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Effectiveness of food literacy on household food waste in the KwaDukuza municipality, South Africa

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Introduction: Every year, over one-third of the consumable food for humans is lost throughout the global food supply chain. In South Africa, almost 10.3 million metric tonnes of food go to waste, representing an average household loss of ZAR21.7 billion. The Primary causes of food waste are consumer behavior and practices in the households during the consumption stage, alongside losses at earlier production stages. Although numerous studies have explored household food waste in South Africa, most of these studies have narrowly focused on how households dispose of food waste. No intervention has been implemented to encourage South African households to reduce food waste. This three-arm randomized control experiment examined the impact of food literacy interventions on environmental, nutritional losses, and household food waste outcome.
Methods: The research included 180 families in a district in South Africa with a middle-to-high living standards measure (LSM). There was a considerable decrease in food waste in households across both the control and intervention groups. Discarded food from households did not vary significantly, as well as nutritional loss or ecological consequences between the intervention groups after 6 weeks of the intervention.
Results: However, from the start of the study to the end, all of the outcomes that were measured went down significantly ($p < 0.001$) for each intervention group indicating that the outcome is unlikely to have occurred by chance alone and that the intervention probably had a real effect.
Discussion: This statistically significant finding indicates that the behavior-targeted interventions and consumer education implemented in this study effectively reduced food waste in households.

KEYWORDS

household food waste, intervention, food loss, environmental impact, nutrient loss

1 Introduction

The global population is undergoing a crisis of food and nutrition security, with over 868 million 2.33 billion people undernourished and roughly two billion suffering from significant health implications as a consequence of micronutrient deficiencies. Experiencing moderate to severe food insecurity meaning that they did not have regular access to adequate food (FAO et al., 2024). Despite the high prevalence of food and nutrition insecurity, Almost it is estimated that a third of all food that is meant for human consumption ends up in food waste as it makes its way from the farm to the table (Gustavsson et al., 2011). This is especially evident in industrialized countries where food waste is estimated to 222 million tons which is almost as high as the total net food production in Sub Saharan Africa (SSA) (230 million tons)

(FAO, 2015). In South Africa, 1.4 million tonnes of food is wasted by households each year (Nahman and de Lange, 2013).

The term "food waste" refers to any potentially usable, nutritious food products that goes to waste, spoils, or is consumed by pests at any point in the food supply chain including retail, food service and household level (Pandey et al., 2021). Only items that are meant for human consumption are suitable for measuring food waste (Chakona and Shackleton, 2017).

Food waste poses significant issues from both social and environmental standpoints. A significant portion of food waste remains consumable, indicating that it could have been utilised to feed people in need, had it been more effectively handled or dispersed (Nahman and de Lange, 2013; Oelofse and Nahman, 2013). Throwing away food waste that cannot be eaten causes a waste of a resource that could have been invested to better use in composting or energy production. Also, organic waste has numerous social and environmental impacts during its decomposition process in landfills or incinerators, eliminate greenhouse gas emissions into the air, especially methane gas (Paraschivu et al., 2022). Food manufacturing that eventually goes to waste consumes resources and emits pollutants throughout the food supply chain. As previously stated, South African households contribute an estimate 1.4 million tonnes of food waste annually and thereby significantly contributing to greenhouse gas emissions.

Numerous studies conducted across various continents among populations from both developed and developing countries reveal that households are the major contributors to food waste at the consumption level (Schmidt, 2016; Wani et al., 2024). The quantity of household waste significantly differs throughout countries, primarily influenced by income, industrialisation, and the developmental status of populations (Chalak et al., 2016; Cronjé et al., 2018). Previous research by Nahman and de Lange (2013) found that South Africa's post-consumer food waste costs over R21.7 billion (about US$2.7 billion) per year, or 0.7% of GDP. This amount is based on estimates made at the household level.

Few studies investigate the causes of food waste, yet comprehending these causes is essential for developing targeted waste reduction strategies that address specific behavioural factors (Painter et al., 2016). It is proposed that most of the food on a household level is wasted due to surplus cooking, preparation, or serving, food not being eaten promptly, or excessive purchasing. According to Williams et al. (2012), more than 40% of food waste in UK households occurs because of preparing, cooking, and serving more food than is consumed. Nearly half of the household food was wasted due to the inability to consume it in time, with contributing behaviours such as poor planning, changes in plans, overpurchasing, reluctance to eat leftovers, and indecision about how to use them (Aschemann-Witzel et al., 2015). Moreover, research indicates that consumers do not randomly waste food; instead, food waste arises from socially constructed practices related to food and consumption (Aschemann-Witzel et al., 2015). The reduction of food waste in households can contribute to the development of a more sustainable food system (Joardder and Masud, 2019; Karwowska et al., 2021; Quested et al., 2020).

