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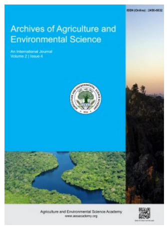

ORIGINAL RESEARCH ARTICLE

CrossMark

Economic and environmental assessment of food wastage in Gauradaha municipality, Nepal

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ABSTRACT

Household food waste presents a growing challenge to both economic security and environmental sustainability, particularly in rural agricultural regions. This study evaluated the economic and environmental implications of food waste at household level in Gauradaha Municipality, Jhapa district, Nepal. Based on a structured survey of 51 households using a self-administered questionnaire, the research examined factors influencing food waste generation and its associated costs. Data were analyzed using MS Excel and RStudio. One-way ANOVA, Pearson correlation, and proportions were analyzed in R to examine the effects of gender, education, and family size on waste generation, whereas MS Excel was used to assess the quantity of economic and environmental impacts. Economic valuation revealed that household food waste results in a loss of approximately NRS 35.21 (0.24 USD) per household per week, equivalent to less than 1% of annual household income. Environmentally, each household's food wastage contributes an estimated 0.92 kg of CO_2 emissions and consumes nearly 477.70 liters of water. Among food categories, cereals were identified as having the highest economic and environmental impact. Furthermore, overcooking emerged as the leading cause of waste, with refrigeration being the most commonly used storage method, yet no measures of value addition, processing and sustainable storage methods were practiced effectively, which reflects changing lifestyles, urbanization, and time constraints. These findings underscore the urgent need for targeted strategies that address food waste behaviour, promote efficient storage practices, and reduce the broader sustainability burdens at the household level in rural Nepal.

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INTRODUCTION

Food waste includes any food intended for human consumption that is discarded, lost, or no longer usable. This can involve inedible parts like peels or entire foods that become unfit for consumption due to spoilage or neglect. Food waste not only represents a loss of the resources invested in growing, transporting, and storing food but also creates significant environmental impacts, such as increased greenhouse gas emissions and wasted energy (Cederberg & Sonesson, 2011). Food loss on the other side refers to the decrease in edible food mass throughout the part of the supply chain that specifically leads to edible food for human consumption. Food losses take place at production, post-harvest, and processing stages in the food supply chain. Food losses occurring at the end of the food chain (retail and final consumption) are often called "food waste", which relates to retailers' and consumers' behaviour (Parfitt *et al.*, 2010). Food loss and waste (FLW) is a growing global issue that undermines food security, environmental sustainability, and economic efficiency. Approximately one-third of food produced for human consumption, equivalent to about 1.3 billion tons, is lost or wasted every year (Beretta *et al.*, 2013). This alarming figure contributes to the widespread issue of hunger and threatens the sustainability of food systems. Food loss and food waste are closely associated with food security, as reducing them will help feed more people and alleviate the pressure on natural resources.

The economic cost of this wastage is estimated at 1 trillion US dollars annually, and the environmental impact includes the emission of 3.3 gigatons of CO_2 equivalents, a significant water footprint, and the occupation of 1.4 billion hectares of land (Khanal & Maharjan, 2024). Moreover, food loss and waste also contribute to other greenhouse gas (GHG) emissions, particularly nitrous oxide (N_2O) and methane (CH_4), which exacerbate global warming (Muth *et al.*, 2019). Food production already consumes up to 70% of the global freshwater resources and is responsible for up to 10-30% of the total global emission of greenhouse gases. The demand for these resources and the associated environmental impacts is expected to go up by the year 2050 due to the anticipated population growth and increase in food production by 25-75% (Garnett, 2011).

In the context of Nepal, food loss and waste have been a serious challenge to food security and livelihoods. Out of 88 countries, Nepal ranked 57th in the Global Hunger Index (GHI) with a GHI value of 19.8, depicting an alarming situation of hunger in different regions of the country. Since the III Five Year plan (1975-80), the government of Nepal has given high priority to agriculture, focusing major approaches on the promotion of integrated farming systems to address food and nutrition security. However, the food security situation is deteriorating (Bista *et al.*, 2013). Climate change has a significant effect on agriculture and food security, creating new risks and challenges and exacerbating existing vulnerabilities from the local to the global level. Climate change and food security are both serious challenges in the context of Nepal, which needs to be addressed together (Chemjong & KC, 2020). At the household level, this food waste has a direct implication. Nepali households invest almost 52% of their total annual income on the consumption of food (NSO, 2024). This figure portrays that the amount of food wastage has a huge share of the economy of households and has a significant impact on poverty and food security, which ultimately decreases the living standard of Nepalese people. The trend of effects of wasted food on the country's food security, environment, and economy is devastating.

