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The impact of dietary rationalization on rural residents' health and happiness

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Introduction: China is facing a dual burden of malnutrition and overnutrition, and dietary rationalization (DR) is an important direction for the transformation of rural residents' dietary habits. The effect of DR on happiness has not been sufficiently researched in existing literature. Verifying the impact of the DR on the happiness of rural residents and analyzing the mechanism of health is necessary.

Methods: This study is based on a mixed cross-sectional data of the 2020–2022 China Land Economic Survey, establish a measurement for the DR and use OLS regression, two-step regression to analyze the effect of DR on happiness and the mechanism of health. The Propensity Score Matching method and Instrumental Variables are used to test the robustness of the effect of DR on happiness. Bootstrap method is used to confirm the robustness of the mechanism of health.

Results: The baseline regression show that rationalizing diet can enhance the happiness of rural residents. A two-step regression shows that health plays a positive mediating role in the impact of the DR on the happiness of rural residents. After robustness tests, the above conclusion still holds. Heterogeneity Analysis shows that rationalizing the intake of fruits and milk can increase the happiness of rural residents, excessive consumption of meat and aquatic products will make rural residents happier. In addition, the marginal effect of rationalizing diet on the happiness of older and less educated rural residents is stronger.

Discussion: This study suggests that dietary rationalization has a significant impact on the health and happiness, expanding the possible ways to improve the happiness of rural residents from a micro perspective and providing references for the formulation of relevant policies like specific directions for improving the food supply system and the popularization of dietary literacy. Next, it is necessary to expand the food type and take a tracking study.

KEYWORDS

foods, dietary rationalization, health, happiness, rural resident

1 Introduction

Happiness, or more broadly subjective well-being, has become an important reference for policy-making of the governments around the world. To help guide public policy, The United Nations has been publishing the World Happiness Report since 2012. Happiness has been an important topic related to the national economy and the people's livelihood (Stephoe, 2019). The pioneer of happiness studies, Ed-Diener, views happiness as the final goal of human development. The happiness of the people is the ultimate aim of promoting high-quality development in China as well. Over the past few decades, China has experienced rapid economic growth, however the

widespread existence of the “Easterlin Paradox” indicates that macro-level income growth does not necessarily lead to an enduring increase in national happiness over the long term (Easterlin and O'Connor, 2022). There is a phenomenon in China where economic growth and people's happiness are disconnected (Graham et al., 2017). After making a great achievement in poverty alleviation, the happiness of rural residents related to income growth has become relatively limited, thus necessitating a greater focus on the non-income factors that enhance happiness for rural residents. Diet is one of the non-income factors that may effect rural residents' happiness.

Global food consumption has undergone significant changes in the past few decades. The trend of meat consumption opposites between some developed and developing countries (Stewart et al., 2021; Henchion et al., 2021). The dietary structure will shift from an increase in meat consumption to a pursuit of health in the long run. China's meat consumption has shown an upward trend over the past years. The per capita consumption of meat products has rapidly increased from 9 kg per year in 1978 to 70 kg in 2022, showing a trend of excessive consumption. Therefore, China intends to make a transformation from “being full” to “eating well.” Dietary structure refers to the types and proportions of different food items in a diet (Chinese Nutrition Society, 2022). The Chinese government calls for the “rationalization” of residents' diets. Rational diets necessitate a varied food intake to achieve nutritional balance and adequacy, which is a critical aspect of “eating well.” However, there are widespread issues of irrational diet, particularly among rural residents in China. A report indicated that there has long been a significant lack of intake of fruits and milk among residents, as well as generally low consumption levels of shrimp, fish, beans, dark vegetables, and whole grains (Chinese Nutrition Society, 2021). In 2015, the average daily fruit intake among rural residents was merely 26.2 g, falling far below the 200–350 g recommended by the “Chinese Nutrition Society, 2022”; the average daily intake of dairy was 14.8 g, significantly lower than the recommended 300–500 g. An unreasonable dietary structure is one of the primary factors contributing to disease incidence and mortality in China. Chinese also believe that “Food is the primary necessity of the people”; thus, food has always been a significant source of happiness in China. Consequently, food has become a significant constraint in promoting health and enhancing happiness among rural residents.

Before happiness, diet is first associated with health. Happiness economics posits that health is a crucial factor influencing happiness, and poor health can impede the enhancement of happiness. Rural residents face issues such as low health literacy (Li et al., 2022) and unequal access to health opportunities (Ma et al., 2021). Their life expectancy is lower than that of urban residents. Clarifying the logical chain linking rational diet, health and happiness can help identify specific deficiencies in health literacy among rural residents. Moreover, it may expand effective ways to improve happiness within the constraints of limited health resources, providing policy references for enhancing health and happiness among rural populations.

This paper aims to investigate whether the DR (dietary rationalization) can improve health and enhance the happiness of rural residents. Utilizing mixed cross-sectional data from the China Land Economic Survey (CLES) for the years 2020–2022, this study will empirically analyze the effects of DR on the happiness of rural residents and the mechanisms of health, helping realize the urgency and necessity of dietary rationalization and provide some references

for the transformation of the food system. The contributions of this study are threefold. First, it evaluates the sufficiency of dietary intake among rural populations while identifying key patterns of nutritional imbalance. Second, it extends the theoretical framework of happiness economics at the micro-level by incorporating non-income determinants, with particular emphasis on dietary patterns, thereby enriching the conceptual understanding of mechanisms underlying subjective well-being enhancement. Third, the research underscores the distinctive characteristics of rural demographics, who typically experience suboptimal dietary patterns and constrained access to healthcare resources, offering specific insights for improving both health outcomes and happiness in these populations.

2 Theoretical framework

2.1 DR and happiness

Most studies adopt a nutritional perspective to explore how the quantity and frequency of consumption of certain foods influence happiness. First, overall dietary structure affects residents' happiness. A diversified dietary structure ensures the intake of essential nutrients such as proteins and vitamins, which fundamentally influence happiness (Muscarioli, 2021). Badri empirically examined happiness by using “feeling calm,” “feeling energetic,” and “feeling down or depressed” as proxy variables and found a significant positive correlation between healthy eating and happiness (Badri et al., 2021). Stenlund used a 9-year cross temporal tracking survey, found that people with healthier dietary habits have happier lives (Stenlund et al., 2022).

Moreover, the impact of different types of food on happiness varies. The intake of fruits and vegetables, for instance, can enhance happiness. Some studies have shown that among all dietary factors, only the intake of fruits and vegetables leads to a stronger sense of happiness and effectively reduces depression (Wickham et al., 2020). Some researches indicate that vegetarians tend to be happier than non-vegetarians (Krizanova and Guardiola, 2021). Additionally, the intake of fats and proteins also influences happiness. Martin et al. (2023) found that the consumption of fats and proteins can effectively alleviate stress and anxiety while enhancing happiness. However, some studies highlight that diets high in carbohydrates and fats may temporarily relieve negative emotions and stimulate so-called “happiness hormones,” but in the long term, they do not necessarily improve happiness and may become negative factors; only a healthy diet can sustain happiness over time (Kaur and Van, 2017).