A study conducted by Pal et al. (2023) in Kwadukuza Municipality, South Africa, revealed that the predominant reason families discard food is due to spoilage, accounting for 41.1% of food waste at home. The study revealed that the presence of mould on food constituted the second most prevalent cause of household food waste (32.6%), followed by prolonged refrigeration of perishables (27.9%) and poor presentation (22.6%). Other factors that also contributed to food loss in households, including over-preparation (14.2%), inadequate storage (4.2%), and inefficient planning of meal and purchasing (4.2%).

Although the majority of research on food waste centres around baseline measurements of household food waste, there is an increasing number of intervention studies which aim to reduce this waste. Implementing food literacy interventions and encouraging the formation of responsible food citizens is one way to encourage behavioral change about household food waste. In several studies, the concept of food literacy 'Implementing food literacy interventions' has been highlighted and encouraging the formation of responsible food citizens is one way to encourage behavioral change about household food waste (van der Werf et al., 2019; Begley et al., 2018).

A lack of food literacy is a behavioural determinant of household food waste (van der Werf et al., 2019). The authors explain that food literacy refers to knowledge, skills and behaviours relating to food provision including planning, managing, selecting and preparing food. According to Begley et al. (2018), food literacy is crucial because it improves people's knowledge of food practices, which in turn helps them make better decisions when it comes to purchasing, eating, and storing food. This, in turn, reduces economic losses, promotes better personal health, and lessens food waste. According to a study by Wharton et al. (2021) in Arizona, food waste among participating households was shown to be reduced by 27.85% when an educational intervention was provided online using a variety of media that were centralised on a website. The results also revealed that the reduction of food waste was associated with enhancements in behavioural change theoretical components, which will likely create a conducive environment for ongoing food waste reduction (Wharton et al., 2021). Household food waste has decreased significantly due to Love Food Hate Waste, UK's community-oriented training and events (Yamakawa et al., 2017). Romani et al. (2018) conducted a field experiment and demonstrated that educating individuals on meal planning, accompanied by recipes and an Excel tool for menus organisation, significantly decreased food waste, a result partially attributed to enhanced consumer perceptions of their meal planning abilities. Community engagement is likely effective due to direct interpersonal connection and the role of community-based activities in establishing social norms about food waste (Yamakawa et al., 2017). According to the US Environmental Protection Agency (US EPA) (2001), the most successful initiatives also require regular stakeholder interaction. The evidence of these studies suggests that community participation and capacity-building efforts around food literacy has the potential to improve household food waste habits.

Addressing food waste at a household level has many advantages, including financial savings, environmental and social advantages (Marx-Pienaar et al., 2019). The studies on household food waste in South Africa has predominately focused on baseline surveys and lacks an investigation into the relationship between food literacy interventions and reduction of household food waste. This formative study identified household food waste behaviors, serving as a needs assessment for developing the food literacy toolkit. The intervention study evaluated the impact of this toolkit on household food waste.

2 Materials and methods

2.1 Location

Eligible participants for this randomised control trial (RCT) included middle- and high-income families residing in five different parts of the KwaDukuza municipality. KwaDukuza Municipality was chosen due to prior formative research conducted in this community, which provided insight into household food waste behaviors (Pal et al., 2023). The area's demographic diversity and relevance to previous findings made it suitable for this intervention study.

2.2 Recruitment of participants

Households with medium to high levels of socioeconomic status (LSM) from five locations within the KwaDukuza municipality were eligible to participate in this randomised control trial (RCT), which was conducted to further understand household food waste behaviors and practices. Socio-economic status was determined using the Living Standards Measure (LSM) tool (Ncube and Serumaga-Zake, 2015) rather than direct income measures. This classification reflects a household's access to goods and services, offering a robust measure of living standards in South Africa. In this study, households belonging to the LSM group 5–10, Households were classified as middle- and high-income, were recruited.

An advert was published in the local community newspaper. Using street maps and a systematic sampling approach, every third household was approached to participate in the formative study. For the intervention study, participants from the formative study were then randomized using a random number generator (Figure 1).

2.3 Study design

This study meets the criteria for a randomized controlled trial (RCT) as households were randomly allocated into three groups using a random number generator. Each household received an assigned number (1, 2, or 3) which corresponded to Group One (intervention with guided sessions), Group Two (intervention with self-directed learning- households using the toolkit independently without structured support) or Control (no intervention). This ensured randomization without selection bias. Comparisons were made between groups to assess the intervention's effectiveness.

At baseline, every household was given three bins and bags with different colours on them. One was green for dry goods and fresh vegetables, one was red for meat, chicken, and fish, and one was clear or black for cooked meals and leftovers. All participants were asked to

FIGURE 1
Geographical view of KwaZulu-Natal displaying its districts and municipalities, including the iLembe municipality of KwaDukuza.

do was gather any cooked food that was left over, put it in the freezer bags given, and label the bags with the primary ingredients.