Despite the vast amount of food wasted, particularly at the household level, there is insufficient data to quantify the loss at the national and local levels in Nepal. This lack of data limits the ability of policymakers and local bodies to implement effective interventions to reduce food waste. Most of the existing studies in Nepal have only focused on food production and supply-side losses, while consumer-level food waste, particularly its economic valuation and environmental footprint, has been very poorly documented. Hence, this study addresses this critical gap by providing a well-detailed assessment of household-level food wastage in Gauradaha Municipality, Jhapa District, Nepal. The novelty of this research lies in its integrated evaluation of both economic and environmental impacts of food waste at the household level, including monetary loss, carbon emissions, and water footprint across different food categories, using primary household survey data. This study aims to assess the economic and environmental impacts of household food wastage in Gauradaha Municipality and to identify key socio-demographic and behavioural factors influencing food waste generation. The findings from the study are expected to support the local policymakers, development agencies, and households in designing targeted strategies to reduce food waste, enhance food security, and promote sustainable consumption practices in Gauradaha Municipality, Nepal.

MATERIALS AND METHODS

Study area

Gauradaha municipality of Jhapa district was selected as the study area with 14,846 total households (NSO, 2021). Despite its high agricultural output, the area faces challenges like inadequate storage facilities, poor waste management systems, and limited awareness about food loss, making it an important site for studying the economic and environmental impacts of food wastage. Gauradaha is a semi-urban area. So, a study conducted in the area can be a representation of the level of food wastage in urbanizing areas of Nepal, and reflect challenges faced by households transitioning from rural to urban settings.

Data collection approach

The primary data were collected through face-to-face interviews with household members in the study area during February 2025. The demographic and socio-economic information and their perception and knowledge on food wastage were recorded. A week-long data about the quantity of food wastage was conducted through a self-administered questionnaire given to each sample household, which contained questions on types of food, amount, raw or cooked, reason for wastage and loss, and route (waste bin, composting, fed to animals, kitchen sink). The variation on the unit of food obtained, such as pieces, slices, spoon, bowl, cup, etc., was standardized to kg before proceeding to the analysis. A total of 99 households were selected by using a simple random sampling technique. The sample size was calculated by using Yamene's formula adopted from (Chaokromthong & Sintao, 2021). The margin of error was set to 10%. And with a population of 14846, the sample size was calculated to be 99. However, data were ultimately collected from only 51 households due to non-response, as our survey was a week-long and repeated unavailability of respondents even after multiple revisits. Many households were unable or unwilling to complete the survey questionnaire during follow-up visits because of competing work and household responsibilities, seasonal agricultural activities, or lack of interest. As a result, despite efforts to revisit and encourage participation, only 51 complete and consistent responses could be included in the final analysis.

Data analysis

The response was entered into MS Excel, and necessary curation was carried out. The processed data were then exported to R-Studio Version 4.2.2, where statistical analysis was performed. One-way ANOVA, Pearson correlation, and proportions were analyzed in R to examine the effects of gender, education, and family size on waste generation, whereas MS Excel was used to assess the quantity of economic and environmental impacts.

Economic valuation of wasted food at the household level

The cooked food was converted to a raw food equivalent and then to agricultural (Adelodun *et al.*, 2021). For economic valuation, the retail price of the food in the Gauradaha market was collected for the week, and the price was also given by the respondents.

$$EHFW= FW_i \times C_{1i} \times C_{2i} \times P_i$$

Where, EHFW = Economic value of the weekly wasted food in the household (Rs.); FW_i = wasted amount of food item *i* in the household (kg); $C_{1i=}$ conversion factor for food item (in kg) to account for changes in water content and cooking loss, converting wasted food into its raw form; $C_{2i=}$conversion factor for raw food equivalent item (in kg) to agricultural products, adjusting for losses across the value chain; P_i =retail price of the food item i in Gauradaha market; All the values of C_1, C_2, and P are given in Appendices 2 and 3.