Return to the definition of happiness, the understanding of happiness can be categorized into two schools: hedonic well-being and eudaimonic well-being (Ryan and Deci, 2001). Hedonism posits that happiness is derived from the pursuit of pleasure and sensory enjoyment, while eudaimonism emphasizes the importance of discovering life's meaning and realizing one's potential. Bentham's utilitarianism serves as a classic expression of hedonism, which later economists built upon to propose the principle of utility maximization (Bentham, 1996). In contrast, the well-known psychological theory of Maslow's hierarchy of needs illustrates the perspective of eudaimonism (Maslow and Lewis, 1987). Food consumption fundamentally meets physiological needs, classified as the lowest level of Maslow's hierarchy.

However, it also serves as a prerequisite for higher-level self-actualization needs. The evolution of food culture reflects humanity's progression from merely satisfying physiological needs to pursuing sensory pleasure, where dietary choices are driven by hedonistic desires, thereby providing joy. Thus, whether viewed through hedonism or eudaimonism, dietary choices play an important role.

Rationalizing diet transcends mere satiation and represents a new pursuit for rural residents who have escaped poverty and are no longer preoccupied with basic sustenance. This pursuit begins with safety needs, which occupy the second level in Maslow's hierarchy. Furthermore, it also reflects a quest for self-perfection. Therefore, from the perspective of eudaimonism, DR can enhance happiness. The pursuit of DR is not entirely consistent with hedonistic views of happiness, as utility maximization requires individuals to consider personal preferences influenced by various factors, including taste, health, cooking difficulty, and price. Theoretically, DR aligns with hedonistic pursuits only when individuals prioritize health as their sole criterion for food choices. As the health literacy of rural residents increases, the importance of health in food selection rises, allowing DR to gradually align with the pursuits of hedonic well-being. Therefore, from a hedonistic perspective, DR can enhance happiness. Based on these analysis, this paper proposes the following hypothesis:

H1: DR can enhance the happiness of rural residents.

2.2 DR and health

Substantial nutritional evidence demonstrates a direct correlation between diet and health, with health serving as a critical reference point for assessing DR. The academic consensus suggests that plant-based diets are generally healthier. Well-established dietary structures, such as the Mediterranean diet, DASH diet, and the balanced diet advocated by the "Dietary Guidelines for Chinese Residents" are types of plant-based diets. A sufficient intake of whole grains, fruits, vegetables, nuts, and other plant-based foods ensures a rich supply of dietary fiber, plant proteins, vitamins, and minerals, thereby promoting health and helping to prevent various chronic diseases, cardiovascular conditions, and obesity (Guasch-Ferré and Willett, 2021; Craig et al., 2021; Satija and Hu, 2018).

A high proportion of animal food intake in the diet is associated with overweight and obesity (Medawar et al., 2020). However, a rational diet also emphasizes the appropriate consumption of animal-based foods, as they provide essential nutrients that the human body requires. For instance, vegans may lack certain vital nutrients, such as vitamin B12 and calcium (Niklewicz et al., 2023; Łuszczki et al., 2023). Foods like fish and eggs provide proteins containing essential amino acids, which are easily digestible and significantly contribute to lowering blood cholesterol levels and mitigating obesity (Puglisi and Fernandez, 2022). The dietary structures of rural residents in China are irrational and insufficient (Wang and Xie, 2020), which hampers improvements in health outcomes. There is a concerning trend toward adopting more animal-based diets, leading to nutritional excesses and an increase in health issues such as obesity (Huang et al., 2021). Based on this analysis, this paper proposes the following hypothesis.

H2: DR can promote the health of rural residents.

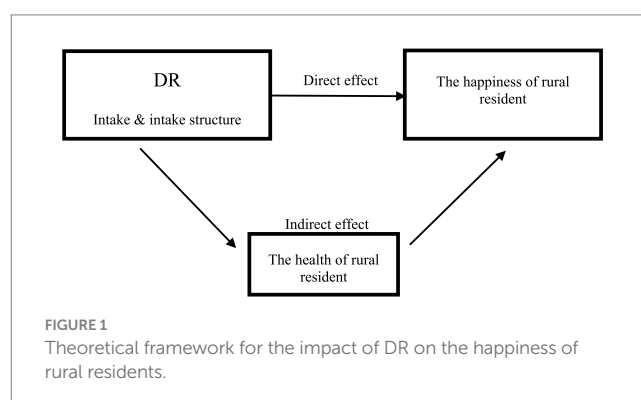
2.3 DR, health, and happiness

Health and happiness are closely connected. The RICH theory uses four factors to explain the happiness, including resources, intimacy, competence, and health. Health is the foundation of all others. Physical illness will impede happiness (Winter et al., 2022). Many studies have examined the effects of health on happiness (Singh et al., 2023). Lamu and Olsen (2016) found that healthier people experience better subjective well-being, and concerns regarding health status are significant factors affecting residents' happiness (Kaya and Yilmaz, 2022). DR, which is benchmarked against health, aims to enhance residents' health, thereby influencing their happiness through this critical factor. From the progression within Maslow's hierarchy of needs, DR satisfies health-related safety needs, subsequently facilitating self-actualization. Additionally, in the context of utility maximization, for DR to approximate the utility maximization condition, it must generate substantial health benefits that elevate the significance of health considerations in the dietary decision-making process of rural residents. Based on these analysis, this study posits the following hypothesis:

H3: DR can enhance happiness among rural residents by improving their health.

The theoretical framework of this paper is illustrated in Figure 1. DR including intake and intake structure have effect on the happiness of rural resident, through both direct effect and indirect effect of the health.

Prior studies provide valuable references for this paper but also exhibit certain limitations. First, most dietary-related research primarily draws from nutritional and biological perspectives. In studying the impact of diet on happiness, scholars tend to link happiness to the intake of specific nutrients. However, happiness is not merely a physiological indicator; it encompasses broader social science domains, thus necessitating an expanded interdisciplinary perspective when examining how dietary structures influence happiness. Second, although a relatively mature indicator system exists for evaluating residents' dietary intake, the application of these indicators is limited. The measurement outcomes are predominantly treated as dependent variables or used solely for analyzing the current state of residents' dietary intake, and relevant studies generally fail to quantitatively investigate the impact of DR on health and happiness under objective measurement frameworks. Third, there is a lack of targeted research on rural residents. Rural populations in China face particular challenges, such as limited dietary knowledge



and health resources. Thus, researching rural resident samples holds significant practical implications.

3 Methods

3.1 Index calculation of DR

Some indicators have been established in academia to assess DR. Chinese studies often utilize the Dietary Balance Index (DBI) to assess dietary quality. The DBI is founded on the “Dietary Guidelines for Chinese Residents,” classifying energy levels and food intake recommendations, assigning scores to 12 food categories. The index uses positive scores to evaluate excessive intake and negative scores for insufficient intake. The total score is calculated by accumulating scores from various food intakes, which reflects the imbalance in overall dietary consumption and is commonly used as a proxy measure for residents’ dietary structures and quality (He et al., 2018).