From October 27, 2022, to December 6, 2022, a baseline food audit was performed at each household ($n = 180$). In this experiment, participants were asked to take any cooked food that was left over and store it in the freezer or refrigerator. They were also given freezer bags and asked to mark the key ingredients on the food samples. Refuse removal days were used to weigh the refuse. Once a week, trained fieldworkers would collect bags from participating families, weigh them on a calibrated hanging scale (in kg), and then separate the contents into three groups: fresh produce, meat, and cooked food/leftovers. In the second week, the process was repeated.

Nutrient loss reflects both the nutritional and economic value of wasted food. By quantifying macronutrient loss, the compounded impact of food waste will be illustrated, not only in volume but in its contribution to nutrition insecurity.

An analysis was conducted on the nutrient losses in kilograms of food waste from the weighed food waste audit. Nutrient loss was calculated using the South African Medical Research Council's FoodFinder 3. To measure the nutrient losses of food wasted at baseline and endline, participants were given labels to record the components they made use of and the number of servings discarded in the bag when cooked food waste was presented. Food waste collected from households was categorized, weighed, and linked to standard nutrient composition data. For composite foods (mixed foods), participants recorded ingredients and serving sizes, enabling nutrient calculations based on known recipes.

For this study, the My Emission Footprint tool was used, which evaluates the total amount of carbon dioxide (CO_2) produced per kilogram of certain food categories, including composite meals (My Emissions, 2022), at both the baseline and endline, to determine the environmental implications. My emission calculator was selected because it can calculate the carbon footprint of the recipes and individual items, covering emissions from farm to store. For each recipe, a report of the total emissions, carbon intensity (kgCO2e / kg of food), and A-E carbon rating, alongside a detailed summary for each product is provided.

Food cost estimations were based on South African retail prices for each food category, obtained from the data of Consumer Price Index (2011). The value of wasted food was derived by multiplying the weight of each food type by its corresponding price per kilogram.

The food literacy toolkit was distributed to households in Group One ($n = 60$). It included a black shopping bag made of recycled materials, which could be reused and recycled again. The bag featured the Sustainable Development Goal (SDG) wheel, representing SDG 12, "Responsible Consumption and Production," and a Zero Waste: A magnetic infographic about food waste in the home, plantable and biodegradable coasters with messages about reducing food waste, an acrylic stand that says "eat me first" to encourage people to eat their food first, clips for food storage bags, and a cookbook and food literacy guide called "Completing Zero Waste Cookbook and Guide" (doi: 10.51415/dut.49). The recipes in the cookbook were developed on the findings of phase one of the study, which identified rice and bread as the most wasted food items. The cookbook serves as an educational resource, informing consumers on food utilisation, offering alternative methods for repurposing leftovers, providing storage tips for proper food preservation, and assisting households in minimising food waste. Also, using the recipes in the cookbook as a basis, Group One participated in a cook-along and received instruction on how to reduce food waste. These classes are available at http://www.youtube.com/@COMPLEATINGZEROFOODWASTE, which are uploaded on YouTube. Lesson one explored the process of making leftover rice into a savoury smoked haddock kedgeree. In lesson two, leftover chicken was transformed into a warm, aromatic noodle dish including chicken, lemongrass, and coriander—ideal for cold winter days. Lesson three presented an innovative approach to overripe bananas by creating banana oat pancakes, and lesson four illustrated the transformation of leftover rice and vegetables into delicious egg fried rice (Figures 2, 3).

Group One ($n = 60$) received both the toolkit and guided educational sessions (including cook-alongs), whereas Group Two ($n = 60$) received only the toolkit and engaged independently, while Control households ($n = 60$) received no intervention. All households received a second round of food waste auditing following the six-week intervention. There were 180 households at baseline, but 5 of them were lost to follow-up. Two were from Group One, two were from Group Two, and one was from the Control group.

2.4 Ethical approval

This study was fully approved by the Institutional Research Ethics Committee (IREC) with the number of ethical clearance IREC 226/22.

3 Results

3.1 Total food waste before and after the intervention, waste separated by food type, and effects on the environment for different intervention groups

3.1.1 Entire group

The average weekly food waste decreased from 1.53 kg (1531.29 g) at baseline to 0.31 kg (307.47 g) by the end of the intervention, according to the food waste audit. After the intervention, there was a substantial decrease in food waste from households; the average amount of household waste (per capita) dropped to 307.47 g.

In terms of food categories, the average fresh produce waste prior to the intervention was 917.73 g, which was considerably more than the 173.43 g recorded after the intervention. Likewise, meat production waste decreased from 109.56 g prior to the intervention to 43.26 g following the intervention. There was a significant drop in cooked food waste as well, going from 387.07 g pre-intervention to 76.39 g post-intervention.

The average carbon emissions from waste decreased from 7664.13 gCO_2e pre-intervention to 6407.67 gCO_2e post-intervention, indicating a notable improvement in lowering the environmental footprint.