Environmental valuation of wasted food at the household level

The environmental impact of food waste was assessed in terms of two environmental indicators following (Adelodun *et al.*, 2021; Ana Giménez *et al.*, 2022): Carbon footprint (kg CO_2 eq. / kg produce) and water footprint (liter/kg). For the carbon footprint, the greenhouse gas potential (GWP) of wasted food items was calculated using the carbon dioxide equivalent (kg CO_2 eq. / kg) of greenhouse gas emissions derived from life cycle assessment studies, which cover the food items' journey from production to retail and distribution system boundaries. Similarly, water footprint was calculated using water equivalent (liter water eq. / kg food production) (Poore & Nemecek, 2018).

$$CFP= FW_i \times C_{1i} \times C_{2i} \times GWP_i$$
$$WFP= FW_i \times C_{1i} \times C_{2i} \times WFP_i$$

Where GWP = greenhouse potential (kg CO_2 eq./kg produced) of the i^{th} food item and WFP =water footprint to produce the i^{th} food item. All the values of GWP and WFP are given in Appendix 1.

Combined environmental and economic impact analysis

To investigate the combined impact of hot-spots of food waste items due to the potential variations in environmental and economic impact perspectives among the food items, this study used a newly developed normalized index called the "EN-EC Footprint Index," which combined environmental and economic impacts of household food waste.

$$\text{EN−EC Footprint Index} = \sum ((WFP + GWP) + \text{Log } W)$$

Were, EN-EC Footprint index =combined environmental and economic loss associated with a particular food waste type; WFP =water footprint (m^3); GWP=greenhouse gas emission (kg CO_2 eq.); W= converted agricultural products (kg)

The above index is normalized in a range of 0 to 1, where 0 represents minimal, while 1 represents the highest level of environmental and economic impacts associated with selected food waste products.

RESULTS AND DISCUSSIONS

Socio-economic characteristics

Table 1 shows that 51% of respondents depend on agriculture as their primary livelihood, highlighting Gauradaha municipality's strong reliance on farming. Income data indicate that most households earn NPR 200,000-500,000 annually from on-farm activities, suggesting the dominance of smallholder agricultural systems with moderate earning capacity. This pattern is consistent with the overall agricultural profile of Nepal, where, especially in semi-urban and rural areas, small-scale farming remains a key source of livelihood (Bista *et al.*, 2013). This income level can be a significant factor in household food management practices, including purchasing frequency, storage capacity, and tolerance for food loss (Afriyie *et al.*, 2022). The majority of people prefer to buy fresh groceries from the local market, purchasing twice a week. For fresh groceries, 90% of respondents prefer buying from the local market, with the majority (55%) purchasing twice a week. A small fraction grows their own food (6%) or buys from supermarkets (4%) (Table 2). The preference for local markets and frequent purchase of fresh produce reflects the limited presence of supermarkets in Gauradaha and mirrors findings from South Asian contexts, where local markets dominate food systems (Chalak *et al.*, 2016). Although frequent buying of fresh food intuitively reduces the long storage times and related spoilage. The lack of proper cold-chain infrastructure and adequate household storage leads to quality loss between purchase and consumption. Similar observations were made by Beretta *et al.* (2013) and Oria & Schneeman (2020), where frequent small purchases coexisted with high consumer waste due to handling and preparation habits. Habit of purchasing may affect the amount of wasted food; buying in bulk of perishable commodities increases the risk of damage (Bouras & Jammali, 2022). Regarding packaged groceries, a significant 69% stated they do not buy them, while those who do prefer buying monthly (72%) mainly from local markets (8%) or convenience stores (21%). This finding indicates the strong preference for fresh over processed food in Nepal, specifically Gauradaha. This can be related to both cultural dietary preferences and economic choices. In the Nepalese context, where packaged food is more expensive and less culturally integrated than fresh home-prepared food (Baral, 2023), households are prioritizing the fresh ones despite their higher risk of quick spoilage on storage.

Table 1. Household income source and annual income of Gauradaha Municipality, Nepal.

Household Income Source	Percentage (%) N=51	Annual Income Range of Household	Percentage (%) N=51
Agriculture	51	<50000	2.02
Business	10	50000-100000	9.09
Job	25	100000-200000	19.19
Remittance	14	200000-500000	40.04
		>500000	29.29

Table 2. Habit of purchasing groceries for the household in Gauradaha Municipality, Nepal.