In addition to DBI, another commonly used indicator is the Healthy Eating Index (HEI), developed by the United States Department of Agriculture based on the “Dietary Guidelines for Americans.” The HEI has been widely adopted in research. Yuan et al. (2017) established the Chinese Healthy Eating Index (CHEI) based on China’s dietary guidelines. Unlike DBI, although HEI also classifies diets into sufficient and adequate categories with scores, it does not strictly categorize foods; for instance, HEI directly incorporates the intake of fatty acids into the scoring system, allowing it to intuitively reflect whether certain nutrients are adequately consumed (Krebs-Smith et al., 2018). Moreover, the Dietary Quality Index (DQI) is another common metric for evaluating dietary intake. The DQI primarily focuses on the intake of major nutrients, assessing whether the consumption of fats, saturated fatty acids, and cholesterol is excessive, evaluating whether the intake of vegetables, fruits, and carbohydrates is sufficient, and judging the appropriate intake of calcium and protein. In contrast to DBI, DQI separates food types and constructs indicators directly from the perspective of nutrient intake (El-Sehrawy et al., 2025).

Based on existing relevant research, this paper defines DR as the objective of promoting health through a diversified diet that achieves balanced and adequate nutrition. Before conducting the quantitative analysis, this paper will construct relevant indicators to measure DR.

The first step involves referencing the measurement methods of the Dietary Balance Index (DBI) to categorize the intake of seven types of foods: vegetables, fruits, dairy products, soybeans, meat (livestock and poultry), eggs, and aquatic products. The classification criteria follow the “Chinese Nutrition Society (2022).” The guideline is established based on nutritional principles and the practical living conditions of Chinese residents, making it a crucial reference for rationalizing diet in China, characterized by both scientific rigor and general applicability.

The first category (I) comprises foods emphasized by the guidelines as “to be consumed more often” or “to be consumed regularly,” primarily evaluating their inadequate intake levels. This category includes vegetables, fruits, dairy products, and soybeans. The second category (II) consists of foods where the guidelines recommend “moderate consumption,” assessing instances of either insufficient or excessive intake, mainly encompassing meat (livestock and poultry), eggs, and aquatic products, as illustrated in Table 1.

The second step involves assigning scores to these food categories. Due to data limitations, this study does not apply the scoring methods of DBI, HEI, or DQI, but the underlying logic of scoring in this study

TABLE 1 Food classification, recommended intake and sample average.

Food type	Classification	Recommended intake	Sample average intake
Vegetables	I	300–500 g/d	302 g/d
Fruits	I	200–350 g/d	124 g/d
Dairy products	I	300 g/d	65 g/d
Soybeans	I	105–175 g/w	325 g/w
Meat	II	300–500 g/w	724 g/w
Eggs	II	300–350 g/w	474 g/w
Aquatic products	II	300–500 g/w	328 g/w

The data is compiled from the “Chinese Nutrition Society (2022).”

is essentially similar to those methods, focusing on analyzing deviations from standard intake levels.

The evaluation method for the first category of foods is as follows:

$$SCORE_A = \frac{MAX - INTAKE}{MAX} \quad (1)$$

In the Equation 1, the score deviation is represented as *SCORE*, *A*(Adequacy) indicates the foods emphasized by the guidelines as “to be consumed more often” or “to be consumed regularly.” *MAX* represents the upper limit of the recommended intake specified by the guidelines, while *INTAKE* denotes the actual average daily intake. As the primary evaluation focuses on inadequate intake, *SCORE* is positive when intake is insufficient, reflecting the final deviation score. When *SCORE* is negative, indicating sufficient intake, the deviation score is assigned a value of 0.

The evaluation method for the second category of foods is as follows:

$$SCORE_{M+} = \frac{MAX - INTAKE}{MID} \quad (2)$$

$$SCORE_{M-} = \frac{INTAKE - MIN}{MID} \quad (3)$$

In the Equations 2, 3, the deviation score is represented as *SCORE*. *M*(Moderation) indicates the foods that the guidelines recommend for “moderate consumption.” *MAX* represents the upper limit of the recommended intake as specified by the guidelines, while *MIN* indicates the lower limit of the recommended intake, and *MID* denotes the mean of these upper and lower limits. *INTAKE* represents the actual average daily intake. Since the evaluation needs to assess both insufficient and excessive intake, the following conditions apply: if *SCORE_{M+}* is negative, indicating excessive intake, the final deviation score is taken as the absolute value of *SCORE_{M+}*. Conversely, if *SCORE_{M-}* is negative, indicating insufficient intake, the final deviation score is also taken as the absolute value of *SCORE_{M-}*. When both *SCORE_{M+}* and *SCORE_{M-}* are positive, indicating moderate consumption, the deviation score is assigned a value of 0 (in the calculations, the specific values of *MAX* and *MIN* refer to Table 1).

The third step involves calculating the deviation scores for the seven types of foods separately. Following this, the entropy weight

method is employed to compute the final index reflecting the DR. While the Dietary Balance Index (DBI) uses dietary quality distance to measure dietary balance, this index merely aggregates the absolute values of food scores. It can indicate overall dietary balance but fails to identify specific foods influencing dietary inequality. The entropy weight method is an objective weighting technique, through calculated weights for various food categories, which helps identify the main issues leading to dietary imbalance among residents; greater weights indicate that the intake of such foods may be a primary contributor to variations in DR.

The calculation process of the entropy weight method is as follows:

The first step involves standardizing the deviation scores. Given that the direction of all deviation scores is consistent (the larger the value, the higher the degree of deviation and the less rational the diet), a uniform negative indicator normalization method is used. The higher the final comprehensive score calculated, the more rational the diet will be.

$$z_{ij} = \frac{SCORE_{ij} - \min(SCORE_j)}{\max(SCORE_j) - \min(SCORE_j)} \quad (4)$$

In the Equation 4, z_{ij} represents the standardized deviation score for the j -th type of food for the i -th sample.

The second step involves calculating the information utility value for the j -th indicator, denoted as d_j . The specific calculation method is shown in the Equation 5:

$$d_j = 1 + \frac{1}{\ln(m)} \sum_{i=1}^m p_{ij} \ln(p_{ij}), \text{ among which, } p_{ij} = \frac{z_{ij}}{\sum_{i=1}^m z_{ij}} \quad (5)$$

Where m represents the number of samples.

