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Effect of Food Waste on Household Dietary Diversity in Nigeria

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Abstract

Food waste significantly undermines food security in Nigeria by reducing both the quantity and quality of available food, thereby threatening dietary diversity. This study investigates the magnitude and determinants of household food waste and its effect on dietary diversity among farming households in Nigeria. Using a cross-sectional comparative design, the study analyses secondary microdata from the Nigeria General Household Survey–Panel (Wave 5) with a sample of 1,953 households. Household food waste was estimated using a commodity flow balance approach, while dietary diversity was measured using the Household Dietary Diversity Score (HDDS). Results reveal that spices and condiments, cereals, oils and fats, and vegetables are the primary contributors to household food waste. Significant spatial disparities were observed, with rural households reporting a substantially higher mean food waste than urban households. While urban households showed a fairly higher average HDDS than rural households, 52.43% of households maintain medium HDDS. Findings further indicate that food waste exerts a strong and statistically significant negative effect on dietary diversity. The study concludes that food waste is a major structural barrier to achieving nutritional adequacy in Nigeria. Thus, investments in rural post-harvest infrastructure and cold-chain logistics for highly perishable food are encouraged to mitigate high waste levels observed in farming.

Keywords: Food Waste, Dietary Diversity, Rural-Urban Gap, Household Nutrition, Nigeria

1. Introduction

Food waste has become a critical problem that affects global food security, nutrition, and sustainable development. This issue is especially prevalent in low- and middle-income countries (LMICs), where limited resources and widespread food insecurity exist [1, 2]. In particular, household food waste imposes considerable economic, nutritional, and ecological challenges, as its repercussions accumulate along the entire food production and consumption continuum. The Food and Agriculture Organisation

[3] reported that around 3 billion individuals worldwide cannot afford a nutritious diet, while concurrently, consumers waste approximately 931 million tonnes of food each year—about 17% of the food available to them [4].

Nigeria ranks among the highest for per capita food waste, with an estimated 187 kg of food discarded per person annually, totaling nearly 38 million tonnes across the country [4]. Considerable food waste reduces both the quantity and quality of food accessible for household consumption in Nigeria, thereby threatening dietary diversity—an essential measure of nutritional adequacy [5]. Given that the Household Dietary Diversity Score (HDDS) quantifies the variety of food groups consumed over a specified timeframe, any reduction in edible food directly jeopardises households' capacity to maintain diverse diets [6]. The waste of nutrient-rich foods, including fruits, vegetables, and animal products, leads to households losing essential micronutrients, which in turn results in lower HDDS scores and compromised nutritional adequacy. Over time, recurrent instances of food waste can intensify food insecurity and perpetuate the cycle of undernutrition [7]. Households in both rural and urban areas encounter distinct challenges in accessing, managing, and utilizing food resources [8, 9]. It has been observed that rural and urban farm households experience food waste through different but interconnected pathways, with significant implications for food security and dietary diversity [10]. Rural households remain highly vulnerable to post-harvest losses due to infrastructural deficits in storage and preservation [11], while urban farm households, though also engaged in production, operate in more market-oriented systems where consumer behaviours, such as over-purchasing, aesthetic rejection, and weak meal planning, drive waste [12]. Despite these distinctions, both groups function simultaneously as food producers and consumers, and the compounded inefficiencies across production, storage, and consumption undermine household dietary diversity.

Empirically, evidence on household food waste in sub-Saharan Africa has confirmed that food waste is a very important problem, but still differs in various food groups. Using household survey data from southwest Nigeria, [13] used descriptive statistics and budget share analysis to evaluate the scale of food waste at the household level and found that cereals, vegetables, oils, and condiments constitute a large part of total waste. Their findings refute the conventional notion that food waste mainly occurs in highly perishable goods and highlight the fact that poor storage, as well as food handling practices, can also lead to food being wasted even if the food stuff is semi-durable.

[9] studied cross-sectional household expenditure data and conducted regression analysis to identify spices, condiments, and cereals as some of the most wasted food items in Nigerian households, give further evidence to this point. The authors linked this trend to exposure to moisture, heat, and improper storage facilities, especially in humid agroecological areas. These empirical findings are consistent with data from Ghana and Kenya, where cereals and cooking ingredients constitute the largest part of household-level food loss [14, 15]. However, these studies only provide insight into the composition of food waste; they predominantly regard food waste as an outcome

variable, without making an empirical link to subsequent nutritional impacts such as dietary diversity or diet quality.

Conversely, dietary diversity has been extensively examined as a measure of household nutritional adequacy through the analysis of empirical survey data. Utilising LSMS–GHS data, [8] calculated dietary diversity scores and discovered that factors such as education, income, access to extension services, and urban living significantly enhance dietary diversity, whereas larger household sizes and poverty levels diminish it. Comparable findings were presented by [16], who employed multivariate regression models and validated the pronounced rural–urban disparities in dietary diversity results. Throughout Africa, studies by [17, 18], who utilised both panel and cross-sectional datasets, revealed that dietary diversity is influenced more by income and food expenditure pathways than by production diversity alone. These investigations empirically confirm that access, utilisation, and food management play a crucial role in determining dietary outcomes. Nevertheless, a significant limitation of this body of literature is the underlying assumption that all food obtained by households is completely consumed. By failing to consider food lost due to spoilage or waste, these studies may inadvertently overstate the actual availability of food and the quality of diets.