Fresh Groceries	%	Frequency of buying fresh groceries	%	Packaged groceries	%	Frequency of buying storable groceries	%
Local market	90(46)	Daily	4(2)	No, I don't buy	69(35)	Weekly	0(0)
Grow your own food	6(3)	Twice a week	55(28)	Convenience store	21(11)	Bi-weekly	10 (5)
Super market	4(2)	Weekly	27(14)	Local market	8(4)	Monthly	72 (37)
Convenience store	0(0)	Bi-weekly	14 (7)	supermarket	4(2)	Once in three months	18 (9)

Note: Figure in parentheses indicates the actual number of respondents.

Table 3. Relation of family size with household food loss in Gauradaha Municipality, Nepal.

Variable	df	Pearson(r)	T-value	P-value
Family size	49	-0.14	-1.04	0.30

Table 4. Causes of household food wastage in Gauradaha Municipality, Nepal.

Cause	Garret value	Rank
Cooked too much food	2330	I
Food looked/smelled/tasted bad	2155	II
Pests, including rodents impacting food quality	2035	III
Lack of meal planning	2030	IV
Disease	1995	V
Food expired or is out of date	1975	VI
Purchased too much food	1975	VII
Purchased damaged vegetables	1900	VIII
Impulse buying due to promotions	1875	IX
Damage during transport or handling	1775	X
No cold storage unit	1700	XI

Comparison of family size and food loss quantity

A Pearson correlation analysis was conducted to assess the relationship between family size (number of household members) and food loss quantity (kg). The analysis revealed a very weak negative correlation between family size and food loss quantity (r=-0.1479, p=0.3001) (Table 3). The weak negative correlation between family size and food waste implies that larger households in Gauradaha tend to waste less food per capita. This supports earlier findings by Hoang & Meyers (2015), who observed that bigger families often manage food more efficiently through shared meals and better consumption of leftovers. The study conducted by MITRE/Gallup also found that smaller households waste more food per capita than larger households (Collins & Hoover, 2024). However, since p>0.05, i.e. (0.3001), the correlation is not statistically significant and may have occurred due to chance in this study.

Causes of food wastage

Table 4 shows the rankings of the causes of food wastage according to their Garrett score, a method for combining individual rankings into an overall rank. The top three causes identified are cooked food too much, food that looked/smelled/tasted bad, and pests, including rodents, impacting food quality. This domination of overcooking as the primary factor in food waste can be connected to the hospitality cultural norms, inaccuracy in portion planning, and the readiness to cook more than enough food to guarantee that it is enough to feed all the family members. Newer literature, such as Rooijen *et al.* (2024), indicated that household food waste is caused by poor portion control and insufficient meal planning in developing and middle-income countries as the primary drivers. Even though the surplus food is sometimes provided to livestock, the food waste is viewed as human consumption-based (Kummu *et al.*, 2012). The second one was food spoilage, which can be attributed to incorrect storage methods, deferred consumption and insufficient knowledge of food shelf life. This is also intensified by the warm and humid weather conditions in eastern Terai. Pest infestation emerged as the third most important cause, which showed that there was a lack of household storage facilities, especially for cereals and vegetables. Factors that are ranked low, like absence of meal planning, expiry of food, overbuying, impulse buying, and damage in the transportation, imply that the market and infrastructure-related factors have a role in food wastage, but the behavioural and household management practice is more dominant. These findings are comparable to those of Lipinski *et al.* (2016), who reported similar causes in rural food systems with poor storage infrastructure.

Table 5. Average per household per week economic and environmental impact of food wastage.

	Economic (NRs)	Environmental		EC/EN	Percentage of weekly income
		CO_2 (kg)	Water (liters)		
Household food wastage	35.21 (0.24 USD)	0.92	477.70	0.01	0.71

Table 6. Categorical household food wastage impact per household in Gauradaha Municipality, Nepal.

Food Category	Economic (NRs/week)	Environmental	
		Water (lit/week)	CO_2 (kg/week)
Cereals	13.78 (0.094 USD)	242.49	0.60
Vegetables	11.89 (0.081 USD)	111.98	0.25
Fruits	7.16 (0.049 USD)	31.85	0.03
Legumes	2.36 (0.016 USD)	91.40	0.02