3.1.2 Group One

Wilcoxon Signed-Ranks test results showed that Group One had significantly higher total waste before the intervention (1,495.03 g per household) compared to waste after the intervention (314.09 g per household). Likewise, fresh food waste decreased from 946.29 g prior to intervention to 157.24 g subsequent to intervention.

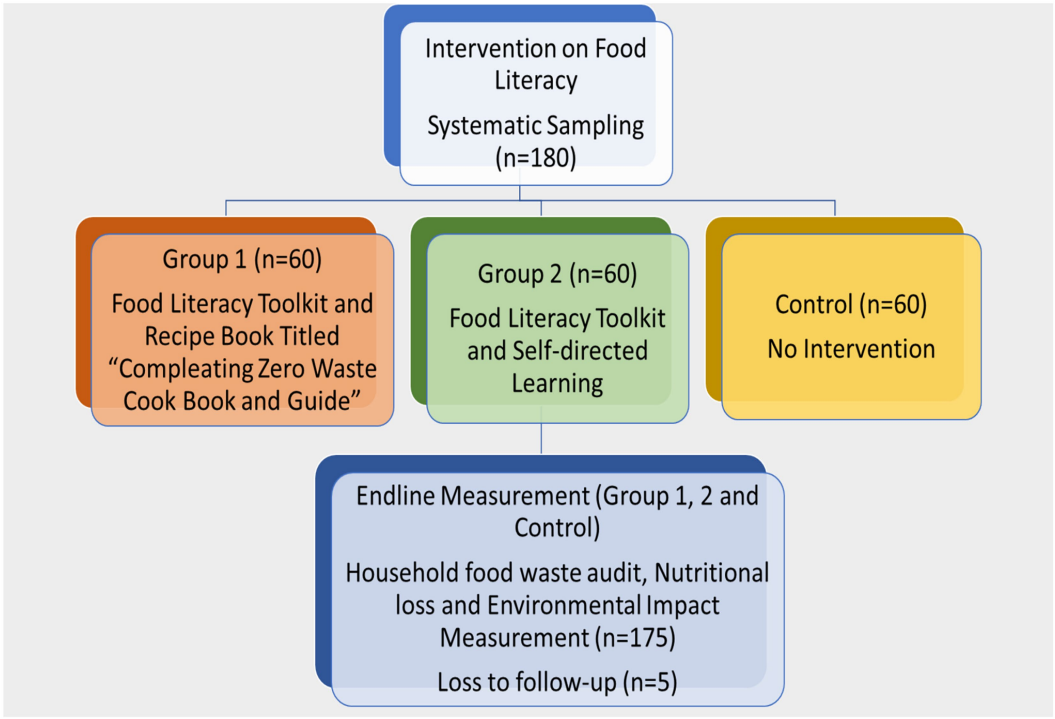

FIGURE 2
Diagramatic reprentation of study design.

Despite a lower reduction in meat production waste, with pre-intervention waste at 82.90 g and post-intervention waste at 63.90 g, the overall trend indicated a decline. The reduction in cooked food waste was significant, decreasing from 403.51 g prior to the intervention to 55.69 g post-intervention.

The average cost of per household food waste decreased significantly, from R182.03 prior to the intervention to R45.30 following the intervention. Furthermore, the intervention significantly reduced the mitigation of environmental damage associated with food waste, as evidenced by the average household emissions from 9179.37 gCO_2e pre-intervention to 5727.76 gCO_2e post-intervention.

3.1.3 Group Two

According to the results of the Wilcoxon Signed-Ranks test, Group Two had significantly higher total food waste (1661.28 g per household) before the intervention and significantly lower post-intervention (316.00 g per household). Similarly, fresh food waste decreased significantly from 1110.16 g prior to intervention to 180.00 g following intervention.

The waste generated from meat production also decreased, with pre-intervention levels averaging 162.93 g compared to 37.08 g post-intervention; however, this reduction was less significant. The quantity of cooked food waste significantly diminished, decreasing from 422.05 g prior to the intervention to 103.82 g subsequent to the intervention.

The environmental effect saw a slight increase, with pre-intervention average emissions of 6521.23 gCO_2e per household rising to 7486.85 gCO_2e post-intervention, indicating a marginal rise in carbon emissions. While overall food waste decreased, certain high-emission food categories (e.g., meat) had variable reductions across groups. In Group Two, despite a reduction in total waste, a proportional increase in discarded meat and high-impact foods led to higher CO_2 equivalents post-intervention.

3.1.4 Control group

According to the results of the Wilcoxon Signed-Ranks test, the control group's total waste before the intervention (1424.7 g per household) was significantly higher than the waste after the intervention (290.27 g per household). Likewise, the waste of fresh food reduced from 694.02 g prior to the intervention to 182.98 g following the intervention.

Meat production waste decreased, with pre-intervention levels averaging 81.52 g and post-intervention levels averaging 28.77 g. The cooked food waste exhibited a similar pattern, decreasing from 335.33 g prior to the intervention to 68.60 g afterwards.