The third step involves calculating the weights w_j of each indicator based on the information utility values, as the Equation 6 shows.

$$w_j = \frac{d_j}{\sum_{j=1}^7 d_j} \quad (6)$$

Finally, the comprehensive score $FSCORE_i$ for DR is calculated based on the weights assigned to each indicator as the Equation 7. This score reflects the overall degree of rationalization in the diet, integrating the standardized deviation scores of various food categories weighted by their respective importance. The higher the comprehensive score, the more rational the diet is considered to be.

$$FSCORE_i = \sum_{j=1}^7 w_j * z_{ij} \quad (7)$$

3.2 Methods of baseline regression

The dependent variable, the subjective well-being of rural residents, is an ordered discrete variable ranging from 1 to 10, which

can be approximated as a continuous variable. In econometric models, Individual rating items with numerical response formats at least five categories in length may generally be treated as continuous data (Harpe, 2015). In this paper, the baseline regression is estimated using OLS, Probit, and Logit models. The baseline regression equation is specified as follows:

$$Happiness_i = \beta_0 + \beta_1 Diet_i + \beta_2 X_i + \varepsilon_i \quad (8)$$

In Equation 8, i represents the i -th sample, $Happiness$ denotes the subjective well-being of rural residents, $Diet$ indicates the score of DR, X comprises the control variables, which include age, age squared, gender, marital status, education level, medical insurance coverage, household annual income, and the number of permanent residents in the household. β_0 is the constant term, β_1 and β_2 are the coefficients of the variables, and ε is the random error term.

3.3 Methods of mechanism test

A two-step regression is used for testing the mediating mechanism. The mediation effect is not widely accepted in the field of economics. We do not care about the specific effects, but focus on the causal relationships involved. A two-step regression's premise is that we can use relevant literature to explain the impact of M on Y. In this case, the causal relationship between the mediating variable (health) and the dependent variable (happiness) is quite direct, a two-step regression can be used instead of using interaction terms, as some researchers have done (Chen et al., 2020). Firstly, regressing M on X, then regressing Y on X and M, as the Equation 9 shows.

$$\begin{cases} Health_i = \gamma_0 + \gamma_1 Diet_i + \gamma_2 X_i + \varepsilon_i \\ Happiness_i = \beta_0 + \beta_1 Diet_i + \beta_2 Health_i + \beta_3 X_i + \varepsilon_i \end{cases} \quad (9)$$

4 Data and variable

4.1 Data and sample

The data used in this study is derived from the China Land Economic Survey (CLES), organized by Nanjing Agricultural University. The CLES survey was conducted in Jiangsu Province, targeting rural households, and covers various aspects of farmers' lives, agricultural production, and rural development. Unlike the China Health and Nutrition Survey (CHNS), which focuses on nutrition and health, CLES does not utilize more complex survey methods such as the 24-h dietary recall to assess residents' dietary intake. CLES surveyed the quantity of food consumed by interviewed households in the previous week (including both purchased and self-produced food). Considering that CLES data is relatively recent and encompasses a wide range of survey content, this paper chooses to employ the CLES data for empirical research.

The sampling method for this survey is probability proportional to size sampling. Beginning in 2020, the survey selected 26 research districts across 13 prefecture-level cities in Jiangsu Province. Within each district, 2 sample towns were chosen, and within each town, 1

administrative village was selected. From each village, 50 households were randomly sampled, resulting in a total of 52 administrative villages and 2,600 rural households. The data used in this study comes from the mixed cross-sectional survey conducted between 2020 and 2022, with an original sample size of 6,248. After selecting the research variables and excluding invalid samples, the final sample size used in this paper is 4,012. Descriptive statistical results are presented in Table 2.

4.2 Variable selection and descriptive statistics

4.2.1 Dependent variable

The dependent variable in this study is the subjective well-being of rural residents, as measured by respondents' self-assessment of their happiness on a scale of 1 to 10, where 1 indicates the least happiness and 10 indicates the most happiness., as many researches chose (Toshkov, 2022; Ji et al., 2023; Xu et al., 2022). The average score in the sample is 8.024, indicating a generally strong sense of happiness among respondents, although a portion still feels unhappy.

4.2.2 Core independent variable

The core independent variable in this study is the score of DR, measured using a comprehensive indicator that reflects the extent of DR, as described earlier. The mean score of DR among rural residents is only 0.378, indicating that the dietary structures are generally unbalanced. Some residents exhibit severe deviations from the reasonable standards.

4.2.3 Mediating variable

When studied on the impact of Mediterranean diet on happiness, Ferrer-Cascales used health-related variables as mediators

(Ferrer-Cascales et al., 2019). We followed studies like it and use health level as the mediating variable. It based on respondents' subjective assessments of their health status: 1 = inability to work, 2 = poor, 3 = average, 4 = good, 5 = excellent. The sample mean is 3.941, nearing the "good" category, suggesting that there is still considerable room for improvement in rural residents' health.

4.2.4 Control variables

We also referred to some previous research to select our control variables. Individual characteristics like age (Toshkov, 2022), gender (Montgomery, 2022), education (Buijs et al., 2021) and type of work (Ji et al., 2023), is related to happiness. Thus, we control these individual characteristics. Considering the possible inverted U-shaped relationship between age and happiness, age^2 will be controlled. From an individual perspective, the sampled population encompasses rural residents aged 17–96, although most respondents are household heads, resulting in an older average age and a predominance of male respondents. The education level is generally low, with fewer than one-third of respondents engaged in non-agricultural work. We also control some family characteristics and village characteristics that related to happiness. The impact of income on happiness has always been controversial, but cross-sectional studies often demonstrate a promotion of happiness (Killingsworth et al., 2023). Health insurance and pension is found to play an important role on improving happiness (Han et al., 2022; Kim and Koh, 2022). Family size has been shown to be positively correlated with happiness in some studies (Zhu et al., 2021). Thus, We control family characteristics including household income, household permanent population, household medical insurance and household pension insurance In terms of family characteristics, medical insurance coverage is relatively high, but pension insurance coverage is low, with around half of the respondents' families lacking any pension insurance, indicating insufficient support for old age. Social and natural environment

TABLE 2 Descriptive statistics.

Variables	Definition	Average	Std. dev	Min	Max
Subjective well-being	Do respondents feel happy?: 1–10, from low to high	8.024	1.596	1	10
Score of DR	A comprehensive indicator with a scale of 0–1	0.378	0.183	0.0317	0.996
Health level	respondents' subjective assessments of their health status: 1–5	3.941	1.064	1	5
Age	Age	62.81	11.16	17	96
Age ²	Age ²	4,069	1,308	289	9,216
Gender	0 = female, 1 = male	0.728	0.445	0	1
Education	Years of formal education	6.986	3.978	0	18
Type of work	Whether engaged in non-agricultural work, 0 = No, 1 = Yes	0.314	0.464	0	1
Household income	Household annual income, in logs	9.089	1.467	0.693	14.728
Household permanent population	The number of household permanent population	3.102	1.620	1	11
Household pension insurance	Does the household have pension insurance? 0 = No, 1 = Yes	0.576	0.494	0	1
Household medical insurance	Does the household have medical insurance? 0 = No, 1 = Yes	0.915	0.279	0	1
Village industry	Satisfaction with the industries in village, 1–5, 1 = very dissatisfied, 5 = very satisfied	3.563	0.964	1	5
Village ecology	Satisfaction with the ecology in village, 1–5, 1 = very dissatisfied, 5 = very satisfied	4.130	0.748	1	5
Village civilization	Satisfaction with the civilization in village, 1–5, 1 = very dissatisfied, 5 = very satisfied	4.062	0.737	1	5
Village governance	Satisfaction with the governance in village, 1–5, 1 = very dissatisfied, 5 = very satisfied	4.131	0.738	1	5

influences happiness, we include them into village characteristics. Social support (Xu et al., 2022), ecology (Zhong and Chen, 2022) and governance (Youssef and Diab, 2021) show influence on happiness. We take these factors into consideration, choose village industry, village ecology, village civilization and village governance as control variables that reflect social support, ecology and governance. Regarding village characteristics, respondents generally express satisfaction with the overall performance of rural revitalization, but there are still significant shortcomings in the development of rural industries.