Economic and environmental impact of food wastage

Table 5 quantifies the economic and environmental impact of food wastage per household, including the cost, CO_2 emissions (kg), and water usage (liters). It also provides a ratio of economic cost to environmental impact (EC/EN) and shows that food wastage accounts for a small percentage of weekly household income (0.71%). The result indicates that average household food wastage carries a notable economic and environmental burden, costing about NPR 35.21762 (0.24 USD) per week and representing less than 1% (0.71%) of weekly household income. Environmentally, each household from their wasted food accounts for approximately 0.92003 kg of CO_2 emissions and consumes nearly 477.705 liters of water weekly that ultimately go unused. The combined EC/EN footprint index of 0.015 means there is not much significant impact of food wastage on the economy and environment till now in Gauradaha municipality. This observed relatively lower economic and environmental impacts of household food wastage in Gauradaha are primarily due to modest income levels, limited consumption of high-value foods, and reliance on locally produced staples. However, continued urbanization and changing patterns of consumption might increase this burden over time in Gauradaha. This finding is in alignment with Baykoca & Yılmaz (2025), who mentioned that country differs in food losses based on consumer perceptions, market standards, and social norms.

Categorical household food wastage impact per household

Table 6 shows the comparisons of the economic and environmental impacts of four food categories: cereals, vegetables, fruits, and legumes. The result indicates that cereals exhibit the highest weekly economic loss (0.094 USD) as well as the greatest environmental burden, with CO_2 emissions of 0.60 kg and water usage of approximately 242.49 liters weekly. In contrast, legumes showed the lowest weekly economic loss, 0.016 USD, 0.02 kg of CO_2 and 91.40 liters of water. Similar patterns were reported by Food and Agriculture Organization (FAO 2013), where cereals were the most resource-intensive wasted category, both economically and environmentally. In Gauradaha, cereals and vegetables dominated waste impacts, aligning with global findings that staple crops and perishable produce contribute disproportionately to resource inefficiency (Yahia & Mourad, 2020). Although household food waste accounts for a small fraction of income (0.71%), its environmental impact is significant in terms of water and carbon footprints. Food wastage emerges as a "silent contributor" to climate change. Globally, food loss and waste account for **8**-10% of total anthropogenic GHG emissions (FAO, 2019). Even a 1% increase in global CO_2 emissions can significantly amplify global warming, exacerbating extreme weather events, melting ice caps, and rising sea levels as reported by Intergovernmental Panel on Climate Change (IPCC, 2023). The emissions linked to household food wastage are rarely considered in national or organizational reporting, suggesting that this sector may be accelerating environmental damage without notice. Similarly, the water embedded in wasted food represents another critical concern. With nearly 478 liters lost per household per week, the cumulative loss at the community level is considerable. Producing just 1 kg of rice requires approximately 2,000 liters of water (Hoekstra & Chapagain, 2006). When such food is wasted, the embedded water is also lost, intensifying pressure on already stressed water systems. Given the projected changes in rainfall patterns and rising water scarcity due to climate change, such wastage urges to highlight the points that this hidden water loss should be used more effectively to grow other crops, support households, or ease water stress in vulnerable regions. Thus, water lost through food wastage should be highlighted in conservation campaigns and incorporated into water-smart solutions (UNESCO, 2020).

Practices adopted to minimize food wastage

After analyzing the responses of different food storage types used by the households, as shown in Figure 1, we found out that refrigeration was used by the majority (87%) of the respondents, also 74% used pickling, 56% used drying, 4% used freezing and 1% used canning. Techniques like freezing and canning are rare, indicating that value addition or form conversion methods are not commonly adopted. This widespread use of refrigeration for food storage is often attributed to its perceived convenience, ease of use, and effectiveness in slowing food spoilage. This suggests that household food storage is largely focused on refrigeration, potentially limiting opportunities for long-term preservation and reducing the risk of food spoilage through traditional or alternative methods. James *et al.* (2016) also suggested that refrigerators being most common food storage device, with very few households at present not possessing one. The dominance of refrigeration raises the question of whether it is perceived as the only modern or effective solution. Traditional preservation methods like drying, pickling, and fermenting are deeply rooted in Nepalese culture (Baral, 2024) and have historically provided reliable ways to extend the shelf life of food without significant energy costs. The decline in these methods may reflect changing lifestyles, urbanization, time constraints, or the influence of modern consumer habits that favour convenience over traditional practices. Findings thus have suggested that traditional food preservation knowledge is gradually being abandoned, even though these methods are energy-efficient and effective in reducing food losses. This situation highlights the need for awareness programs and capacity-building initiatives to revive and adapt traditional food preservation techniques. Encouraging households to combine refrigeration with traditional methods could enhance food security, reduce wastage, and ensure more sustainable use of resources. Understanding why these age-old customs are underutilized today is essential for designing effective interventions that balance modern technology with culturally ingrained practices. This is in accordance with Ariyamuthu *et al.* (2022), who suggested the need for strategic promotion of traditional food preservation methods to the mass public to sustain their relevancy, while simultaneously updating the methods with scientific improvements where possible.