Pre-intervention waste generated an average of 7336.10 gCO_2e per household, which decreased to 5979.07 gCO_2e post-intervention, indicating a beneficial reduction in carbon emissions (Table 1).

Overall, and across intervention groups, this randomised controlled trial found that household food waste decreased significantly (n = 180).

3.2 The amount of nutrients lost through food waste in each intervention group before and after the intervention

3.2.1 Group One

According to the results of the Wilcoxon Signed-Ranks test, Group One's energy loss was significantly higher before the

FIGURE 3
Food literacy toolkit provided to Group One and Group Two.

intervention (6736.34 kJ for each household) than after the intervention (1236.16 kJ). Total protein loss declined from 56.13 g prior to the intervention to 12.17 g following the intervention.

Total lipid loss went from 50.35 g prior to the intervention to 15.94 g following the intervention. Carbohydrate reduction had a similar trend, with pre-intervention levels at 251.99 g and post-intervention levels at 43.84 g. Furthermore, the total dietary fibre loss showed a substantial decline, reducing from 31.53 g prior to the intervention to 3.16 g thereafter.

3.2.2 Group Two

According to the results of the Wilcoxon signed-ranks test, Group Two had significantly more energy loss (6256.51 kJ per household) prior to the intervention (1213.06 kJ) than after it. Total protein loss decreased from 57.09 g prior to the intervention to 13.40 g subsequent to the intervention. The overall loss of lipids also decreased, going from 34.15 g before the intervention to 13.82 g after. The same pattern was seen in the amount of carbohydrates lost, which went from 255.92 g pre-intervention to 49.25 g post-intervention. Furthermore, there was a remarkable decrease in the overall loss of dietary fibre, which dropped from 30.02 g prior to the intervention to 4.18 g subsequently.

3.2.3 Control group

A statistically significant difference was seen in the amounts of energy loss in the control group before and after the intervention, as demonstrated by the Wilcoxon Signed-Ranks test. The control group's energy loss levels were 5297.04 kJ and 1149.28 kJ, respectively. Similarly, after the intervention, the total protein loss dropped from 52.85 g to 10.52 g. Reductions in total lipid loss were also observed; it decreased from 43.13 g pre-intervention to 12.19 g post-intervention. The amount of carbohydrates lost decreased in a similar manner, going from 221.79 g pre-intervention to 50.71 g post-intervention. Furthermore, the total dietary fibre loss decreased from 26.20 g prior to the intervention to 4.73 g subsequent to the intervention (Table 2).

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TABLE 1 Total food waste before and after the intervention, waste separated by food type, and effects on the environment for different intervention groups.

Groups	Item	Mean (SD)		n	*p*-value
		B\L	E/L		
Entire group ($n = 180$)	Total waste (g)	1531.29 (1793.15)	307.47 (308.99)	175	<0.001
	Fresh produce (g)	917.73 (1019.60)	173.43 (152.01)	175	<0.001
	Meat produce (g)	109.56 (392.59)	43.26 (78.00)	175	0.006
	Cooked food (g)	387.07 (778.60)	76.39 (142.29)	175	<0.001
	Environmental impact (gCO_2e)	7664.13 (12274.81)	6407.67 (11590.04)	175	0.016
Group 1 ($n = 60$)	Total waste (g)	1495.03 (1478.77)	315.09 (375.22)	60	<0.001
	Fresh produce (g)	946.29 (984.36)	157.24 (117.56)	60	<0.001
	Meat produce (g)	82.90 (116.42)	63.90 (108.68)	60	0.244
	Cooked food (g)	403.51 (972.54)	55.69 (87.05)	60	0.001
	Environmental impact (gCO_2e)	9179.37 (16923.82)	5727.76 (10223.72)	60	0.057
Group 2 ($n = 60$)	Total waste (g)	1661.28 (1420.80)	316.00 (293.89)	60	<0.001
	Fresh produce (g)	1110.16 (1135.60)	180.00 (151.27)	60	<0.001
	Meat produce (g)	162.93 (647.26)	37.08 (59.54)	60	0.164
	Cooked food (g)	422.05 (642.50)	103.82 (210.69)	60	0.001
	Environmental impact (gCO_2e)	6521.23 (7237.77)	7486.85 (12819.33)	60	0.289
Control group ($n = 60$)	Total waste (g)	1434.78 (2350.38)	290.27 (245.98)	60	<0.001
	Fresh produce (g)	694.02 (894.41)	182.98 (182.22)	60	<0.001
	Meat produce (g)	81.52 (154.21)	28.77 (49.527)	60	0.019
	Cooked food (g)	335.33 (696.65)	68.60 (84.32)	60	0.032
	Environmental impact (gCO_2e)	7336.10 (10887.12)	5979.07 (11653.93)	60	0.253

*$p < 0.001$.