5 Estimation results

5.1 Baseline regression

The baseline regression results are displayed in Table 3 (1) and (2), representing the regression outcomes without and with control variables, respectively. The estimated coefficients for the score of DR are statistically significant at the 1% level and are positive. For each unit increase in the score of DR, the subjective well-being of rural residents increases by an average of 0.914 units. This indicates that as dietary structure improves from completely unreasonable (0) to completely reasonable (1), the happiness of rural residents significantly increases. The more rational the diet of rural residents, the stronger their subjective well-being becomes. Hence, H1, which posits that “DR improves the happiness of rural residents,” is established.

The estimated coefficients and significance results of the control variables indicate that age is not a major factor affecting happiness. Male rural residents report higher levels of happiness compared to their female counterparts, which contradicts the findings of some scholars (Xu and Chen, 2020). It might be that overall happiness between women and men does not differ significantly. Easterlin posits that women may experience higher happiness until mid-life, while men may find greater happiness afterward, suggesting that overall equality may obscure the differences across gender life cycles (Easterlin, 2021). The average age in the sample used in this study is relatively older than that of other studies reaching opposite conclusions, which typically feature younger samples.

Rural residents with higher education levels, those engaged in non-agricultural work, higher household annual incomes, and those who possess medical and pension insurance report greater happiness, aligning with conclusions drawn from most cross-sectional data studies. Satisfaction with the four aspects of rural development significantly positively influences rural residents' happiness, with rural industrial development and improved rural governance showing a stronger marginal effect on happiness. The conclusions drawn from the estimates of the three models are entirely consistent.

5.2 Mechanism test

Building on the baseline regression, this paper further examines the mediating role of health in the impact of DR on the happiness of rural residents. In the first step, we analyze the effect of the independent variable, the score of DR, on the mediating variable, health level. In the second step, both the score of DR and the health level are included in the regression to estimate their effects on the

dependent variable, happiness. The results are presented in Table 4 (1) and (2).

In (1), the estimated coefficient for the score of DR is positive and statistically significant at the 1% level, indicating that DR has a significant positive impact on the health of rural residents. The more rational the diet, the healthier the rural residents become. In (2), both the estimated coefficients for the score of DR and health level are positive and significant at the 1% level. These results suggest that health plays a mediating role in the influence of DR on the subjective well-being of rural residents, highlighting the important role that health plays in their dietary choices. Thus, H2, which states that “DR promotes the health of rural residents,” and H3, which posits that “DR enhances happiness among rural residents by improving their health,” are both supported by the findings.

5.3 Robust test

5.3.1 Robust test on the baseline regression

Firstly, to address potential selection bias—particularly the possibility that individuals with higher levels of subjective well-being may exhibit greater awareness of and engagement in healthy dietary practices, thereby introducing self-selection issues, this study employs the Propensity Score Matching (PSM) methodology. Since the independent variable, the score of DR, is a continuous variable, it is further classified into a binary variable of 0 and 1. Households with a relatively DR are designated as the experimental group and assigned a value of 1, while those with a relatively unreasonable diet are classified as the control group and assigned a value of 0. The score of DR calculated in this study is similar to the dietary quality distance used in the Dietary Balance Index (DBI). Accordingly, the standard for assessing dietary imbalance is referenced from the dietary quality distance, where 60% of the full score serves as the threshold for classifying a highly imbalanced diet. In this study, the maximum score for the score of DR is set at 1, which indicates that there is neither insufficient intake nor excessive intake of foods. This is in contrast to the dietary quality distance. Therefore, the chosen cutoff point is set at 0.4, where a score of DR of ≥ 0.4 is deemed rational, while a score of < 0.4 is considered unreasonable.

This study employs four propensity score matching methods: nearest neighbor matching, radius matching, caliper matching, and caliper k-nearest neighbor matching. The matching results are presented in Table 5, where the unmatched samples amount to a maximum of 61. To ensure the effectiveness of matching, for nearest neighbor matching and caliper k-nearest neighbor matching, k is set to 4, indicating a 1-to-4 matching ratio. In the case of caliper matching, radius matching, and caliper k-nearest neighbor matching, a caliper width of 0.024 is established.

The average treatment effects estimated by the four methods are shown in Table 6. All average treatment effects are positive, and the *T*-test values exceed 2.56, demonstrating significance at the 1% level. Therefore, it can be concluded that rural residents with rational diets experience greater happiness, which is consistent with the results of the baseline regression.

To ensure the quality of matching, a balance test was further conducted, with results shown in Table 7. The bias values for all covariates after matching are less than 10%, and none pass the *T*-test, indicating that covariates are balanced and the matching results are

TABLE 3 Baseline regression.

Variables	Subjective well-being		Subjective well-being		Subjective well-being	
	OLS		Oprobit		Ologit	
	(1)	(2)	(1)	(2)	(1)	(2)
Score of DR	1.323*** (0.136)	0.914*** (0.133)	1.500*** (0.156)	1.068*** (0.161)	0.881*** (0.0908)	0.641*** (0.0936)
Age		−0.00190 (0.0156)		−0.00841 (0.0188)		−0.00338 (0.0110)
Age^2		0.000113 (0.000133)		0.000187 (0.000159)		9.37e-05 (9.30e-05)
Gender		0.193*** (0.0574)		0.206*** (0.0689)		0.128*** (0.0400)
Education		0.0364*** (0.00711)		0.0466*** (0.00849)		0.0259*** (0.00496)
Type of work		0.167*** (0.0552)		0.204*** (0.0663)		0.111*** (0.0387)
Household income		0.0652*** (0.0164)		0.0806*** (0.0198)		0.0457*** (0.0115)
Household permanent population		0.00215 (0.0157)		−0.000320 (0.0186)		−0.000691 (0.0109)
Household pension insurance		0.164*** (0.0543)		0.179*** (0.0651)		0.107*** (0.0379)
Household medical insurance		0.205** (0.0866)		0.223** (0.105)		0.133** (0.0602)
Village industry		0.184*** (0.0283)		0.237*** (0.0340)		0.139*** (0.0198)
Village ecology		0.0972** (0.0428)		0.174*** (0.0513)		0.0832*** (0.0297)
Village civilization		0.146*** (0.0450)		0.196*** (0.0546)		0.105*** (0.0313)
Village governance		0.249*** (0.0432)		0.311*** (0.0528)		0.171*** (0.0301)
R ²	0.023	0.127				
Obs	4,012	4,012	4,012	4,012	4,012	4,012

Standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$.

robust. Thus, the conclusion that “DR enhances the happiness of rural residents” is reliable.