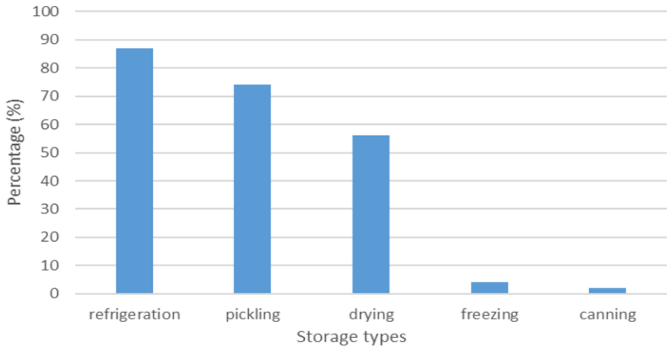

Figure 1. *Storage practices adopted by households in Gauradaha Municipality, Nepal.*

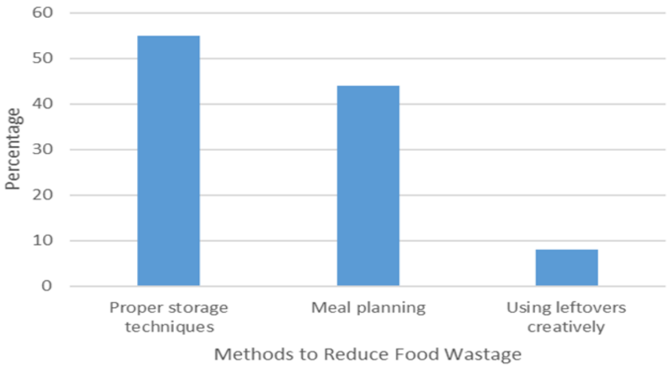

Figure 2. *Methods to reduce food waste at the household level.*

Methods to reduce food waste at the household level

Figure 2 illustrates that 55% of the people used proper storage techniques, followed by meal planning (44%). Abid *et al.* (2025) also found that proper food storage practices significantly influence food wastage behaviour among households. The prominence of storage techniques over other strategies may reflect familiarity and convenience with storage. Proper storage is often viewed as a straightforward, low-effort method to prevent spoilage, whereas meal planning and creative reuse require more time, planning, and sometimes culinary skills. In rural or semi-urban settings, such as Gauradaha, limited resources, lack of structured guidance, and busy daily routines may discourage households from investing effort in planning meals or creatively repurposing leftovers. The implications of these results are significant for both policy and household-level interventions. The moderate adoption of proper storage techniques indicates that households have some awareness of basic food preservation, which could be leveraged through educational campaigns. Promoting meal planning and creative use of leftovers could further reduce waste, improve household food security, and decrease the environmental burden associated with wasted food.

Conclusion

In conclusion, food loss and waste in Gauradaha Municipality is a significant issue with notable economic and environmental impacts, particularly from cereals and vegetables. Households primarily lose food due to overcooking, spoilage, pests, and inadequate storage, while purchasing habits and limited cold-chain facilities exacerbate the problem. Although the economic burden per household is relatively low, the environmental footprint measured in CO_2 emissions and water use is substantial. Awareness of food waste is high, but willingness to adopt solutions is limited. Addressing behavioural practices, improving storage infrastructure, and promoting efficient food management can reduce waste, enhance food security, and minimize environmental impacts in the municipality. Improving household-level storage practices for cereals and vegetables to minimize spoilage and encouraging wider use of effective traditional preservation methods like drying and pickling is recommended in extending food shelf life to reduce food wastage.

DECLARATIONS

Authors contribution

Conceptualization: S.B, N.G., N.P. and B.T.; Methodology: S.B, N.G., N.P. and B.T.; Software, Validation: S.B., N.G. and N.P.; Formal Analysis: S.B, N.G., N.P. and B.T.; Investigation: S.D., N.G, and N.P.; Resources: S.B., N.G. and N.P.; Data curation: N.G and N.P.; Writing -original draft preparation: S.B and N.G.; Writing-review and editing: S.B., N.G. and N.P.; Supervision: B.T. All authors have read and agreed to the published version of the manuscript.

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