3.3 Intervention effect between groups

Economic loss, nutritional loss, environmental impact, and household food waste were not significantly different between intervention arms after the 6-week timeframe. All assessed outcomes, however, decreased significantly between baseline and endline for all intervention groups. The primary explanation for this finding could be that households likely felt observed during the food waste audit, both at the beginning and at the end. This finding suggests that raising awareness about how much food ends up in people's homes can be a powerful way to get them to be more conscientious about reducing their own food waste.

3.4 Intervention effect

According to various studies, the quantity of per capita food waste in developed nations (95–115 kg per year in North America and Europe) is significantly larger than in developing nations (6–11 kg per year in Sub-Saharan Africa and South/Southeast Asia) (Gustavsson et al., 2011). The present study contributed to measuring nutrient loss because food waste is not just a volume or economic concern but also a major nutritional one. The energy, proteins, fats, carbohydrates, and micronutrients that may have contributed to the nutrition security of households or communities are lost when food is wasted. By directly connecting wasted food to nutritional deficiencies, quantifying nutrient losses offers a more comprehensive view of the impact of waste (Khalid et al., 2019; Von Massow et al., 2019). Our results reveal that the amount of energy lost in a household each week went down from 6135.90 to 1235.29 kJ after the intervention. Such quantification highlights the dual burden of food waste: it exacerbates food insecurity while compounding the environmental and economic impacts of resource use (de Lange and Nahman, 2015).

3.4.1 Impact on food security

There has been a shift in focus toward the environmental, social, and economic costs of food waste. Edible or preventable food waste accounts for as much as 81% of this, according to research. This includes food that could have been eaten if distributed, handled, or cooked differently. According to de Lange and Nahman (2015), only 19% of food waste is actually unavoidable. This includes inedible substances like peelings and bones. The study found that when comparing Group One before and after the intervention, the average weekly energy loss per home was 6135.90 and 1235.29 kJ, respectively. In 2019, Khalid et al. conducted a study in Pakistan, but the amount after the intervention was higher. In that study, the average energy loss from food waste was 54.42 kcal (227.69 kJ) per capita per day, which amounts to about 1593.83 kJ per week. This study relied on secondary data and determined food waste using a recall method along the whole supply chain. As a point of contrast, Von Massow et al. (2019) found that Canadian households wasted an average of 3,366 kcal per week (14083.34 kJ). Retail and consumer food waste in the US amounts to 789 kcal per capita per day, according to Buzby and Hyman (2012). On the other hand, our research found that weekly energy losses from food waste were 6135.90 kJ before the intervention and 1235.29 kJ after it. This study's findings, along with global viewpoints, show that food waste energy losses vary from country to country. As a result, there needs to be an awareness campaign and intervention tailored to each region to successfully deal with and reduce these concerns. The implementation of contextualized interventions, informed by formative research on household food waste disposal practices and behaviors in the same neighborhood (Pal et al., 2023), led to a decrease in energy loss to 1235.29 kJ.

TABLE 2 The amount of nutrients lost through food waste in each intervention group before and after the intervention.

Intervention arm	Item	Mean (SD)		n	p-value
		PRE	POST		
Entire group (n = 180)	Energy (kJ)	6135.90 (6877.82)	1235.29 (2111.80)	180	0.000
	Total protein (g)	55.60 (56.17)	12.07 (20.19)	180	0.000
	Total lipids (g)	42.39 (64.15)	14.01 (18.69)	180	0.000
	Carbohydrate total (g)	245.17 (278.86)	47.90 (81.74)	180	0.000
	Total dietary fibre (g)	29.51 (27.89)	4.01 (8.36)	180	0.000
Group 1 (n = 60)	Energy (kJ)	6736.34 (7950.41)	1236.16 (2219.23)	60	0.000
	Total protein (g)	56.13 (59.04)	12.17 (18.03)	60	0.000
	Total lipids (g)	50.35 (88.49)	15.94 (24.12)	60	0.000
	Carbohydrate total (g)	251.99 (273.90)	43.84 (90.29)	60	0.000
	Total dietary fibre (g)	31.53 (30.51)	3.16 (4.51)	60	0.000
Group 2 (n = 60)	Energy (kJ)	6256.51 (6448.48)	1313.06 (2139.95)	60	0.000
	Total protein (g)	57.09 (52.60)	13.40 (24.11)	60	0.000
	Total lipids (g)	34.15 (35.95)	13.82 (15.84)	60	0.000
	Carbohydrate total (g)	255.92 (307.04)	49.25 (73.41)	60	0.000
	Total dietary fibre (g)	30.02 (27.07)	4.18 (7.24)	60	0.000
Control group (n = 60)	Energy (kJ)	5297.04 (6037.56)	1149.28 (1998.42)	60	0.000
	Total protein (g)	52.85 (58.17)	10.52 (17.78)	60	0.000
	Total lipids (g)	43.13 (55.64)	12.19 (14.76)	60	0.000
	Carbohydrate total (g)	221.79 (248.74)	50.71 (82.29)	60	0.000
	Total dietary fibre (g)	26.20 (25.65)	4.73 (11.95)	60	0.000

$p < 0.001$.