Secondly, to avoid potential reverse causality issues, introduce an instrumental variable. Follow some researches, use the mean of score of RD of other respondents in the same county (CMRD) as an instrumental variable (Tong and He, 2025). On the one hand, the diet of rural residents is related to the diet of their location. On the other hand, the diet of other residents is not directly related to their individual happiness. Therefore, this variable satisfies the two validity conditions of the instrumental variable.

Results of two stage least square are shown in Table 8. The arrow (1) shows the relation between RD and CMRD. We further validate the first stage and obtain a F -value of 82.3 that prove the strong correlation between instrumental variables and independent variables.

The arrow (2) is the final consequence. The impact of DR on happiness is significant at the 10% significance level with the coefficient of 1.631. The results of baseline regression are still robust. DR enhances the happiness of rural residents.

Thirdly, considering that happiness is a long-term stable subjective feeling, respondents’ answers may be influenced by short-term shocks, possibly leading to biases. Life satisfaction is commonly used as a proxy variable for happiness in happiness research. By substituting the dependent variable with life satisfaction to further validate the robustness of the conclusions, the results are shown in Table 9. The estimated coefficient for the score of DR is positive and statistically significant at the 1% level, indicating that DR significantly enhances the life satisfaction of rural residents, thereby reinforcing the robustness of the conclusion.

TABLE 4 Mechanism.

Variables	Health level	Subjective well-being
	(1)	(2)
Score of DR	0.394*** (0.0876)	0.815*** (0.131)
Health level		0.253*** (0.0236)
Control variables	Controlled	Controlled
Obs	4,012	4,012
R ²	0.145	0.152

Standard errors in parentheses, *** $p < 0.01$.

TABLE 5 Results of PSM.

	Off support	On support	Total
Untreated	4	2,469	2,473
Treated	2	1,537	1,539
Total	6	4,006	4,012

5.3.2 Robust test on the mechanism of health

Another method to verify the mediating effect is used to ensure the robustness of the mechanism of health. Bootstrap method is commonly used. The bootstrap method provides more accurate confidence intervals through repeated sampling. After 1,000 times sampling, we get 1,000 estimated values of γ_1, β_2 that presented in the Equation 9. Sort them by number, the 2.5th percentile and 97.5th percentile form the confidence interval at the 95% statistical level. Finally, by whether the confidence interval contains 0, we can determine whether the mediating effect is significantly different from 0. The confidence interval is shown in Table 10. Indirect effect's confidence interval do not include zero, indirect effect is significantly different from 0, the mediating effect of health is robust. Health plays a mediating role in the influence of DR on the subjective well-being of rural residents.

5.4 Heterogeneity analysis

5.4.1 Differential effects of food intake

The previous sections verified the impact of the score of DR on the subjective well-being of rural residents, but they did not reflect the influence of specific types of food intake on happiness. This absence prevents us from determining the specific directions of DR. Therefore, this study substitutes the standardized scores of the seven types of food as independent variables in the original regression. The regression results are presented in Table 11 (1).

Among these results, the estimated coefficients for dairy products and meat (livestock and poultry) are significant at the 1% level, the estimated coefficient for fruits is significant at the 5% level, and the estimated coefficient for aquatic products is significant at the 10% level. The estimated coefficients for the remaining four food types did not pass the significance test. The positive coefficients for fruits, dairy products, and aquatic products indicate that when the intake of these foods becomes more balanced, the subjective well-being of rural residents significantly increases. Conversely, the negative coefficient for meat suggests that rationalizing meat intake leads to a decrease in the happiness of rural residents.

TABLE 6 ATE of PSM.

Method	ATE	S.E.	T-stat
Neighbor matching ($k = 4$)	0.334	0.051	6.51
Radius matching (caliper = 0.024)	0.339	0.049	6.89
Caliper matching (caliper = 0.024)	0.344	0.058	5.96
Caliper k-nearest neighbor matching (caliper = 0.024, $k = 4$)	0.335	0.051	6.51
Average	0.338		

TABLE 7 Results of balance test before and after PSM matching.

Method	Ps R ²	LR	Bias (%)
Before matching	0.031	164.63	42.1
Neighbor matching	0.001	2.48	5.7
Radius matching	0.000	0.23	1.7
Caliper matching	0.002	7.11	9.6
Caliper k-nearest neighbor matching	0.001	2.41	5.6

TABLE 8 Two stage least square.

Variables	Score of DR	Subjective well-being
	(1)	(2)
Score of DR		1.631* (0.975)
CMRD	0.720*** (0.0839)	
Control variables	controlled	controlled
Obs	4,009	4,009
R ²	0.0725	0.122

Standard errors in parentheses, *** $p < 0.01$, * $p < 0.1$.

Social psychologist Gilovich posits that fundamental consumption represented by food does not have a significant effect on subjective well-being, regarding adaptation as the greatest enemy of happiness (Gilovich and Gallo, 2020). This perspective aligns with the psychological set-point theory, which holds that happiness has a stable baseline—eventually returning to a level determined by genetics or personality traits. In contrast, economics often operates under the principle that more is better. In this sample, the consumption of vegetables, soybeans, and eggs among rural residents can be qualitatively characterized as fundamental consumption, to which they have already adapted, yielding no significant impact on happiness. However, the intake of fruits and dairy products is inadequate and considerably deviates from recommended levels. For current rural residents, these foods do not represent fully adapted fundamental consumption; thus, increasing their intake may still have a substantial marginal effect on enhancing happiness.

Additionally, from a health perspective, rural residents appear to be over-consuming meat but remain unsatisfied, leading to a trend of continued consumption increase. Whether happiness will revert to the set-point level once residents fully adapt to fruits, dairy products, and meat requires further investigation using panel data in the future.

Considering the potential existence of an inverted U-shaped relationship between the intake of various foods and happiness, this study further incorporates the levels of food intake and their squared

TABLE 9 DR on life satisfaction.

Variables	Life satisfaction
Score of DR	0.868***
	(0.130)
Control variables	Controlled
Obs	4,012
R ²	0.141

terms as independent variables, replacing the score of DR in the regression analysis. The results of the regression are shown in Table 11 (2) and (3), which present the estimated effects of food intake and their squared terms.

