant's comprehension and to observe the overall application process of the adapted FFQ. Trained YLS interviewers administered the adapted FFQ using the portion-size photos. The pilot study data was analyzed, and changes were included in the adapted version resulting in a new version with 99 food items, 7 semi-open frequency options (never, 1 per month, 2–3 per month, 1 per week, 2–4 per week, 5–6 per week, and daily), and a reference quantity for portion sizes and number of portions. The additional food

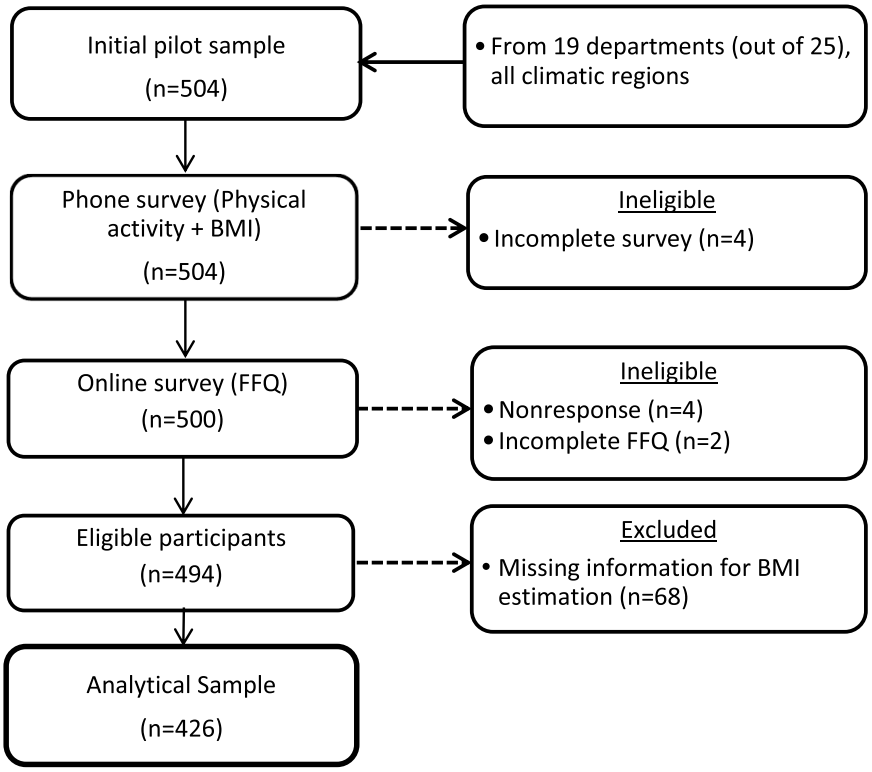

FIGURE 1
Flow chart showing the selection criteria for the identification of the analytical sample.

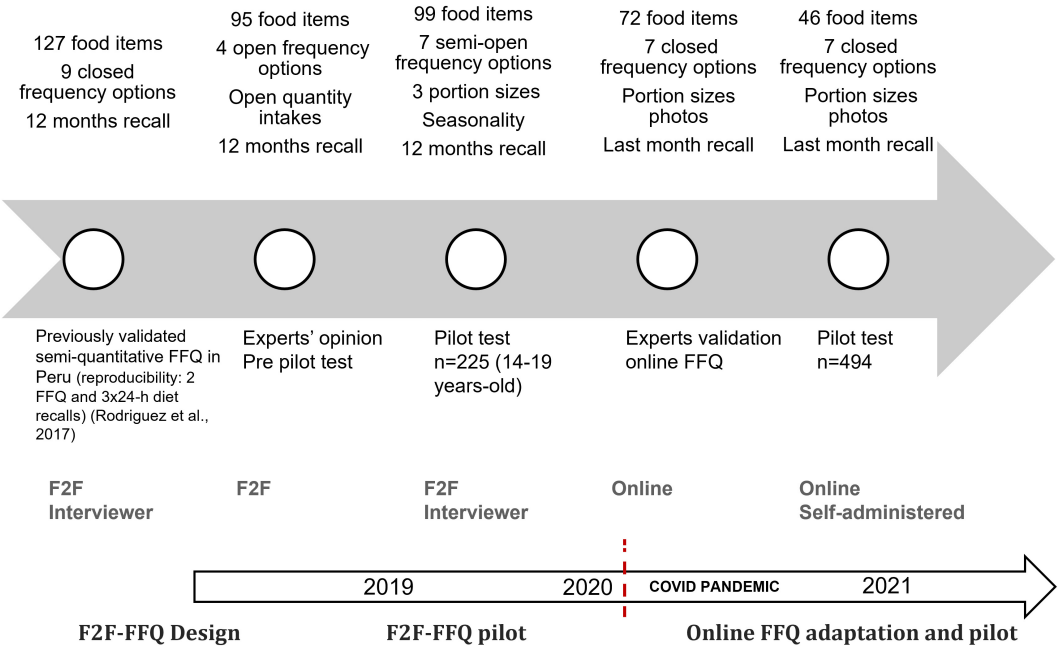

FIGURE 2
FFQ development processes. F2F, face-to-face; FFQ, food frequency questionnaire.

items were excluded due to the low frequency of intake and different food presentations. For instance, around 92–99% have never consumed fresh skim milk, evaporated skim milk, "light" versions of products, such as sodas and yogurt, and hard cheese. In addition, the period for recalling food intake with the FFQ was reduced to the last month instead of the last 12 months because this facilitated the understanding and recall of the participants.

Adapting process from a face-to-face to an online food frequency questionnaire

As aforementioned, the COVID-19 pandemic made it impossible to conduct face-to-face fieldwork, so the YLS adapted its data collection methods for phone and online assessments; designing a new survey to measure the impact of the pandemic on both cohorts (25) and retaining the FFQ. Therefore, the adapted and piloted face-to-face FFQ was re-adapted for an online self-administered mode. This adaptation was performed by a panel of experts composed of two specialized nutritionists from the IIN, and a technical team to develop a digital software to assess dietary intake. To facilitate the comprehension and use of the self-administered online FFQ, it included specific instructions with examples at the beginning of the FFQ. In addition, questions about the frequency, portion sizes, and quantity of portion sizes were modified to be self-administered, and photos of the portion sizes for food items that are more difficult to identify were included. Furthermore, a help button that offers a simple explanation and examples was also included in the online FFQ.

The online self-administered FFQ was designed by a web developer who contributed to present a user-friendly FFQ layout that could be undertaken on small screens such as mobile phones. The online FFQ required access to the internet to fill it out. The final online FFQ was tested multiple times by the YLS research team of experienced interviewers to assure its functionality. Following this process, we reduced the number of food items from 72 to 46 to minimize the questionnaire self-application time considering that most of the participants would answer using mobile devices. We excluded food items based on the low frequency of consumption or merged them within the same group (e.g., Individual fruits were grouped according to the similarities in the nutritional content). We tested this new online version in the pilot study and the results are presented in this paper.

Variables

Dietary assessment

We assessed the dietary intake by analyzing the data obtained from the online FFQ applied in the pilot study. We estimated the usual frequency of specific food intake during the last month and estimated the nutrient intake (energy, carbohydrate, protein, fat, iron, calcium, and fiber intake). The online FFQ was self-administered by each participant accessing the online platform. Participants were asked to recall the frequency and number of portions consumed during the last month, as well as the number of portions consumed on each occasion that they were eaten. For estimations of the quantity consumed per day, the number of days was multiplied by the number of times per day that the food item was consumed in the last month. For the estimation of the nutrient intake, a specific nutrient composition for each food item of the online FFQ was constructed based on the food composition database built with data from the *IIN, Lima-Peru*, which has information from local foods; the Peruvian food composition table of the National Center for Food and Nutrition of Peru (CENAN) and a Latin-American food composition table.

Body mass index

Body mass index (BMI) was used as an indicator of nutritional status that is calculated by dividing weight in kilograms by the square of height in meters (kg/m^2). The body weight and height were reported in the phone survey used in the pilot study of the online FFQ. The BMI was classified as overweight (BMI $\geq$ 25 and $<$ 30 kg/m^2), obesity (BMI $\geq$ 30 kg/m^2), and underweight (BMI $<$ 18.5 kg/m^2) (26).

Sociodemographic characteristics

Prior to the online survey, through the phone survey, we collected sociodemographic characteristics of each respondent, including sex, age (18–22 and 23–27 years old), geographical area (urban and rural), education level (secondary education or lower and higher than secondary education), and main activity (studying or working).

Validation of the online food frequency questionnaire using the misreporting of energy intake

We estimated the misreporting of EI as a way to validate the online FFQ. Misreporters were identified using the method developed by McCrory et al. (27). One of the most common procedures used for identifying inaccurate reports of EI is the method that was first developed by Goldberg et al. (28), which identifies under-reporters (U-R), over-reporters (O-R), and plausible reporters (P-R) of EI. This method estimates a confidence interval (CI) for the level of agreement between PAL and the ratio of EI to Basal Metabolic Rate (BMR) based on the coefficients of variation (CV) of subjects' EI (CV^2_{wEI}), BMR (CV^2_{wB}), and PAL (CV^2_{tP}).

Since this first approach, many other procedures have been developed to identify misreporting based on the comparison between EI and Estimated Energy Requirement (EER) using CI and cut-off points. In an attempt to overcome some of the

problems associated with the most classical methods, McCrory et al. (27) developed an alternative approach to the one originally proposed by Goldberg et al. (28). The use of this method will allow us to theoretically eliminate the potential error of assigning inaccurate PALs with only limited information on the activity of individuals under study (27). From the below equation, the SD is calculated from the CV^2_{wEI} over the numbers of days of diet assessment (d), CV^2_{wpTEE} is the CV measuring the total energy expenditure (TEE) by the doubly labeled water method and CV^2_{pTEE} is the CV for predicting the TEE.

$$\pm\ SD\ = \sqrt{\frac{CV^2_{wEI}}{d} + CV^2_{wpTEE} + CV^2_{pTEE}}$$

According to the results of the Latin American Study of Nutrition and Health (ELANS) study for the Peruvian sample, the CV^2_{wEI} is set to 26.18% and based on two 24-h dietary recall (d) (16). CV^2_{wpTEE} use is 8.2% from the estimations of Black (29) and CV^2_{pTEE} 31.2% according to results of Vinken et al. (30). From the above formula, it is possible to calculate the ± 2 SD for the agreement between of the reported EI and the predicting TEE.

Assessment of reliability of the online food frequency questionnaire

The reliability of the FFQ was assessed by estimating the internal consistency reliability of the overall FFQ, which included 14 different food groups, and within food groups. For this purpose, we used Cronbach's alpha, a widely used statistic for estimating the internal consistency of items within a scale (31, 32). Previous studies have used Cronbach's alpha for estimating the FFQ internal consistency reliability (33, 34).

Ethics

The YLS in Peru has been approved by the ethical board of the *Instituto de Investigación Nutricional*, IIN (180-2002/CEI-IIN) and by the Oxford Department of International Development (SSD/CUREC2/07-026). Subsequently, each new survey round has received approval from these departments. All participants were informed in each of the data collection phases and gave consent to participate in the study. Approval for the data under analysis was obtained from the IIN Ethical Board in June 2021 (157-2021/CIEI-IIN).

Statistical analysis

For discrete variables, a Chi-squared test is applied to evidence differences among the U-R and O-R groups in the characteristics of the participants (Table 1). Similarly, the Kruskal-Wallis illustrated differences among misreporting groups for the total energy and nutrient intake (Tables 2, 3). Logistic regressions reporting odds ratio (OR), p-value, and 95% confidence intervals (CI) were used to assess the risk of being classified as an over-reporter, compared to a plausible reporter, according to the McCrory method (Table 4). All analyses were carried out using the STATA software (version 16.1; College Station, TX: StataCorp LLC). $p < 0.05$ was considered statistically significant.

Internal consistency reliability of the online FFQ was assessed with Cronbach's alpha. Before conducting the analysis, the food intake values were log-normalized to avoid any possible disturbance due to non-normal distributions (35, 36).

Results

The pilot test that was conducted in 2021 *via* phone and online modes included 426 participants (analytical sample) from 19 different departments and from the three climatic regions in Peru (Table 1). About 69% of the participants were classified as P-R, 16.2% as O-R, and the remaining as U-R. The sample was sex- and age-group balanced, representing nearly 50% for each category. Among men, 72% of them were classified as P-R, while this share scales up to 66% among women. In addition, 21% of the men were identified as O-R and 22% of the women as U-R. Furthermore, 68% of participants aged 18–22 years old were classified as P-R, and 19% as O-R, whereas among 23–27 years old, 18% were classified as U-R. Regarding the area of residence, 88% of the participants lived in urban areas, and 70 and 65% of those living in urban and rural areas were classified as P-R, respectively. Likewise, 43, 33, and 24% of participants lived in the coast, highlands, and jungle regions, respectively, with 70, 72, and 63% of participants from each region assigned as P-R, respectively. The jungle region concentrated a higher proportion of O-R (24%). With respect to education, only 23% of the participants have completed a higher education (HE) degree (vocational or university), among those, 66% are classified as P-R, yet 26% were classified as U-R, whereas 19% of those from the lower education level were identified as O-R. Furthermore, 67% were studying as a primary activity, and 72% were classified as P-R. Regarding the participant's nutritional status and physical activity, 61% were classified as normal weight, while 30% were classified as overweight, and 6% as with obesity. No major differences among P-R were found according to the nutritional status categories, reaching around 70% among all the participants. Small differences suggesting a lower U-R and higher O-R among participants with obesity were identified, when compared to their normal weight counterparts. Additionally, 34% of the participants were sedentary, 74% were non-active, and 72 and 64% were identified as P-R, respectively.

TABLE 1 Characteristics of the participants stratified by misreporting status.

	All sample		Plausible reporters (P-R)	Under-reporters (U-R)	Over-reporters (O-R)	Chi2 *P*-value	
	Mean/% (*N*)	*SD*	Mean/%	Mean/%	Mean/%	U-R	O-R
Total	100 (426)	–	69.0	14.8	16.2	–	–
Sex							
Men	50.2 (214)	0.4	72.0	7.5	20.6	0.000	0.014
Women	49.7 (212)	0.3	66.0	22.2	11.8		
Age group							
18–22 years-old	59.9 (255)	0.4	68.2	12.9	18.8	0.190	0.072
23–27 years-old	40.1 (171)	0.4	70.2	17.5	12.3		
Area of residence							
Rural	12.0 (51)	0.3	64.7	21.6	13.7	0.146	0.610
Urban	88.0 (373)	0.4	69.6	13.9	16.5		
Climatic region							
Coast	42.72 (182)	0.4	70.3	14.3	15.4	0.839	0.050
Highlands	33.3 (142)	0.3	71.8	16.2	12.0		
Jungle	23.9 (102)	0.4	62.7	13.7	23.5		
Education							
Secondary education or lower	77.2 (97)	0.4	69.9	11.6	18.5	0.001	0.016
Higher than secondary education	22.8 (329)	0.3	66.0	25.8	8.2		
Studying as a primary activity							
No	32.9 (140)	0.4	62.9	19.3	17.9	0.067	0.515
Yes	67.1 (286)	0.4	72.0	12.6	15.4		
Nutritional status (BMI category)							
Underweight	3.3 (14)	0.4	71.4	14.3	14.3		
Normal	60.8 (259)	0.4	68.3	15.8	15.8	0.887	0.969
Overweight	29.8 (127)	0.4	70.1	13.4	16.5		
Obese	6.1 (26)	0.5	69.2	11.5	19.2		
Sedentary							
No	66.2 (282)	0.4	67.7	14.9	17.4	0.932	0.355
Yes	33.8 (144)	0.4	71.5	14.6	13.9		
Active							
No	74.2 (316)	0.4	70.9	13.9	15.2	0.394	0.339
Yes	25.8 (110)	0.4	63.6	17.3	19.1		

Higher than secondary education includes university (undergraduate and postgraduate studies) as well as non-university education (vocational and technical training); Sedentary: spends more than 4 h in a seated position; Active: 4 days or more a week doing at least 1 h of active exercise. P-R: Plausible reporters; U-R: Under reporters; O-R: Over reporters; SD: Standard deviation; BMI: Body mass index. The significance among categories was assessed using the Chi-square test for two mean comparisons of proportions and ANOVA with the Bonferroni multiple comparison test for comparison of more than two categories.

Misreporting of EI estimation was conducted by using the McCrory method, with a prevalence of 14.8% of U-R and 16.2% of O-R, respectively. Logistic regressions show the odds ratio (OR) for the risk of being a U-R and O-R compared with a P-R, according to sociodemographic characteristics and nutritional status (Table 4). On the one hand, results show that men have a 72% lower risk of being a U-R, when compared to women. On the other hand, men have an 89% higher risk of being an O-R, when compared to women. Additionally, having a HE degree significantly increases the risks of being an O-R by 1.18 times, when compared to participants with a lower educational level. Furthermore, having a HE degree reduces the risk of being an O-R by 64%, when compared to participants with a lower educational level. Neither the age group (19–22 vs. 23–27), living in urban vs. rural areas, studying as a primary activity nor the nutritional status when contrasted to the normal weight category presented a significant difference in U-R nor O-R.

As shown in Table 2, P-R presented a mean and median total EI of 3,673 and 3,541 kCal/day, respectively, which is significantly higher than 1,632 and 1,713 kCal/day among U-R, and lower than 10,307 and 9,051 kCal/day for O-R. Regarding the relationship between macronutrients and EI, U-R

TABLE 2 Total energy intake and nutrient intake by misreporting status.

	All sample		Plausible reporters (P-R)		Under-reporters (U-R)		Over-reporters (O-R)		Kruskal-wallis H test	
	Mean (*SD*)	Median (P25-P75)	Mean (*SD*)	Median (P25-P75)	Mean (*SD*)	Median (P25P75)	Mean (*SD*)	Median (P25–P75)	PR vs. U-R	PR vs. O-R
Total energy intake (EI)	4445.3 (3300.6)	3596.3 (2452.5–4970.2)	3672.6 (1088.8)	3541.3 (2708.4–4339.6)	1631.8 (295.0)	1712.9 (1443.3–1863.4)	10306.6 (4243.3)	9051.3 (8045.8–10236.4))	0.00	0.00
Carbohydrate (% EI)	59.0 (9.7)	59.1 (52.6–65.6)	59.2 (9.2)	59.3 (53.2–65.4)	60.7 (10.1)	60.0 (55.9–68.9)	56.6 (11.0)	57.7 (48.6–63.6)	0.00	0.00
Carbohydrate (g)	646.8 (491.6)	520.1 (358.1–756.3)	541.3 (175.6)	516.3 (406.1–655.7)	248.4 (63.6)	253.4 (196.1–288.2)	1460.2 (709.4)	1287.0 (1031.6–1511.2)	0.00	0.00
Protein (% EI)	17.5 (3.5)	17.2 (15.1–19.5)	17.5 (3.4)	17.3 (15.1–19.4)	18.4 (3.8)	18.4 (15.6–20.8)	16.8 (3.6)	16.4 (14.9–18.3)	0.00	0.00
Protein (g)	192.3 (149.2)	154.1 (105.9–220.9)	160.4 (56.5)	153.4 (114.2–189.8)	74.3 (17.4)	73.6 (62.0–84.0)	436.0 (217.2)	382.1 (326.1–437.0)	0.00	0.00
Total fat (% EI)	24.3 (6.4)	23.9 (19.7–28.2)	24.1 (5.9)	23.9 (20.0–28.0)	22.9 (6.7)	22.3 (17.3–26.4)	26.3 (7.6)	25.7 (21.4–31.7)	0.00	0.00
Total fat (g)	123.4 (106.4)	90.9 (62.7–145.9)	99.1 (41.1)	90.5 (70.4–116.8)	41.5 (14.0)	42.9 (29.6–50.9)	302.1 (148.1)	263.2 (207.6–342.2)	0.00	0.00
Iron (mg)	36.7 (30.2)	29.2 (20.4–41.9)	30.8 (10.7)	29.1 (23.4–36.7)	14.6 (3.1)	14.8 (11.5–17.1)	81.6 (50.3)	67.2 (58.0–80.7)	0.00	0.00
Calcium (mg)	1288.9 (1301.2)	940.1 (618.2–1450.9)	1036.4 (481.8)	935.9 (696.5–1248.9)	437.9 (160.5)	410.8 (323.4–530.8)	3141.8 (2253.0)	2407.8 (1834.4–3513.7)	0.00	0.00
Fiber (g)	21.6 (20.4)	15.8 (11.1–25.2)	17.3 (7.7)	15.7 (12.2–21.8)	8.0 (3.5)	7.5 (5.9–9.6)	52.2 (33.6)	41.6 (32.7–56.9)	0.00	0.00

EI, Energy Intake; g, grams; mg, milligrams; SD, Standard deviation; P-R, Plausible reporters; U-R, Under reporters; O-R, Over reporters.

TABLE 3 Food groups contribution to total energy intake by misreporting status.

	All sample		Plausible reporters (P-R)		Under-reporters (U-R)		Over-reporters (O-R)		Kruskal-wallis H test	
	Mean (*SD*)	Median (P25-P75)	Mean (*SD*)	Median (P25-P75)	Mean (*SD*)	Median (P25-P75)	Mean (*SD*)	Median (P25-P75)	PR vs. U-R	PR vs. O-R
Group 1: Cereals	21.6 (11.5)	19.1 (13.5–28.9)	22.0 (11.2)	19.4 (13.9–28.9)	26.5 (13.1)	26.3 (15.9–34.9)	15.4 (8.3)	13.9 (9.1–19.6)	0.00	0.00
Group 2: Whole grains	1.5 (2.7)	0.6 (0.2–1.6)	1.6 (3.0)	0.6 (0.2–1.6)	1.0 (1.2)	0.5 (0.2–1.3)	1.4 (2.6)	0.8 (0.2–1.7)	0.27	0.71
Group 3: Starchy	14.2 (9.3)	12.5 (7.2–18.8)	14.3 (9.0)	13.1 (7.2–19.7)	14.6 (10.9)	11.1 (7.5–20.8)	13.6 (9.1)	11.0 (7.2–17.4)	0.52	0.18
Group 4: Stew/menestras (vegetables)	4.9 (5.1)	3.3 (1.6–5.9)	5.0 (5.1)	3.4 (1.6–6.2)	5.1 (4.6)	3.6 (1.7–8.1)	4.3 (5.6)	2.9 (1.4–5.0)	0.34	0.01
Group 5: Nuts and seeds	0.7 (1.8)	0.2 (0.0–0.6)	0.7 (1.9)	0.2 (0.0–0.5)	0.7 (1.2)	0.3 (0.0–0.9)	0.7 (1.5)	0.2 (0.0–0.4)	0.23	0.79
Group 6: Dairy	5.5 (4.8)	4.3 (2.2–7.3)	5.6 (4.6)	4.3 (2.4–7.4)	4.8 (4.2)	4.0 (1.6–7.1)	6.0 (6.2)	4.1 (2.0–8.3)	0.00	0.95
Group 7: Animal protein	13.9 (7.4)	12.7 (8.7–17.4)	13.9 (7.3)	12.8 (8.3–18.0)	13.7 (8.2)	12.3 (8.5–17.2)	13.6 (6.8)	12.6 (10.1–17.0)	0.26	0.73
Group 8: Seafood	2.6 (2.6)	1.8 (1.0–3.3)	2.4 (2.3)	1.6 (0.9–3.0)	3.0 (2.9)	2.1 (1.2–3.6)	3.0 (3.0)	2.0 (1.0–4.1)	0.01	0.11
Group 9: Vegetables	2.8 (3.4)	1.9 (1.0–3.6)	2.6 (2.4)	1.8 (1.0–3.3)	3.3 (3.3)	2.8 (1.1–4.7)	3.4 (5.9)	1.9 (1.0–3.6)	0.00	0.44
Group 10: Fruits	8.0 (5.9)	6.7 (3.7–10.3)	7.7 (5.4)	6.5 (3.5–10.1)	8.0 (6.2)	6.6 (3.8–10.0)	9.5 (7.4)	7.0 (4.4–12.5)	0.57	0.00
Group 11: Refined cereals	5.1 (4.7)	3.9 (1.9–6.8)	4.7 (4.0)	3.8 (1.8–6.5)	4.1 (3.2)	3.2 (1.8–5.8)	7.7 (7.1)	5.3 (2.7–11.8)	0.00	0.00
Group 12: Added fats	10.7 (7.2)	9.3 (5.0–14.8)	10.8 (6.9)	9.5 (5.4–14.9)	8.9 (7.5)	6.1 (3.4–11.5)	11.9 (7.8)	10.6 (5.8–16.2)	0.00	0.00
Group 13: Added sugars	6.6 (5.5)	5.4 (2.7–8.8)	6.9 (5.3)	5.8 (3.2–9.0)	5.4 (4.4)	4.3 (2.1–8.0)	6.4 (6.8)	4.7 (2.1–9.0)	0.00	0.00

SD, Standard deviation; P-R, Plausible reporters; U-R, Under reporters; O-R, Over reporters.

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TABLE 4 Association of sociodemographic factors with misreporting status.

Socio demographic factors	Under-reporters (U-R)			Over-reporters (O-R)		
	Odds ratio	95% CI	$P > \|z\|$	Odds ratio	95% CI	$P > \|z\|$
Sex (ref. Women)						
Men	0.28	[0.13; 0.62]	0.00	1.89	[1.09; 3.28]	0.02
	(0.11)			(0.53)		
Age group (ref. Younger Cohort)						
Older cohort (23–27)	1.15	[0.65; 2.05]	0.63	0.62	[0.34; 1.15]	0.13
	(0.34)			(0.20)		
Residence area (ref. Rural)						
Urban	0.62	[0.31; 1.25]	0.18	1.18	[0.66; 2.14]	0.58
	(0.22)			(0.36)		
Educational level (ref. Secondary education or lower)						
Higher than secondary education	2.18	[0.94; 5.07]	0.07	0.36	[0.18; 0.70]	0.00
	(0.94)			(0.12)		
Studying status (ref. Not studying)						
Study: Yes	0.80	[0.41; 1.55]	0.51	0.54	[0.26; 1.13]	0.10
	(0.27)			(0.20)		
Nutritional status (BMI category) (ref. Normal weight)						
Underweight	0.84	[0.17; 4.18]	0.84	1.03	[0.24; 4.49]	0.97
	(0.69)			(0.77)		
Overweight	0.84	[0.47; 1.48]	0.54	1.14	[0.61; 2.13]	0.67
	(0.24)			(0.36)		
Obese	0.61	[0.13; 2.85]	0.53	1.44	[0.46; 4.52]	0.53
	(0.48)			(0.84)		

Robust standard errors in parentheses. OR U-R, U-R vs. PR+O-R; OR O-R, O-R vs. PR+U-R. P-R, Plausible reporters; U-R, Under reporters; O-R, Over reporters; CI, Confidence intervals; ref., Reference category.

has a relatively higher % of total EI from carbohydrates and protein, whereas O-R has a relatively higher % for total fat intake. When comparing the food group's contribution to total EI to P-R, U-R presented a significantly higher contribution from cereals and vegetables, and a lower relative contribution from dairy products, refined cereals, added fats, and added sugars (**Table 3**). Meanwhile, O-R showed a relatively higher contribution from fruits, refined cereals, added fats, and added sugars, and a lower contribution from cereals, stews and added sugars, when compared to P-R. Overall, the piloted FFQ shows good internal consistency with a Cronbach's alpha of 0.82 for food groups (**Supplementary Table 1**), which is higher than the recommended 0.7 threshold (31, 32). The exclusion of individual food groups varies the total Cronbach's alpha from 0.801 (refined cereals) to 0.819 (whole grains), supporting the FFQ reliability for measuring dietary intakes. Three food groups (cereals, starchy, and stews) present insufficient internal consistency with Cronbach's alpha values ranging from 0.26 to 0.54. Exclusion of individual items was found to improve their food group Cronbach's alpha, mainly due to its low-frequency intake (**Supplementary Table 2**).

Discussion

Our study aims at adapting, developing, and validating a self-assessed online FFQ administered during the COVID pandemic to younger adults (18–27 years old) in Peru. It describes a detailed account of the multi-stage process for adapting a previously validated face-to-face FFQ to an online self-administered dietary intake questionnaire. Together with the analysis of the misreporting of EI and its associated characteristics, we have assessed the reliability by measuring the internal consistency of the FFQ and its food groups. While previous studies have assessed misreporting of EI within Latin-American countries (16), to our knowledge, this is the first study assessing misreporting of EI and its related characteristics together with estimating the internal consistency of a self-administered online FFQ.

Our study (n = 426) reported that 14.8 and 16.2% of the participants can be classified as U-R and O-R, respectively, with mean total EI values of 1,632 and 10,307 kCal/day (SD U-R = 295; 4,243). Our results were similar to those from the ELANS study including adults from eight Latin-American countries (N = 9,218), which reported 12.1% U-R and 14.1% O-R with means for total EI of 5,570 and 11,567 kCal, respectively (SD = 1,429 and 2,828, respectively). A study including US adults based on data from NHANES 2003–2012 (N = 19,396) reported 25.1% U-R and only 1.4% O-R (37). While a study in the US children and adolescents aged 2–19 years (N = 14,044) reported 13.1% U-R and 5.4% O-R (38), and a study in post-pubertal Brazilian adolescents (N = 96; mean age = 16.6) reported 64.6% U-R and 1% O-R (39), an Australian study from the Childhood Determinants of Adult Health Study (CDAH) including adults aged 26–36 years-old (N = 1,919) reported 28.6% U-R and 6.1% O-R (40). The larger variation in the prevalence of misreporting in comparison with previous studies from diverse contexts can be attributed to differences in the dietary intake assessment methods and cutoff values for delimiting misreporting used by different studies. Our

study assessed dietary intake with a semi-quantitative FFQ and estimated misreporting by using the McCrory method (± 2 SD). The ELANS study assessed two non-consecutive 24-h dietary recalls (24HR) and used the McCrory method with a cutoff value of ± 1.5 SD based on pTEE (16). Moreover, the NHANES study used two 24-h dietary recall for each of the seven rounds included in the analysis and used the Goldberg method with a cutoff value of ± 2 SD of the ratio of EI to BMR [Murakami and Livingstone (37)]. The Australian CDAH study assessed EI using a qualitative FFQ and estimated misreporting by using the Goldberg method (± 2 SD) and the predicted total energy expenditure method (± 1.5 *SD*) (40).