3.4.2 Environmental impact

According to the results, each household's average carbon footprint before the intervention was 7664.13 g (7.66 kg) CO_2e per week, or 398.53 kg CO_2e per year. From 333.20 kg CO_2e per annum before the intervention to 6407.67 g (6.41 kg) CO_2e per week for each family, the average carbon footprint decreased. There was an average carbon footprint of 9179.37 g (9.18 kg) CO_2e at baseline and 5727.76 g (5.73 kg) CO_2e at endline per week/household for intervention 1, which translates to 447.36 kg CO_2e at baseline and 297.96 kg CO_2e at endline per annum. Regarding intervention 2, the average carbon footprint per household was 6521.23 g (6.52 kg) CO_2e before the intervention and 7486.85 g (7.49 kg) CO_2e after the intervention. This amounts to 339.04 kg CO_2e at the beginning and 389.43 kg CO_2e at the end of the year. The average carbon footprint per household for the control group at baseline was 7336.1 g (7.34 kg) CO_2, and at endline it was 5979.07 g (5.98 kg) CO_2. This roughly translates to 381.68 kg CO_2 at baseline and 310.96 kg CO_2 per annum. Depletion of natural resources and emission of hazardous emissions that accelerate climate change are two of the many negative environmental impacts of food production and supply (Abiad and Meho, 2018). According to Boulet et al. (2021), household food waste has significant detrimental effects on the ecosystem, causing harm to both human and environmental well-being in various ways. According to the researchers, it speeds up environmental degradation, affects sustainability, and increases concerns about global warming. Food waste increases the need for arable land, further straining the world's depleting forests and deteriorating environment. A US study (Weber and Matthews, 2009) found that yearly emissions associated with food waste in households averaged 3,934 kgCO_2e, which is far lower than this figure. Furthermore, Gooch et al. (2022) found that 282 kg of food waste resulted in 742 kgCO_2e, according to their study. Also, every Chinese home releases an average of 148 kg of CO_2 per year, according to research by Song et al. (2015). Households in this study decreased food waste, which directly affected emissions, despite the intervention treatment.

4 Discussion

There is a significant decreases in waste observed among all groups, even the control group, showing that the act of measuring the baseline itself prompted people to modify their behavior. The potential for a Hawthorne effect, in which participants changed their food management techniques just because they knew they were being monitored, should be taken into account when interpreting these results (McCambridge et al., 2014). The noticeable decrease in waste in the group that did not receive any intervention suggests that the baseline evaluation and the expectation of being monitored influenced their behavior. This effect of "measurement reactivity" might reduce internal validity; however, it also presents an opportunity: simple, low-cost methods to raise awareness, such as self-monitoring tools or food waste diaries, could lead to behavior change even without significant interventions (Quested et al., 2020; Wharton et al., 2021). Therefore, future research is recommended to look into whether

longer-term, more intensive, or multi-component interventions can reduce food waste after the first behavioral improvements that come from observing. People can learn to control their food waste and be more aware of how they handle, store, and consume food when they are observed or intentionally keep records of it (Schmidt, 2016). Adding self-monitoring tools like waste diaries or audits to possible future food literacy initiatives could make people more interested and help them change their behavior (Wharton et al., 2021). The results also support the use of participatory strategies that provide families more control over their waste reduction goals. The study's results also show that behavior-focused interventions, whether they be guided sessions or self-directed toolkits, may decrease food waste in households by an average of more than 1.2 kg per week per household. This decrease is in line with similar trials in high-income countries, which shows that food literacy techniques work in middle- and high-income South African households as well (Wharton et al., 2021; Romani et al., 2018). These modifications led to measurable decreases in loss of nutrients and carbon emissions which indicates that food literacy programs can have several advantages for the economy, the environment, and the wellness of individuals at the same time.

5 Strengths and limitations

In this study there are a number of significant strengths and limitations that should be acknowledged.