The regression results indicate that the estimated coefficients for the intake of fruits, dairy products, meat (livestock and poultry), and aquatic products are all positive, while the corresponding squared terms estimated coefficients are negative; all are statistically significant at least at the 10% level. This finding suggests that there is indeed an inverted U-shaped relationship between the intake of fruits, dairy products, meat, and aquatic products and happiness.

On the other hand, the estimated coefficients for vegetables, soybeans, and eggs are not statistically significant. This may be attributed to the generally sufficient intake of these three food categories among rural residents.

Further, an inverted U-shaped curve has been illustrated, as shown in Figure 2. For foods that require sufficient intake, when fruit consumption reaches approximately 450 g per day and dairy intake reaches about 250 g per day, further increases in intake do not lead to additional enhancements in happiness. The turning point is close to the reasonable consumption levels. Given the current context of generally insufficient intake of fruits and dairy products, rationalizing the consumption of these items aligns to enhance the happiness of rural residents.

Regarding foods that should be consumed in moderation, the turning point for meat (livestock and poultry) intake exceeds 2 kg per week, which is significantly higher than the recommended level. This phenomenon can be attributed to three main reasons: first, humans have an inherent preference for protein and fat, and health is not the sole consideration regarding dietary intake; thus, the turning point does not align with the requirements for rationalizing consumption. Second, meat has historically been a scarce commodity, and for rural residents, “eating meat” symbolizes prosperity; having meat at every meal is a humble aspiration for them. Third, there is a perception among some rural residents that associating “being fat” with “eating meat” equates to health. This reflects, to some extent, the lack of dietary knowledge among rural residents.

The turning point for aquatic product intake also exceeds the upper limit for reasonable consumption; however, current consumption levels among rural residents remain within a rational or even slightly insufficient range. In the short term, rationalizing aquatic product intake will continue to enhance the happiness of rural residents. However, long-term monitoring is required to avert the potential trend of excessive intake of aquatic products. Educating rural residents about proper dietary knowledge and altering traditional perceptions so that health factors are considered more in their food choices is a crucial prerequisite for promoting happiness through DR.

TABLE 10 Bootstrap results.

	95% conf. Interval	
Indirect effect	0.0510321	0.1478367
		(0.130)
Direct effect	0.5665856	1.062821

TABLE 11 Different foods on happiness.

Variables	Subjective well-being	Subjective well-being	Subjective well-being
	(1)	(2)	(3)
Vegetables	−0.0361	−0.0323	0.00232
	(0.0842)	(0.0243)	(0.00186)
Fruits	0.217**	0.0689**	−0.00655*
	(0.0894)	(0.0317)	(0.00348)
Dairy products	0.515***	0.112***	−0.00879**
	(0.0915)	(0.0300)	(0.00415)
Soybeans	−0.0190	−0.0747	0.0128
	(0.0583)	(0.0863)	(0.0303)
Meat	−0.684***	0.197***	−0.0218**
	(0.212)	(0.0524)	(0.00978)
Aquatic products	0.253*	0.181**	−0.0536*
	(0.137)	(0.0818)	(0.0296)
Eggs	0.0104	0.0258	−0.000879
	(0.159)	(0.0767)	(0.0183)
Control variables	Controlled	Controlled	Controlled
R ²	0.132	0.039	0.039
Obs	4,012	4,012	4,012

① Standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$; ② (2) (3) belongs to the same regression, (2) is the estimated result of the impact of various food intake on happiness, and (3) is the estimated result of the square term of various food intake on happiness.

5.4.2 Differential effects on various groups

In addition, this study will further analyze the differences in the impact of DR on the happiness of different groups, categorizing the sample based on age and education level.

The samples are divided into two groups based on age: those aged 65 and older and those younger than 65. The regression results are presented in Table 12. For both age groups, the estimated coefficients for the score of DR are statistically significant at the 1% level, demonstrating a significant effect on subjective well-being. A comparison of the estimated coefficients reveals that DR has a greater impact on the happiness of rural residents aged 65 and older. In the sample, there are 2,086 rural residents aged 65 and above, with an average DR score of 0.366, compared to 1,926 residents under 65, who have an average score of 0.391. This indicates that older rural residents tend to have a more unreasonable dietary structure, leading to a stronger marginal effect of rationalization on their happiness.

The samples were also categorized based on education level, dividing them into two groups: those with 9 years of education or more and those with less than 9 years of education. The regression results are presented in Table 13. For both groups with differing education levels, the estimated coefficients for the score of DR are

statistically significant at the 1% level, demonstrating a significant effect on subjective well-being.

A comparison of the estimated coefficients indicates that DR has a greater impact on rural residents with less than 9 years of education. Among the 1,831 rural residents with 9 years of education or more, the average score of DR is 0.413, while for the 2,181 rural residents with less than 9 years of education, the average score is 0.349.

The disparity in DR between the different education groups is more pronounced than the differences observed across the age groups; as a result, the differences in estimated coefficients are also more significant. It appears that groups with less reasonable dietary structures exhibit a more pronounced effect of rationalization on happiness. This suggests that interventions aimed at improving DR could yield greater benefits for individuals with lower levels of education, who may have less awareness or access to proper dietary practices.

6 Conclusion, suggestions and limitations

6.1 Conclusion

This study utilizes mixed cross-sectional data from the “China Land Economic Survey” conducted from 2020 to 2022 to empirically

analyze the impact of DR on the subjective well-being of rural residents and the mediating role of health. The findings reveal several key points: Firstly, rural residents with a higher score of DR exhibit stronger subjective well-being. Secondly, DR promotes the health of rural residents and enhances their subjective well-being through the mediating effect of health. Thirdly, rationalizing the intake of fruits, dairy products, and aquatic products significantly improves the happiness of rural residents, while the rationalization of meat (livestock and poultry) intake correlates with a decrease in happiness. Fourthly, rural residents who consume excessive amounts of meat and aquatic products may experience greater happiness, indicating that DR and the enhancement of happiness is contradictory in some ways. Fifthly, DR has a stronger marginal effect on the happiness of older and less-educated rural residents. At present, the happiness gained by rural residents of China from the RD may mainly be attributed to the satisfaction of dietary adequacy. The rationalization behavior among rural residents exhibits passive characteristics. The lack of dietary knowledge hinders DR and its impact on happiness. It's necessary to inhibit the trend of excessive dietary intake, removing the contradiction between DR and the improvement of happiness. These findings suggest that DR can improve the health status of rural residents and enhance their happiness. China is currently transitioning toward high-quality development, having achieved great results in poverty alleviation, with rural residents no longer facing hunger. The