Higher misreporting of EI in our study is associated with sex and education, with women and higher educated participants at higher risk of U-R, and men and low-educated participants for O-R. These findings are consistent with previous studies in Latin American countries (16). In contrast, a study in the US adults presented higher risks of O-R among men and underweight participants, whereas older adults, low-educated participants with lower family poverty income ratio, and participants with overweight and obesity were at higher risk for both, U-R and O-R (37). Meanwhile, among US children and adolescents, the risk of being O-R was related to a lower family poverty income ratio and younger age children (2–5 years old) (38). Our findings suggesting a higher risk of U-R among women and O-R among men are similar to several studies, thereby providing evidence for the association between misreporting and sex, regardless of their age and other characteristics (16, 37, 41, 42). The reasons underpinning these sex differences can relate to the higher social desirability regarding EI among women, who tend to underreport more to match dietary guidelines and media messages regarding healthy eating (13). Additionally, women across the globe encounter different sociocultural pressures toward thin and slender body ideals that are imposed by western media (43). These body ideals are introduced from developed to developing countries by colonial and social class differentiation processes that are based on racial and body type ideals that do not necessarily reflect the perceived ideals for Peruvian or Latin American women (44, 45). As obesity rates among women from developed and developing countries are increasing at a speedy rate (46, 47), matching the thin body ideals becomes an impossible goal to achieve (48). Therefore, the social desirability of thinness may contribute to the underreporting of EI among women found in our study. In contrast, the reasons behind the relatively higher risk of men for O-R are not clear and require further investigation.

Our results have underpinned a significant negative association between education level and misreporting, consistent with several studies suggesting a higher risk of U-R among the higher educated, and higher O-R among the low-educated participants (16, 37). However, other associated variables assessing socioeconomic position (SEP), including education, income, and occupation (49, 50), have also been related to misreporting (41). For example, the ELANS study reported a higher risk of U-R among the low-educated participants but a higher O-R among those from the lower SEP (16). The NHANES study reported a higher risk of O-R among the higher family income-poverty ratio compared to children and adults from the lower family income-poverty ratio (37, 38). On the one hand, one of the main explanations given by the literature for the higher risk of misreporting among those from the lower SEP is the relative poorer literacy skills among this group, which could impact the questionnaire's comprehension and the relative higher social desirability due to a higher health or diet consciousness leading to under-reporting or report plausible values among better-off socioeconomic groups (41). Despite the fact most of the participants in our study had completed secondary education, international standardized tests have concluded that Peruvians aged 25–65 years with secondary education or below have the lowest scores for reading comprehension and mathematics among a group of Latin American countries (51). Therefore, this underperformance in key competences among the lowest educated could have impacted the FFQ comprehension. Moreover, education has also been related to social desirability of self-reported dietary intakes, with the higher educated under-reporting and reporting plausible EI more than their lower educated counterparts (13).

Previous studies including adults and children from different regions have highlighted the association between misreporting of EI and specific anthropometric and socio-demographic characteristics, including high BMI, being a woman, and having a low education level (13, 42). Our findings did not encounter significant differences between nutritional status nor physical activity or sedentary behaviors and the risk of misreporting, yet several studies have reported differences in misreporting according to these characteristics. Latin American individuals with overweight and obesity have been identified as having a greater risk of U-R, whereas underweight of O-R (16). The underlying reasoning for misreporting among the more extreme BMI categories can be related to the stigma these populations experience (52). As such, individuals deviant from the normal weight category can have their body image affected and be more prone to respond to what is considered to be socially desirable (13, 53). Other sources of misreporting of EI can be due to unconscious incomplete recordkeeping (e.g., due to omission of eating occasion/item, memory fatigue, portion size misrepresentation) or conscious misreporting (e.g., due to social desirability) (13). Despite all nutritional surveys being prone to a certain degree of misreporting (16), identifying the characteristics related to this phenomenon can offer insights for developing mitigation strategies to minimize the systematic bias among the participants of similar age groups and contexts.

The second aim of this study was to assess the reliability of the FFQ among a younger adult Peruvian population during the COVID-19 pandemic. Results suggest good reliability, measured as internal consistency of this FFQ (Cronbach's

alpha = 0.82) (32, 54). When assessing internal consistency within food groups, only three out of the fourteen food groups presented poor internal consistency (Cronbach's alpha < 0.50) (31). Several reasons could explain the relatively lower internal consistency among these three food groups, including the smaller number of items in certain food groups (e.g., stews), and the high heterogeneous intake of food items within food groups (e.g., cereals). Future studies facing changes in their dietary intake data collection methods due to extenuating circumstances should aim at validating their instruments within the context where the study is conducted. Having valid dietary intake instruments can offer valuable insights for assessing and comparing dietary intakes across the population and between different time periods. Additionally, these instruments can provide valuable information about compliance with dietary guidelines, and examine the factors associated with a differential uptake of dietary recommendations at the country and international level using the most updated recommendations for ensuring a healthy and sustainable diet (55–57).

Strengths and limitations

This is the first study, to our knowledge, to assess the validity and reliability of a FFQ applied during the COVID-19 pandemic in a LMIC. Despite the many difficulties in assessing dietary intakes during this period, including the impossibility of conducting face-to-face studies with trained fieldworkers, the YLS managed to adapt its methods to a varied population across different regions of Peru. However, as the FFQ was self-administrated *via* an online survey, there are several limitations to consider. First, online self-administration can challenge technologically unskilled and less educated participants (58). Although web-based users can be easily distracted, studies have shown that online surveys have a higher survey competition rate and are equally reliable compared with paper-based questionnaires (59, 60). Second, self-administered questionnaires reduce the interaction and communication between participant and interviewer, placing a cognitive burden depending on the questionnaire presentation (61). Our study aims at providing clear instructions and memory aids based on the suggestions from expert validation and previous face-to-face pilot, reducing the cognitive burden and respondent fatigue (5). In addition, the inclusion of photos of portion sizes and closed-ended frequency options contribute to reducing the cognitive burden but also minimizes coding time and transcription errors or misinterpretations that might not be able to clarify when responding to a self-administered survey (62). Third, BMI estimations relied on self-reported weight and height, introducing a potential bias due to the tendency for overreporting height and underreporting weight and BMI among individuals with overweight and obesity from different countries across the globe (63, 64). However, studies among younger adults have suggested that despite the relative overestimation of height and underestimation of weight, self-reported data is accurate for nutritional status classification based on BMI (65, 66). Fourth, shifting from interviewer-based to self-administered can affect the participant's answering process due to the method's impersonality and the lack of rapport and control over the order of the questionnaire (61). However, self-administered questionnaires have the advantage of offering a safer space for the disclosure of sensitive behaviors, reducing the risk of misreporting behaviors that are perceived as socially undesirable (67). Several health-related studies comparing interviewer-based and self-administered questionnaires have concluded no differences in data quality between these two administration modes (68–71). Few studies have compared differences in dietary intakes between interviewer-administered and a self-administered questionnaires and have reported different results. Similar findings were reported by a self-administered and an interviewer-administered 24 h recall (72), whereas higher EI misreporting among respondents of a web-based self-administered FFQ when compared to a trained interviewer-based FFQ (73), and small differences in the estimation of nutrients intake between a diet history recall and a self-administrated FFQ not affecting the prediction of disease outcomes (74) have been reported by different studies. Additionally, self-administered web-based FFQs have also proved to be valid when compared to food records and paper-based FFQs (75, 76). Further studies comparing different data collection methods, interviews, and assessment modes for measuring dietary intakes are needed to estimate the validity and reliability of cost-effective and time-saving instruments that can be used when facing mobility and resource restrictions such as the ones endured during the COVID-19 pandemic. Despite the limitations encountered, we believe this online self-administered FFQ was the most reliable option for assessing dietary intakes during the COVID-19 pandemic, offering a less-expensive and valid option for futures studies within the Peruvian population seeking to estimate diet-related outcomes. Based on our experience, reducing the number of food items, without affecting the food group's internal consistency, as well as providing visual aids and clear instructions, can contribute to reducing the possible respondent fatigue and miscomprehension of frequency options behind the group of misreporters of EI.

Conclusion

Our study is the first, to our knowledge, to assess the validity and reliability of an online self-administered

FFQ among a younger-adult population in Peru during the COVID-19 pandemic. We describe the development process for elaborating this FFQ including the selection of food items, portion sizes, and food frequency response options. We classified 31% of the participants as misreporters, with a higher risk of O-R among men and the less educated, and a higher risk of U-R for women and the higher educated. These results are similar to previous studies assessing misreporting of EI, making our FFQ a valid instrument for assessing dietary intakes. Also, our questionnaire proved to have a good internal consistency based on Cronbach alpha, making it a reliable instrument for the context and population under study. Despite quantifying dietary intake as a complex task susceptible to inaccuracies (5), FFQs are still useful for informing dietary guidance and public health policy (12). Therefore, it is key to identify the characteristics associated with misreporting and take advantage of this information for mitigating these biases in future studies assessing dietary intakes across the population. Further research adapting dietary intake data collection methods should aim at validating their instruments to provide trustworthy information for public health researchers and policymakers targeting malnutrition.

Data availability statement

The original contributions presented in this study are included in the article/**Supplementary material**, further inquiries can be directed to the corresponding authors.

Ethics statement

The studies involving human participants were reviewed and approved by the Instituto de Investigación Nutricional, IIN (180-2002/CEI-IIN) and the Oxford Department of International Development (SSD/CUREC2/07-026). Approval for the data under analysis was obtained from the IIN ethical board in June 2021 (157-2021/CIEI-IIN). The patients/participants provided their written informed consent to participate in this study.

Author contributions

KC-Q, AS, and KV designed the research. MV-S, KC-Q, KM-C, and AS designed the methodology for the research. AH-A and NL-B performed the statistical analysis. MV-S, KC-Q, AS, AH-A, and NL-B analyzed and interpreted the data. MV-S led and wrote the draft of the manuscript. KC-Q critically revised and edited the final draft of the manuscript. AH-A, KM-C, NL-B, LA, MF, MP, AS, and KV provided comments, revised the manuscript, and approved the final version. KC-Q and KV confirmed that they had full access to the data in the study and final responsibility for the decision to submit for publication. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fnut.2022.949330/full#supplementary-material

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Food insecurity and its determinants in a vulnerable area of Santiago, Chile

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This study aims to identify the determinants associated to food insecurity in a group of households composed of schoolchildren and their mothers/caregivers, who lived in a low-to-medium community development index area of the city of Santiago, Chile with a high presence of migrant population. The non-probabilistic and convenience sample was made up of 646 people, who answered a series of surveys with the aim of characterizing this group in sociodemographic terms (sex, age, number of inhabitants in the household, place of food purchase, conditional or non-conditional state transfer program beneficiary status, persons in charge of purchasing food for the household, mothers/caregivers education level and basic knowledge of food and nutrition). To assess moderate-to-severe food insecurity and severe food insecurity, the Food Insecurity Experience Scale-FIES was applied between September and October 2021. Logistic regression analysis were used to carry out multivariate analyses, with the use of stepwise back-and-forward strategies for the selected variables and defining $p < 0.05$. These models were adjusted per number of inhabitants in the household. The results indicate that 25.4% of households presented moderate-to-severe food insecurity, and 6.4% severe food insecurity experience. The variables that presented significant odds of risk to food insecurity were being a migrant, low maternal education level, low performance on basic knowledge in nutrition and when the father was responsible for food purchases. Several public policies have been implemented in Chile during the most recent decades aimed at increasing access to healthier foods and the implementation of healthier food environments. Despite this, there are still social and economic health determinants that contribute to the risk of odds insecurity for the most vulnerable groups in the country, thus putting at risk the fulfillment of the human right to adequate food at risk.

KEYWORDS

food insecurity, Chile, migrant, maternal education, public policies, food and nutrition, Food Insecurity Experience Scale

Introduction

During the most recent decades, Chile has stood out among Latin American countries for a sustained growth in its economy, and a decrease in poverty and indigence indicators [Economic Commission for Latin America and the Caribbean (ECLAC), 2022]. The country has achieved great advances to ensure a better health and quality of life for the population. This includes the eradication of primary children undernutrition, the drastic reduction in infant mortality and excellent access to basic sanitation conditions practically throughout the country, giving Chile a Human Development Index that is considered "very high" (0.851 in 2020) [United Nations Development Programme (UNDP), 2020]. Simultaneously, and in line with the epidemiological transition that occurred in the country, overnutrition increased, as well as chronic diseases. Chile is currently one of the countries in the world with the highest prevalence of obesity in children and adults [Organization for Economic Co-operation and Development (OECD), 2019].

As is the case for several other Latin American countries, Chile is a large producer and exporter of agricultural and fishery products of great nutritional value, which have a great influence on its economy (Lebdioui, 2019). In contrast, sustained studies and national surveys in recent decades have been warning about the poor quality of the population's diet, mainly in vulnerable groups that have a low socioeconomic status (Vega-Salas et al., 2021). These groups have a low level of compliance with the Dietary Guidelines for fruits, vegetables, fish, legumes, dairy products, and water along with an excessive consumption of ultra-processed foods. In addition, these groups present a higher prevalence of diseases associated mainly with risk factors related to poor diet and sedentary lifestyle, such as obesity, metabolic diseases and cardiovascular risk (Ministry of Health, 2014). Foods with a high nutritional value produced and exported by Chile have low domestic consumption and the reasons are mainly related to physical and economic barriers to accessing them throughout the country. Natural foods (vegetables, fruits, fish) that are considered healthy are expensive (Verdugo et al., 2016).

Also, data for food insecurity in the country was scarce until 2017, when the Food Insecurity Experience Scale (FIES) by the Food and Agriculture Organization of the United Nations (FAO) was used for the first time in a national survey (Ministry of Social Development, 2017). The scale identifies experiences/perceptions and behaviors of the respondent or the household related to food, specifically when they experience difficulty accessing food due to limitations of physical and/or financial resources. The results classify the individual or the household in a state of moderate-severe insecurity (they do not have money to buy healthy food, they are uncertain about their ability to obtain food and possibly they were left without food due to lack of money), severe food insecurity (no accessed food, went a whole day without eating several times a day) or food secure (does not have difficulties accessing food) [Food and Agricultural Organization (FAO), 2022a]. Using this scale, which consists of questions related to the perception of people's physical and economic access to adequate food, 13.1% of households present moderate-to-severe food insecurity and 3.4% present severe food insecurity. These percentage increase considerably when analyzed by income decile (with a difference of 25.3 percentage points between the 1st and 10th deciles), or by other factors such as family structure and the presence of children or persons with disabilities in the household (Ministry of Social Development, 2017).

In 2020, at the end of the first year of the COVID-19 pandemic, the results of a new national survey using the FIES scale showed that the indicators related to moderate-to-severe food insecurity and severe food insecurity worsened during this period. This was observed mainly in those households with the presence of dependent populations, such as children, adolescents, and the elderly (Giacoman et al., 2021). In addition, a study using online surveys carried out by Araneda et al. (2021), which considered 2,767 Chilean households at the beginning of the COVID-19 pandemic, indicated that more than 60.0% of families were concerned about not having enough money to buy food, highlighting the high perception of food insecurity in households.

Factors such as gender, level of education and knowledge level of food and nutrition are determinants of food insecurity. For instance, in a high-income community in Australia, gender was observed to affect the association between the level of education, food, nutrition knowledge and food insecurity. Knowledge about food and nutrition were inversely associated with food insecurity among men, but not among women (Gallegos et al., 2022).

Different studies point to the worsening of food insecurity in several countries because of the COVID-19 pandemic (Dondi et al., 2020; Elsahoryi et al., 2020; Niles et al., 2020). This impact is greater for the most vulnerable groups, including the migrant population (Smith and Wesselbaum, 2020). Recent data from the World Bank indicates an increase in food inflation for various countries, which implies an increase in the price of the retail market, thus worsening the status of food insecurity in households (World Bank and Food Safety Update, 2022). This requires that governments identify the most vulnerable groups, to take more focused measures that reduce short- and long-term effects of food insecurity, in addition to identifying the most critical factors affect this risk.

The objective of this work was to identify the determinants associated to food insecurity in the household in a group of mothers/caregivers of schoolchildren from a Southern area of the city of Santiago, Chile, which is characterized by a concentration of communes with a low-to-medium communal development index and a high presence of migrant population.

Materials and methods

Design, setting and subjects

This observational cross-sectional study is part of a research project named "Development, scaling up and validation of an integrated system of interventions in schoolchildren in nutrition, physical activity and community environment" (FONDEFIT18I0016). This project seeks to build an integrated intervention model for healthy school environments, through increasing hours of physical activity, promoting the availability of healthier foods within and around the school environment and school community participation. Seven public schools from six low-income municipalities of Santiago, Chile (El Bosque, La Granja, San Ramón, Lo Espejo, San Joaquín, and Pedro Aguirre Cerda) were invited to participate and compose the setting for the research. More information about this project has been previously published (Bolados et al., 2021; Suárez-Reyes et al., 2021).

A non-probabilistic convenience sample was analyzed, which included 646 mothers/caregivers of students from second to fourth grade of primary education during 2019–2021, who were enrolled in public schools of the aforementioned municipalities. The non-response rate for some of the variables only reached 0.6%. This protocol was approved by the Ethics Committee of the University of Santiago de Chile (record number 187/2019). Data collection was carried out between September and October 2021 and the selection criteria were (a) oversee the direct care of the student enrolled in the project during 2019–2020; (b) have command of the Spanish language or be accompanied by a translator (in the case of Creole-speaking migrants); and (c) agreed to participate in the study.

Instruments and data collection

Three different strategies were used to apply the surveys. The first strategy was online and consisted of sending an electronic form through REDCap (3.5%). A telephone interviewer supported the survey responses when necessary. The second strategy consisted of applying the survey by telephone (66.5%). The third strategy was the application of the survey in person (30.0%). The mothers/caregivers of the schoolchildren who were beneficiaries of the School Feeding Program (PAE) were interviewed at the time of receiving the benefit. During the COVID-19 pandemic, these families received a box of food from the school. When mothers/caregivers did not have a good understanding of the Spanish language, because Creole was their native language, the support of a translator was requested. The surveys were conducted by trained and standardized nutrition and/or physical activity professionals. All information was recorded in an electronic form to create databases, using the REDCap platform (https://www.project-redcap.org/) licensed by Universidad del Desarrollo.

The sociodemographic variables were determined by using information of the person responsible for the student (age, sex, relationship, nationality) and characteristics of the household (number of inhabitants, changes in the work activity of the head of household in the previous 12 months, person responsible for the purchase of food, and place of purchase of fruits and vegetables). They were also asked if there were any beneficiaries of state subsidies within the household: food boxes; the National Complementary Food Program (PNAC), which consists in delivering powder milk to children under 18 months and powder milk beverages to children between 18 and 36 months; the National Complementary Food Program for the Elderly (PACAM), which delivers powder milk drinks and powder cream soups to people over 70 years of age; any type of monetary subsidy; or PAE with breakfast and lunch delivery.

To determine the prevalence of the perception of moderate-severe food insecurity and severe food insecurity and the household probability of moderate-severe and severe food insecurity, the Food Insecurity Experience Scale (FIES) was used. This scale consists of 8 questions, which seek to record the experience of food insecurity and hunger related to the household in the last 12 months. The possible answers are *Yes*, *No*, *I don't know*, or *No answer*. These responses were transformed into a dichotomous format (0: Yes, I don't know/ No answer; and 1: No) for later analysis, according to the proposed methodology for processing the FIES [Food and Agricutural Organization (FAO), 2022b].

To evaluate basic knowledge of nutrition and food, a validated survey was used that evaluates eating practices in Chilean families of schoolchildren. This survey consists of 8 questions related to items of the Chilean Food-based Dietary Guidelines and their relationship with health benefits (Lera et al., 2013). These questions are related to: (1) benefits of consuming fruits/vegetables and fibers/antioxidants, (2) having dinner vs. a fast meal, (3) consumption of legumes instead of meat; (4) consumption of dairy and calcium; (5) consumption of sugary drinks and water; (6) consumption of salt and sugar; (7) consumption of saturated fats; and (8) consumption of fish and omega-3. The answers follow a Likert-type scale model with 5 points, varying from "strongly disagree" to "strongly agree."

Variables and data analysis

Sociodemographic characterization

All the following variables were transformed into dichotomous values (0 and 1) for subsequent logistic regression analysis. The risk factors were: being a migrant, being raised by a mother whose education level was lower than secondary education (incomplete primary and complete primary), not being a beneficiary of state subsidies during the period studied

(PAE, PNAC, PACAM, food boxes, monetary subsidy), either individually or combined, and regularly buying food and fruit/vegetables in supermarkets. Regarding the age variable of the person responsible for the student, being ≤ 36 years old (median age of the group studied) was considered a risk (value = 0).

Knowledge of food and nutrition

Due to the nature of the questionnaire (Lera et al., 2013), the answers were grouped into "correct" (value = 0) or "incorrect" (value = 1). The sum of the correct scores ≥75% was considered adequate (value = 1), and a performance lower than 75% was considered inadequate (value = 0).

Food Insecurity Experience Scale

The scale processing methodology followed the guidelines indicated by FAO [Food and Agricultural Organization (FAO), 2022a], which are based on the use of the Rasch model and indicate whether the information collected by application of the FIES presents an acceptable quality. The application developed by FAO was used for this process [Food and Agricutural Organization (FAO), 2022b]. The missing values were within the acceptable range (10.0%), indicating that there were no difficulties in understanding the questions. Once the database was loaded in the application, the INFIT values (which identify items with low performance in the evaluated population) were between 0.7 and 1.2 (accepted values between 0.7 and 1.3). For the OUTFIT values (which identify cases with a high pattern of unexpected responses), only two items presented values ≥ 2, which corresponds to 25% of the total number of items (acceptable up to 25% of the total). The reliability of the Rasch model obtained was 0.79 (acceptable value = 0.7). Evaluation of the overlap of items was analyzed using the residuals of the correlations and the values found ranged between −0.08 and 0.25 (acceptable values <0.4). Considering the results obtained, and accepting the model, the prevalence values of moderate-severe food insecurity and severe food insecurity were obtained for the group studied, in addition to the probabilities of moderate-severe food insecurity and severe food insecurity for each household. These values were used in the regression models to identify the variables most associated to food insecurity.

The household values for the probabilities of moderate-severe food insecurity and severe food insecurity were transformed into dichotomous variables (values 0 and 1). The cut-off point established as an increased risk for moderate-severe food insecurity was 75% of the distribution. For severe food insecurity values >0 were considered. Due to their low occurrence, values >0 were above 75% of the distribution.

Statistical analysis

Categorical variables were presented according to their absolute frequency and the bivariate analysis between moderate-severe food insecurity and severe food insecurity and the independent variables was analyzed using the chi-square test. The variables that met the established significance criteria ($p < 0.1$) entered the multivariate analyses. For this, logistic regression tests (LOGIT) were used to contrast the moderate-severe food insecurity and severe food insecurity variables with each independent variable selected in the previous stage. The procedure was subsequently repeated using stepwise backward and forward strategies for the selected variables, and for the final model the stepwise forward technique was used. Stata 16.0 software (College Station, TX, USA) was used for statistical analyses, using $p < 0.05$ as significant and calculating the 95% confidence intervals (95% CI).

Result

The sample consisted of 646 subjects, of which 642 answered the questions on the FIES scale for perception of food security. Fourteen percent of the group declared to be a migrant, coming mainly from Haiti and Colombia. In the households surveyed, there was an average of 5 people (CI 95%: 5.0–5.2). The average age of the respondents was 38.4 years (CI95%: 37.6–39.1) and more than 70% were mothers/stepmothers of the students (Table 1).

Preliminary analyses indicate that the prevalence of moderate-severe food insecurity in households was 25.4% and that of severe food insecurity was 6.4%. More than 80% of the mothers/caregivers did not reach secondary education and in those households that present moderate-severe food insecurity, this condition prevailed (χ^2: 13.1; $p < 0.01$) as well as in those households that presented severe food insecurity (χ^2: 10.0; $p = 0.04$). About 50% of the people responsible for the children underwent a change in their work activity within the 12 months prior to the interview, which coincides with the period of restrictions imposed by the COVID-19 pandemic in Chile. That condition was not associated with the perception of moderate-severe food insecurity (χ^2: 13.7; $p = 0.032$) and or severe food insecurity (χ^2: 13.67; $p = 0.034$).

Table 2 presents the items related to knowledge about food and nutrition according to the Chilean Food-based Dietary Guidelines and their association with household moderate-severe food insecurity and severe food insecurity. Only in one concept (item 5, consumption of water and sugary drinks) an acceptable performance presented a positive association with absence of severe food insecurity (χ^2: 4.2; $p = 0.04$). On the other hand, a total value performance >75.0% in all questions was related to absence of food insecurity (χ^2: 6.4; $p < 0.01$).

Table 3 shows that, when analyzing the questions of the FIES scale individually, the concern of not having enough money

TABLE 1 General characterization of the sample studied.

Characteristics	Overall	MSFI		SFI	
		No *n* (%)	Yes *n* (%)	No *n* (%)	Yes *n* (%)
Nationality					
Chilean	557 (86.2)	365 (71.0)	149 (29.0)	404 (79.2)	106 (20.8)
Migrant	89 (13.8)	37 (53.6)	32 (46.4)	46 (66.7)	23 (33.3)
Mother's education		χ^2: 13.1; *p*: 0.01		χ^2: 10.0; *p*: 0.04	
Incomplete primary education	145 (22.4)	82 (63.6)	47 (36.4)	95 (74.2)	33 (25.8)
Complete primary education	410 (63.6)	252 (68.1)	118 (31.9)	281 (76.4)	87 (23.6)
Incomplete secondary education	47 (7.3)	25 (80.6)	6 (19.3)	28 (90.3)	3 (9.7)
Complete secondary education	33 (5.1)	38 (88.4)	5 (11.6)	39 (92.9)	3 (7.1)
Higher education	10 (1.5)	5 (50.0)	5 (50.0)	7 (70.0)	3 (30.0)
Family relationship to student		χ^2: 6.11; *p*: 0.106		χ^2: 4.22; *p*: 0.239	
Mother/stepmother	489 (75.7)	304 (68.6)	139 (31.4)	347 (78.7)	94 (21.3)
Father/stepfather	74 (11.5)	47 (73.4)	17 (26.6)	50 (78.1)	14 (21.9)
Grandfather/grandmother	52 (8.0)	27 (57.5)	20 (42.5)	31 (65.9)	16 (34.0)
Other	31 (4.8)	24 (82.7)	5 (17.2)	22 (81.5)	5 (18.5)

MSFI, Moderate-Severe Food Insecurity; SFI, Severe Food Insecurity.

TABLE 2 Performance for the basic knowledge test on food and nutrition (percentage of correct answers ≥75.0%) according to perception of Moderate-Severe Food Insecurity (MSFI) or Severe Food Insecurity (SFI) in the household.

Contents	All *n* (%)	MSFI		SFI	
		No *n* (%)	Yes *n* (%)	No *n* (%)	Yes *n* (%)
1. Fruits and vegetables contain fibers and antioxidants that are good for your health.	633 (98.6)	396 (68.9)	179 (31.1)	444 (77.8)	127 (22.2)
2. It is better to have afternoon tea than to have dinner at night.	272 (42.4)	177 (72.5)	67 (27.5)	192 (79.0)	51 (20.1)
3. You can eat beans, chickpeas, lentils, or peas, instead of meat.	550 (85.8)	354 (69.8)	153 (30.2)	395 (78.5)	108 (21.5)
4. Dairy products such as milk, yogurt and cheese provide calcium for the health of bones and teeth.	605 (94.4)	384 (68.7)	175 (31.3)	430 (77.5)	125 (22.5)
5. It doesn't matter if you drink soft drinks, juices or water, the most important thing is to drink 6 to 8 glasses of any liquid a day to stay hydrated.	489 (76.2)	320 (70.6)	133 (29.4)	359 (79.6)	92 (20.4)*
6. It is good to eat little salt and sugar.	574 (89.41)	368 (69.7)	160 (30.3)	409 (78.0)	115 (21.9)
7. Saturated fats are healthy; you should prefer foods that contain them.	475 (74.1)	305 (70.3)	129 (29.7)	342 (79.3)	89 (20.6)
8. You need to eat fish 2 times a week for its content of proteins, minerals and omega 3 fatty acids.	617 (96.1)	389 (69.2)	173 (30.8)	437 (78.3)	121 (21.7)
Performance survey knowledge about food and nutrition ≥75%.	539 (84.2)	354 (70.8)	146 (29.20)**	390 (78.6)	106 (21.4)

MSFI, Moderate-Severe Food Insecurity; SFI, Severe Food Insecurity; *p < 0.05; **p < 0.01.

to purchase food prevailed in the whole group (65.4%). The perception of moderate-severe food insecurity is shown as the most prevalent. Being a migrant was significantly associated with moderate-severe food insecurity ($p = 0.003$) and severe food insecurity ($p = 0.024$), as well as a maternal education that only reached complete and/or incomplete levels of primary education ($p = 0.010$ y $p = 0.007$, respectively) (Table 4).

In the multivariate analyses, both the stepwise backward and forward strategies resulted in the same final model, which corroborates that there is no divergence between the procedures. In the group studied, being a migrant doubled the risk of experiencing moderate-severe food insecurity at home (OR: 2.2; $p = 0.004$; 95% CI: 1.3–3.8) as well as of severe food insecurity (OR: 2.2; $p = 0.006$; IC95%: 1.2–3.8). In turn, mothers/caregivers who managed to complete basic education are more likely to have households with a lower risk of severe food insecurity (OR: 0.3; $p = 0.004$; IC 95%: 0.1–0.7). Both a performance above 75% in the tests on basic knowledge on food and nutrition (OR:0.6;

TABLE 3 Distribution of the affirmative answers (yes) to the questions on the FIES scale according to the perception of Moderate-Severe Food Insecurity (MSFI) or Severe Food Insecurity (SFI) in the household.