The findings may not be a true reflection of the South African population as a whole, but they are representative of middle- and high-LSM households in the KwaDukuza Municipality (KDM). Data on food waste from restaurants, hotels, and animal feed were excluded. The recruitment of households via the systematic method encountered difficulties, as many people declined owing to the commitment required by the duration of the study. Though our household-level intervention reduced waste in a significant way, it did not get more people in the community involved, which has been demonstrated to help behavior change last longer. In contrast, campaigns like Love Food Hate Waste in the United Kingdom were able to increase and maintain their influence through community engagement (Yamakawa et al., 2017). Cultural factors, such as centuries-old customs regarding cooking and attitudes around leftover food, as well as economic variables, such as income-driven overpurchasing, may influence the extent to which an intervention works (Aschemann-Witzel et al., 2015). Community-based programs set shared standards and hold people accountable, which often leads to more changes in behavior than programs that only work with one home (US Environmental Protection Agency (US EPA), 2001). So, adding food literacy programs to community platforms like schools, or city-wide initiatives could help them reach more people and be more effective over time. Several other intervention initiatives have shown statistically significant decreases in food waste at the household level. These initiatives provide concrete instances that can help future efforts to teach people about food. Project Wasteless, which has been going on in Hungary since 2016, has reduced overall household food waste by 12% and avoidable waste by 27%. Educational outreach has reached more than 35,000 students and nearly 1,900 educators. The Stop Wasting Food campaign in Denmark fostered collaboration among consumers, retailers, and policymakers. Between 2010 and 2015, national food waste went down by 25%. The decrease was due to public pledges, price changes at supermarkets, school programs, and policy partnerships (Halloran et al., 2014). In Sweden, grassroots groups like Foodsharing Stockholm have moved significant quantities of surplus food through volunteer networks, showing that a peer-to-peer redistribution model may operate and stop plenty of food waste from households and stores (Berns et al., 2023). Another limitation of our study is that there may have been underreporting, which affects the accuracy of the data, even though participants were instructed to maintain regular protocols for household food waste. Homeless people, canines, vervet monkeys, and garbage collectors from the city all had access to the bins before the research group did, which sometimes made it difficult to collect waste food from households. Ultimately, the study's seasonal limitation may have affected the diversity of food waste documented in the dataset.

On the other hand, our study focused more on households with middle-to high LSM. Our study utilized a three-arm randomized controlled design, emphasizing food literacy toolkits and self-directed learning over national campaigns or redistribution models. Our measured decreases in household waste (from 1.53 kg to 0.31 kg per week) are similar in amount to those seen in other countries when scaled, but our intervention was the only one that looked at both nutritional and environmental losses along with waste quantity. This approach gave us a more complete picture of the impact. These features establish our study as a significant model for combining the reduction of food waste with the assurance of nutrition security and the assessment of environmental effects. It provides a complete framework that goes beyond what many current worldwide initiatives offer. Secondly, participants recognised that their food waste would be subject to audit, potentially motivating both the intervention and control group to modify their behaviours, either consciously or subconsciously, throughout the course of the study. One of the strongest points of the study is that it used weighted food waste audits that were conducted at the household level for 2 weeks at the beginning and end of the research. This allowed for the collection of precise data on food waste in households, the identification of specific items thrown out, and the correlation of waste to specific families. Household food waste is connected with nutrient loss and environmental consequences, which may be calculated using the audit data that was evaluated. Research by Pal et al. (2023) examined food waste disposal behaviors in KwaDukuza Municipality, South Africa, and its formative findings informed the development and content of a food literacy toolkit. Qualified fieldworkers conducted the food waste audits, ensuring the reliability of the data.

These results will be extremely important for South Africa, where there is a considerable amount of food waste and people are still food insecure. Our study shows that low-cost, household-focused food literacy programs may significantly reduce waste while also improving health and environmental outcomes. The combination makes it an effective model for local and national efforts. Including these kinds of initiatives in educational institutions, community platforms, and municipality programs could make them more effective and connect more people, just like other international campaigns like Love Food Hate Waste did in the UK (Yamakawa et al., 2017). In South Africa, this has the potential to enhance current efforts to ensure food security and contribute to the objectives of a food system that is more resilient and equitable as well as sustainable.

6 Conclusion

This investigation establishes a strong connection between food waste in households, nutrition, and the ecological and financial impact. There are a number of social, environmental, and economic issues caused by the widespread and significant impact of household food waste disposal on the food chain. The findings of the study confirm that food literacy interventions can significantly reduce household food waste. However, the long-term feasibility of these new behaviours remains uncertain. It is possible that without continuous support and monitoring, participants may have reverted to previous habits or shown less effort over time if the intervention extended or closed. It is suggested that future research should include a longer follow-up period to assess the durability of the behavioral change. Given the stark difference between the amounts wasted in high-income households and the widespread hunger and food insecurity in many communities, the social implications of food waste are immense. It is critical to address and reduce home food waste in order to build a food system that can be more resilient and less harmful to the environment. This calls for concerted efforts to educate consumers, establish efficient waste management systems, and enforce regulations that promote responsible consumption.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found in the article/supplementary material.

Ethics statement

This study was fully approved by the Institutional Research Ethics Committee (IREC) with thenumber of ethical clearance IREC 226/22.

Author contributions

NM: Data curation, Investigation, Writing – original draft, Writing – review & editing. AN: Conceptualization, Funding acquisition, Methodology, Resources, Supervision, Validation, Writing – original draft, Writing – review & editing. HG: Supervision, Writing – original draft. IP: Formal analysis, Investigation, Supervision, Writing – original draft, Writing – review & editing.

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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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