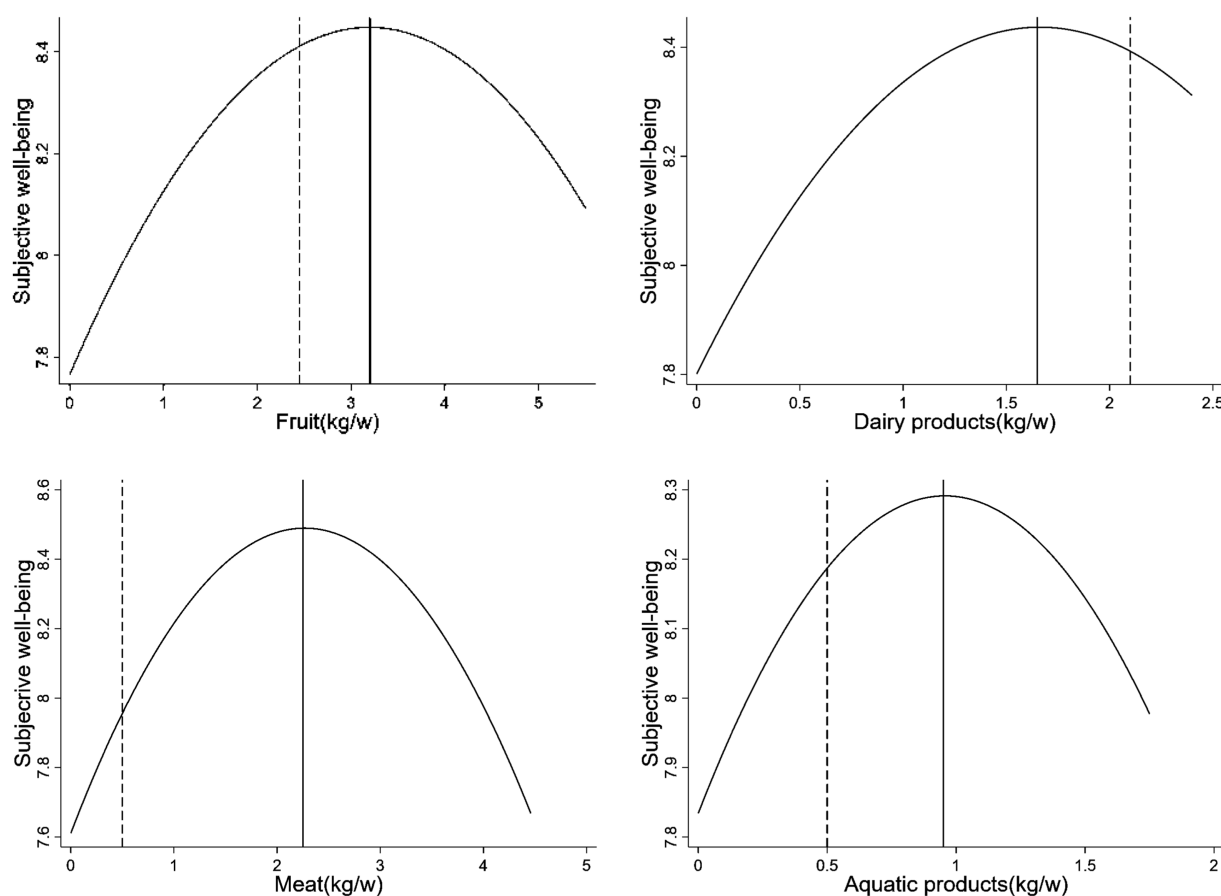


FIGURE 2

U-shaped relationship between intake of fruits, milk, livestock and poultry meat, and aquatic products and happiness. There are two reference lines in the figure, where the dashed line represents the reasonable intake level and the solid line represents the inflection point.

TABLE 12 Age heterogeneity.

	Subjective well-being	Subjective well-being
Variables	65 and above	Under 65
Score of DR	0.952***	0.813***
	(0.180)	(0.198)
Control variables	Controlled	Controlled
R ²	0.136	0.125
Obs	2,086	1,926

Standard errors in parentheses, ****p* < 0.01, ***p* < 0.05, **p* < 0.1.

TABLE 13 Education heterogeneity.

	Subjective well-being	Subjective well-being
Variables	9 and above	Under 9
Score of DR	0.768***	1.052***
	(0.178)	(0.197)
Control variables	Controlled	Controlled
R ²	0.111	0.120
Obs	1,831	2,181

Standard errors in parentheses, ****p* < 0.01, ***p* < 0.05, **p* < 0.1.

structural upgrade in food consumption in China has been largely completed and is now entering a phase of gradual adjustment (Quan and Zhang, 2023). The shift from merely having enough food to focusing on quality underscores the new aspirations of rural residents toward DR. Our conclusions support the Chinese government to promote the construction of a diversified food supply system.

6.2 Suggestions

To promote the DR among rural residents, efforts must be made on both the supply and demand sides. On the supply side, the nutrition orientation of China's food supply system is still limited, it is essential to enhance the food supply system across various food categories in rural areas. Although rural residents can produce some of their food, there are limitations in terms of variety and quantity, especially for items such as fruits and dairy products, which are markedly scarce. In contrast, urban residents can purchase a range of food products through supermarkets, wet markets, and e-commerce platforms. There needs to be an adjustment in the supply side to align with the evolving demand structure of food. In addition, China is committed to increasing residents' consumption of meat, eggs, and milk, using meat, eggs, and milk consumption as an important measure of living standards. But this paper suggests the excessive trend of meat consumption. Among meat, eggs and milk, more attention should be paid to the increase of dairy consumption.

On the demand side, strengthening the dissemination of dietary knowledge in rural areas is crucial. It can help suppress the trend of excessive meat consumption among rural residents and shift their source of happiness from sufficient food intake toward health food intake. This can be effectively facilitated through digital means, complementing online and offline efforts. With the rapid spread of mobile internet in rural areas, the use of platforms such as short

videos can serve as valuable content for sharing dietary knowledge. Given the relatively low digital literacy among rural residents, offline educational activities are necessary supplements. Special attention should be focused on targeting elderly individuals and women. The level of DR among elderly residents in rural areas is relatively low, and their diets are often limited in variety, exacerbating health issues associated with aging. In rural households, daily dietary decisions are generally made by women; therefore, promoting dietary knowledge among women can help rationalize the diet of the entire household.

6.3 Limitations

Finally, this study has some limitations. Due to data constraints, this study's scope of food types is limited, and individual dietary intake can only be approximated through the weekly food consumption reported by households, without more detailed classifications based on energy intake levels. Second, as this research employs cross-sectional data, it cannot reflect the long-term effects of DR on the happiness of rural residents. Consequently, there may exist a phenomenon similar to the Easterlin Paradox, supporting the psychological theories of set point and adaptation. Future research should include longitudinal tracking studies to enrich the variety of food types, consider regional differences, expand on related mechanisms, and further validate and refine the conclusions drawn.

Data availability statement

The data analyzed in this study is subject to the following licenses/restrictions: we have the right to use data but not to share it. Requests to access these datasets should be directed to <https://www.njau.edu.cn/>.

Author contributions

WL: Formal analysis, Methodology, Project administration, Writing – original draft, Writing – review & editing. SZ: Formal analysis, Methodology, Writing – original draft, Writing – review & editing. WF: Formal analysis, Writing – review & editing.

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