FIES scale questions	All *n* (%)	MSFI *n* (%)	SFI *n* (%)
1. You were worried you would not have enough food to eat?	420 (65.4)	172 (44.6)	121 (31.6)
2. You were unable to eat healthy and nutritious food?	291 (45.3)	170 (63.4)	124 (46.8)
3. You ate only a few kinds of foods?	296 (45.1)	171 (64.0)	124 (46.6)
4. You had to skip a meal?	127 (19.8)	110 (94.8)	103 (88.8)
5. You ate less than you thought you should?	218 (34.0)	170 (85.4)	126 (63.6)
6. Your household ran out of food?	94 (14.6)	79 (91.9)	73 (84.8)
7. You were hungry but did not eat?	107 (16.7)	96 (98.0)	91 (92.9)
8. You went without eating for a whole day?	32 (5.0)	31 (100.0)	29 (93.5)

MSFI, Moderate-Severe Food Insecurity; SFI, Severe Food Insecurity.

TABLE 4 Associations between the perception of household food insecurity and characteristics of the sample studied, according to perception of Moderate-Severe Food Insecurity (MSFI) and Severe Food Insecurity (SFI) in the household.

	MSFI			SFI		
Attribute	**No *n* (%)**	**Yes *n* (%)**	***p***	**No *n* (%)**	**Yes *n* (%)**	***p***
Being a migrant	37 (53.6)	32 (46.4)	0.003	46 (66.7)	23 (33.3)	0.024
Incomplete/complete primary maternal education	334 (66.9)	165 (33.1)	0.010	376 (75.8)	120 (24.2)	0.007
Knowledge about nutrition (beverages and water)	320 (70.6)	133 (29.4)	0.100	359 (79.6)	92 (20.4)	0.041
Performance knowledge about food and nutrition >75%	46 (56.8)	35 (43.2)	0.012	58 (71.6)	23 (28.4)	0.159
Purchase of food made by the father	127 (73.0)	47 (27.0)	0.170	147 (85.0)	26 (15.0)	0.006

$p = 0.048$), as lower-than-median maternal age (OR: 1.5; $p = 0.003$) turned out to be risk factors for moderate-severe food insecurity, as well as the cases where the father was responsible for the household food purchases, which increased the risk of severe food insecurity (OR: 0.5; $p = 0.006$). The models were adjusted by number of inhabitants in the household (Table 5).

Discussion

In 2017, Chile began the systematic measurement of the level of food insecurity in households, through national surveys. The results indicated that the prevalence of moderate-severe food insecurity was 13.6% and, of severe food insecurity was 3.4% in the country, which increased to 25.3 and 7.4%, respectively in the first income quintile (Ministry of Social Development, 2017). Our study provides similar results, with moderate-severe food insecurity prevalence of 25.4 and 6.4% for severe food insecurity in the group studied, although the factors related to the increased risk of food insecurity differ. At the national level, households with the presence of children, older adults, and with more than 5 members presented a higher risk of food insecurity. In the group studied, being a migrant and having maternal education that did not reach secondary level (incomplete primary and complete primary school) prevailed as factors of greater risk. The results of our analyses highlight the strong association between social determinants of health and the risk of food insecurity in the country.

A recent national study with used telephone surveys conducted in June 2020 and repeated in July 2021 in more than 5,000 households, showed that the perception of moderate-severe food insecurity decreased from 17.4 to 7.6% in the period. Of the households surveyed, 41.8% decreased the perception of moderate-severe food insecurity (Ministry of Social Development, 2021).

In recent decades, Chile has implemented a series of policies and programs focused on improving the health conditions of the population, mainly by the installation of healthier food environments (Rodriguez et al., 2021). Several regulations obtained great international recognition, such as the application of frontal warning labels (FOP) on packaged foods that are high in critical nutrients, as well as advertising regulations (Ministry of Health, 2013, 2015) and the increase in taxes on sugary drinks (Treasury, 2014). Evaluation of these regulations has shown a decrease in the content of critical nutrients in packaged foods and the use of FOP for food selection (Quintiliano-Scarpelli et al., 2020, 2021), in addition to a lower consumption of sugary drinks (Cuadrado et al., 2020).

Although these measures have contributed to better food environments in the country, they are strongly influenced by the socioeconomic gradient. This relationship was verified by evaluating the food environments in school aged children, in

TABLE 5 Association between characterization variables of the group studied and the risk of presenting Moderate-Severe Food Insecurity (MSFI) and Severe Food Insecurity (SFI) in the household.

Variables	MSFI			SFI		
	OR*	*p*	95%CI	OR*	*p*	95%CI
Nationality	2.21	0.004	1.29–3.75	2.19	0.006	1.24–3.85
Maternal education level	0.45	0.009	0.24–0.81	0.33	0.004	0.16–0.70
Performance knowledge about food and nutrition >75%	0.61	0.048	0.36–0.99	-	-	-
Mother's age	1.49	0.003	1.02–2.18	-	-	-
Purchase of food made by the father	-	-	-	0.51	0.006	0.31–0.82

*Models adjusted per number of inhabitants in the household.

the southern area of Santiago, Chile. Schools located in areas with a higher community vulnerability index presented a lower offer of healthier foods 100 m around these establishments (Pinheiro et al., 2022). These results highlight the strong influence of the socioeconomic determinants of food insecurity. In addition to the household vulnerability, children are inserted in school spaces that do not favor the rupture of this model.

Evaluation of the individual determinants of food insecurity in Europe shows that women are affected by very specific factors such as education, poverty and residence area, whereas the stronger mitigating factor for food insecurity is education. The authors conclude that people with a higher education degree have a decreased risk of food insecurity, which is independent of gender (Grimaccia and Naccarato, 2020). These results agree with the conclusions of our study, where a lower education of mothers/female caregivers increases the risk of both moderate-severe food insecurity and severe food insecurity.

In our study, being a migrant was also a risk factor for both moderate-severe food insecurity and severe food insecurity, which coincide with other research carried out in Chile. Maury-Sintjago et al. (2019) studied the risk of food insecurity in a group of migrant population of Haitian origin residing in southern Chile. Their results indicate that the presence of children in the household, difficulties in understanding of Spanish, lack of access to basic services (electricity, water, sewerage, etc.) and not having legal residence are associated with a higher risk of food insecurity. Other migrant groups residing in Chile have a higher risk associated with the access to healthier foods, such as migrants from Colombia who have a lower overall diet quality compared to the Chilean diet (Hun et al., 2021).

Another finding of this research indicates that, in the group studied, having basic knowledge on topics related to food and nutrition is not related to a lower risk of moderate-severe food insecurity or food insecurity, contrary to the observations made by Dollahite et al. (2003) and Eicher-Miller et al. (2009), where interventions aimed at providing nutritional education to vulnerable families were able to reduce the impact of food insecurity risk.

Facing the latent problem of food insecurity in Chile requires inclusive public policies that consider the socioeconomic determinants of health. Being a beneficiary of government programs of conditional or non-conditional transfer of food and/or financial resources was not associated with a lower risk of food insecurity in our study. In Brazil, the use of a conditional financial transfer program in a vulnerable municipality managed to reduce the prevalence of food insecurity by about 17.0% and the authors conclude that this increase on food security is more related to the benefit itself than to an improvement in family income over time (Palmeira et al., 2020).

Access to healthier food in sufficient quantity and quality for a full life, in Chile, is permeated by different factors that are not only related to physical access to food through state benefits. Deep structural measures must be considered in order to find a possible solution to this problem.

Great efforts must be made to reverse school dropout, which has a national level prevalence rate that increases according to the age range of the students, increasing from 1.7% for the group between 5 and 13 years to 3.9% for the group between 14 and 17 years in 2019. This percentage is projected to grow during the COVID-19 pandemic (Ministry of Education, 2020). This effort to retain students in the school system, in addition to reducing the risk of food insecurity in their homes, can be accessed *via* the School Feeding Program (PAE), which should be universal in Chile, and consider the vulnerability of the school and not of the student's family as a criterion for admission. The current criterion makes it possible for students who are beneficiaries of PAE and others who are not, to coexist in the same school.

Measures related to bringing healthier foods closer to less favored populations should first consider a better distribution of the points of sale of these foods, such as expanding the presence of fruit and vegetable markets in urban spaces. In February 2022, the largest increase in commodity prices (meat, dairy products, cereals, vegetable oils, sugar) was observed, according to the Food Price Index of the United Nations Agency for Food and Agriculture (FAO) [Food and Agricutural Organization (FAO), 2022c]. Therefore, healthy products that are the basis of the diet of most families, such as meat, dairy products, and cereals,

are more expensive, which can further aggravate the state of food insecurity.

Recent analyses carried out by our research group have shown that, in Chile, Brazil and Ecuador, during the 2019–2021 period, the least processed food groups had a greater variation in consumer prices than what was observed for processed and ultra-processed products (data not yet published). Therefore, unhealthy products are more financially accessible to the population than those considered healthy. This data leads to the idea of an increase of taxes on unhealthy foods as a strategy to reduce their consumption. It has been widely discussed to restrict their access and in the case of Chile, it was implemented on sugar-sweetened beverages in 2014, increasing taxes from 13 to 18% on sugary beverages with a sugar content above or equal to 6.25 g/100 m, while taxes were decreased from 13 to 10% on beverages with a content of sugar <6.25 g/100 ml (Treasury, 2014; Rodriguez et al., 2021). This must be reviewed considering the new global scenario, from the perspective of food insecurity. This measure should be accompanied by a reduction in the tax on healthy foods that are recommended by the Chilean Food-based Dietary Guidelines (fruits, vegetables, dairy products, fish, legumes) (Olivares et al., 2013, 2015).

One of the limitations of this study is related to the fact that the instrument used to measure the state of food security in households, despite being internationally validated and widely used in the literature, considers the subject's perception. To delve into analyses, it is important to consider other factors and their relationships, which could be addressed by qualitative research methodology. Another limitation of the study is that the application period of the survey was between the months of September and October 2021, the final period of the mobility restriction due to the COVID-19 pandemic in Chile. This factor could have increased the perceptions of food insecurity detected by the FIES scale.

The human right to adequate food has been ratified by several countries and includes among other concepts adequate availability and accessibility. However, as the United Nations Office of the High Commissioner for Human Rights emphasizes "The right to food is not the same as the right to be fed" and "The denial of the right to food is NOT the result of the lack of food in the world" (Office of the United Nations High Commissioner for Human Rights, 2010). Under this premise, it is imperative that public policies both in Chile and in Latin America are aimed at guaranteeing these rights, mainly for those groups that are most vulnerable according to their socioeconomic status, and also for the migrant population.

Data availability statement

The datasets presented in this article are not readily available because the project is in the phase of finalization and writing of reports for the financing fund. Requests to access the datasets should be directed to ACP, apinheiro@udd.cl.

Ethics statement

The studies involving human participants were reviewed and approved by Ethics Committee of the University of Santiago de Chile (record number 187/2019). The patients/participants provided their written informed consent to participate in this study.

Author contributions

ACP and MM: conceptualization. ACP, MM, and JA-F: methodology. ACP, RO, and DQ-S: formal analysis and data curation. ACP and DQ-S: software and resources. ACP, DQ-S, MS-R, and TP: investigation, supervision, and project administration. ACP: writing—original draft preparation. ACP, DQ-S, MM, JA-F, TP, MS-R, and RO: writing—review and editing. ACP, DQ-S, and MM: visualization. ACP and TP: funding acquisition. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2022.924921/full#supplementary-material

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Food democracy and sustainability in France and Chile: Community gardens promote ecological citizenship

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This study explored cases of sustainable food production in urban and non-urban areas, including the development of urban gardens, and particularly the social relations involved in these community projects. A qualitative approach was used to compare four case studies in Chile and France: shared gardens in Lyon, family and workers' gardens in Santiago in Chile, an indigenous agricultural project in Lonquimay in the southern Andes, and the work of the NGO Cultivos Urbanos. The data was collected through surveys, participant observation and semi-structured in-depth interviews. The results show that tending gardens in these settings (worker, family, collective, or shared gardens) promotes social values that can lead to more sustainable forms of community living. As opposed to intensive agriculture, small-scale gardening practices, specifically in urban and peri-urban gardens, encourage human/non-human relationships, and the transmission of caring for nature and for others, which promotes ecological citizenship.

KEYWORDS

food production, ecological citizenship, community gardens, Chile, France

Introduction

The COVID-19 pandemic triggered not only a health crisis, but has also had significant economic and ecological impacts, including on food production and supply. Since the onset of the pandemic, the global food market has shown clear signs of disruption (Sepúlveda, 2022). When the effects of climate change and the consequences of Russia's war against Ukraine are added to this, food supply and costs seem unlikely to improve in the near future.

In response to these multiple challenges, social and solidarity economy initiatives have emerged in both urban and rural areas, led by stakeholders such as farmers, gardeners and consumers. For example, local "farm-to-table" systems have begun to reemerge in France, reorganizing both the way food is produced and sold. In the case of Chile, small and medium-sized farms are increasingly seen as a safety net for the food security and sovereignty of communities and the sustainability of regional economies (Sepúlveda, 2022).

The cases studied pre-date the health crisis. However, these cases show that gardens and cooperatives have historically contributed to addressing food insecurity, particularly in contexts of poverty. During various types of crises–e.g., social, political, and health–food sovereignty responses emerge to sustain and promote food production in fragile contexts.

Although the cases considered in this article are prior to the COVD-19 health crisis, they allow us to see how, in contexts of poverty or crisis, orchards and cooperatives have historically contributed to facing food insecurity.

The processes of "relocating" agriculture through more local production (*circuit court, in French*)[1] involve the development of proximity agriculture based on the quality of the relationship with the land between humans and non-humans (examples include organic farming, agroforestry and permaculture). The greening of agricultural practices (Lamine, 2017) entails the use of non-intensive techniques, production tools and work organization methods.

In the different local food production initiatives that have arisen, what is the implication on social relations? How are alternative forms of production to industrial, capitalist agriculture—for example, self-production in family or collective gardens—embedded in communities? If the effect is positive, is it possible to increase the presence of these gardens?

This study examined alternative agriculture and urban gardening initiatives with an integral approach (Arora, 2019) in different settings in order to understand how new or renewed community food production practices may be a response to the challenges raised by current crises.

We adopted an "ecology of practices" approach (Stengers, 2005), focusing on understanding how sustainability and ecological citizenship can develop in different ways, at different scales, with different types of connections between stakeholders who may have different understandings of the crisis, and with different targets.

The aim of these ecological practices is not solely about optimizing food production, but about connecting the collective with a local area. The case studies reveal the political actions of individuals and collectives to protect a locality and its links with food production. This study thus explores the relation of these practices not only on human and ecological wellbeing, but also on territorial belonging, the relationship of humans with their environment, and on the notion of ecological citizenship. Through the investigated case studies, we examine the possibilities of creating new relationships between people and agriculture, looking at issues such as productivity, the relationship with nature, social production and new forms of consumption.

Regarding the concept of ecological citizenship, it is necessary to identify how environmental aspects are—or are not—incorporated into the exercise of being a citizen: whether stakeholders have or demand the opportunity to participate in environmental management. This can vary from community to community—some achieve greater visibility in their quest for participation while others remain marginalized from political action (Gudynas, 2009). Gudynas also points out the potential of ecological meta-citizenship, which requires looking at different scales and at the different stakeholders involved. In this study, we focused on three considerations emphasized by this author: (1) the relationship between citizens and the environment, including the social, political, ecological and cultural aspects of the territory; (2) the environmental concerns, for example, of indigenous, rural and urban communities, including the challenge of incorporating the valuation of non-human elements that do not necessarily meet productive concerns or human satisfaction; and (3) as "any meta-citizenship must consider a political dimension" (Gudynas, 2009, p. 66), how, in food production, the stakeholders at different levels (including environmental, peasant and indigenous movements) deepen the relationship between environmental and political action.

We examined these issues with four case studies in France and Chile. In France, we focused on shared gardens in the urban area of Lyon co-sponsored by citizens' collectives and public agencies; the latter partly financed these projects to promote the ecological food transition. In Chile, we focused on three cases of collective cultivation: (i) new urban garden projects in the city of Santiago led by the NGO Cultivos Urbanos, (ii) a project in an indigenous community in the southern Andes, and (iii) workers' gardens in the town of La Pintana.

We analyzed how the discourse and experience of citizens and other stakeholders in the local or national contexts transformed as a result of these collective practices and public policies. The findings indicate how, through concrete participation (Zask, 2011), processes of food democratization can emerge (Maurines, 2019; Paturel, 2019). Yet these processes demand political action that seeks to overcome problems of environmental or food justice (Hochedez and Le Gall, 2016). In Chile, for example, urban policies created during the 1930s promoted collective workers' gardens. This allowed the physical existence of productive spaces in the city, permitting the inhabitants to develop sustainable means of living even in vulnerable contexts.

The examined case studies add support to the argument that collective gardens are an indispensable tool to enhance food democracy. As Zask (2016) points out, cultivating gardens or land collectively favors the development of democratic values. While not everyone's aspirations are the same, shared values and their transmission converges with the concept of

1 *Circuit court* is the French term for farm-to-table systems in which agricultural products are either directly sold from the producer to the consumer or indirectly via one sole intermediary. In France, the term officially requires <80 km between the place of production and the consumer and no more than one intermediary (2002 decree, France).

meta-citizenship (Gudynas, 2009) in the sense that what the group aspires to has a political dimension.

In our comparison of cases in Chile and France, the scales and stakeholders are different; however, all show how individuals and collectives are trying to implement a more viable food and farming system.

The first section of the analysis describes the case studies in Chile and France. In each, the stated claim of the different collectives is to develop participatory action that seeks to strengthen relationships with the environment and with the human collective. The second section considers how the individuals and collectives involved try to implement agricultural systems that promote food democratization based on citizen participation. In the third section, we review how public policy in France is attempting to develop local food production and improve access to high-quality local food. Finally, we examine how working collectively in these food systems has effects on the participants' relationship with nature and on ways of being in the world.

Methods

The study was based on comparative problematization (Hibou, 2014) in a multi-site approach (Marcus, 1995). The data was collected from ethnographic research and interviews and involved observing, describing and analyzing the interactions between the different agri-food systems and social processes. We sought to identify the differences and similarities in these varied contexts through a comparative method, understanding this as an exercise for organizing different elements to create a general representation, and unifying multiple techniques for collecting data in order to offer a different understanding of ecological citizenship (Denecheau et al., 2021). In terms of describing and characterizing different approaches to ecological citizenship, we develop a comparative case study with a logic of "tracing across" proposed by Bartlett and Vavrus (2017), where we select different cases seeking to understand how from different places, scales, and organizations, have tried to build citizenship. Our selection criteria were to choose cases that affronting crisis, develop answers in front to food insecurity and try to change the relationship with nature. While the contexts and organizations we compared are very different, they have recognizably similar participatory processes in that they seek to strengthen social bonds.

For the case study in France, we conducted a long-term (1994–2008), socio-historical ethnographic study supplemented with data from various archival sources. The fieldwork was mainly carried out in the Rhône-Alpes region with different social groups and stakeholders in different contexts. The methodology was based on collaborative research with a pragmatic approach that aims to establish strong links between science and society. Data collection included conducting surveys in Lyon in a process of co-construction and co-comprehension of local issues through working with various stakeholders (Guber, 2011). We sought to collect information from a range of stakeholders working to develop sustainable food in their local area (e.g., farmers, gardeners, social and solidarity economy organizations, project leaders, elected local officials, etc.). This long-term investigation involved participant observation *in situ* (e.g., at meetings or events) and participatory investigation methods (e.g., guided walks, photo elicitation).

The case studies in Chile involved different methodology, based on conducting in-depth ethnographic interviews with stakeholders. In Santiago, we conducted three non-structured interviews (from September 2021 to March 2022) with key stakeholders in the NGO Cultivos Urbanos. Since 2010 when the NGO was created, the number of members has changed. Today, five people implement current projects and strategize for future projects. The interviews focused on this core group, all of whom were between the ages of 30–40 and have been involved in the organization for over 10 years. We also conducted a documentary analysis of their work (e.g., project descriptions, public presentations, books, *ad-hoc* virtual library) available on their website.

In Lonquimay in the southern Andes, an ethnographic study on the collective agricultural project of this indigenous community was conducted in November 2017 and January 2018, and November 2019. Ten semi-structured interviews were conducted with participants selected according to two criteria: (i) Mapuches over the age of 30 belonging to the community of Pacunt Pedregoso ($n = 5$); (ii) Government officials in charge of the "Sustainable Mediterranean Communities" project ($n = 5$). The interviews sought information about the objectives, barriers, aspirations, and evaluation of a project led by the Ministry of Environment to create family gardens. The Mapuche participants were also asked about their response to and evaluation of this government action and their expectation of its effects on their lives. We also observed the performance of officials in the field (in offices, community meetings and Mapuche homes) and their interaction with community members.

In La Pintana (a working class municipality on the southern outskirts of Santiago), we collected data on a workers' garden, primarily through participant observation with Alberto, who has lived for almost 60 years on a 5,000-sq-m plot that is part of a family vegetable garden cooperative. These observations and interviews were part of more extensive research in Santiago on environmental activism in the city. We met Alberto when he attended meetings with different public authorities in the context of the changes resulting from the Urban Plan of Santiago (*Plan Regulador Metropolitano*) that came in force in November 2010.

In all cases, the approach was an in-depth, contextualized, long-term ethnographic study in which the researcher is embedded in and participates in changes as they occur in the

field. This allows a constant process of experimentation with and for the fields of investigation, making possible privileged relationships with the participants.

The case study conducted in France was part of a larger research project on food democracy as a common action and represents a more in-depth case than those analyzed in Chile. Yet this comparison is of interest as it shows the diversity of practices and the policies that sustain them in different locations. The French case is particularly interesting in contrast to those in Chile because of the many forms of citizen participation that have emerged in the last 20 years around healthy food produced in local or shared gardens.

Our comparative analysis focused on two main aspects to contrast the concepts that emerged from the data. The first was ecological citizenship, looking at how the interviewees aspire to a political project that allows them to manage their land and incorporate environmental aspects into the exercise of citizenship (Gudynas, 2009). The second was the notion of democratic values developed by Zask (2016), comparing the extent to which the different cases, at different scales, favor the development of democratic values. In fact, both concepts are intertwined. The collectives studied combine the objectives of cultivation and the protection of nature with the aspiration of the development of citizenship (Zask, 2016), which is transmissible in different spaces through social ties.

While this comparative analysis sheds light on important aspects of community-based land management and food production, the challenge in comparing these cases is the pronounced difference between the contexts. In France, there is a long history of food democracy (Maurines, 2019). In Chile, these initiatives have only recently emerged in urban and peri-urban contexts, indicating that local governance of food production is still weak.

Results

From a priority on productivity to sustainability

Chile

In Santiago, workers' gardens were created in a period (1930–1945) when working families were experiencing multifactorial problems such as overcrowding, low wages or unemployment (Yáñez and Deichler, 2018). Workers' gardens, promoted by public authorities and businesses, were seen as "home industries" (*industrias caseras*). The focus was on economic performance to allow families to achieve self-subsistence through a plot of land. Behind this lay an objective of improving the living conditions of low-income families in the city through a model of progressive cooperativism (Gurovich, 2003) that gave rise to various collective and community organizations, such as water-access groups and sports clubs, among others (Catalán and Fernández, 2014).

In the following decades of economic, political and social crises in Chile, particularly during the Pinochet dictatorship, these vegetable gardens were spaces where workers could supply themselves with food to meet their needs, and shared plots, workshops and cooperatives were created (Fuentes, 2015). Urban gardens for workers were originally intended to produce food for the family. "I planted everything … and a good part of it was for my family, which was large," as Alberto puts it. The collective gardens of La Pintana are paradigmatic in this way: although groups promoting urban agriculture have proliferated in Santiago in recent years, they do not seek to develop food production in this way (Fuentes, 2015).

In contrast to these workers' gardens, today's collective urban gardens in Santiago are less about the productive function of supplying healthy food than a political project on the margins of public and private institutions (Biskupovic, 2015), a point made by Fuentes, co-founder and former director of the NGO Cultivos Urbanos (Fuentes, 2015). This NGO works in different areas in the region around the capital. They develop projects in "lower middle class" urban areas such as Peñalolén, San Joaquín and Recoleta, but their main project is located in Santiago, in a historic neighborhood called Yungay. Santiago has around 500,000 inhabitants, and Yungay 35,000 inhabitants. The poverty rate in Santiago is 8.43% (Ministerio de Desarrollo Social y Familia, 2020). Since 2011, through a concession from the city administration, the NGO has had access to a house on the edge of a large urban park (Quinta Normal), where they have created ecological workshops and have maintained a green space over the last decade.

In the case study in an indigenous context, Lonquimay is the second poorest town in Chile's poorest region, La Araucanía: 64.4% of its inhabitants experience multidimensional poverty (Ministerio de Desarrollo Social y Familia, 2020). Because of this, Lonquimay is highly dependent on state assistance. Moreover, being in the high mountains, it is very susceptible to environmental changes (Marchant, 2011); climate projections indicate that Lonquimay is highly vulnerable to drought (ARClim, 2020). This scenario is combined with increased risk of wildfires and biodiversity loss (Center for Climate Resilience Research, 2015). These impacts are especially felt by the Mapuche-Pehuenche inhabitants (Carmona, 2021), who represent 57% of the population (Ilustre Municipalidad de Lonquimay, 2022). This population dates back to Chile's internal colonization in the late nineteenth century, when to escape the Chilean and Argentine armies, Mapuche families from the valleys took refuge in the mountains. Later, the Chilean government distributed land titles, however, many families were not granted these, making land restitution a constant struggle over the last century (Bengoa, 2000). Currently, Mapuche communities inhabit highly degraded areas due to extensive exploitation of the native forest during the twentieth century

and overgrazing encouraged by the government in recent decades (Carmona, 2022). Their primary income comes from livestock, which has been promoted by the government since the occupation of the territory (Paillacheo, 2009). Other sources of income are state aid and the sale of non-timber forest products.

France

In France, Lyon (population: 522,000) has implemented a policy to support shared garden associations since 2009: the primary of these is Passe-Jardins.[2] This non-profit group coordinates the Rhône-Alpes network of shared gardens and provides a resource center, supporting 404 shared gardens in Lyon. Since 1990, Passe-Jardins has been a precursor in local organic production and has helped to create a charter for citizen action for shared gardens, supported by the city of Lyon.

The total surface area of Lyon's collective gardens is 1.9 hectares, with two-thirds on public land (Lyon or Greater Lyon) and one-third on private land (social landlords or church parishes). More than 800 members are involved in these gardens, 60% women and 40% men, which is similar to the shared gardens in the larger Rhône-Alpes region. This is also close to the population structure of Lyon (53% women and 47% men).

All generations are represented in those involved in the gardens (21% under the age of 20, 52% between 20 and 60, and 26% over 60). These figures are in line with the population distribution in Lyon (22% under 20, 59% between 20 and 60, 19% over 60). There is a slight overrepresentation of people age 60 and over, which can likely be explained by the fact that this category has more free time to invest in the gardens on a daily basis. Of the hundreds of shared gardens, 19 have salaried facilitators, corresponding to the equivalent of about four full-time workers divided between 13 people. Most of the gardens have collective plots and harvests.

In all these different cases, working collectively makes it possible to build more sustainable living places in socially heterogeneous areas. In this sense, there is a continuity in the concept of the garden as a supplier and producer, as well as a transition to the concept of a sustainable third place: a space that allows for political participatory action and promotes ecological citizenship.

Conceptions of community farming collectives

Community agricultural collectives have the aim of contributing to meet human nutrition needs and therefore can respond to food security issues. However, there are heterogeneous conceptions of and within these collectives. An understanding of these conceptions reveals how individuals and collectives are trying to implement urban food systems through participatory action, promoting the defense of the territory through ecological commitment.

Workers' gardens in La Pintana

One of the aims of the workers' and family gardens (*Huertos Obreros y Familiares*) in the district of La Pintana (Santiago, Chile) is to develop gardening training for the community and to improve ecological interactions in urban contexts. They arose out of a cooperative model in the government policies of the 1930s and were seen as a way to create forms of subsistence. We were interested in investigating the transition from a state intervention project to alternative agro-food models such as community gardens and urban orchards.

In an interview with Alberto, who has tended a plot here for over 50 years, we asked if, in his experience as a neighborhood leader, people are interested in citizen participation and in defending the cooperative vegetable gardens. He distinguished between those who arrived more recently and live in public housing, who have no prior roots in the neighborhood, and those like him who have lived here for decades. Yet beyond this, the key distinction he made is based on affect and care:

> "Yes, it's true, we defend what is ours, but the saddest thing today is those who don't participate, who don't engage: they don't defend what we have, because you have to like something to be able to defend it." (November 2010)

In this way, caring about something can foster local participation, indicating that there is a community component to food security (Mooney and Hunt, 2009). It has been found that affect and care participate in the greening of agricultural practices (Lamine, 2017) and promote the emergence of food democratization processes (Maurines, 2019; Paturel, 2019). They are the drivers of political actions that seek to overcome environmental problems or food injustice (Hochedez and Le Gall, 2016), encouraging the participation of stakeholders (Zask, 2011).

> "A study from the University of Chile that I read the other day says that in 2004 the desert will arrive in Santiago and that it is already in the region of Valparaíso, so if they [the authorities] stupidly continue to destroy the [community gardens], the desert will arrive…" (Alberto, November 2010).

Alberto's comments show that in addition to the value anchored in local, agricultural practices and the care necessary to defend these, community gardens also have a more global function, and could contribute to combating processes such as the ecological crisis.

2 https://www.lepassejardins.fr/

Shared gardens in Lyon

In France, collective urban agriculture has its roots in the concept of "citizen and solidarity urban agriculture," which promotes food democracy and sustainable food for all. This aims to make city dwellers' agricultural and horticultural practices more ecological in the context of climate change. Many forms of citizen participation have emerged over the last 20 years around locally produced, healthy, quality food and shared gardens.[3] This participation takes direct forms, such as the implementation of collective projects, and indirect forms, such as mobilizing around a cause to defend (e.g., providing healthy food or maintaining biodiversity). In both cases, the aim is to repair real or assumed degraded environments and the cause is a motor for action.

In 2017, Lyon asked Passe-Jardins, which develops collective and solidarity-based urban agriculture projects, to evaluate the food production of the city's shared gardens. This was found to be low, in part because many gardens do not consider themselves production spaces. Furthermore, vegetable production is challenging to quantify because few gardens weigh their crops, and there is no common basis of measurement as different types of produce cannot be quantified according to the same criteria. Only seven gardens could provide the quantity of vegetables produced, which was equivalent to 1 ton of organic vegetables per year. This is low, considering the number of members. The findings indicated that the gardens are mainly seen as a social support: for example, 33% offer cooking workshops. This is in line with the fact that they are the result of public policy promoting social cohesion; food provision is considered, but is not the central motivation for development. This is a major topic of research and development within Passe-Jardins. Developing the aspect of food supply could bring new jobs and spaces related to urban agricultural practices.

Within the Lyon metropolitan area, in recent years there has been a push to develop local and sustainable organic food production. To this end, a food non-profit/business/research cluster, The Bol,[4] brought together some 30 stakeholders[5] and two research laboratories from 2015 to 2020.[6] The Bol enabled a level of relocation of food production both through the pooling of collaborative research and the creation, for example, of the harvest festival, a public event for Lyon's inhabitants. During the event, different collectives showed how they take care of a particular resource, whether a seed, a plant or a consumable processed food, up to the recycling of waste to promote a circular economy (composting, bottle recycling, local currency, etc.). The Bol has also been involved in discussions concerning sharing logistics to save farmers transportation time and to reduce energy consumption. Although the Bol existed for a limited time, it allowed a place of experimentation between organizations, some of which have continued to work together. This is the case, for example, of the *Territoires à Vivre(s)* project and the *Maisons Sociales de l'Alimentation* (community food houses).

The projects of the NGO cultivos urbanos

This NGO was created in Chile at the beginning of the 2010s by a group of young agronomy professionals, who developed a variety of workshops and projects in several regions to enhance knowledge about urban crops. Since the outset, the NGO has focused on increasing ecological knowledge and raising awareness, putting educational activities at the center of their work. Over the last decade, they have carried out seven main projects. The largest was started in 2011 and is located in the center of Santiago. With the support of Santiago's municipal government, the NGO has created an open 120 m^2 space for cultivation and training in urban agriculture and environmental education. They have also developed projects including promoting the modification of home landscapes and gardens and training for public workers about urban gardens. Although the NGO's main scope continues to be environmental education, strengthening and organizing the community are central themes of its projects.

For this organization, the concept of community has at least two levels. On one level, the community is the target group for workshops, which is mainly the community near the garden, but this relationship cannot always be developed because the community members do not have time or live too far from the garden to maintain it. On another level, the wider community is understood as all workshop participants and members of other urban garden organizations. This community is a resource as it opens different spaces and offers links to institutions (schools, grassroots organizations, municipal governments, etc.).

The Lonquimay project in the Mapuche-Pehuenche community

Both climate change and many of the policies that have been designed to address it pose challenges for indigenous communities (Carmona et al., 2022). The emphasis on mitigation, mainly through reducing deforestation and forest degradation, has led to new territorial conflicts in developing countries. In many cases, the motivation to access international

3 A shared garden is a space created and maintained by the inhabitants of a town, village or, more often, an urban neighborhood. Its purpose is to create social links between users of all ages, backgrounds, social categories, etc. through social, cultural or educational activities. A shared garden is managed by a non-profit organization whose members participate in the garden. The harvest of vegetables, fruits, aromatic and medicinal plants, flowers, etc. is shared.

4 https://www.lelabo-ess.org/ptce

5 https://letsfoodideas.com/fr/initiative/pole-cooperation-alimentation/

6 Centre Max Weber (Sociology Laboratory) and Coactis (Management Science Laboratory).

funding has reinforced the dynamics of territorial control that exclude or even displace indigenous communities from the ecosystems where they have lived for centuries (Paladino and Fiske, 2017; O'Reilly et al., 2020). The claims of various indigenous movements have strengthened the debate on the protection of rights and pushed for the creation of various safeguards to ensure the wellbeing of affected communities (Claeys and Delgado Pugley, 2017). While forest conservation continues to present multiple challenges, the awareness of the importance of indigenous peoples' participation in mitigation measures has been strengthened internationally. Their participation has been associated with the success of mitigation policies as well as various social benefits, leading to the provision of certain guarantees of their rights (Brugnach et al., 2017).

International safeguards, coupled with the growing recognition of indigenous peoples' contributions to mitigation policies (Carmona et al., 2022), have pushed the Chilean state to encourage these communities to access international funding. In Lonquimay, the project "Sustainable Mediterranean Communities" funded by the Global Environment Facility (GEF) was implemented between 2017 and 2018. The GEF is an independent financial organization that provides funding to developing countries and countries with economies in transition. Its main objective is to address global environmental issues while supporting national sustainable development initiatives. Its funds are earmarked to develop projects related to biodiversity, climate change, international waters, land degradation, ozone layer depletion, and pollutants. The project, led by the Ministry of Environment in Chile, aimed to integrate community organizations to deliver globally significant environmental benefits.

The Lonquimay project was implemented in the Mapuche-Pehuenche community of Pacunto Pedregoso. This area was selected due to its high levels of environmental degradation. According to an official, the project aimed to mitigate greenhouse gas emissions through reforestation and the sustainable management of vegetation resources. As ministry officials were obliged to consult with the communities, they held initial meetings about the project. During these, the community demanded more involvement in the project design: as one leader noted, "We are tired of having solutions imposed on us from Santiago. We are not naive; our rights were violated. Treating us like children is over!" (Mapuche leader, Ilustre Municipalidad de Lonquimay, 2022). The aim of the community leaders was to improve their livelihoods, which were threatened by drought due to rising temperatures, overgrazing, and deforestation.

The Pehuenche are also influenced by the demands of international indigenous movements, which have established strategic alliances with environmental organizations (Wenz, 1996). These movements are increasingly raising their voices in multilateral processes such as the Conferences of the Parties (COP) of the United Nations Framework Convention on Climate Change and the Convention on Biological Diversity (Claeys-Mekdade, 2006). Like many of these movements, community leaders in Pedregoso aspired to advance their political aims through this project. Above all, they wanted to address what they identify as the main cause of the environmental crisis: the lack of respect of nature. They aimed to revitalize practices of reciprocity and recover the spiritual connection to the land, which they consider central to strengthening their autonomy. They thought that reforestation should go hand in hand with territorial control.

The community proposed building greenhouses to grow seedlings and reforesting an area of the forest. However, the ministry did not accept this because the area was too small. In the end, both parties negotiated an agreement that strengthened the project for all stakeholders. This feedback process took 2 years, and generated the idea of working with family gardens and reforesting through community nurseries. The project was called "Pehuenche High Mountain Gardens."

Promoting ecological citizenship to change the relationship with the environment

The collective gardens in our case studies were created by citizens to respond to different problems. Climate change, environmental conflicts, resource scarcity, growth and urban pressure have created spaces where citizens seek to change the established environmental relationship and hierarchy. Thus, the objective of these gardens is not solely to provide food. In the cases of La Pintana, Cultivos Urbanos and Lyon, one of the main objectives is to strengthen the community, promote a collective connection with the land, and reinforce social bonds.

Some of these gardens have a long history—in La Pintana, they were created in the 1940s by legal decree (Law 6.815) (Fernández et al., 2013). These gardens were established on the border between the city and the countryside, allowing the rural to be extended into the urban. These spaces have managed to survive despite urban pressures thanks to the cooperative spirit of community members (Gurovich, 2003). To this day, these lands cannot be subdivided or used for activities unrelated to agriculture. For Gurovich, this makes these gardens an example of the ideality provided in spaces destined to transform society, now embedded in the inner edge of the urban–rural interface of Gurovich (2003). This case shows how a social approach to agriculture allows stakeholders to demand a leading role in land management and to resist climate change and urban growth. This can be considered a form of ecological citizenship, in which stakeholders participate in land administration, deciding on the environmental future of the local area where they live.

The more recent example of the projects of the Cultivos Urbanos NGO, while promoting a different experience of

urban gardens, also involves the systematization of citizen participation in gardens. These projects meet the multiple objectives identified by Heitmann (2013) of urban gardens: an arena for ecological education, a therapeutic space and resource, and an opportunity to rebuild social bonds. Ecological citizenship is developed by connecting the community through various tasks. In their founding statement, the Cultivos Urbanos leaders declare that they seek ecological practice that understands diversity as a manifestation of life. They promote biodiversity not only for science, but as an inexhaustible source for art, culture, spirituality, and the expression of individuals and communities. This ecological practice and its materialization in ecological education is the cornerstone of the NGO's work; this does not mean that other objectives have disappeared, but that for its members, the guiding theme is ecological practice through which the progress of other objectives will be achieved. In this sense, community development is understood as a two-way street with the sustainability of the practice of urban gardening. On one hand, the time and effort of community members are needed to maintain an urban garden, and on the other, the garden provides resources and benefits to the community, not least the education and the social link allowed through the NGO.

In the indigenous context, the Pehuenche High Mountain Gardens project arose when community leaders in Lonquimay challenged the usual procedures depriving them of resource management and demanded involvement in the project design. Expectations were high. Officials hoped to generate global environmental benefits, and the community hoped to strengthen food sovereignty, autonomy and social bonds. Those most involved wanted the project to promote a new paradigm that would allow the community to rely less on livestock and diversify food production, allowing a healthier diet. "The essential thing is food for the people—that is the paradigm shift. We need to eat fruit, we need to eat meat, we need to eat other things" (Mapuche leader, Lonquimay, 20/12/2017). There was also hope that any surplus could be sold non-profit to diversify incomes and strengthen social capital. Collaborative work is in itself a mechanism to strengthen the community: as one leader stated, "When we work together, when we join forces, we are much stronger than each on his own" (Mapuche leader, Lonquimay, 15/12/2017).

In a methodology based on local decision-making, all stakeholders envisioned long-term objectives for the Pehuenche community and beyond. It was decided to reforest the mountain area with more productive species, such as fruit trees, and the inhabited area with native species to allow more firewood to be harvested. Coordinated local management provided the community with an international platform as well as support from the municipality, which offered economic, human and technical resources. In the community, 27 families joined the project.

To achieve the project's goals, the indigenous leaders proposed strengthening local knowledge and complementing it with research, training and new technology. The leaders wanted to put local knowledge into practice after it had been underestimated for decades. A priority was to revitalize the lost notion of reciprocity: "Giving something back to the land, not only receiving, but also giving: what do we as Mapuche give back?" (Mapuche leader, Lonquimay, 15/12/2017). The leaders expected that awareness on this could be raised through the reforestation process. The community also promoted "clean agriculture," strongly opposing the use of pesticides promoted by the state. Local agroecological practices, such as ash to fertilize and smoke to control frost, were revived. Plots were reorganized to protect the gardens from animals, promoting reflection on the sustainability of livestock. In this way, the project has both benefited from and had an impact on local knowledge: while rooted in the territory, it is also dynamic and, above all, enacted and co-constructed with the place (Lander, 2000).

Promoting social connection and care of the environment

Small-scale garden practices, specifically in the context of urban and peri-urban gardens, are based on the care and transmission of human/non-human relationships and stand in contrast to intensive agriculture, whether high-tech urban agriculture or large-scale farming. Networks of community gardens are organized to promote social links and care of urban spaces. Historically, Cultivos Urbanos has focused its work on encouraging citizens to establish another type of relationship with nature. For this reason, they develop workshops dedicated to community education on urban agriculture in different areas of Santiago. In parallel to cultivating care for nature and developing connections, the NGO tries to empower the communities where their projects are inserted, which has not always been effortless.

In the indigenous context, the Pehuenche High Mountain Gardens project set a new paradigm in the policy targeted at native peoples in Chile. It demonstrated how meaningful engagement at the local level could change the perception of policy and boost the commitment of beneficiaries and their interest in caring for the environment. Nevertheless, implementing the Pehuenche project was not easy. The biggest challenge was to change the individualism imposed by government policy. Tensions also arose between the young leaders who led the process, and the older participants attached to livestock. For the GEF/ministry, the biggest challenge was carbon sequestration, as corroborated by an official: "The resources only allowed for specific activities on a predial scale" (Ministry of Environment official, Santiago, 18/02/2022). There was also no clarity on how to involve the community in this goal. The indigenous leaders argued that officials did not promote a discussion on the carbon aspect, so they did not know how to contribute.

Despite these ups and downs, the stakeholders consider that there have been many achievements, both material in the form of new infrastructure, and immaterial in that the project has strengthened social relations. Those involved perceived a difference compared to other government initiatives, especially the consideration of local knowledge. The project was managed by local leaders and promoted participation and collaboration, with greater accountability and transparency. This enhanced the self-esteem of stakeholders; little by little, this collaboration allowed project leaders to reestablish local trust and involve the community in actions rather than feel victimized in the face of environmental challenges. It enabled the villagers to feel capable of repairing their territory and perceive that the government recognizes their efforts. This is indeed the case: officials have a high opinion of the initiative and its progress.

The success of the project is largely due to the inclusion of local stakeholders, who live in the territory, and who were involved in planning and executing it. For example, an emphasis on developing a more self-sufficient and diverse diet benefitted from the cultivation of species that were previously not viable, made possible by rising temperatures. This led to the creation of a cooperative that works with products derived from pine nuts. The project works two ways, both building on the knowledge of the community and raising its awareness, for example, by promoting the importance of the forest and of water *via* local media: "We have a community radio station, and we strongly emphasize education and environmental issues, and within that, the issue of water plays a fundamental role" (Mapuche leader, Lonquimay, 15/12/2017). A reciprocal exchange also occurred in the planning of the gardens, which encouraged self-reflection on local production methods and livestock farming, while also reintegrating the community's cosmovision into landscape management. This is important because it allows the issue of climate change to be incorporated into the community's everyday life through its own cultural conceptions. It equally prompts institutions to observe the landscape in a more holistic manner, as a ministry official explained: "When they talk about the springs in the forest, I am hearing that they are talking about the spirits" (Ministry of Environment official, Santiago, 18/02/2022). This case shows how a local approach can be used for solutions to global issues such as climate change, through projects that local stakeholders help to define, are integrated into their cultural dynamics, and boost their ability and motivation to effectively repair the territories in which they live with the support of institutions.

These experiences illustrate the political dimension of ecological citizenship. Local stakeholders can be given a greater role in environmental management, taking into consideration cultural aspects, which allows them to strengthen their autonomy. This (re)appropriation of the territory in turn transforms the stakeholders, placing them in an active role: they are no longer "vulnerable," acquiring citizenship and rights over their territories.

The community projects in these case studies can be seen as social and civic commons in the sense of Bollier and Le Crosnier (2014). Social commons are diverse: for instance, they can include community gardens, civic associations, ecovillages, and various forms of community-supported agriculture. They encourage personal involvement and peer support. In each of these cases, citizen participation is crucial. According to Zask (2011), this can be broken down into three stages that promote the process of building the common good. Participation starts with an individual "taking part" in involvement in an activity (gardening, for example). From this can emerge a phase of collective mobilization around a project. Finally, participation becomes a benefit for oneself and others and can thus be extended further to form new ways of participating and contributing, all of which form social connections and can promote care of the environment.

Food democratization

Over the last few years, in both Chile and France, many organizations have developed to promote food justice. This trend has continued, with the COVID-19 pandemic giving greater visibility to the problem of food insecurity for an increasing number of people: students, migrants, and others on low incomes. France experienced a dramatic 45% increase in the demand for food aid in 2020. In Chile, rural areas have been more affected than urban areas, with impacts on food supply and food security (RIMISP Centro Latinoamericano para el Desarrollo Rural, 2021).

New forms of organization are emerging to respond to these social and ecological emergencies by local collectives working in networks at local, regional or national levels. In France, these include farm-based collectives that organize the provision of food in third places,[7] such as the Volonteux[8] or Martinière[9] farms. Their aim is to take care of nature, resources and people, and to pass on other ways of being on the land. Another mode of emerging collective organization is to build inter-organization interfaces with local groups that have a well-established operation and network and will share their skills with new projects, developing synergy and a capacity to act.

On a smaller scale, shared gardens are in full expansion. These involve cultivation on collective plots of land belonging to a local community and are created and maintained through interpersonal relationships. This is part of a wider movement of urban agriculture flourishing in many cities worldwide (e.g., the Incredible Edible in England, rooftop gardens in Quebec, community gardens in the United States, urban agriculture in Latin America and Africa, the gardens of Berlin, and many other examples).

7 http://fablim.org/tiers-lieux-nourriciers/

8 https://www.fermedesvolonteux.com/blog

9 https://fermedelamartiniere.fr/

Studies such as those of Zask (2016) have shown that shared gardens allow the realization of collective goals in alternative ways, putting democracy into action and restoring specific democratic values. The consideration of the "other" (both human and non-human) benefits community life by enabling people to work in common, stop destruction, and create collective projects.

In France, shared gardens are a response to social, economic and food issues. This renewal of urban gardens provides solutions as diverse as the self-production of food, the creation of social links, the improvement of the living space, the exercise of participative democracy, and environmental education. They welcome people of all ages, all cultures, and all social backgrounds. Collective gardens make it possible to obtain fruits and vegetables at lower cost, energy and environmental impact. They diversify the places of food production and allow people, including the most vulnerable, to take an active part in producing their food. They are also a place of social connection and transmission, allowing the exchange of culinary and cultural knowledge, the (re)discovery of less common fruits and vegetables, and awareness of seasonality. Shared gardens have embraced their environmental and social role, and since the 1990s public policy has enshrined this. For example, in 2003 the French Ministry of Agriculture proposed a law including the promotion of solidarity, social ties and environmental education through shared gardens.

In the case of Chile, the redrafting of the Chilean constitution that began in 2021 following the massive protests in 2019 could have an impact on urban agriculture. In the draft of the new constitution, the role and definition of nature have changed, with "nature" appearing 35 times as a subject in its own right, rather than as an object or thing, and a specific point defining the rights of nature (constitutional article proposal number 297). This development may present a new scenario; the Cultivos Urbanos NGO sees it as a step forward. When interviewed, its members see two positive impacts: the first is a change in the relationship with nature, from a relationship of production to one based on conservation and biodiversity regeneration; the second is the inclusion and participation of grassroots organizations working to change the relationship with nature in the constitutional arena and discussions, thus the possibility for greater food democracy.

Food as a driver in human and human/non-human relations

It the case studies examined, the contact zones (Haraway, 2007) between humans and between humans and non-humans directly affect actions: in gardens, on farms, and within social and solidarity economy organizations. The resource, whether it is a plant, a seed or an animal, sets in motion interdependent relations and gives meaning to the activity (Maurines, 2019). By taking care of the resource and the land, a collective shares ideals that add meaning to the action. This is the case whatever the objective of the collective, whether it is to produce local, accessible, healthy food or to transform people's roles through agriculture (as with Cultivos Urbanos).

Working with natural resources affects one's relationship with nature, one's way of being in the world. However, collective transformation and the capacity to build extensive social links is complex. As expressed by interviewees, contradictions and tensions are evident when combining the will to generate global change with a reduced framework for action. Community garden projects are small, and production is limited and can even be lost if the plants are not tended (for example, when participants go on vacation).

Yet cultivating the land is not a job like any other, as pointed out by Zask (2016). It involves dialogue and participation, collective learning, cooperation, and sharing. Under certain conditions, agriculture can therefore represent a considerable power of change and a real hope for democratic ecology. The case studies we analyzed strengthen ecological citizenship, establishing reciprocal relationships between the community and collective gardens. Through collective work or a collective ideal of nourishment, stakeholders develop civic commitment, encouraging a participatory spirit that aspires to an ethical relationship with the environment. Sustainability is constructed in a multidimensional way: caring for oneself, for other humans and for non-humans.

This involves caring for the resource in designs that favor biodiversity, pollination and local fauna (e.g., hedges, birdhouses, insect hotels, ponds, etc.). This can be "politically institutionalized" with the creation of charters or organic or permaculture certification: public policy mechanisms that stabilize the recognition and legitimacy of the resource. The viability of the resource can also be supported by developing interfaces between different spheres, bringing together researchers, businesses, and citizen groups around cross-cutting science/society issues that aim to decolonize knowledge and produce shared knowledge.

Concretely, aspiring to ethical agriculture displaces the quest for productivity. This can foster food production based on ethical convictions, such as choosing to plant with endangered seeds entrusted by the Applied Botany Resource Center (*Center de Ressources de Botanique Appliquée,*[10] CRBA). After the seeds have multiplied after each harvest, some are then returned to the CRBA for conservation. This system also favors the reintroduction of local vegetable varieties that may be more resilient or have other valuable attributes.

In this way, gardening collectives assume their share of responsibility for the viability of the resource that gives meaning to their actions. They do so by putting themselves at the service of a common cause, to create a sustainable relationship with the

10 http://www.crba.fr

resource of which they are relays and whose role is indispensable in building a good life in common. These gardeners and farmers tend not to talk about the relationship they have with their plants in terms of production (Kazic, 2022).

The human population needs secure food chains and productive land to ensure the survival of agriculture. In the context of current crises, not the least of which is climate change, the viability of small-scale collective agricultural projects becomes particularly relevant. Beyond the green practices of collective gardens, individuals are motivated by a cause that favors the collective itself: benefit for oneself as well as for others (Zask, 2016). The aims of these groups—to produce food locally and ethically, to develop educational and restoration work, and to inform political projects—strengthen democratic values and develop relationships between humans and between humans and nature.

Conclusion

The proximity agriculture case studies we analyzed demonstrate how these collectives strengthen relationships with the environment. The findings show how their collective engagement with the land goes beyond food production: protecting the environment, revitalizing urban spaces, and creating social links.

The groups studied were organized around an initial common project. Based on collective action and relations with the environment, through its defense and maintenance, they address daily challenges in which the aspiration of ecological citizenship is often threatened. Human beings transform the world by preserving it, as Zask (2022) points out, creating a common life. Ecological citizenship appears as a horizon; these community projects—and the work they demand—imply a common project. These experiences materialize citizenship, consolidate its exercise, and enhance it. This can be attributed to collective action but also to the different contexts of threats that make them face new challenges—-for example, urban pressure and scarce available land.

The NGO Cultivos Urbanos promotes ecological citizenship by putting educational activities at the center of their efforts. Historically, their workshops on urban crops and native species have sought to change the relationship between people and nature. Over time, they additionally began to make the link between urban crops and alternative health programs, making collective gardens a therapeutic space for community health. In this sense, ecological citizenship is nourished by the activities of the NGO participants. However, it is also an aspiration that is constantly promoted through various experiences.

In the case of La Pintana, there is a stated objective to defend the workers' gardens from urban growth, demonstrating social values that aim to safeguard the sustainability of life in the city. The desire to maintain them is a way of opposing the growth of the city and pollution Now the challenge is orienting the community project toward the future so that it can be sustained over time.

The ecological practices of the shared gardens in Lyon connect the collective to the local area. While French public policy supports collective environmental projects, beyond food production the stakeholders seek new forms of participation that strengthen community ties and democratic values. Through participation, ecological citizenship is an aspiration to work together. Practices are renewed; although they do not aspire to definitive solutions, they do aim at an ecological transition that allows a better living in the city.

In the indigenous context, the Pehuenche High Mountain project is an example of how collective gardens can be an opportunity to revitalize traditional practices and rebuild trust. The participation of the community, wary from past government policy, alongside institutions, with their more global agenda, reestablished confidence in local capacities. Local involvement allowed agricultural practices to be reconsidered and new initiatives to be tried.

The point is not solely whether local collectives succeed in viable agricultural projects that effectively increase food democracy. It is equally how these initiatives seek opportunities to participate in food policy and social or cultural action. "Being part of," "contesting," "promoting," and "presenting solutions" are all democratic values encouraged in the projects we analyzed. Our aim is not to present these cases as miraculous solutions to environmental or food problems, but to show how these practices can be essential in revitalizing the human relationship with nature and thus improve ecological citizenship. In addition to promoting democratic values, they offer the possibility of establishing reciprocity and recovering the spiritual connection to the land, which is particularly central to strengthening autonomy in indigenous contexts. We see these relationships between the environment and human collectives as key in future food production and environmental management.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving human participants were reviewed and approved by Fondo Nacional de Desarrollo Científico y Tecnológico. The patients/participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

CB, BM, and RC contributed to the conception and design of the study. BM wrote the first draft. CB edited and completed the article. CB, BM, RC, and EC drafted different sections of the manuscript. CB, EC, and RC contributed to the revision of the manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

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Public policies, sustainability, and smallholder producers' access to the market. The Productive Alliance Programme in Chile: A case study

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This study analyses the role of Chile's Productive Alliance Programme (PAP) in increasing welfare and improving access to the market for smallholder producers, by developing a sustainable agriculture in both social and environmental terms. This programme started in 2007 under the Ministry of Agriculture and now serves 3,600 smallholders in Chile. It seeks to create commercial partnerships between these smallholders and large companies, providing subsidies to establish conditions that allow the farmers to build new capabilities and skills. This case study used qualitative methodology and carried out 36 semi-structured interviews over July and August 2020. Interviewees included companies and smallholder producers within different productive chains, as well as public officials. The purpose of this analysis is to discuss the opportunities family farmers have to become a fundamental link in the supply chain of competitive companies at the national and international level. By providing targeted training on market requirements, agricultural management, risk management and sustainable use of resources, the programme enables smallholder producers to establish stable commercial alliances, improving their productive and management capacity. Although the programme's main outcome is not related to a significant increase in smallholders' income, participants perceive more stable earnings, reduced uncertainty, and improve their productive skills, mainly in terms of management and sustainable farming practices.

KEYWORDS

Chile, sustainability, public policies, qualitative research, small farmers

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Introduction

Sustainable agricultural production and food security are two of the most pressing challenges in the face of the various crises unleashed by global environmental change. With a growing population and increased demand for agricultural goods to produce food, fuel and fibers, these concerns call for investment in agriculture, rural infrastructure, natural resource management and resilience to climate change.

Within this context, constructing public policies for food security has been primarily based on promoting the development of an intensive and territorially extensive agro-industrial sector. This has led to a series of environmental and social impacts that have been widely documented in the literature. The environmental impact of this type of agriculture include the use of agrochemicals, configuration of agro-export enclaves and an intensive use of water, among others. Regarding the social effects, although there has been a sustained increase in income for rural workers, this has tended to be accompanied by labor precariousness and a large-scale urbanization process. In this regard, the question of how to convert family and sustainable agriculture into a scalable food production model that represents an economic and environmental alternative for the territories is of great relevance, particularly in the case of Latin America, a region with a high percentage of rural population and poverty.

This article analyses the effects of the Productive Alliances Programme (PAP), a government training and support program designed to increase human capital and improve the productivity of smallholders in Chile. Using a model of agricultural human capital investment, this programme creates a commercial alliance between purchasing (typically large) companies and smallholder producers that the government mediates through Chile's National Agricultural Development Institute (INDAP in its Spanish acronym). This alliance is strengthened, first, by technical monitoring provided by the purchasing companies and, second, by the government's support to companies and producers to develop skills and capabilities.

Chile's economy and agricultural support

Chile is one of the fastest-growing economies in Latin America and has reduced poverty significantly over the last three decades (Agostini et al., 2008; Abner Campos and Foster, 2013; Cazzuffi et al., 2017). Between 2006 and 2017, monetary poverty decreased by more than 20 percentage points while extreme poverty fell by ten. However, rural monetary poverty remains high and above the national average at 16.5%. Even though progress has been made in reducing poverty, Chile still has one of the most unequal economies of the Organization for Economic Co-operation and Development (OECD). Despite the still high poverty rate, in recent decades, rural areas have also experienced significant economic growth, a major increase in exports and a marked reduction in poverty (López and Anríquez, 2004; Foster et al., 2016). Overall, rural workers have increased their income around 1.64% between 1990 and 2006 (Valdés et al., 2008) and an average of 2.3% between 1998 and 2017 (Pérez et al., 2020).

The Chilean government's support for agriculture is weak and one of the lowest among OECD countries (Ortega and Valdés, 2019). Spending on agriculture represents 5% of total government spending, and a mere 0.5% of agricultural GDP is allocated to research and development in this sector. Finally, the country does not have a national agricultural investment policy, but several sectoral investment programmes assigned to different government agencies, such as the one implemented by the National Agricultural Development Institute (INDAP) that we analyse here.

The Productive Alliance Program: Smallholder producers for sustainable development

The National Agricultural Development Institute (INDAP) forms part of the Ministry of Agriculture. It was created in 1962 to promote the economic, social and technological development of smallholder producers. In addition, it works to improve their administrative, organizational and commercial capabilities by promoting their participation in rural development and improving their efficiency in the use of productive resources (INDAP, 2020). INDAP started the Productive Alliances Programme (PAP) in 2007 with the objective of "*Creating conditions for smallholders*[1] *and agricultural producers who are members of INDAP to access better commercial alternatives and new markets in order to contribute to the improvement of sustainable and transparent commercial relations with purchasing groups*" (INDAP, 2020). This programme seeks to eliminate informal intermediaries between smallholders and purchasing companies, establishing a direct commercial link between the two. It also aims to strengthen the capacity of smallholders as permanent suppliers to purchasing companies, developing their skills to meet high production and safety standards in accordance with market requirements. A basic depiction of the alliance's structure can be found in Figure 1: smallholders sell fresh produce to larger companies, who in turn provide technical assistance and training to smallholders, for them to maintain their production in both quantity and quality to

1 INDAP defines smallholders are those who work an area of up to 12 hectares with basic irrigation infrastructure and assets with a total value of less than 100 million Chilean pesos (about US$150,000). Their primary income is from agriculture, and they are directly involved in agricultural production regardless of land ownership (INDAP, 2020).

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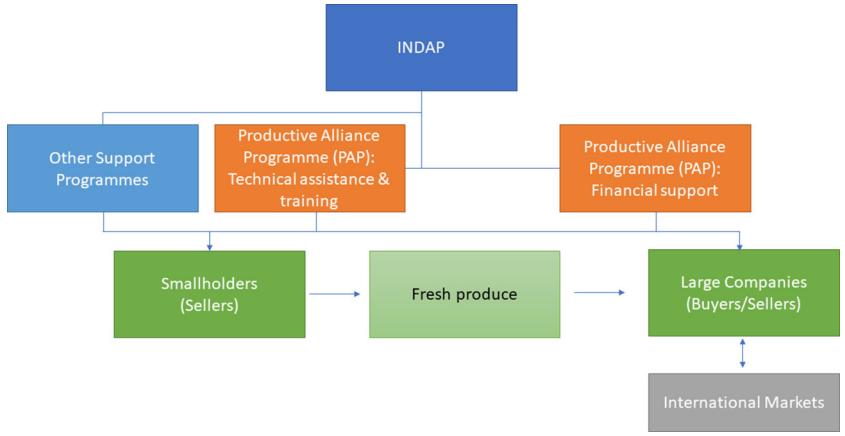

FIGURE 1
Process flow chart of the PAP. Source: Own elaboration.

meet international standards to access international markets. The alliance is created and, to some extent maintained by the government through INDAP, where smallholders participate in PAP and other programmes oriented to the support of small-scale agriculture.

PAP began with a pilot project focussing on technical assistance for two products in three regions: sheep farming in the O'Higgins and Maule regions and berry production in the O'Higgins and Biobío regions. The programme was formally established in 2009 when it began operating with its own regulations and procedures. It expanded in 2010 to cover 10 of the country's 16 administrative regions, from Coquimbo to Los Lagos. Most PAP's users are located in the Maule region, south of the Metropolitan region, where Santiago, the capital, is located (Table 1). In 2018, the programme's regulations changed to increase its size and scope. As a result, the programme has more resources and an investment fund that complements the initial technical assistance and involves value chains outside the food sector, such as rural tourism and handcrafts. The investment fund has a lump sum that PAP users can apply for to help finance investment projects (e.g., irrigation or storage infrastructure) that will enable them to comply better with buyers' requirements. The new regulations also allow PAP users to participate in other INDAP programmes. Thus, in 2019, 43% of PAP users received complementary support from technical assistance programmes such as SAT (Technical Advisory Service), PRODESAL (Local Development Programme), PDTI (Indigenous Territorial Development Programme), PRODEMU (Foundation for the Promotion and Development of Women) and PADIS (Agricultural Programme for the Integral Development of Smallholders). In the same year, about 40% of PAP users also received small-scale loans from INDAP, and 5% obtained funding for irrigation programs (INDAP, 2020). In addition to the programmes, other INDAP initiatives also interact with PAP in a significant way. Some examples are the Farmers Associative Companies (EAC in Spanish) and the Economic Associativity Programme (PAE), which encourage association among farmers. In 2019, 15 EACs participated as buyers, and six received funding from PAP to provide farmers with specialized technical assistance in management and associativity issues.

TABLE 1 PAP users by region, 2019.

Region	Companies[a]	Contracts	Users
Coquimbo	2	2	170
Valparaíso	1	1	48
Metropolitan Region	1	2	66
O'Higgins	1	2	77
Maule	23	42	1,464
Ñuble	11	11	526
Biobío	5	6	242
Araucanía	7	7	336
Los Ríos	10	12	483
Los Lagos	5	5	184
Total	66	90	3,596

Source: INDAP (2020).
[a]In total, 54 individual companies participate in PAP. However, some are present in more than one region simultaneously, which takes the total in the table to 66.

PAP farmers are a diverse group in terms of production, with products varying from fruit (in particular berries) to rural tourism, handcrafts, vineyards and others. Despite this heterogeneity, most of PAP producers focus their production on berries (28%), honey (17%), vineyards (11%), dairy products (10%) and cattle (6%). In 2019, 54 buyers and 3,596 smallholder producers were part of the programme, culminating in 90 active

contracts. Many companies have a local presence in various regions through independent contracts.

The agreement consists of a 4-year work plan where all three actors (INDAP, smallholders and purchasing companies) participate. This plan includes organizing various activities for producers, such as technical advice on production management, training activities on commercial and technical issues, laboratory tests to detect pests, international meetings and workshops, all provided for by the purchasing companies. PAP represents the formalization of this commitment, including the financial contribution of each participant to implement the agreement. It should be noted that the agreement is not a binding commercial contract between buyers and small producers, which means neither party is obliged to buy or sell. Even though the producers may leave the alliance at any time and sell to other buyers, in practice, most of them seek stability in the relationship with the purchasing company.

Generating an agreement usually begins with an interested buyer submitting a technical, methodological and financial proposal to INDAP. Once the proposal is approved, INDAP and the buying company work together to find potential partners among local smallholders. Producers are not randomly assigned to the programme but are carefully selected by INDAP and the purchasing companies. Therefore, most selected producers are former INDAP users or smallholders who have already sold to the purchasing companies. This implies that vulnerable smallholders or those not enrolled in any of INDAP's programmes may find it difficult to participate in PAP, as they may lack a general knowledge on how to access government benefits allocated to small agricultural producers or may not have generated the trust within the buying company seeking the establishment of an alliance. Once the alliance is established, each partner has a specific role. Buyers organize training to improve smallholder production to suit companies' requirements. Producers, on the other hand, attend these activities and use them to improve their production. INDAP acts as an intermediary in this relationship, supervising its implementation and funding a large part of the programme (between 40 and 70% of the cost of the alliance, depending on the size of the purchasing company). Today, PAP operates in 16 different products or value chains covering a wide range of economic and productive activities.

Methodology

This case study uses primary qualitative data to clarify the opportunities and challenges faced by family farmers in the development of sustainable agriculture with better marketing channels, more stability, and stronger territorial roots. The study is based on semi-structured interviews aimed at understanding the perspective of key actors working with the Productive Alliance Programme (PAP): we conducted 36 interviews with participants selected according to the criteria detailed in Tables 2, 3 in the qualitative sampling section. These interviews were then processed using inductive qualitative content analysis.

Qualitative sample

Qualitative research implies having a comprehensive and relevant criterion for selecting a sample without being guided by statistical representativeness. In this case, we worked with case-type sampling, a qualitative sampling technique that searches for relevant profiles. This ensured representation of the heterogeneity within the value chains in which the programme operates (Hsieh and Shannon, 2005; Rapley, 2014). Due to the large number of value chains (16 in total) and the need to narrow down the qualitative sample, these 16 chains were grouped into seven general ones.

Taking into account these groupings, the cases were selected purposefully, distinguishing the different geographical areas where the programme was implemented and paying special attention to the regions of Maule and Los Ríos, where 40.7% and 13.5% of the PAP participants operate, respectively. In addition, PAP users were interviewed in each region where the programme is applied, covering all value chains. Table 3 details the final sample selection.

Qualitative analysis

The information analysis, carried out through content analysis, had three steps: transcription, coding in matrices and content analysis of each dimension of the matrices. In this final step, the most important elements from each dimension of the analysis were retrieved. These elements have been presented narratively in a synthetic way in this article. Verbatim quotations, duly cited, are only used when needed to illustrate the actors' perspectives.

Results

While one of the PAP programme's key objectives is to train farmers to provide them with access to the market, its main outcome is providing farmers with a stable income. Producers mention that such market access is only feasible when a commercialization link with the main buyers is established; therefore, this link is vital to PAP producers.

Although the agreement between small producers and buyers is the base of the programme, there is no obligation for companies to buy or for producers to sell. The stability of the alliance is observed when companies show greater commitment to the programme. This commitment to the

TABLE 2 PAP participants by product and product category.

No.	Product grouping		Programme users	
	Category	Product	By product	Category total
1	Fruits	Berries	994	1,094
		Other fruits	100	
2	Apiculture	Honey	623	623
3	Vineyard	Grapes	392	392
4	Oils	Essential oils	40	40
5	Dairy and meat (animal products)	Dairy	348	688
		Beef cattle	219	
		Sheep	75	
		Pigs	46	
6	Vegetables, legumes and cereals	Vegetables and potatoes	193	483
		Beets	172	
		Legumes	46	
		Cereals	72	
7	Farm specialities, handcrafts and rural tourism	Farm specialities	50	276
		Handcrafts	131	
		Rural tourism	95	

Source: INDAP's Users Baseline Survey (2015).

TABLE 3 Sampling criteria for interviewees.

Programme participants	Sampling strategy	Number of interviews
INDAP Professionals (programme executors)	One interview per category, plus one with the general coordinator	8
Buyers (purchasing companies)	One interview per category	7
Smallholders (programme users)	Three interviews per category. At least one of the interviewees must be a woman.	21
Total		36

Source: Own elaboration.

producers translates into high-quality training, support in product delivery management and support when they request investment funds or other funding resources to improve their production. As mentioned by the producers, the companies that show this level of commitment are mainly cooperatives that are part of INDAP's Farmers Associative Companies. These companies have a tradition of working with smallholders, their markets demand small-scale production, or they are companies innovating in fair trade markets or agroecological farming. With respect to the producers' commitment to sell to the buyers with whom they have established their alliance, the qualitative data show different strategies: (A) some farmers sell them all of their production; (B) others sell part of their production, preferring to look for a better price for the remaining goods; (C) a small share of farmers do not commit to sell to the buyer in their alliance, these farmers prefer to look for the best price in other markets. The data indicates that this latter group is a minority and is usually associated with larger production volumes.

PAP and smallholder farming. Developing commercialization skills

Producers emphasize how important this support has been for improving their productive practices and developing their capabilities, particularly with respect to their *specialized technical skills*. Farmers receive training in input use, pest and disease control, and equipment to improve quality. Training also covers meeting market demands and risk management. Additionally, they highlight their training in planning. Producers are taught to follow protocols that monitor productive activity through recordkeeping: *"As farmers, we are sometimes a bit reluctant to keep records, we have had to learn to record, when, for example, a calf dies or similar"* (interview with farmer 2, beef producer, August 2020). Developing these skills translates into improved yields and increased capacity to meet certification requirements.

In capacity building, one of the key elements for small-scale producers is specific production methods, such as fair trade

and agroecological agriculture. These two methods are highly compatible with the forms of production of family farming and their productive capacities and therefore represent potentially attractive niches for their products. These markets usually require certification processes from the purchasing companies. The qualitative sample of PAP producers in these alliances showed that they positively evaluated their participation and the development of production skills oriented to these markets. This appraisal is due to the much higher prices paid, as well as the opportunities farmers see for future growth: *"the future of food supply is headed in this direction, and that gives us hope"* (interview with farmer 5, berry producer, August 2020). Training in this direction has an important correlate in terms of sustainable land management, since agroecological market requirements modify cultivation methods: *"We used to burn everything to prune, now we do not burn at all; we have incorporated controlled pruning. We learned how to take care of nature. Before we used to hunt birds, now we realize that we should do quite the opposite; they provide us with a service"* (interview with farmer 8, berries area, August 2020).

A final point highlighted by the farmers is the development of social skills, namely communication and interpersonal skills, particularly among female producers. Although this programme does not target specific groups such as women, youth or people with disabilities, some female participants felt that they particularly benefitted from it. As a result of the programme, they have built up the confidence to participate further, in turn generating a new or more stable source of income. The female participants stated that the programme has been particularly important for women. As a way of example, one woman stated: *"I am one of the women who has dared to go out in the field thanks to this, to have a voice that asks questions and to sign up for projects"* (interview with farmer 14, beekeeping, August 2020).

PAP. A model that encourages commercial alliances

In this section, we review the core elements of the PAP model that encourage buyers and small producers to participate in the programme.

Regarding the purchasing companies, the interviewees first mention the financial incentives. They receive direct contributions from INDAP for the maintenance of the alliance (from 40 to 70% of the total cost). These incentives are quite significant for small or emerging companies and allow them to face the first stages of cultivation, such as exports or opening new markets. In addition, they reduce the risks involved in implementing the alliance. For this reason, this programme benefits precisely those companies seeking to establish themselves in niche markets such as agroecology and/or organics.

In this line, one of the most important incentives for the purchasing companies is the need to comply with certain quality requirements in international markets. This need can be met through specific training to the producers. Consequently, by participating in the PAP programmes, these companies can improve quality by training smallholders and thus reach the companies' markets of interest. Small producers are key to achieving optimal production and quality in some markets, such as berries, honey, local crafts, domestic potatoes, fruits and organic beef. Therefore, the quality of training, follow-up, and the relationship between the two actors are key to the success of the alliance.

Finally, PAP has allowed for the consolidation of some associative and cooperative models of sustainable family farming. A paradigmatic case is that of the 15 Farmers Associative Companies (EAC), which offer technical assistance and guarantee distribution channels for their members. This helps farmers to improve and increase honey production as well as innovate in the means of production. We also find companies that, despite never having related with the cooperatives or any other productive society, have been working on a distinctive trademark with projects in conjunction with local communities, strengthening their interest in participating in the programme.

In the case of producers, incentives for their participation fall into two areas: firstly, in specialized technical assistance. Producers highlight the importance of improving productivity through more efficient business relationships with buyers. They also value technical field visits, which allow them to address specific production issues (e.g., crop, beehive, or animal diseases), aspects of production, and economic and management areas (e.g., accounting and data records). Second, one of the main attractions of the programmes is the possibility of consolidating their access to markets, thus reducing risk and uncertainty. Although interviewees emphasize that this channel offers lower prices than those encountered outside of the alliance, access to a stable market is the most important factor for producers, given that it guarantees them financial stability. Finally, in terms of investment, the programme has offered producers access to capital, such as trucks, and investments in storage space and other supplies. Funding from other INDAP programmes are complementary and has contributed to increasing producers' production capacity, improving their products, making them more attractive to consumers and enabling them to gain access to previously inaccessible markets.

Discussion

The research findings indicate that small producers benefit in the following areas:

Improved productive skills in smallholders in terms of volume and yield

Cereal and vineyard sectors in particular, achieve significant increases in production by providing smallholders with greater land use and investment capacity. In turn, honey and handcraft producers are able to convert their small-scale agricultural activities into their main source of income. We also see producers successfully specializing in production with specific requirements that allow them to participate in alternative business models such as fair trade or agroecological farming. The success of the programme in terms of increased yields was common to all interviewees.

More stable income

Developing the capacities mentioned above and establishing commercial relationships allowed all producers to improve their incomes. This was achieved not only through increasing income (several cereal, wine and handcraft producers confirmed this) but also by providing stability, formality and a real possibility of earning a living in the countryside with agricultural activities such as berry, honey or beef production. In the case of handcrafts, it is worth mentioning that one reason for the increased income had little to do with improvements in production but was instead due to the programme's opening of a business channel that previously did not exist.

Promoting associative development

Although not one of its objectives, strengthening producer associations is a third successful result of the programme. Among its producers, PAP has 15 Farmers Associative Companies that operate as cooperatives and were empowered as a result of their participation in the programme. For example, the associative companies in the honey and berry industries, acting as buyers in the PAP programme, could develop as trading companies or become exporters. Producers who were not cooperative members also benefitted from the opportunity to cooperate and coordinate with PAP members because each of the alliances succeeded in generating a stable group of producers who worked together, allowing for peer learning and price negotiation. Likewise, associating and organizing themselves helped them gain access to investment resources or purchase machinery and agricultural inputs for their collective use.

However, three important aspects should be reviewed in order to improve the farmers' long-term sustainability.

First, while the programme improves the quality of the production, this is not necessarily sufficient to significantly increase producers' income. This implies that, without the programme's assistance, producers may not be able to cover the full cost of maintaining production quantity and quality, for example, paying for the expert advice provided by the programme.

Second, despite successfully introducing producers into the commercialization cycle, the risk for small producers has not diminished. A drought or the wrong decision regarding seeds, fertilizers or other inputs can result in the complete loss of the crop. In fact, producers feel they need permanent assistance. In fact, only a small percentage of participants indicate product diversification as the aspect PAP has improved the most, and several mention that they would like to focus on product diversification in the future, possibly as a way to reduce risk and income fluctuations.

Finally, the programme designs alliances that last 4 years. At the end of the fourth year, producers and buyers who renew their alliance within the PAP have to repeat the same training and progress that were developed during the first alliance, with no recognition of the progress made nor an increase in the depth or complexity of the content taught. A producer may participate in three consecutive alliances and receive similar training each time, which prevents them from advancing their development. To that extent, a programme that incorporates different levels of training, designed to allow for different paths of progress in order to establish long-term alliances, is recommended.

Conclusions

Given the challenges posed by global environmental changes in the food sector, it is essential to identify and discuss public policy initiatives that seek to strengthen value chains that incorporate sustainable small-scale agriculture.

The PAP programme is successful in guaranteeing a stable income and market access for small producers in such a context. It achieves this by creating alliances with larger export-oriented companies or buyers that produce and export the same product. This is important because the programme improves the welfare of producers and creates conditions for them to remain in agriculture. It does so by consolidating the position of small producers and promoting sustainable forms of production in social and environmental terms.

One of the most pressing issues in Chile's rural areas is the decrease in the number of jobs in agriculture and the urbanization of these territories. By promoting small-scale agriculture, the programme can potentially reduce the outmigration of labor at a rural and sectoral level while, simultaneously, providing a space in the market for fresh and healthy food for the population in and outside rural areas.

Regarding the programme's efficiency, while INDAP promotes the creation of the alliance and actively seeks

participants, the buyer is responsible for training producers and assisting with additional resources for the work of the alliance, which significantly reduces costs for INDAP. This is especially true for larger companies, to whom INDAP offers less financial assistance. If the alliance extends beyond the 4 years of the initial agreement in which INDAP participates, the extension could operate without the government's assistance so that INDAP can include new smallholders or new companies in the same alliance or in others within the programme in general.

However, it is important to consider that, although a significant proportion of producers increase their capacities as a result of participating in the program, this does not seem to create a sufficient accumulation of human capital among smallholders to enable them to maintain the alliance independently of INDAP after the end of the alliance. This could be improved by modifying how the training is structured so that is develops in conjunction with the alliance. The programme has gone from being a local initiative to a national one covering almost all the country's agricultural and productive areas, an important feature and measure of its success. In the same sense, and despite not being a direct objective of the programme, it has enhance women's empowerment, especially in rural areas, and has consequently helped to reduce poverty.

Finally, and whereas the PAP is not strictly a contract farming programme but resembles one, it is important to highlight that our results are very much in line with those of Masakure and Henson (2005) for Zimbabwe, who found that small-scale farmers see in contract farming a way of improving welfare, but also a way of acquiring knowledge, to reduce uncertainty, and to access alternative markets otherwise unreachable. Similarly, previous studies have reached similar conclusions regarding the benefits of alliances between smallholders and larger companies. These studies have pointed to gains in welfare, mostly associated with income increases (Barrett et al., 2012; Bellemare, 2012) but also with other aspects of welfare, such as improvements in food security (Bellemare and Novak, 2017). Interestingly, some of these studies have noted that these welfare increases are more marked when associated to the production of organic foods (Jouzi et al., 2017), as farmers are more able to reach international markets and sell at higher prices, something also found in our study. Overall, we believe our results are able to show that the PAP programme can serve as an important tool to increase welfare and to generate the necessary conditions for smallholders to access international markets by eliminating important barriers and reducing transaction costs, something proven to be crucial in the success of these kind of initiatives (Pingali et al., 2005).

Data availability statement

Publicly available datasets were analyzed in this study. This data can be found here: CGIAR Research Programme on Policies.

Ethics statement

The studies involving human participants were reviewed and approved by CGIAR Research Programme on Policies. The patients/participants provided their written informed consent to participate in this study.

Author contributions

MC and RP-S: conception, design, and drafting. MC, CC, and MS: analysis and data interpretation. MC: editing. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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Dietary habits during the COVID-19 pandemic. Are work environments part of the problem?

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The COVID-19 pandemic pushed a large number of workers out of their offices and to their homes for a significant period of time for teleworking. However, some workers continued to work in their offices and others went home only partially. This arguably exogenous shock to the way in which workers performed their jobs opened the opportunity to evaluate whether work environments are ideal for promoting healthier diets and reducing overweight among office workers. We explore the results of two consecutive surveys (pre- and during-COVID-19) to examine whether workers working from home perceived their situation as more favorable in terms of healthy eating habits and weight gains. Our results show that workers did perceive their homes as places where they can follow healthier eating habits, but this was not accompanied by weight loss. On the contrary, workers fully teleworking were more likely to perceive weight gains and diet-related health problems than their in-office counterparts. Among teleworkers, those only partially teleworking were the most affected. This study opens many questions about food environments at work that remain unanswered. More studies in this area are needed to understand how the food at work affects the worker's health.

KEYWORDS

healthy eating habits, teleworking, food environments, COVID-19, food at work

Introduction

In 2020, over 3.1 billion people could not afford healthy diets, as they are estimated to be five times more expensive than those that only satisfy calorie requirements (FAO, 2022). Unhealthy diets are often based on cheap food products rich in simple carbohydrates and fat, and many include high percentages of ultra-processed foods high in calories and critical nutrients, such as sodium, sugars, and trans-fat. High calorie intake coupled with the absence of nutritious foods (rich in micronutrients, fiber, and phytochemicals) often leads to overweight and/or obesity and dietary related chronic diseases such as diabetes, cancer, or cardiovascular diseases. The costs produced by diet-related morbidity and mortality of mainly non-communicable diseases are projected to globally surpass USD 1.3 trillion per year by 2030 (OECD, 2019). Furthermore,

unhealthy diets not only have repercussions on health and are an important economic burden, but also generate other hidden costs related to different Sustainable Development Goals (SDGs), such as climate change (Lang and Pamela, 2018). For instance, diet-related greenhouse gas (GHG) emissions are estimated to surpass USD 1.7 trillion by 2030 (FAQ, 2020).

In Chile, 28% of adults are obese, and up to 80% of the deaths in Chile are attributable to diet-related diseases (FAO, 2019) that, in 30 years, are estimated to be responsible for an expected decrease of 3.5 years in the life expectancy (OECD, 2019). Probably many of these deaths will correlate with an increase in mortality in working-age adults, as reported for the United States in a report by the National Academies of Sciences, with a negative effect on the US workforce, productivity and competitiveness of their businesses, economy, and even national defense (National Academies of Sciences Engineering, 2021). An increase in mortality in working-age adults also impacts health care costs for both government and employers.

The Chilean workforce represents almost 60% of the population (INE, 2020), and workplaces are an important feeding context because people spend most of their day working. Chile has ratified the International Labor Organization (ILO) Convention No. 187 (2006) on the promotional framework for safety and health (International Labour Organization, 2012) and even though there are good examples related to improving food at work and costs seem to not be a barrier for employees (only stated as such by 13% of the companies (International Labour Organization, 2012), many employees do not benefit from access to healthy food at work. The Chilean Supreme Decree N° 594 (1999), which complements Law 16.744 establishes a minimum requirement on nutrition for workplaces referred to as providing a safe place to eat and ensuring at least 30 min for meal consumption (International Labour Organization, 2012). However, many companies, especially smaller companies, and those with a predominantly female workforce do not achieve even one of these obligations. The larger the company, the more likely it is to comply with these minimum requirements and to have a canteen, which is the food benefit preferred by workers (International Labour Organization, 2012). Nonetheless, only 30% of people work in companies with more than 200 employees, while the vast majority (43% of men and 51% of women) work in companies smaller than five people (INE, 2020). As a result, almost a quarter of the workers do not even have a place to eat. These situations are exacerbated within informal jobs. In a Colombian study of informal work, an average daily working time of 10 h was estimated, and more than half of the respondents declared to not have established eating hours during the working time (Duque et al., 2019).

The global work force experiences unequal access to healthy food, time for eating, and the possibility to eat at their workplaces (Wanjek, 2005). The access to adequate food within workplaces in Chile is also related to income: income is positively correlated with more time to eat, more options of places to eat, more probability to include fruits and vegetables at lunch and to receive food-related benefits, which were received by 61% of the workers, as stated by the same study (Wanjek, 2005).

The main causes mentioned for skipping lunch in Chile were lack of time and money, leading to up to 30% of workers skipping lunch on a regular basis (International Labour Organization, 2012). This leads to fatigue, headache, lower concentration, and irritability, among other symptoms, which in turn impact productivity at work. A direct relationship can be found between productivity, labor safety, and a healthy diet. Wanjek (2005) found that adequate nutrition could improve productivity by up to 20%, while iron deficiency lowers work capacity and performance by up to 30%. Therefore, improving food at work not only impacts the individual health, but also the companies' economy: obese workers are twice more likely to show absenteeism (International Labour Organization, 2012), have higher risks of work accidents (Hoffmeister et al., 2014) and cost the company up to 6 times more than a non-obese worker (Ávila, 2015).

The COVID-19 pandemic has had important impacts on living and eating habits worldwide. Weight gains of 10% modify the brain, causing personality impairments leading to impulsiveness and lesser resistance to desires (Navarro-Cruz et al., 2021). Due to at least temporary lockdowns and teleworking, for many people eating has shifted from at work canteens and restaurants to home cooking or food delivery (Ferrante et al., 2021). Thus, the COVID-19 pandemic has changed and exacerbated many social inequities, eating habits being one of them.

In France, an increased snacking and consumption of sweets, biscuits, and cakes accompanied by a decreased consumption of fresh products such as fruits and fish was found, leading to weight gain in 35% of adults participating in a national survey (Deschasaux-Tanguy et al., 2021). A review studied the dietary habits due to the lockdown, and even though there are some people that improve their dietary habits, those who worsened them were associated with other detrimental lifestyle changes, such as mental health issues, weight gain, and less physical activity (Bennett et al., 2021). Furthermore, another review found that every socioeconomic group increased their caloric intake, estimating that 2 years after the pandemic offset, adults would increase by five percentual points in overweight (O'Connell et al., 2022).

On the other hand, positive changes were also reported in the same study in France: about a quarter (23%) of interviewees lost weight, 40% increased home cooking and 19% increased physical activity (Deschasaux-Tanguy et al., 2021). In an Italian study weight loss was also found in almost 60% of participants (Izzo et al., 2021). As shown in a Canadian study (Carroll et al., 2020), families with children were found to eat more food, more snacks, especially among mothers, and fewer fast food and takeout, showing a preference for at-home cooking, and also

involving the children more in the process. Furthermore, an observational study carried out in 38 countries, found increased planning, selecting, and preparing of healthy foods, leading to an improved food literacy related to confinement and perception of more time availability (De Backer et al., 2021).

The pandemic has also changed the diet in Chile. A sub-national study that surveyed students, administrative officials, and teachers of the University of Bio-Bio found the pandemic to be positive in relation to higher adherence to the Mediterranean diet (Navarro-Cruz et al., 2021), therefore, the confinement led in some cases to healthier dietary habits. One study carried out on a total of 700 adults found that increased cooking was higher in women compared to men, and more than a half responded to eating more than before the pandemic, including junk and fried food up to two times a week by 63% of respondents (Reyes-Olavarría et al., 2020). The same study found associations between weight gain with many factors, including cooking less. The authors also found longer quarantines to be associated with a greater desire for pleasant foods. On the other hand, an increase in fruit and vegetable cooking was associated with weight loss (Navarro-Cruz et al., 2021), whereas weight gain was associated with lifestyle deterioration during confinement and not due to emotional influence. As said before, women cooked more during the pandemic, and this could be related to significantly higher healthy eating index scores in female compared to male workers (Schifferli-Castro et al., 2020).

While some employees continued to work in person, many were partially or totally teleworking during the pandemic. This change in working conditions then represents an important opportunity to test whether work environments affect eating habits and specifically whether they are associated with healthier or worse eating habits compared to the pre-COVID-19 situation.

Although the described evidence is not conclusive in terms of the effects of the lockdowns on eating habits and weight loss, the aim of the study is to explore if there were any differences between dietary habits when teleworking compared to working from the office and if these differences had impacts on participants' perceived weight.

Data and methods

Two nationwide online surveys on the work environment in relation to food intake and dietary patterns were conducted during September 2019 (pre-COVID-19 survey) and between November 2020 and early January 2021 (COVID-19 survey). The google forms survey was sent by mail to every person who contacted the Job Portal Laborum (https://www.laborum.cl/), which is an open well-known website to look up for jobs vacant in any field and apply, mostly for professionals. The two questionnaires covered some similar questions ($n = 20$), but the COVID-19 survey had 13 more questions regarding the status of teleworking and its changes. The questions were related to socio-demographic dimension (e.g., gender, age, educational level, current employment status); work modality (full presence, half-teleworking, full teleworking – in the COVID-19-survey); eating at home/office; food provision by employers; if the employer should be responsible for nutrition during working hours; which food benefit is the most valued by workers; if they spend more/less money on food during teleworking compared to working at the office (in the COVID-19-survey); an approximation of the money spent in food at work; mandatory food pauses; healthiness of their food (subjectively answered, and if improved or worsened during the pandemic); the understanding of healthy diet; if there is a place to eat at the office; and eventual weight variations (perception about gaining or losing weight – in the COVID-19-survey) among others (refer to Supplementary material). In particular, the survey included a question investigating the presence of possible diet-related health problems since the beginning of the pandemic in terms of high cholesterol, diabetes, weight loss, overweight, gastritis, arterial hypertension, and "other" as the last option. The full questionnaire used for the two surveys can be found in the Supplementary material.

From the pre-COVID-19 survey, a total of 1,962 responses were obtained. However, after excluding participants providing incomplete survey forms and those who were unemployed for more than 2 months, 1,732 cases were considered for the analysis. From the COVID-19 survey, 757 responses were obtained, 520 out of which were used for the analysis, after applying the same exclusion criteria as the pre-COVID-19 survey.

Data analysis

We estimated the association between the place of working (teleworking or at the office) and several diet-related outcomes. These are changes in food habits, overweight, weight reduction, and diet-related problems as reported by the individuals included in the surveys.

Let Y_{ij} be the outcome of interest, such as overweight for individual i working under condition j (fully teleworking, partially teleworking, in the office), we estimate a logit model as follows:

$$Y_{ij} = \alpha + \beta W_{ij} + \gamma X_{ij} + \varepsilon_{ij} \quad (1)$$

Here, Y_{ij} is a dichotomous variable at the individual level indicating whether the individual considers him or herself as being overweight, W_{ij} is a categorial variable identifying whether the individual works at the office, partially from home, or fully from home. X_{ij} is a vector of control variables, such as age, sex, and schooling.

We then estimated the same logit model for other outcome variables, such as having experienced weight reduction, diet-related problems, and perceived changes in food habits, which were applied as dichotomous variables, therefore suitable to run logit models. We report the results of all these models in the respective section.

As mentioned in all cases, the outcome variable is dichotomous, with value one when the perceived problem occurs (and zero if not), and the main independent variable of interest is a categorical variable indicating the working place, with mutually exclusive alternatives (in office, partially teleworking or fully teleworking).

Results

Participants characteristics

The characteristics of the participants are listed in Table 1. A large share (85%) of the total sample works in the office (n = 1,909), while only 13% is fully teleworking (n = 284) and less than 3% of the sample partially teleworks (n = 59).

As reported in Table 1, having healthier eating habits is more likely among fully teleworking workers, as declared by almost 65% of them. Lower proportions have been reported instead for workers fully working in the office (57%), and for those partially teleworking (56%).

Nonetheless, fully teleworking people are more prone to experience overweight (29%) and to experience diet-related health problems (46%) than fully in-office workers (19% and 36%, respectively). However, workers who partially teleworking are the ones with the highest declaration of overweight (36%) and diet-related health issues (68%).

Workers operating from home, either partially or fully, are on average older than those working from the office. This is noticeable when looking at the percentage of workers over 45 years old, which is 34% for workers fully teleworking, and 39% for those partially teleworking. On the other hand, around 22% of the workers working in the office are over 45 years old.

Women are more common among workers either in the office (60%) or fully teleworking (62%) compared to workers partially teleworking (49%). With respect to education, more educated workers are either partially teleworking (93%) or fully teleworking (89%), but a large share of them is working from the office as well (64%; Table 2).

It is worth noting that despite almost 9% of respondents working in administration or administrative related jobs and 10% of workers in sales, there is not a clear occupation or work area that stands out in relation to the others. As an example, 5% of workers work in technology, 6% in education, almost 4% in engineering, and above 3% in medicine, construction, and finance. Unfortunately, we could not properly characterize around 38% of the sample because almost 23% of it did not provide a response, and above 15% stated that his/her work was in the "other" area, without providing any specification.

TABLE 1 Descriptive statistics of the sample.

	In-office working (n = 1,909)	Partially teleworking (n = 59)	Fully teleworking (n = 284)
Participants	84.8	2.6	12.6
Gender			
Women	60.3	49.2	61.9
Men	39.7	50.9	38.0
Age range			
18–24 years	7.4	1.7	5.3
25–34 years	39.1	32.2	34.2
35–44 years	31.1	27.1	26.8
> 45 years	22.5	38.9	33.8
Education			
High school or less	9.1	3.4	1.1
Technical school	26.6	3.4	9.9
College or more	64.3	93.2	89.1
Experiencing weight increase			
No	8.1	64.4	7.8
Yes	18.9	35.6	29.2
Experiencing weight loss			
No	98.3	96.6	97.5
Yes	1.7	3.4	2.5
Healthier eating during the pandemic	56.6	56.0	64.8
Diet-related health problems	36.4	67.8	46.5
Gastritis	8.2	10.2	3.2
High blood pressure	1.4	0.0	0.7
Diabetes	0.8	0.0	1.1
High cholesterol	1.3	1.7	1.8

Data are expressed as number (%).

From the obtained results 59% of the respondents in both surveys reported that a healthy diet is one low in sugar, salt, and fats; 18% considered healthy diets those with no processed and packaged food, 14% believed healthy diets are those with no fast/*junk* food; 12% selected the option related to the inclusion of food having no front of package nutritional "high in…" signs.

A share of 34% of the participants receives a food "benefit" from their employers, of which 74% are food that is given from the employer (voucher, canteen, or extra money in the salary for food expenses). A low percentage (12%) of the participants think the employer should be responsible for their food during working hours, while among those who partially teleworking,

10.3389/fsufs.2022.961908

TABLE 2 Respondents' work areas.

Work area	Number ($n = 2,252$)	%
No response	516	22.9
Other	338	15
Sales	274	12.2
Administration	223	10
Mathematic	210	12
Education	131	5.8
Medicine	74	3.3
Construction	72	3.2
Logistics	64	2.9
Communications	58	2.6
Gastronomy	51	2.2
Human Resources	48	2.1
Mining	41	1.9
Law	40	1.8
Insurance	22	1.0
International trade	21	0.9
Design	9	0.4

For this table, we grouped: engineering, technology, and finance sector into mathematical; marketing and communications into communications; sales and callcenter into sale; and administration and secretary into administration.

only 3% (a quarter of who agreed with this statement) still believed it when only teleworking. More than half of the sample (63%) think it is a shared responsibility and 26% think it is their own responsibility. In addition, 22% of the respondents preferred a food benefit a food voucher, 19% preferred the canteen at work, while 18% preferred extra money in the salary.

Considering the expenses related to food at work, 4% declare spending more than CLP$6000, 8% between CLP$4000 and CLP$6000, 43% between CLP$2000 and CLP$4000, and 9% less than CLP$2000. Half of the respondents declared not to spend money on food at work, of which 36% because they were given food at work, and the remaining because they brought their own food which in 23% of the cases was cooked by somebody else and only 24% cooked by themselves. Less than 20% of the COVID-survey respondents stated they were spending less money during the pandemic on food, while 43% reported spending more money.

Regarding the regulated mandatory pauses of eating at work, 91 and 6% declared to have lunch and only snacks, respectively, while 5% included breakfast as a mandatory pause, and 2% selected dinner. Multiple options could be selected, however, showing different combinations. Most of the sample (65%) of the sample had 1 h to eat, 25% had half an hour, and 8% had 1 h and a half. The same percentage (18%) declare to have increased and lowered the time spent eating during the pandemic. For those partially teleworking, 29% declared to spend 30 min eating at home, while in the office it increased to 58%. Finally, 61% mentioned having a canteen, 11% were not functioning during the pandemic, while almost one quarter (24%) of respondents declared eating at their workstation.

Associations between healthy eating habits, place of work, socio-demographic characteristics, healthy eating habits, body weight change, and health-related conditions

We present three sets of results from the regression analysis. The first set (Table 3) deals with the association between the working place and changes in eating habits, the second set (Table 4) shows the results of the association between the working place and perception of being overweight, and finally (Table 5) the third set presents the results for the association between working place and perceived diet-related problems.

In Table 3, we present three different models for the association between place of work and eating habits. The first column (1) is our baseline model, with no controls. The second model (2) includes demographic characteristics, such as gender, age, and education. The final model, in column (3), adds controls for health problems declared by the individual. All presented estimates are coefficients from the logit regression, but the interpretation is given in terms of odds ratios ($e^{(\hat{\beta})}$).

As shown in Table 3, in all regression models, the coefficients showed that the impact of being fully teleworking on healthy eating habits is significantly positive, both when univariate (1) and multivariate models are considered (2, 3).

When looking at the fully specified model in column (3), we observe that being fully working from home is associated with a 45% increase in the likelihood of having a healthy eating habits (with a point estimate of 0.378). Thus, workers who work from home are 1.5 times more likely to declare that they eat healthy than those who work in the office.

It is worth noting that the significant associations between the workplace and perceiving eating healthier only appear when comparing workers who are fully working from home with respect to those fully in the office. Workers who are partially teleworking do not perceive themselves as having healthier eating habits.

Regarding control variables, there are no differences between men and women in terms of healthy eating habits, but older workers tend to have healthier eating habits. Workers aged 35–44 years, for instance, are almost two times more likely to declare eating healthier (point estimate of 0.641 in the fully specified model) with respect to their younger counterparts (18–24 years). Also, more educated workers tend to have healthier eating habits than those workers who did not attend technical or college education. As was the case with age, the likelihood of declaring having healthier eating habits increased with education, with point estimates of 0.607 for workers who

10.3389/fsufs.2022.961908

TABLE 3 Regression analysis for having healthy eating habits by considering 3 sub-sets of variables: place of work (Logit model 1), place of work, age and education level (Logit model 2), place of work, age, education, weight status, and health conditions (Logit model 3).

	Logit regression model		
	1	2	3
Dep. Variable: Healthy eating habits	Coeff. (SE)	Coeff. (SE)	Coeff. (SE)
Intercept	0.264** (0.0462)	−0.787** (0.221)	−0.661** (0.227)
Place of work			
In office	−1-	−1-	−1-
Partially teleworking	−0.0261 (0.266)	−0.229 (0.272)	0.0944 (0.286)
Fully teleworking	0.345*** (0.133)	0.196 (0.137)	0.378*** (0.145)
Gender			
Males		−1-	−1-
Females		0.00921 (0.0903)	0.102 (0.0949)
Age range (years)			
18–24		−1-	−1-
25–34		0.326* (0.177)	0.491*** (0.183)
35–44		0.452** (0.181)	0.641*** (0.187)
> 45		1.048*** (0.189)	1.221***
Education level			
Secondary education level or less		−1-	−1-
Technical education		0.504*** (0.178)	0.607*** (0.184)
Tertiary education		0.649*** (0.165)	0.711*** (0.171)
Experiencing overweight			
No			−1-
Yes			−1.403*** (0.117)
Experiencing weight reduction			
No			−1-
Yes			−0.709** (0.322)
Experiencing gastritis			
No			−1-
Yes			−0.590*** (0.137)
Having high blood pressure			
No			−1-
Yes			−1.852*** (0.428)
Having diabetes			
No			−1-
Yes			−1.243** (0.485)
Having high cholesterol			
No			−1-
Yes			−1.386*** (0.394)

Considers only employed workers at the time of each survey. Number of observations: 2,252; SE: standard error; $^{*}p < 0.1$ $^{**}p < 0.05$, $^{***}p < 0.01$.

TABLE 4 Regression analysis of experiencing overweight by considering 2 sub-sets of variables: place of work (Logit model 1); place of work, age, and education level (Logit model 2).

	Logit regression models	
	1	2
	Coeff. (SE)	Coeff. (SE)
Intercept	−1.459** (0.0585)	−2.355** (0.313)
Place of work		
In office	−1-	−1-
Partially teleworking	0.866** (0.278)	0.936** (0.283)
Fully teleworking	0.575** (0.143)	0.597** (0.148)
Gender		
Males		−1-
Females		0.275* (0.112)
Age range (years)		
18–24		−1-
25–34		0.595* (0.251)
35–44		0.635* (0.254)
> 45		0.236 (0.265)
Education level		
Secondary education level or less		−1-
Technical education		0.288 (0.237)
Tertiary education		0.232 (0.222)

Considers only employed workers at the time of each survey. Standard errors in parentheses; SE, standard error; $^{*}p < 0.05$, $^{**}p < 0.01$.

graduated from technical education, and 0.711 for workers who graduated from college.

Finally, all diet-related health problems, such as overweight and high blood pressure, are negatively correlated with healthy eating habits. Notice that this does not mean that workers eat unhealthier *because* they are overweight. This association, and all the others related to health problems, act as controls for the main variable of interest and should only be interpreted as correlations.

Associations between experiencing weight change, place of work, and socio-demographic characteristics

Table 4 provides an interesting picture when compared with the results of Table 3. In our previous results, it seems that workers perceive themselves as eating healthier because of their time working from home. However, all workers who are teleworking, either partially or fully, think that they have gained weight since working from home. For instance, workers fully teleworking are 82% more likely to perceive themselves as overweight than those fully working in an office. Interestingly, workers only partially teleworking are those who declare being overweight the most.

TABLE 5 Regression analysis of experiencing diet-related health issues by considering 2 sub-sets of variables: place of work (Logit model 1); place of work, age, and education level (Logit model 2).

	Logit regression model	
	1	2
	Coeff. (SE)	Coeff. (SE)
Intercept	−0.560** (0.0476)	−1.350** (0.236)
Place of work		
In office	−1-	−1-
Partially teleworking	1.304** (0.283)	1.446** (0.288)
Fully teleworking	0.419** (0.128)	0.474** (0.133)
Gender		
Males		−1-
Females		0.463** (0.0929)
Age range (years)		
18–24		−1-
25–34		0.524** (0.191)
35–44		0.506** (0.195)
> 45		0.290 (0.201)
Age 25–34 years old (Ref. 18–24)		
Education level		
Secondary education level or less		−1-
Technical education		0.247 (0.183)
Tertiary education		0.007 (0.171)

Considers only employed workers at the time of each survey. Number of observations: 2,252; Standard errors in parentheses. **p < 0.01, *p < 0.05.

Associations between experiencing diet-related health issues, place of work, and socio-demographic characteristics

Finally, in Table 5 we present the results for the association between diet-related health problems and teleworking in univariate and multivariate models. As before, our dependent variable is dichotomous, taking the value of one if the worker presents any diet-related health problem (and zero otherwise). This includes having weight gain or loss since the change in their place of work, and/or gastritis, high-blood pressure, diabetes, or high cholesterol.

Discussion

We tested whether the place of work is perceived as a part of the problem when it comes to healthier diets. To do this, we used two online surveys conducted before (2019) and during (2020-2021) the COVID-19 pandemic, directed to workers in different economic sectors and with heterogenous responses to lockdowns. Since lockdowns were imposed exogenously on workers, they were forced to either work from home or to continue working in the office. Among those who were sent home, some of them did it only partially, providing variation in responses to changes in diets and weight gain, among other diet-related issues.

We performed several analyses attempting to first show whether changes in working conditions (moving from in-office to at-home work) modify workers' eating habits and whether it influenced the possibility of experiencing weight gain, including overweight.

Methodological constraints

It is important to note that we do not include year dummies, because in the first wave of the survey no question was asked regarding the place of work. Given that, we assume that all workers in the first wave were working from their offices, which was common in Chile before the COVID-19 pandemic, but that prevents us from using year dummies as there is no variation in terms of places of work within one of the years. Similarly, it is relevant to note that the surveys were voluntary and self-administered, so there is a potential issue regarding the validity of the answers, which could then in turn affect the estimates and results. This is if the motives for taking the survey are related to health, eating habits, or concern for overweight (say, those with healthier eating habits are more interested in answering the survey than their counterparts), then that could affect the estimates by mostly capturing the answers of one specific type of worker. However, since the topic covered in the survey is work environments without a direct and explicit link to eating habits, we do not have a good reason to believe that respondents are more prone to be healthier or have more/less concern for weight gain/loss than they would if the survey was randomly assigned.

Moreover, given that we are using two consecutive online surveys, even if that is true, that should not be a relevant problem as we are not interested in estimating levels in these variables for each specific year, but changes in these conditions over time. To the extent that the potential bias is highly relevant to be constant over time, then the estimation of these changes should be unbiased.

We are, however, aware that our sample is more educated and richer than the local population, and that could have an impact on the outcome variables, mainly in relation to the perception of being overweight, places of work, and eating habits. Our interest is to estimate changes in those conditions that should be unbiased, as the primary outcomes are not levels *per se*. Nevertheless, our results should be interpreted as being representative of a subsample of the Chilean population, which is on average more educated, have access to the internet, and perform white collar jobs usually in offices.

Individual perceptions and sociodemographic aspects

Respondents believe a healthy diet is those low in critical nutrients (sugar, salt, fat), selected by 59% of the sample, which is interesting as probably the easiest way to classify food is related to the front of package nutritional "high in…" signs, but this option was selected only by 12% of the respondents. This could suggest that people in Chile base their general food choices on these nutrients as a result of the educational campaign and the labeling of food packages in the country, as they are the same nutrients as in the stop signs.

Only one in three people received a food "benefit", which leaves two-thirds of the sample with no support for their diet during work hours. The most common benefit is having free meals provided by the employer (74%), which is the most preferred form (41%). Interestingly, for respondents that did believe the employer was responsible for their food at work, only a quarter of them still believed the same if they were teleworking, which could be interpreted as a feeling of independence from the employer, lack of supervision, and less support.

Despite the economical constraints were not an objective of this study, the results showed a tendency to not spend money on food at work, mostly by employees that bring their own food from home. This could be related to the fact that money is one of the most important drivers of what to eat, and people prefer to save money by bringing their own food, which could be especially easier for the quarter of respondents that somebody else cooked for them.

Even though for almost all of the respondents' lunch was the most common mandatory pause to eat, 6% of the respondents declared to have no main meal pause possibility at work, leaving them only with the possibility to have snacks, which could contribute to worse nutrient intake. One quarter of the sample declare having only half an hour to eat at work. For those with hybrid modalities (in office and teleworking), having less time to eat at home versus at work was a common finding. Even worse, a quarter declared to eat at their workstation. This means no social interaction, a break full of distractions instead of being focused on the meal, and probably not a proper break at all. During the pandemic, for those living alone probably this was the most common scenario to eat.

It was interesting to note that the more educated the respondent, the more chances to be fully teleworking or partially teleworking. It is clear that the sample of respondents is skewed to the right in terms of the skill distribution with respect to the Chilean population, which is not a representative sample of the Chilean population. This is similar to other surveys, that also found that the more educated had a higher chance to telework (O'Connell et al., 2022). Also related to this, the same study found that being at home increased the chances of increasing the calories, although we did not observe significant associations with education level. In our study, we noticed that the perception of being overweight is more likely among older workers. This is something we should expect, as metabolism and physical activity decay with age. However, we do not see differences between workers at both ends of the age distribution regarding their perception of being overweight. Workers who are partially teleworking do not perceive themselves as having healthier eating habits. Whereas this is an interesting finding, it is also expected as workers who are partially teleworking probably also eat out of home, or even if they do eat at home, they probably have less time to cook a healthier meal.

Together, these results suggest that, since teleworking started massively during the COVID-19 pandemic, weight gain could be related to a reduction in the number of days/hours dedicated to exercise, an increase in alcohol consumption, snacking, and stress, among other factors (Bennett et al., 2021; Fukushima et al., 2021). It is worth noting that the lockdowns in Chile were very strict so a reduction in physical activity is certainly possible during the pandemic. To that extent, it is not surprising that even though workers were eating healthier, they would still gain weight. This could be consistent with other studies, that have found an increase in the purchase of calories mostly from ingredients, that is, food to cook at home that could be healthier than eating out but still represent an increase in the calories consumed (O'Connell et al., 2022). However, we cannot rule out the possibility that the perceptions regarding healthy eating habits are somewhat misaligned with the actual eating habits workers were having.

Workers who were either fully or partially teleworking were significantly more likely to experience diet-related health problems than in-office workers. In particular, workers fully teleworking were 60% more likely to experience a diet-related health problem than those working in the office. What is interesting is that workers only partially teleworking are far more likely to experience these problems than their in-office counterparts, but also than their peers fully teleworking. As mentioned, one potential reason for these results is that workers only partially teleworking experience the "worst of both worlds". That is, they do not have the time to cook and prepare healthier meals, but at the same time, they only go out to work. Therefore, lack of exercise and an increase in snacking or alcohol consumption could be also a factor here, with the addition of not having the time to actually make changes in the diets. This is consistent with our initial results, in which we see that workers only partially teleworking do not think that they are eating healthier than those working from the office.

It is important to mention that this survey was carried out during the first period of the pandemic, therefore, the results could be different from those that could arise in the later stages of the pandemic. Another important aspect to consider is that eating unhealthy and lack of well being (or *vice versa*) could be a vicious circle, i.e., people tend to eat less healthy when experiencing anxiety or stress, while it could also be true that the well being could also affect the healthiness of the diet (Xiao et al., 2021). More studies are needed to understand how the work environments -either in the office or at home- affect the diet

and health outcomes of the workers. Surprisingly, most of the studies in the literature during the pandemic and teleworking reported more mental health than physical health, a tendency that was contradictory with the research prior to the pandemic (Oakman et al., 2020), therefore our results are difficult to compare with as we assessed primarily the dietary habits. Finally, most of the evidence is from the global north showing a lack of data and evidence in the global south (Islam, 2022), where the sociodemographic characteristics such as education level and social protection policies could be very different.

Conclusion

Our results showed that workers perceive an improvement in their eating habits, transitioning to healthier diets as a consequence of working from home. However, despite workers eating healthier, working from home was associated with weight increase and diet-related health problems, probably due to an excessive caloric intake and lack of physical exercise. Taken together, these results suggest that working conditions are suboptimal for Chilean workers, who perceive that their chances of eating healthy decrease when they have to do in-office work.

As mentioned, our results also suggest that those who only partially teleworking are the most affected. We believe this is because they experience an overall worse situation regarding the adoption of healthier diets since they still have to move to and from the office, but at the same time were forced to stay home for other activities, potentially related to physical activity and other aspects of a healthy life, such as snacking and an increase in alcohol consumption.

Our study is limited in the sense that it stems from two voluntary online surveys, mostly responded to by white collar, educated workers in Chile. We expect these results would be even more alarming for those less educated workers. A broader and potentially more alarming result could be found if we had access to information on the consumption of healthy diets and diet-related health problems for blue collar workers. However, we believe our results are informative of the changes in eating habits and the consequences of the COVID-19 pandemic on physical health.

Data availability statement

The data that support the findings of this study are available from the corresponding author, upon reasonable request.

Ethics statement

Ethical review and approval/written informed consent was not required as per local legislation and institutional requirements.

Author contributions

OT-O and RP-S: conceptualization, methodology, validation, formal analysis, and investigation. RP-S: software. OT-O: data curation. OT-O, RP-S, BB, and FS: writing—original draft preparation, writing—review and editing, and visualization. RP-S and FS: supervision. FS: project administration. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

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Food losses perceived by family farms: Challenges and policy implications from a micro-approach quantification

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During the last decade, food loss and waste (FLW) has been gaining more attention due to its negative effect on food security. However, the lack of information about FLW quantification and characterization remains a problem, especially from the perspectives of local citizens and farmers. There is limited literature examining food losses (FL) in primary production of the food supply chain (FSC) and specific policies are needed to improve the FLW measurement. The aim of this research is to analyze how much FL is generated at the farm level using a micro-approach methodology from harvest to primary commercialization stages among farmers located in Central Chile. Additionally, we explore factors affecting FL using a fractional regression model with special emphasis on the harvest stage. Data were collected using phone interviews, conducted in 2019, with 177 small-scale producers of vegetables and berries. FL generated by the sample from harvest to primary commercialization was 14.5% on average. Farmers identified a considerable volume of FL during primary production, mostly during the harvest. The factors that increased FL among small-scale farmers were the production system and its harvest period, commercialization channels, labor shortage, and cosmetic standards. As a case study, the information collected here can be useful for encouraging further research emphasizing the harvest stage and the role of the production systems in generating FLW.

KEYWORDS

food losses, primary production, harvest, horticulture, berries, family farms, Chile

Introduction

Before the COVID-19 pandemic, the Food and Agriculture Organization (FAO) estimated that roughly 8.9% of the world's population (690 million people) is undernourished. Also, at least 2 billion people suffer "food insecurity" at moderate or severe levels due to the lack of access to quality and nutritious food (FAO, 2020). The global population is expected to increase by 10 billion people by 2050 (FAO, 2019) and will put pressure on agriculture to be more sustainable (Alexander et al., 2017). Recent studies of productivity growth reveal that the agricultural sector's progress has been stalled mainly due to climate issues, a problem that is exacerbated if food is not completely consumed (Future Foods, 2022).

Food loss and waste (FLW) impacts food security by reducing the availability of local food that is appropriate for human consumption (FAO et al.,, 2019). Food access for food supply chain (FSC) stakeholders is also negatively affected. For instance, the farmers may experience income losses due to high levels of FLW. Additionally, consumers are impacted by rising prices caused by the reduction of food supply due to FLW (HLPE, 2014). One-third of the global food produced is lost or wasted across the FSC (Gustavsson et al., 2011). FLW globally represents 24% of water, fertilizers, and farmland that are employed in agricultural production (Kummu et al., 2012), and 8% of the world's greenhouse gas (GHG) emissions (FAO, 2014). The economic loss attributed to FLW is estimated by FAO to be one trillion USD per year (FAO, 2014).

Discarding good quality food at any stage of the FSC implies that output and inputs are being wasted, namely, valuable calories and nutrients, labor, energy, and natural resources (Corrado et al., 2017). Therefore, to improve the efficiency and sustainability of the food system, FLW needs to be evaluated from social, economic, and environmental points of view. An important obstacle to standardizing FLW information is the application of different quantification methodologies among studies and the lack of agreement in the use of a distinct procedure, which have generated a gap in data precision (Bellemare et al., 2017; van der Werf and Gilliland, 2017). Furthermore, definitions also fragment FLW analysis: "food loss" (FL) is defined as good quality food that is discarded during the first stages of production, whereas "food waste" (FW) corresponds to good quality food that is not consumed during the second part of the FSC from the point of view of the retail stage (FAO, 2014). Obtaining information about the real scope of FLW is a central challenge that must be faced before formulating any policy or taking action regarding saving food (Delgado et al., 2021). However, given the heterogeneity that characterizes the food industry in different countries, it is necessary to establish boundary systems to facilitate data processing and subsequent FLW quantification (Chaboud, 2017). Regarding this matter, the recent FAO study (2019) openly discusses the dichotomy between, on the one hand, the aggregated percentage number of the Food Loss Index and, on the other, the call for specificity and precision in shaping policy measures, based on cost/benefit analyses (Koester and Galaktionova, 2021).

In low- and middle-income countries, a significant part of food is produced by small-scale farmers who operate under production limits (Fabi et al., 2021). In those countries, the role of FLW is crucial since it is commonly linked with farm management and technical and financial issues (Liu, 2016). Since FLW can negatively affect farmers' income (Delgado et al., 2021), proper research and agricultural extension seem necessary to develop strategies to reduce and/or prevent FLW, and to find crucial areas to be improved in the food production system.

The data available for the measurement of FLW are focused on FSC stages, and few studies on primary production can be found (Teuber and Jensen, 2020). Data scarcity can be attributed to the lack of agreement on FLW definitions, the diversity of food products (Stenmarck et al., 2016), and the lack of information about how FLW affects business and society (Liu, 2016). Accurate data about FL on farms can be beneficial for policymakers because it can fill the gap in the debate around food producers and their role in FLW, and it can provide pivotal information to make better decisions regarding the matter (Johnson et al., 2018).

In 2015, Chile adhered to the UN's 2030 Agenda for Sustainable Development and, 2 years later, the Agricultural Ministry's Office of Agricultural Studies and Policies (ODEPA) created the National Committee for the Prevention and Reduction of Food Losses and Waste. Despite the current effort, there is still a lack of national data that can support the calculation and quantification of FLW (Eguillor and Acuña, 2019) which is crucial to understanding the FLW scenario and to implementing suitable political actions.

Few studies of food loss using quantification methodology and data are found in Chile, yet these are needed for policy decisions given the heterogeneity of agricultural products along the FSC. Thus, the objectives of this study are 2-fold: (1) to estimate how much FL is generated during primary production using a micro-approach methodology from harvest to primary commercialization stages in Chile and (2) to understand the factors affecting FL with special emphasis on the harvest stage. Data collection is achieved through surveys conducted during 2019 among small-scale producers that belong to family farms that produce berries or vegetables. The producers are beneficiaries of the extension program Technical Advisory Service (SAT) supported by the National Institute for Agricultural Development (INDAP). Farmers who are beneficiaries of INDAP in Chile are called Family Farm Agriculture (FFA) and contribute 22% of the agricultural gross domestic product (AGDP), own 38% of the irrigated area, and hire 33% of agricultural employees (INDAP, 2016).

1.1. Boundary System

The High-Level Panel of Experts (HLPE) on food security and nutrition emphasizes that standardizing FLW measurement and FLW definitions is crucial to enhancing information accuracy (HLPE, 2014). Currently, an international agreement on a single definition of FL and FW is still lacking (Teuber and Jensen, 2020). According to Delgado et al. (2017), even though the terms "FL" "Post-Harvest Loss" (PHL), "FW", and "FLW differ from each other, they can be used as equivalents in the literature. FAO definitions are the most regularly used due to the organization's initial effort in 2014 to summarize the existent terminology and definitions (Corrado et al., 2017). FL is defined

as "the decrease in the quantity or quality of food resulting from the decisions and actions by food suppliers in the chain (…) and occurs from post-harvest up to, but not including the retail level", while FW is defined as "the decrease in the quantity or quality of food resulting from decisions and actions by retailers, food service providers, and consumers". The sum of total FL and food waste that occurs along a value chain is included in the FLW term (FAO, 2014).

Regarding FL, the losses during the pre-harvest and harvest stages are not considered by this definition because of the challenges of quantifying food discarded during agricultural procedures (FAO, 2019). Although the Global Food Policy Report (IFPRI, 2016) shows the relevance of preharvest losses in its proposed methodology to get a complete overview of FLW, most of the definitions suggested by the latest research define FLW from the harvest stage of the process onward (Teuber and Jensen, 2020).

Proper quantification of FLW requires boundaries that facilitate the studies, treatments, and subsequent interpretation of collected information. Thus, each study should specify the food category and stage of the FSC selected according to the methodological scope and the geographical location of the study (Hanson et al., 2016). The rest of this article is structured as follows: Section Quantification methods presents a discussion of quantification methods; Section Methods is dedicated to explaining the data, area of study, and the elucidation of the econometric model; Section Results presents the results of the study; and, finally, Sections Discussion and Conclusion present the discussion and conclusion of the research.

2. Quantification methods

Quantification methods can be classified as "macro" or "micro" approaches given the variability of FLW (Delgado et al., 2017). The former describes methods that analyze a broad perspective of FLW at the global or regional level, and it can be achieved by contrasting non-processed inputs to final production, using records of mass balances measured by weight or caloric content. For example, Parfitt et al. (2010), using an old data set from the 70s to 80s, suggested that a range of 10 to 40% of total production is lost worldwide. Kummu et al. (2012) analyzed global FLW in kcal terms and natural resources such as freshwater, cropland, and fertilizers; and Lipinski et al. (2013) used FAOSTAT data to quantify the calories that are not being consumed, classifying FLW according to food commodities groups.

While the study of Gustavsson et al. (2011) provides a broad perspective of the FLW with "regional" estimates and suggests general guidelines, it is still crucial that each country creates its own database. Several country-specific reports have been published, mainly in the United States and European countries that fit into the "macro" approach category, using mass balance data and specific assumptions about production yields to understand the current scenario (Delgado et al., 2017). The "macro" approach is limited by the lack of representativeness that results from using incomplete and obsolete data, which reduces its utility for planning actions to prevent and reduce the FLW (Thyberg and Tonjes, 2016; Delgado et al., 2017). Most recently, the FAO report presents the advance on SDG target 12.3 and its 12.3.1 indicator: "Global FLW", which was divided into two sub-indicators: Food Loss Index (FLI, 12.3.1a) and Food Waste Index (FWI, 12.3.1b). The development of FLI led to the first estimation of global FL, reporting that, in 2016, 13.8% of the food produced in the world was lost (FAO, 2019). Regarding FWI, in 2019, approximately 931 million tons of food waste were generated in the world, which is twice the amount estimated by FAO in 2011 (UNEP, 2021).

Methods classified as "micro" approaches are characterized by the specificity of the data since they are focused on particular locations and contexts of the FSC. APHLIS (2014) estimates that in Sub-Saharan Africa, between 14.4 and 15.8% of cereal crop production is lost during post-harvest (Hodges et al., 2014). Hartikainen et al. (2017) estimated 800,000 tons of food lost in primary production per year in Finland, Sweden, Norway, and Denmark. The mechanisms to achieve "micro" approach research can be on-site measurements, stakeholder records, interviews, and surveys—all of which can be beneficial in focusing research on specific objectives but which are often time-consuming and costly processes (Delgado et al., 2017). Therefore, measurement settings should be organized according to the specific FSC scenario (Fabi et al., 2021).

The majority of FLW publications reporting on low- and middle-income countries focus on the first stages of FSC (Thyberg and Tonjes, 2016). Most of them are from Asia or Africa, while Latin America and the Caribbean countries (LACs) are underrepresented in the literature (Xue et al., 2017), even though they contribute almost 20% of the FLW produced in the world (FAO, 2019). LACs have asserted their concerns about FLW, making the commitment to reduce their FLW by 50% per capita by 2025 (FAO, 2016). With this objective, a Regional Alliance of LACs formed by National Committees supported by FAO has been created to work in their respective countries. The alliance is composed of 10 nations, including Chile. However, few initiatives related to FLW have been developed in Chile, particularly studies that evaluate production chains (either encompassing all or certain stages) of specific commodities. For example, the National Agricultural Research Institute (INIA) has studied techniques that enhance the postharvest life of fresh and processed vegetables to reduce FLW during the packing, storage, and transport stages (Eguillor and Acuña, 2019). In terms of legal regulations, a specific normative that regulates FLW is absent. Still, two bills seek to modify the Food Code to avoid waste at the commercialization stage (Eguillor, 2017).

At the institutional level, ODEPA announced in 2017 the formation of the National Committee for the Prevention

and Reduction of Food Losses and Waste (CN-PDA): a public-private partnership with the aim of creating an appropriate legal framework, public policies, and concrete actions to prevent and reduce FLW. In addition, the committee encourages FLW quantification and raising public awareness (Eguillor and Acuña, 2019). In an important step toward this, the Chilean Ministry of Agriculture has already accepted the request for CN-PDA institutionalization (ODEPA, 2020). However, the actual amount of FLW produced by the vegetable and livestock product supply chains in Chile remains undetermined. Therefore, significant efforts should be directed at FLW data collection. Such information is crucial to improve decision-making at the production level, reduce FLW, and facilitate the operation of national committees (Eguillor and Acuña, 2019).

The lack of research on FL is counterintuitive since collecting data at the farm level is a valuable resource for improving agriculture management and efficiency (Johnson et al., 2018). According to Beausang et al. (2017), data scarcity on primary production may be caused by the poor habit of farmers to record FL amounts during the production process. In Europe, Stenmarck et al. (2016) estimated that FL levels across the FSC and primary sector were found to be the most complicated stages to quantify. One reason is the diversity of crops produced (e.g., wine grapes, fruits, vegetables), leading to highly variable degrees of FL (Stenmarck et al., 2016). Hence, to calculate FL, it is necessary to carry out specific and comprehensive evaluations of each food chain related to primary production and its respective stages (Beretta et al., 2013). Another challenge is related to what farmers understand as FL (Franke et al., 2016). Many producers recognize that an un-marketable edible food could be used as animal feed or organic matter for the soil, even though this could imply an economic loss, and it could be considered an FL. Also, an unrecognized environmental cost is triggered due to the use of energy involved in agricultural production (Hartikainen et al., 2017).

According to Eguillor (2019), Chile is not an exception, and one of the main problems with quantifying FL is the lack of records by farmers. Therefore, actions are being taken to explore ways in which losses can be quantified. An exploratory study estimated that 16,550 units per hectare of lettuce and 1.1 tons per hectare of potatoes are lost during harvest, in addition to 1.1 tons per hectare during storage (Eguillor, 2019). Additionally, the project called "Measurement and management of fruits and vegetable losses on production stages at national level in Chile" was implemented in 2019 to validate a quantification methodology in four specific products along the FSCs: lettuce, tomato, potato, and raspberry. The results yielded a methodology that measures production system losses of fruits and vegetables (Eguillor and Acuña, 2019; Giraldo et al., 2019). The "Guide to prevent and reduce vegetable and fruit losses" provides definitions of FLW and explains the relevance of FL prevention with simple terminology. With this objective, the guide mentions a list of suggestions to farmers regarding planning, crop management, and critical points during harvest, post-harvest, storage, and transportation (ODEPA, 2019).

3. Methods

3.1. Data and study area

We estimated how much FL is generated during primary production using a micro-approach from harvest to primary commercialization stages in two agricultural areas of Central Chile: Maule (34°41' S) and Ñuble (36°43' S) regions. Both regions contribute 13.9 and 14.2% respectively to the country's Gross Domestic Product for forestry and agriculture, and together represent approximately 34% of national farms and 31.5% of national hectares destined for annual and permanent crops (ODEPA, 2019).

We randomly selected a representative sample of 400 producers from the Maule and Ñuble regions. Due to the COVID-19 pandemic, our initially planned on-site interviews had to be replaced by phone surveys, which we conducted between June and September 2020. The final sample is composed of 177 vegetable and berry producers who answered the phone survey.

We applied a questionnaire using the script created by Beausang et al. (2017). Also, we used a set of questions addressed to producers used by Jara-Rojas et al. (2020). Additionally, by the "Measurement and management of fruits and vegetables losses on production stages at national level in Chile" project (Giraldo et al., 2019). The questionnaire was divided into four parts: I. Production and management records, II. Production information, III. Losses information, and IV. COVID-19 Contingency.

3.2. Methodology

For the purpose of this study, we defined Food Loss (FL) as "a decrease in the mass of edible food originally intended for human consumption. Food losses occur at the production, post-harvest, processing, and storage stages" (Giraldo et al., 2019). The FL analysis was done in the harvest, packing, transport, and primary commercialization stages of vegetable and berry supply chains.

To calculate FL volume, yield and percentage of losses generated by each crop are needed. Yield information is obtained through question 6: "Could you specify further information about your last season's crops?" in Section II of the questionnaire. To get information about FL, self- reported percentages of losses (during harvest, packing, transport, and first commercialization) were collected through question 7: "In a normal season, how much of your crops (estimate) do you lose during the next stages?" in Section III.

After obtaining yield and FL percentages information, FL volume is calculated using as a reference the Giraldo et al. (2019) project. Although the study is considered a "micro" dimension case, "medium" dimension methodology is used as a reference to calculate FL quantities because it facilitates calculation using self-reported information. The medium methodology proposes the following equation to calculate losses that occur during primary production, without the need for on-farm measurements:

$$FL_{PP} = \left(\frac{\%FL}{1 - \%FL}\right) \times TY \quad (1)$$

where FL_{PP} is the food losses during primary production in tons, $\%FL$ is the percentage of food loss, and TY is the total yield in tons.

According to equation [1], FL is calculated using self-reported yields and estimated percentages of losses. Production outcome coherence is corroborated using ODEPA technical data sheets for each crop.

Since the boundary system covers from harvest to the primary commercialization stage, loss calculation in the FSC is made in the opposite direction, assuming that TY is the result of the production chain after losses occur at each stage. First primary commercialization losses (the last of the studied stages) are calculated using equation 1. Next, to calculate losses of the remaining (previous) stages, FL calculated previously is added to TY, as follows:

$$FL_i = \left(\frac{\%FL_i}{1 - \%FL_i}\right) \times (TY + FL_{i-1} + FL_{i-n} \ldots) \quad (2)$$

where FL_i is the food loss during the *ith*-stage in tons, $\%FL_i$ corresponds to the percentage of food lost during stage i reported by farmers, TY is defined in [1], and FL_{i-n} is the food loss produced during the prior stage, previously calculated, with n being the position of the stage in the FSC.

Finally, caloric and water content losses are calculated for each product, using available information on Food Data Central of the United States Department of Agriculture[1] (USDA). Due to the relevance of fruits and vegetables in the human diet, fiber, and protein contents are also calculated using USDA values as reference. Furthermore, the economic evaluation of FL is carried out based on Kitinoja et al.'s (2018) simple calculation, using producer prices per kilogram given by farmers (FONDECYT 1121122 Project database) for the approximately 20 crops mentioned in the sample.

3.3. Econometric model

This section assesses the effect of sociodemographic, farm, and principal crop characteristics, as well as the most frequently mentioned causes of FL (labor problems, cosmetic standards, and weather phenomena) in the total FL amount estimated by farmers. According to Kitinoja et al. (2018), the majority of FL analyses are focused on volumetric losses and tend to omit the economic value of losses as indicators. Some reasons for this could be the lack of good quality databases and the absence of information on economic losses, which limits data comparisons or the replication of methodologies.

Since the volume of FL represents data relevant to the national context due to the lack of FLW information in Chile (Giraldo et al., 2019), FL in tons produced by farmers is set as the dependent variable and is expressed as a proportion of the food produced. Therefore, resulting values will be a fraction within a range of 0 and 1, inclusive.

Linear regression models such as Ordinary Least Squares (OLS) are inappropriate to predict fractional dependent variables. One important limitation is the inability of such a model to guarantee that its predicted values stand within the unit interval (Papke and Wooldridge, 1996). Additionally, due to the bounded nature of the variables, linear models usually present non-constant outputs of regressors variations (Ramalho et al., 2011; Gallani and Krishnan, 2015; Chegere, 2018) and negatively affect the precision of estimates (Bravo-Ureta et al., 2017).

An alternative approach to OLS may be the implementation of the Tobit model for censored data, specifically a two-limit Tobit model (Baum, 2008). According to Ramalho et al. (2011), the latter can be implemented only if the sample contains observations in both limits, which is not always the case with fractional dependent variables. Using a Tobit model only within the [0, 1] interval is difficult to support conceptually since those observations of fractional variables that lie in extremes are not a consequence of censure, but the outcome of single choices. McDonald (2009) also mentions the importance of considering that some elements of the data generating process may not be suitable with the Tobit approach, due to the fractional nature of the response variable. Additionally, this model turns out to be rigorous regarding the assumptions of normality and homoscedasticity of dependent variables (Ramalho et al., 2011).

To deal with the proportion as dependent variables, Papke and Wooldridge (1996) propose a Fractional Regression Model (FRM). For the conditional expectation of fractional dependent variable, Papke and Wooldridge (1996) assume the following model:

$$E(y_i|x_i) = G(x_i\beta) \quad (3)$$

1 We use the USDA webpage https://fdc.nal.usda.gov/index.html to ask the nutritional status of the following crops: blueberry, tomato, cucumber, paprika, chili, watermelon, raspberry, blackberry, onion, squash, beans, strawberry, lettuce, coriander, chard, potato, melon, cabbage, asparagus, corn, wheat, cauliflower, broccoli, chickpeas, spinach, zucchini, and oatmeal.

where G (·) is a knowing function satisfying $0 \leq G(z) \leq 1$ for all $z \epsilon R$, ensuring that predicted values of y lie in the [0,1] interval. The FRM is estimated using a Quasi Maximum Likelihood Estimator (QMLE) that states the simple maximization of the Bernoulli log-likelihood:

$$l_i(b) \equiv y_i \log\left[G\left(x_i b\right)\right] + \left(1 - y_i\right) log[1 - G(x_i b)] \quad (4)$$

Regarding the assumptions of generalized linear models (GLM), the method suggested by Papke and Wooldridge (1996) is efficient and fully robust. Chegere (2018) implemented this approach to analyzing the role of handling practices on food loss reduction during post-harvest of maize crops, keeping the original specification of Papke and Wooldridge (1996).

Based on Papke and Wooldridge (1996) and Chegere (2018), the empirical regression model applied to the total sample (n = 177) is the following:

$$E(FL|x) = G(\alpha_0 + \alpha_1 SOCIODEM + \alpha_2 MAINCROP + \alpha_3 CAUSES + \varepsilon_i) \quad (5)$$

where *SOCIODEM* corresponds to a vector of sociodemographic variables (including age, level of education and agricultural experience of farmers, family size, and total area of the productive farm). Since a part of the sample includes farms that manage up to three crops, *MAINCROP* captures information about the main crop (whether it is grouped in vegetables or berries, harvest period, and commercialization channel). *CAUSES* correspond to the three most mentioned causes of FL during the harvest stage.

3.4. Descriptive statistics

Table 1 shows the descriptive statistics of the dataset of 177 farmers, for which the average age of producers is 57 years, with a mean of 8.3 years of education and 35 years of agricultural experience. The average farm size of the sample is 2.6 hectares, with a mean food production per farmer of 25.2 tons per hectare. However, there is a high variability between the minimum and maximum yield values due to the high diversity of crops and the high range of farm size.

With respect to the production systems and managerial abilities, 37.3% of the farmers cultivate vegetable crops, 45.7% produce berries, and 16.9% produce both crops. A total of 72.9% of the sample has technical records of farm activities, and 83.1% maintain records of the production during the harvest stage. In addition, 80.2% keep records of their accounting activities. Diversity of species is a common FFA feature, as well as the heterogeneity of its commercialization channels. Approximately 33.6% of the respondents sell their production to agroindustry, 21.6% sell through an intermediary, and 15.3% sell on the wholesale market. A smaller portion (9.6%) sell their products directly on the field, while 7.9% use informal channels, and 2.3% sell directly to retail. The other 5.8% of producers use a combination of the channels mentioned above.

4. Results

4.1. FL estimation

A total of 144 (81.4%) farmers identify FL at least at one production stage, while the remaining 18.6% declare that FL is not occurring from harvest to commercialization. This identification differs depending on the FSC stage. All farmers report losses during harvest, 9.0% of them report losses during packing, 0.7% report losses during transportation, and 9.7% report losses during commercialization.

Food loss statistics in the following tables are calculated using a sample size of 144 farmers. According to our calculations, farmers lose on average 14.5% of their total production during the entire FSC. Regarding production stages, farmers estimated that 12.1% of their production is lost during harvest, 11.5% during packing, 1.7% during transportation, and 8.3% during primary commercialization. Total food production reported by the respondents equals 10,600 tons, but a total of 1,312 tons are not consumed, which is equal to an approximate consumption of fruit and vegetables by 202,692 individuals during a 30-day period according to the World Health Organization (WHO) recommendation. Note that this estimate does not consider the inedible parts of the food products. Similarly, the estimated FL is equal to 456 million calories which could cover the energy requirements of 6,610 adults for 30 days. As a reference, the total gross income represented by this FL corresponds to 807,515 USD or 2,240 USD/ha (refer to Table 2).

According to the production system (Table 3), vegetable producers lose on average 7.2 ton/ha which is statistically different from the 1.6 ton/ha of FL calculated for berries producers and the 1.1 ton/ha for mixed producers. Regarding calories losses, the three production systems are also statistically different: vegetable crops show the highest calorie losses on average (1,762,240 kcal/ha), followed by berries with 747,086 kcal/ha, and finally mixed crops, with a loss of 438,532 kcal/ha. As for water and protein content losses, vegetable crops are statistically different than berries and mixed crops. The former represents the higher loss of these two indicators, being 6.7 m^3 of water content per hectare and 746.1 kg on average of protein per hectare. In terms of fiber, no statistical differences are reported. The results of the FL for the most representative crops are presented in Table 4.

As Table 5 shows, commercialization channels affect significant FL perceived by farmers. Vegetable farmers that sell their products to the agroindustry or in the wholesale market lost 8.9 ton/ha and those vegetable

TABLE 1 Descriptive statistics of the sample of farmers surveyed in two agricultural regions of Chile during June and September of 2020.

Variable name	Code	Mean	Std. Dev.	Min	Max
Food loss ratio (%)	FL_ratio	0.12	0.10	0	0.43
Age in 2019 (years)	age	57.21	11.30	24	87
Education level (years)	educ	8.34	3.04	0	17
Farm experience after 15 years old (years)	agri_expe	34.95	13.51	8	70
Family size (persons)	fam_size	3.36	1.52	1	13
Total of productive hectares	total_area	2.59	2.77	0	20
Main crop managed by farmers (1 = berries; 0 = vegetables)	main_crop	0.56	0.50	0	1
Weather phenomena as FL cause during harvest (1 = yes; 0 = no)	weather_harv	0.19	0.39	0	1
Cosmetic parameters as FL cause during harvest (1 = yes; 0 = no)	cosmetic_harv	0.20	0.40	0	1
Labor problems as FL cause during harvest (1 = yes; 0 = no)	labor_harv	0.50	0.50	0	1
Harvest period of main crop is less or equal to 1 month (1 = yes; 0 = no)	one_month	0.08	0.27	0	1
Harvest period of main crop is less or equal to 2 months (1 = yes; 0 = no)	two_months	0.56	0.50	0	1
Harvest period of main crop is less or equal to 3 months (1 = yes; 0 = no)*	three_months	0.36	0.48	0	1
Main crop is sold to Main crop is sold to intermediaries (1 = yes; 0 = no)	intermed	0.26	0.44	0	1
Main crop is sold to agroindustry C1 (1 = yes; 0 = no)	Agroindustry	0.56	0.50	0	1
Main crop is sold to retail or direct sale (1 = yes; 0 = no)*	directsale	0.18	0.39	0	1

*Omitted variable in the econometric model.

TABLE 2 Loss estimation calculated from farmers' perception.

Estimated losses	Mean	Std. Dev.	Min	Max
Weight food losses (ton/ha)	3.67	5.28	0.03	31.67
Lost water (m^3/ha)	3.35	4.97	0.02	29.93
Lost energy (kcal/ha)	1,094,728	1,185,567	13,684	7,519,780
Lost protein (kg/ha)	386	484	3	2,793
Lost fiber (kg/ha)	772.84	751.24	14.22	3,941.96
Economic losses (CLP/ha)	1,573,009	1,626,859	14,491	9,975,000
Economic losses (USD/ha) *	2,240.69	2,317.40	20.64	14,209.00

*1 USD = 702.02 CLP, USD observed 28.04.2021, Central Bank of Chile.

producers that use direct sale systems or that sell in retail perceived 7.2 ton/ha of FL. Both FL values are significantly higher than vegetable farmers using an intermediary commercialization channel (4.7 ton/ha). Berries farmers perceive higher values of FL in the agroindustry (1.6 ton/ha) compare to the intermediary (1.2 ton/ha) and direct sale (0.2 ton/ha).

Regarding the FL perceived by farmers grouped according to sociodemographic characteristics, the younger group of farmers–aged 20 to 39 years–report 5.1 ton/ha on average, which is at least one additional ton than the rest of the sample. At the same time, higher education implies a higher perception of FL, but the tendency is not significant. As for FL causes during the harvest stage (Table 6), farmers mentioned labor shortage, followed by cosmetic standards, and climate or weather events.

4.2. Fractional regression output

Table 1 shows a statistics summary for dependent and independent variables included in a fractional regression model. On average, the mean ratio of FL is 0.12 ranging from 0 to 0.43. The socioeconomic and productive variables were described earlier. The same applies to the FL causes mentioned by farmers during the harvest stage and commercialization stages. Regarding the period dedicated to harvesting the main crop, 7.9% of the sample dedicate 30 days or less, 55.5% devote between 31 and 60 days, and 35.6% need more than 60 days.

According to the results presented in Table 7, sociodemographic characteristics and farm production areas are not statistically significant in the fractional

TABLE 3 Mean differences of food loss (FL) in tons, and nutritional and economic losses, calculated according to productive systems (vegetables = 56 obs.; berries = 66 obs., mixed = 22 obs).

Losses		FL	Std. Err.	[95% conf. interval]	
Tons (tons/ha)					
	Vegetables	7.29[a]	0.93		
	Berries	1.51[b]	0.13		
	Mixed	0.94[b]	0.16		
Calories (kcal/ha)					
	Vegetables	1,762,240[a]	211,348	1,344,469	2,180,011
	Berries	747,086[b]	64,966	618,668	875,504
	Mixed	438,532[c]	79,374	281,633	595,431
Water (m^3/ha)					
	Vegetables	6.77[a]	0.88	5.03	8.51
	Berries	1.30[b]	0.12	1.07	1.52
	Mixed	0.82[b]	0.14	0.54	1.09
Protein (kg/ha)					
	Vegetables	746.11[a]	81.01	585.98	906.24
	Berries	160.56[b]	15.10	130.72	190.40
	Mixed	147.79[b]	29.16	90.16	205.43
Fiber (kg/ha)					
	Vegetables	946.86[a]	118.21	713.19	1,180.54
	Berries	764.60[a]	81.54	603.42	925.78
	Mixed	354.61[b]	88.16	180.35	528.87
Economic losses (USD/ha)*					
	Vegetables	3,288.94[a]	419.14	2,460.43	4,117.45
	Berries	1,728.81[ab]	155.66	1,421.11	2,036.51
	Mixed	1,108.06[b]	185.35	741.67	1,474.44

[abc] Different superscripts indicate differences in median according to Kruskal-Wallis.
*1 USD = 702.02 CLP, USD observed 28.04.2021, Central Bank of Chile.

TABLE 4 Average information for the most representative crops.

Crop	% representativeness	Food production (ton/ha)	FL (ton/ha)	FL (%)
Raspberry	19.87	8.24	1.10	13.33
Tomato	11.54	83.90	11.48	13.68
Blueberry	11.22	9.41	1.21	12.83
Asparagus	6.73	5.91	0.70	11.87
Blackberry	5.13	10.80	1.58	14.66

regression model. The main crop managed by farmers had a significant effect, being 5.2 percentage points less if the principal crop is berries. Regarding FL causes, cosmetic parameters seem to increase the FL ratio by 5.5 percentage points, while the existence of labor problems, such as a shortage of personnel, raises the FL ratio by 5.1 percentage points. Weather problems were not a significant factor.

If the harvest period is <1 month, FL is significantly lower by 6.5 percentage points. A larger harvest period (2 months) has a less significant effect, reducing the ratio by 3.6 percentage points. Commercialization channels also proved to be statistically

TABLE 5 Food loss (ton/ha) estimated in the main crop according to commercialization channels.

Commercialization channels		Vegetables	Berries
Agroindustry/wholesale market	Mean	8.88[a]	1.59[b]
	Std. Dev.	9.11	1.06
Direct sale/retail	Mean	7.24[a]	0.23[c]
	Std. Dev.	6.11	0.18
Intermediary	Mean	4.72[b]	1.19[c]
	Std. Dev.	6.89	0.94

[abc] Different superscripts indicate differences in means according to Fisher Hayter.

TABLE 6 Causes of food loss (FL) mentioned by farmers during the harvest stage.

FL causes	Farmers (%)
Labor problems	58.33
Cosmetic standards	23.61
Climate/Weather	19.44
Plagues and diseases	13.89
Others	9.72
Water availability problems	3.47

significant. While selling the products to intermediaries increases FL by 4 percentage points, agroindustry and wholesale market channels increase FL by 3.6 percentage points.

5. Discussion

A total of 81.4% of the sample identified FL at the harvest stage. Chaboud (2017) mentions that farmers are the stakeholders that most commonly identify FL. The "absence" of FL in the remaining 18.6% of the sample might be explained by the lack of awareness among farmers about FL as a relevant topic. This may also explain why farmers give less attention to FL and fail to notice and record it (Liu, 2016; Beausang et al., 2017). Additionally, low levels of FL perceived during packing, transport, and primary commercialization could be associated with the fact that most of the farmers are not involved in those stages.

Regarding the FL amounts calculated, an average of 14.5% of the production per hectare is lost from harvesting to primary commercialization. Based on FAO data published in 2011, Lipinski et al. (2013) estimated that 24.0% of total food production is lost during the production stage, 14.0% is generated by developing countries, and 10.0% is in developed countries. Most recently, FAO in 2019 reported that 13.8% of produced food in 2016 was lost in primary production. A meta-analysis by Fabi et al. (2021) shows that fruit and vegetable FL percentages exceed 10.0% in Latin America.

Food losses of the most representative crops, raspberries and tomatoes, represent on average 13.3% and 13.7% of the total production, respectively. The project "Measurement and Management of Fruits and Vegetables Losses on Production Stages at National Level in Chile" report 23.0% of the tomato and 5.0% of the raspberry harvests are lost (One Planet, 2020). Differences between the results of both studies can be explained by the magnitude of samples, the boundary systems used, and the absence of field FL measurement. Delgado et al. (2021) found that self-reported methodologies could generate FL underestimations. Hanson et al. (2016) suggested supplementing surveys with different quantification methods, e.g., FLW weighing.

Concerning sociodemographic characteristics of producers, despite the lack of significance shown by mean comparisons and fractional regression, this study provides interesting results about the age and education level of the sampled farmers. According to Delgado et al. (2017), higher levels of education and agricultural experience are associated with less FL during production, which explains why younger farmers reported losing more food due to their lack of agricultural experience. In addition, younger farmers have had access to more years of education. Understanding how sociodemographic characteristics affect the generation of FL is crucial to improve food security (Delgado et al., 2021) and future research must more deeply consider the aforementioned characteristics.

Vegetable producers perceive more losses than those producing berries or mixed producers according to fractional regression results. This might be related to the target market since vegetables are mostly sold in the local or wholesale market. On the other hand, raspberries and blueberries are produced mainly for export (Retamales et al., 2014; Jara-Rojas et al., 2018) that involve high-quality standards. Raspberry producers also had as an alternative market the agroindustry, where esthetic and quality characteristics are less relevant.

Significant differences between economic losses on vegetable and mixed agricultural products could be explained by the lower yields obtained by the latter, due to the different management required by their production systems. Still, a comprehensive analysis of production costs is required in this matter. With respect to nutritional losses, values reflect a clear difference in nutritional content between vegetables and berries. These results represent useful new information to initiate discussion about nutritional losses. Indeed, Kitinoja et al. (2018) indicated that of 268 articles about post-harvest losses reviewed, only 62 studies gave primary data about economic losses and only six about nutritional losses. Since production systems differ, it is essential for future research to account for a disaggregated sample and to analyze each crop's FLs separately.

The econometric model results show a significant effect of harvest periods on the FL ratio, which increases the longer the

TABLE 7 Fractional regression model explaining variation in food loss (FL) reported by farmers surveyed in two agricultural regions of Chile during June and September of 2020.

Variable	Coeff.	Standard error	Signif. level[a]	Marg. effect
age	−0.005	0.010	NS	0.000
educ	0.029	0.026	NS	0.003
agri_expe	0.006	0.007	NS	0.001
fam_size	−0.067	0.053	NS	−0.007
total_area	−0.017	0.029	NS	−0.002
main_crop	−0.520	0.190	***	−0.052
weather_harv	0.108	0.168	NS	0.011
cosmetic_harv	0.505	0.152	***	0.055
labor_harv	0.520	0.155	***	0.051
one_month	−0.890	0.292	***	−0.065
two_months	−0.365	0.190	*	−0.036
intermed	0.387	0.199	*	0.040
agroindustry	0.373	0.180	**	0.036
Constant	−2.121	0.762		
Observations	177			
Log-pseudolikelihood	−62.129			

[a]Significance level.
***P < 0.01; **P < 0.05; *P < 0.1; NS, not statistically significant.

harvest period. Extended exposure to the produce may cause it to overripen or may affect its composition and consequently shorten its post-harvest life (Elik et al., 2019). While the ripening of produce is the main harvest parameter, often the decision to harvest sooner or later could also be influenced by economic reasons (Elik et al., 2019). Therefore, more research is needed about this factor affecting FL.

The interaction between the main production system and its commercialization channel was statistically significant. While FL amounts are statistically different between vegetables and berries in general, these differences are increased by the retail/direct sale commercialization category. The fact that more FL originated by vegetable producers that sell to retail may be related to quality standards imposed by the sector, leading to produce rejection if these standards are not met (Canali et al., 2017). Intermediary and agroindustry channels increase FL. Recognizing that the farmer's choice of commercialization channel can have an effect on FL produced during primary production is crucial and requires further research.

Among farmers' insights about FL causes, labor problems, cosmetic standards, and climate/weather effects were highlighted in the study, significantly increasing the FL ratio according to fractional regression. Those results are in line with Verma et al. (2019), who mention that labor shortage delays the harvest and increases FL. Another problem may be related to high labor costs and low market prices, which lead farmers to decide not to harvest and leave the produce in the field (Beausang et al., 2017; Johnson et al., 2019). HLPE (2014) shows that farmers' harvest decisions are directly influenced by market requirements—requirements that, most of the time, are related to visual aspects more than the nutritional value of the food. While poor weather conditions or abrupt weather changes are not statistically relevant to FL in our fractional regression model, it is worth mentioning that weather can lead to damage to vegetables and soft fruit, shortening their post-harvest life and/or causing cosmetic loss (Beausang et al., 2017).

6. Conclusion

The objective of this study was to measure food losses generated during primary production using a micro-approach methodology from harvest to commercialization stages among small-scale farmers. Furthermore, to understand the factors affecting FL, we used a fraction regression model with special emphasis on the harvest stage. On average, the FL was 14.5%, and factors that increase FL are the production system and its harvest period, commercialization channels, labor shortage, and cosmetic standards.

Food loss and waste information across the FSC and its causes in each stage of the production chain are quite scarce

in Chile (Eguillor, 2019) and, thus, any attempt to measure the magnitude of the FL problem can positively contribute to policy discussions. While the study's sample size does not make it representative of the studied area, and the measurement of FL on the field was not possible, the results obtained contribute to generating evidence that FL originated in FFA primary production in Central Chile.

From this micro-approach study, it can be concluded that farmers report a considerable volume of FL during primary production, mostly during the harvest stage. This can be translated into an economic loss for producers and a nutritional loss for consumers. Calculating losses using these approaches provide a holistic point of view that will facilitate the generation of sustainable solutions for the FLW issue.

Production systems affect the amount of FL generated, as well as the way the product is commercialized. Additionally, problems such as labor shortages seem to increase FL, as well as long- established customs in agriculture, like cosmetic standards. This supports the idea that FL quantification should be calculated according to specific products, involving all FSC actors.

Chile has put in place different initiatives to prevent FLW produced by the FSC stakeholders and consumers (Eguillor, 2020). According to Bahadur et al. (2016), when policy efforts focus on FL reduction, changes seem to be very effective. Existing literature with policy implications can be considered as a first step to addressing the FLW from an institutional perspective. Nevertheless, methods and FLW definitions are still scarce and remain understated (Cattaneo et al., 2021). Finally, collecting data and evidence is an imperative action, since FLW represents a multidimensional issue, with its causes intertwined throughout the FSC (Canali et al., 2017).

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. The patients/participants provided their written informed consent to participate in this study.

Author contributions

RJ-R and GH-Q contributed to conception and design of the study. GH-Q organized the database and wrote the first draft of the manuscript. RJ-R performed the econometric analysis and wrote sections of the manuscript. All authors contributed to manuscript revision, read, and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Revisiting fruit and vegetable determinants: Evidence from Latin America

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Introduction: In the past decade, the public health discussion regarding fruit and vegetable (FV) consumption has been dominated by economic and physical accessibility.

Methods: Using an online survey in four Latin American countries, we applied a set of tobit models to compare the determinants of desirable and current consumption of FV levels for satisfied and unsatisfied respondents.

Results: We found that, even when consuming less than five FV portions a day, most of the respondents were satisfied with their current FV consumption level. Satisfied respondents consumed significantly more FV than unsatisfied ones. In general, the desirable and current consumption of FV levels were associated with different sets of determinants, while years of education were relevant in both cases. Finally, in a hypothetical case where unsatisfied respondents would not face any physical or economic access restrictions, unsatisfied respondents would not reach the goal of five FV portions a day.

Discussion: Assuming that physical and economic access improved, this would automatically increase FV to reach the five-a-day recommendation may be inaccurate in some cases. We also need to take mental access into account. We may ask how to improve the desirable level of FVs and then how to close the gap between the current and desirable FV levels.

KEYWORDS

food access, fruits and vegetables, consumer behavior, food consumption, fruit, vegetable

1. Introduction

In the context of the Nutrition Decade, the United Nations General Assembly (2019) proclaimed 2021 the International Year of Fruits and Vegetables, an entity that instructs the Food and Agriculture Organization (FAO) of the United Nations as the agency responsible for the implementation of the year. Through this resolution, all Member States, organizations of the United Nations system, other international and regional organizations, and other relevant stakeholders, including civil society, the private sector, and academia, were invited to participate in the International Year, through different activities.

Fruit and vegetable (FV) consumption is a necessary, but not sufficient condition of a healthy diet. FVs consumption is associated with a lower prevalence of diet-related diseases (Aune et al., 2017; Wang et al., 2021), decreased risk of depression (Liu et al., 2016), and increased natural immunity (Hosseini et al., 2018). In the past decade, the public health discussion has been dominated by accessibility. Recognizing that it would depend on many determinants, physical (Larson et al., 2009) and economic (Lee et al., 2013) access to FVs have been historically pointed out as one of the reasons why low-income households consume less than the recommended amount of FVs. Physical access to FVs means that is expected that a household located close to healthy food stores, such as FVs selling points, would facilitate to purchase of healthy food (Silva et al., 2021b), while a household has economic access when it can afford FVs.

The Latin American region exports a large variety of fruit to the world (Long and Roberts, 2005). However, the FV consumption in the region is relatively low (Uauy et al., 2001; Kovalskys et al., 2019). Trying to explain this apparent contradiction, some authors have argued that companies are exporting fruits that can be consumed domestically. However, in an open-market economy, countries export product that holds competitive advantages (Carter and Zhong, 1991). While countries also benefit from importing other products, with competitive disadvantages, that would be more expensive if they were produced domestically. In the end, households have a wider variety to choose from as part of their food basket (Shim et al., 2001). For instance, Chile exports table grapes to Ecuador, while it imports bananas from Ecuador. Since Chile, mostly in the Central Valley, has Mediterranean weather, it cannot produce bananas. Banana is the most purchased and most consumed fruit in Chilean households. In this way, an open-market economy allows households to access a wider variety of products that are cheaper when they are produced domestically. In an open market, the production decision of companies and the consumption decision of households are taken separately.

Fruit export companies that face developing restrictions, such as export taxes, technological restrictions, and financial constraints, would make the industry less competitive and thus affect the overall fruit production (Whitfield, 2012). In Latin America, most of the fruit that is sold domestically are products that do not achieve export quality standards in terms of shape, size, or color (Balsevich et al., 2003). Second-quality fruit is sold domestically at cheaper prices than the exported fruit (Balsevich et al., 2003). Developing restrictions would create a disincentive to invest such as new varieties, irrigation systems, and expand production land, and this would lead to a contract, exports as well as fruit to the domestic market, supply (Scherr and Hazell, 1994). A contraction on the supply side, while keeping demand conditions, would likely be translated into higher domestic fruit prices. Therefore, although industry developing restrictions may seem attractive to increase domestic fruit availability in the short term, it is likely to make fruit more expensive and then less affordable for everyone in the long term.

Another possibility to increase FV consumption is to promote their consumption. A variety of health policies have been implemented in different countries to encourage the consumption of FVs. The WHO/FAO (2003) recommends eating, at least, five portions of FVs per person per day, each portion weighing 80 g. Local governments and related agencies have promoted the five-a-day recommendation to the population. The recommendation, in each case as part of a different media campaign, started being promoted in the late 1980s in the United States; then, it spreads to Australia, the United Kingdom, and many other countries (Carreño and Silva, 2019). In Latin America, the five-a-day recommendation started in 2003 in Mexico, in 2006 in Chile, and in 2007 in Colombia (Zacarías et al., 2020), while the starting date is not clear in the case of Ecuador.

The five-a-day campaign is likely the most well-known informational campaign to promote FV intake in the world (Carreño and Silva, 2019). The Global Alliance to Promote Fruit and Vegetable Consumption "5 a Day" is a non-profit organization that gathers 39 institutions from 32 countries with the purpose of promoting FV consumption, preventing non-communicable diseases, and enhancing global health. Nevertheless, no country has been able to reach such a level yet (Micha et al., 2015). Among nutritionists, there is agreement that five portions of FVs a day should be considered a minimum basis. In this article, we distinguish between the five-a-day recommendation from the five-a-day campaign. In our questionnaire, we asked respondents about the five-a-day recommendation. The five-a-day recommendation is the content that advises consuming at least five portions of FVs a day. Instead, the five-a-day campaign is the specific media selection to disseminate the five-a-day recommendation. We cannot talk about a single five-a-day campaign worldwide since each country has used a different set of media to promote the five-a-day recommendation (Rekhy and McConchie, 2014).

In Colombia, the Government puts in place initiatives from early childhood to programs for the elderly (Ortiz-Moncada et al., 2006). Then, the five-a-day recommendation has been promoted to a wider range of population segments. In Ecuador, the five-a-day recommendation has just stayed as a recommendation rather than a campaign. In Chile and Mexico, the five-a-day campaign has focused on education programs at elementary schools in low-income neighborhoods (González et al., 2020). In addition, in these countries, the five-a-day campaign has focused on social networks, such as Facebook and Twitter. Social networks can be a cost-effective way to reach young population segments (Grassi et al., 2016; Coates et al., 2019).

Substantial attention has been paid to the existence of areas with limited access to affordable healthy food, also known as "food deserts" (Beaulac et al., 2009; Allcott et al., 2018). The underlying assumption is that a household located in a food desert would have difficulties purchasing FVs. In this way, the lack of access to FVs would lead to unhealthy food and then to a higher prevalence of malnutrition-related diseases (Bridle-Fitzpatrick, 2015). In the same way, higher consumption is a factor that contributes to the transition toward healthier diets and would pose a cross-cutting benefit between public health and sustainable production (Mason-D'Croz et al., 2019). However, there is no agreement on the actual effect of food deserts on purchasing behavior and diet-related diseases (Larsen and Gilliland, 2009). While some research has found that food deserts are determinants in terms of the prevalence of obesity and diet-related diseases (Hendrickson et al., 2006; Morris et al., 2019), other research has found an ambiguous relationship (Schafft et al., 2009; Rodier et al., 2017; Allcott et al., 2018; Pitts et al., 2018). Ver Ploeg and Wilde (2018) concluded that households in the same neighborhood, and the same food environment, can have different food purchasing patterns.

Recognizing that physical and economic access is likely to play a relevant role in FV intake, especially in the very low-income population, the objective of this article is to analyze FV consumption level satisfaction as a proxy of mental access. We do not directly assess mental access in this study. Instead, we analyze data regarding current and desirable FV consumption levels and the level of satisfaction of the respondents with their current FV consumption level. We consider it illustrative that most of the people surveyed while consuming less than the public health recommendation level were satisfied with the FV consumption. For this purpose, we used data from an online survey of food purchases in four Latin American countries.

2. Background

Recently, mental access has been gaining attention (Ma et al., 2021). Ma et al. (2021) defined mental access based on having the knowledge to access FVs for consumption, dietary knowledge, or

food skills. Knowledge to access refers to being aware of where/how to find FVs. Dietary knowledge means having nutritional knowledge about the relevance of an adequate amount of FVs as part of a healthy diet and avoiding diet-related diseases (Rasmussen et al., 2006; Riediger et al., 2007). Finally, food skills refer to knowing how to prepare FVs (McGowan et al., 2017). Hartmann et al. (2013) found that cooking skills are positively associated with vegetable consumption in both genders, while it is positively associated with fruit consumption only in the case of women. Therefore, although dietary knowledge is different from food skills, we can define mental access as having the knowledge to access FVs, nutritional FVs knowledge, and food skills to prepare FVs.

Social marketing helps social change using contemporary commercial marketing theory and practice (Dann, 2010). In FV consumption, social marketing campaigns can provide information and raise awareness. Mental access, to some extent, can be similar to education level. It can be argued that an educated person is more aware of the relevance of consuming abundant FVs. However, mental access and education are not the same. Mental access, in a more holistic way, is to be willing to increase FV consumption when the consumption level is under the five-a-day recommendation. Fresh vegetables, and some fruits, are time-consuming to prepare, and in some cases, this requires culinary skills that not everyone is willing to develop. Fresh FVs, in most cases, are less convenient. For instance, fresh FVs can be difficult to select at the store, to carry on, to eat (to separate edible from not edible portions), and to store. Despite the convenience challenges, some people still may want to eat FVs because of their nutritional and health benefits. However, few surveys explicitly measure nutritional and health benefits knowledge; some examples can be found in the work done by Scalvedi et al. (2021) in Italy and Koch et al. (2021) in Germany. In this sense, using education as a determinant of FV consumption, education is likely to capture indirectly nutritional and health benefits knowledge. We argue that it is necessary to develop instruments to measure directly the dimensions that are included in mental access.

According to Barlow et al. (2016), people who choose unhealthy foods tend to have higher temporal discount rates, which means they focus more on immediate satisfaction. In contrast, people willing to consume more FVs would have lower temporal discount rates. People with a low discount rate care about future benefits in a similar way that this food presents benefits (Barlow et al., 2016). Since most of the health benefits, associated with high consumption of FVs, would be experienced in the long term, people with higher discount rates may not be as attracted to handle the inconvenience of FV consumption. Previous research has found that a high temporal discount rate is associated with obesity (Barlow et al., 2016), depressive disorders (Pulcu et al., 2014), and low-income conditions (Yang, 2016). However, it may be not straightforward to the actual causal path between FV consumption and discount rate. It may be the case that the discount rate leads to FV consumption, or *vice-versa*, or both are correlated and are the result of another determinant. For instance, Levens et al. (2019) analyzed temporal discount and healthy food choices as simultaneous outcomes, while Kao et al. (2019) studied the effect of temporal discount that leads to healthy food choices.

An illustrative example of mental access can be found in the study done by Silva et al. (2021a). In this study, the authors found that FV produce sellers, who should have been granted physical and economic access, do not consume more FVs than the rest of the population. Despite practicing more physical activity, FV produce sellers have a higher prevalence of being overweight than the rest of the population, and similar weight to people with the same educational level (Silva et al., 2021a). Consequently, educational level, rather than physical or economic access, can help explain body weight and body mass index.

Therefore, mental access may indicate whether low FV consumers actually pursue increasing their FVs consumption. Mental access challenges the previous belief that everyone wants to consume at least five portions of FVs a day. Someone with physical and economic access may not consume five FV portions a day because they may not feel like it. Following the study presented by Silva et al. (2021a), our article challenges the assumption that low FV consumers, who eat less than five portions a day, do not eat more FVs exclusively due to restrictive physical and economic access conditions. Of course, physical and economic access may be relevant in many cases; we just want to highlight to take also into account other determinants that are influencing the FV consumption level.

3. Methodology

We conducted an online survey. The survey was implemented using SoGo and distributed through Facebook from November to December 2021. Our study is non-experimental; therefore, we did not have a random treatment assignment or a control group. In the beginning, the respondents needed to agree with the informed consent form to be able to continue. After that, the respondents needed to confirm they were of legal age. In this way, the survey was distributed online to adults in Chile, Colombia, Ecuador, and Mexico. Each respondent had one opportunity to answer the survey; at the end, the data set corresponded to cross-sectional data.

In total, we received 1,987 surveys, of which 1,698 were completed surveys. As an incentive, the respondents who completed the survey had the chance to win a prize equivalent to US$100 in local currency. Since we did not have a random sample, we cannot argue that our estimation corresponds to a representative sample of the population. In this sense, we want to take our results with some caution. We pursue to show that current and desirable FV consumption levels may not differ, rather than estimate the FV consumption level with accuracy.

The survey included an FV consumption section, pesticide risk section, sociodemographic information section, and a food security section. The complete questionnaire is presented in Supplementary material. The questions regarding FV consumption estimation used visual aids from the *Encuesta Nacional de Salud* of Chile. Before its final field implementation, the survey questionnaire was tested using *focus groups* and a small sample. We also conducted interviews with experts who helped to improve the survey questionnaire. The data collection process was approved by the Ethical Review Board of the *Universidad Central de Chile*.

We are aware that FV consumption is the result of many factors and determinants. Our article analyzes the determinants of FV desirable consumption level (question Q23 in the questionnaire in the Supplementary material) and the potential gap compared to the current FV consumption level (question Q13 and question Q16 in the questionnaire in the Supplementary material). We modeled the desirable FV consumption as the dependent variable in a regression model. Since the gap between desirable and current FV consumption

levels can be zero, we needed to use a Tobit model to take into account the censored nature of the data.

As defined in the "Introduction" section, mental access has three dimensions (FV access knowledge, nutritional knowledge, and cooking skills), which we were not able to directly assess in the survey. Therefore, we do not have evidence to argue that lack of mental access is associated with low FV consumption. Nevertheless, it may be interesting to consider that most of the people surveyed were satisfied with the FV consumption level.

The Tobit model shows a linear relationship between amount variables when the dependent variable is left- or right-censored. Censoring happens when the variable cannot take values beyond a certain point. Following Wooldridge (2010), the Tobit model can be written as $y = max\ (0,\ X\beta + u)$, in which the error term is normally distributed and independent of x, $u|x \sim N\ (0,\ \sigma^2 I)$. In our case, y is FV consumption, dependent variable, which is left-censored at zero (people cannot consume a negative amount of FVs).

As explanatory variables, X, we used food shopper characteristics (age, gender, and education), household characteristics (urban vs. rural), and four variables associated with the five-a-day recommendation: achieve the recommendation, aware, meaning, and classification knowledge (as presented in Table 1). We asked whether the respondent had heard about the five-a-day recommendation. Then, we gave choices only to the people who were aware of the five-a-day recommendation, to find out whether they knew what it meant, such as five types of FVs, five portions, or five colors. Finally, we tested the people to find out whether they knew the type of elements included in the five-a-day recommendation. For instance, potatoes, corn, and sugar-sweetened juices are not included in the five-a-day recommendation.

4. Results

4.1. Descriptive statistics

Table 1 compares satisfied and unsatisfied FV respondents. In our sample, 70.1% of the respondents were satisfied with the current level of FV consumption. Moreover, among the satisfied ones, 43.3% achieve the five-a-day recommendation. In other words, most people are satisfied with the current FV consumption level, which is less than five portions a day. Among the unsatisfied ones, 31.3% achieved the five-a-day recommendation. The respondents who were aware of the five-a-day recommendation stated to consume 4.5 portions a day, while those unaware respondents stated to consume 4.1 portions a day. Based on descriptive statistics, we cannot argue causality; however, there seems to be an association between awareness of the five-a-day recommendation and FV consumption.

In general, unsatisfied respondents are younger, and more educated women. These results suggest that unsatisfied ones are people who may be more aware of the relevance of including FVs as part of a healthy diet. However, unsatisfied respondents have a desirable FV consumption level that is similar to the current FV consumption level of satisfied ones. Therefore, Table 1 shows that there is a need for improving the desirable FV consumption level to reach at least the five-a-day recommendation.

As presented in Table 1, we found that the current consumption of FV is 4.3 portions and the desirable consumption of FV is 6.2 portions. Since confidence intervals overlap, we cannot argue that they are statistically different. In other words, even being lower than the five-a-day recommendation level, there is no statistical difference between the current and the desirable FV consumption levels.

Regarding the five-a-day recommendation, most of the respondents indicate to be aware of the five-a-day recommendation. They correspond to 61.5%, which shows a the high penetration level of the recommendation. However, a small proportion of respondents know the correct meaning of the five-a-day recommendation. Particularly, 21.9% of respondents know that five-a-day means five portions, or servings, a day, and 17.9% of respondents are able to identify correctly the FVs that are recommended. For instance, potatoes are tubers, which are not recommended as part of the five-a-day recommendation. Therefore, Table 1 shows that the five-a-day recommendation has been disseminated widely; however, most of the respondents do not understand the message correctly.

COVID-19 has led to relevant effects on the supply and demand sides. In contrast, the consequences of sanitary restrictions due to COVID-19 may be different depending on factors such as age, gender, socioeconomic level, and location, which could aggravate existing inequalities (Bann et al., 2021). According to our survey, 26.1% of the population has maintained their FV consumption, and 30.9% of the respondents stated to have decreased their FV consumption after COVID-19, of which 84.0% is the result of economic access barriers. Then, 43.0% of the respondents stated to have increased their FV consumption after COVID-19, of which 77.0% is the result of health concerns.

Overall, our results show that 73.9% of the respondents have changed their FV consumption level after COVID-19. Among unsatisfied respondents, 63.2% of them stated to have decreased FV consumption after COVID-19. In contrast, among satisfied respondents, 53.3% of them stated to have increased FV consumption after COVID-19. Therefore, it seems that the current level of satisfaction with FV consumption is highly associated with consumption changes led by COVID-19.

4.2. Tobit results

Table 2 shows the results of a Tobit model to explain FV consumption, desirable FV consumption, and the difference between them, known as the consumption gap. Gender, education, and country of the respondent at least have a relevant role to explain FV consumption. Rather than focusing on specific determinants, it is worth noticing that most determinants are different in each Tobit model. Therefore, the determinants that explain current FV consumption are different from desirable FV consumption and from the gap between current and desirable levels.

We found consistently with previous research that education level and gender do play a significant role. On the education side, Silva et al. (2021a), using the Oaxaca-Blinder decomposition in two waves of a national data set in Chile, found that FV disparities can be better explained by a change in the effect of education of the household head rather than a change on his/her number of years of education. On the gender side, according to Wardle et al. (2004), weight control, rather than a stronger belief regarding healthy eating, explains that women are more likely than men to report avoiding high-fat foods, eating fruit and fiber, and limiting salt consumption. In Canada, Colapinto et al. (2018) found that women are more likely to eat FV

10.3389/fsufs.2022.1001509

TABLE 1 Descriptive statistics by fruit and vegetable consumption.

	Unsatisfied		Satisfied		Overall	
	Mean	SD	Mean	SD	Mean	SD
FV current consumption	4.01	(1.64)	4.48	(1.76)	4.34	(1.74)
FV desirable consumption	4.41	(1.56)	6.99	(0.15)	6.22	(1.46)
Foodshopper characteristics						
Age, years	47.73	(13.32)	51.55	(13.83)	50.40	(13.79)
Gender, 0 = man, 1 = woman	0.87	(0.34)	0.82	(0.39)	0.83	(0.37)
Body mass index categories, foodshopper						
Normal	0.37	(0.48)	0.40	(0.49)	0.39	(0.49)
Overweight	0.34	(0.48)	0.35	(0.48)	0.35	(0.48)
Obese	0.29	(0.45)	0.25	(0.43)	0.26	(0.44)
Education category, foodshopper						
No education	0.21	(0.41)	0.21	(0.41)	0.21	(0.41)
High school	0.47	(0.50)	0.39	(0.49)	0.41	(0.49)
College and more	0.32	(0.47)	0.40	(0.49)	0.38	(0.48)
Household characteristics						
Household size, number of members	3.88	(1.70)	3.67	(1.71)	3.73	(1.71)
Zone, 0 = rural, 1 = urban	0.79	(0.41)	0.82	(0.38)	0.81	(0.39)
Country						
Chile	0.25	(0.43)	0.27	(0.44)	0.26	(0.44)
Colombia	0.25	(0.43)	0.25	(0.43)	0.25	(0.43)
Ecuador	0.21	(0.41)	0.23	(0.42)	0.22	(0.42)
Mexico	0.30	(0.46)	0.25	(0.43)	0.27	(0.44)
Five-a-day recommendation						
Achieve recommendation, 0 = no, 1 = yes	0.31	(0.46)	0.43	(0.50)	0.40	(0.49)
Aware, 0 = not aware, 1 = aware	0.58	(0.49)	0.63	(0.48)	0.62	(0.49)
Meaning, 0 = incorrect, 1 = correct	0.19	(0.39)	0.23	(0.42)	0.22	(0.41)
Classification knowledge, 0 = incorrect, 1 = correct	0.21	(0.41)	0.16	(0.37)	0.18	(0.38)
FV consumption change after COVID-19						
Decreased	0.63	(0.48)	0.17	(0.38)	0.31	(0.46)
Maintained	0.18	(0.38)	0.30	(0.46)	0.26	(0.44)
Increased	0.19	(0.39)	0.53	(0.50)	0.43	(0.50)
Observations	508		1,190		1,698	

A fruit and vegetable portion corresponds to 80 g. In the case of mutually exclusive categorical variables, the mean can be interpreted as a percentage. For instance, 61.5% of the overall sample indicates that is aware of the five-a-day recommendation. However, in the case of continuous variables, such as current FV consumption, the mean is interpreted as the average.

more frequently than men and consume the recommended amount of FVs.

In Table 1, we show that most of the respondents were aware of the five-a-day recommendation, while they did not know the correct meaning. Table 2 shows that not knowing the correct meaning of the 5-day recommendation is not as relevant as not knowing being aware of the five-a-day recommendation. In other words, if someone does not know whether the recommendation is five portions or five types of FVs is not as relevant in terms of current and desirable consumption. Meanwhile, being aware of the five-a-day recommendation is associated with a higher level of current and desirable FV consumption. Finally, knowing the FVs that are included in the five-day recommendation is not associated with changes on the current or desirable FV consumption levels.

Therefore, we found that, even when consuming less than five FV portions a day, most of the respondents were satisfied with the current FV consumption level. Moreover, according to Table 1, satisfied respondents state to consume 0.5 portions more than unsatisfied ones. In general, the desirable and current consumption FV levels are associated with different sets of determinants, while

10.3389/fsufs.2022.1001509

TABLE 2 Tobit results.

Variables	Current FV consumption	Desirable FV consumption	Consumption gap
Age, years	−0.01	0.01	0.02
	(0.004)	(0.004)	(0.007)
Gender, 0 = man, 1 = woman	0.23	−0.07	−0.36
	(0.08)	(0.15)	(0.18)
High school	0.07	−0.13	−0.26
	(0.09)	(0.07)	(0.11)
College and more	0.24	0.22	−0.07
	(0.14)	(0.10)	(0.08)
Zone, 0 = rural, 1 = urban	0.29	0.04	−0.31
	(0.15)	(0.06)	(0.14)
Five-a-day awareness, 0 = not aware, 1 = aware	0.27	0.18	−0.16
	(0.13)	(0.10)	(0.05)
Five-a-day meaning, 0 = incorrect, 1 = correct	0.18	0.06	−0.14
	(0.08)	(0.11)	(0.13)
Five-a-day classification, 0 = incorrect, 1 = correct	0.05	−0.10	−0.20
	(0.11)	(0.14)	(0.23)
Var(e)	2.93	2.11	5.64
	(0.09)	(0.11)	(0.29)
Constant	3.69	5.89	2.06
	(0.18)	(0.17)	(0.39)
Observations	1,694	1,694	1,694

A fruit and vegetable portion correspond to 80 g. The estimation uses the country as a cluster variable.

years of education are relevant in both cases. Finally, in a hypothetical case where unsatisfied respondents would not face any physical or economic access restrictions, most of the unsatisfied respondents would not reach the goal of five FV portions a day.

5. Discussion

In Latin American countries, the FV consumption is low compared with developed countries. According to Miller et al. (2016), who compared 18 countries involving 143,000 participants, the average consumption was 3.8 portions of FVs (95% CI 3.7–3.9). The consumption varied based on income: 2.1 servings in low-income countries, 3.2 portions in lower-middle income countries, 4.3 portions in upper-middle income countries, and 5.4 portions in high-income countries. The FV consumption is close to 3.9 portions in Chile (Silva et al., 2021a), 2.0 portions in Colombia (Delgado et al., 2010), 2.0 in Ecuador (Freire et al., 2015), and 3.0 in Mexico (López González and Alarcón Osuna, 2018). It is likely that the higher consumption is due to the higher education level of the survey sample. For instance, in Chile, in the survey sample, 37.6% of the respondents held a college degree, while according to national surveys, it should be around 28.8% (INE, 2018).

As presented in Table 2, current and desirable FV consumption are led by different sets of determinants, which have relevant policy implications. In order to increase FV consumption, we may need to address two separate questions. First, we would need to increase the desirable FV consumption level, which can be done by improving the awareness of the five-a-day recommendation. Most people are satisfied with the FV consumption even when they do not achieve the five-a-day recommendation. Second, we would need to increase the current FV consumption level which at least can be done by improving the five-a-day awareness, while also explaining which is the actual meaning of the five-a-day recommendation.

In terms of household location, similar to the findings of Dean and Sharkey (2011), urban respondents state to consume 0.3 portions a day per person more than rural ones. This result, consistent with previous studies, can also seem contradictory, to some extent. In a rural setting, it is expected to have a food environment with more abundant FVs; however, rural respondents report eating fewer FVs than urban ones. This fact also suggests that FV consumption is not only a matter of physical and economic access.

Also, from the respondents that have decreased FV consumption, our study found that only 18.7% state that price is the main determinant for fruit consumption, and 14.9% for vegetable consumption. Ares et al. (2017) found that convenience was the most relevant barrier to healthy eating among mid-income households, while for low-income households, satiety—feeling full—was a key food consumption determinant. Arce et al. (2021) found that the acceptability of some FVs is reported to have a high influence on consumption. In this sense, price as an FV consumption barrier is likely to be hiding other determinants (Livingstone et al., 2020;

Hohoff et al., 2022; Young and Stewart, 2022). Of course, price is relevant in many consumption decisions; however, in some cases, it is likely to have overstated their actual effect on consumption.

COVID-19 has a heterogeneous effect on FV consumption (Picchioni et al., 2021). Our results show that 73.9% of respondents have changed their FV consumption level after COVID-19. Unsatisfied respondents have mainly decreased FV consumption. In contrast, satisfied respondents have mainly increased FV consumption after COVID-19. However, we do not have information to assess whether the respondents were unsatisfied before COVID-19, or they became unsatisfied after COVID-19. Therefore, COVID-19 had a heterogeneous and relevant effect on FVs in a large proportion of respondents, and this research topic keeps unfolding.

COVID-19 made some households increase their FV purchases looking for a way to boost their immune systems (Zupo et al., 2020; Jordan et al., 2021; Yedjou et al., 2021). However, other places have been experiencing FV supply restrictions. In Colombia, the high dependence of the nation on the importation of not only processed but also fresh products has been evidenced; there is a shortage of FVs in some cities (Vivas Carbó, 2020). In Mexico, after the COVID-19 pandemic, 18.7% of the population began to consume fewer fruits and 13.3% fewer vegetables (Shamah-Levy et al., 2021).

6. Conclusion

Our results show that 61.5% of respondents were aware of the five-a-day recommendation, which shows that the message has been widely disseminated. The fact that most of the respondents also were satisfied with their current FV consumption level, even not reaching the five-a-day recommendation, can be taken as an opportunity to redesign informational messages to promote FV consumption. We may need to have a clearer, simple message based on nutritional evidence.

Substantial evidence has been developed to measure physical and economic access. Now, it would be interesting to work on mental access indicators beyond years of schooling. In this article, we use the level of satisfaction as a proxy for mental access. However, there is a need to further develop indicators to assess each one of the mental access dimensions presented by Ma et al. (2021): knowledge of FV access, nutritional knowledge, and food skills. The understanding of these dimensions in a population segment can help tailor messages according to the specific objective to increase current and desirable consumption FV levels.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material. The dataset will be made available from the corresponding author upon request.

Ethics statement

The studies involving human participants were reviewed and approved by Universidad Central de Chile—Ethics Board. The patients/participants provided their written informed consent to participate in this study.

Author contributions

AS supervised the data collection and analysis and wrote the manuscript. AA contributed in data analysis and literature review. SD-A contributed in data collection. AD revised the manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2022.1001509/full#supplementary-material

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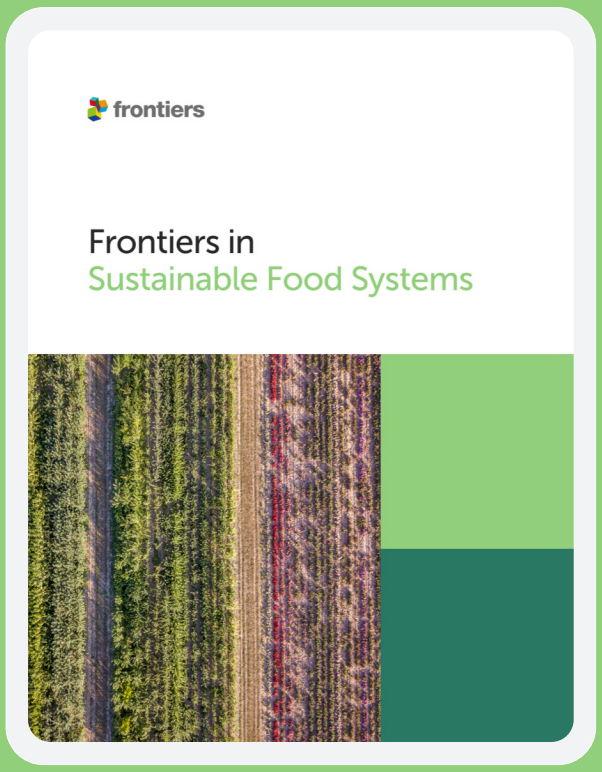

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