Nevertheless, none of these studies empirically model the causal or structural relationship between food waste and dietary diversity. Consequently, the nutritional consequences of food waste largely remain inferred rather than directly quantified. The empirical literature identifies three significant gaps. Firstly, food waste and dietary diversity are predominantly examined as distinct phenomena, despite their strong conceptual interconnections. Secondly, studies from Nigeria seldom quantify the nutritional costs of household food waste using nationally representative data. Thirdly, existing research tends to concentrate on the determinants of food waste without assessing its welfare implications. This study filled these gaps by empirically estimating the impact of household food waste on dietary diversity using LSMS–GHS Panel data and an econometric framework that accounts for household heterogeneity. By establishing a statistically significant negative correlation between food waste and dietary diversity, the study offers direct empirical evidence that food waste represents a concealed barrier to nutritional adequacy in Nigeria.

2. Materials and Methods

2.1. Study Design and Data Source

This study adopts a cross-sectional, comparative design using secondary microdata from the Nigeria General Household Survey-Panel (GHS-Panel, Wave 5), conducted by the National Bureau of Statistics (NBS) in collaboration with the World Bank's LSMS-ISA program. The GHS-Panel is nationally representative and provides rich information on agricultural production, household food acquisition, consumption, sales, storage, income, and welfare. Its breadth makes it uniquely suited for analysing household-level interactions between food production, consumption, and dietary

diversity. However, an important limitation of the GHS-Panel data is that it does not provide disaggregated production across food groups, particularly for livestock. The livestock module is generalised and fails to specify the type, quantity, or value of animals produced or owned by farm households, making it difficult to assess waste in meat, milk, or other livestock products.

Given these constraints, this study focused primarily on crops and their derived products for estimating food waste. This emphasis is also justified by the fact that most food waste in Nigeria occurs at the crop level, driven by post-harvest losses, storage inefficiencies, limited processing, and poor utilisation practices. Several studies highlight that in developing countries, including Nigeria, food waste is most acute in the upstream stages of the food supply chain, particularly in crops, while losses in livestock products are relatively smaller and less systematically measured [11, 19]. For dietary diversity estimation, however, all food groups were incorporated, including livestock and animal-sourced foods, using a binary (dummy) coding system in which consumption of a given food group is coded as “1” and non-consumption as “0.” This approach ensures a comprehensive assessment of dietary diversity while aligning the food waste analysis with the most empirically robust and contextually relevant data sources available.

3.2. Data Collection

The GHS is a cross-sectional survey that covers approximately 22,200 households nationwide. A random sample of 5,000 households from the GHS was used to establish the GHS-Panel, with supplementary data gathered on agricultural practices, consumption patterns, and household income. The GHS-Panel incorporates essential components from the Harmonised National Living Standards Survey (HNLSS) and the National Agricultural Sample Survey (NASS).

The fifth wave of the GHS-Panel (2023–2024) was conducted in two phases: the post-planting phase (July–September 2023) and the post-harvest phase (January–March 2024). During each visit of the GHS-Panel, Wave 5, three instruments were employed: the household questionnaire, the agriculture questionnaire, and the community questionnaire. This extensive dataset facilitates a thorough examination of food production, consumption, and welfare at the household level, making it an essential resource for understanding the connection between food waste and dietary diversity in Nigeria.

To maintain consistency in seasonality, estimates of food waste from post-planting and post-harvest visits were compared, and a thorough verification was conducted using both the weight and value of food waste. Additionally, sensitivity analyses were conducted by recalculating the Household Dietary Diversity Score (HDDS) and omitting extreme outliers in food group consumption to guarantee the robustness of the findings.

The sample size for this study is 1953. The primary reduction stems from merging variables of interest. The initial wave 5 dataset contained 4,976 households. For this study, we first identified 2,500 households with food consumption and food waste. From this group, we excluded 547 observations due to missing data and negative estimated food waste values. The final sample for regression models comprises 1,953 households, with 324 and 1,629 from the urban and rural sectors, respectively.

3.3. Measurement of Key Variables

3.3.1. Estimation of Household Food Waste

Food waste ($FW_{i,h}$) was measured using two principal indicators: total food produced, estimated by total crop production (PC), quantity purchased (QP), and quantity received as a gift (G_n)- and total consumption estimated by total quantity consumed (QC), quantity sold (QS), quantity given as a gift (G_{out}), and quantity used for non-food purposes (QO). Food waste (FW) was computed using a commodity flow balance approach based on the following specifications:

$$FW_{i,h} = (PC_{i,h} + QP_{i,h} + G_{n,i,h}) - (QC_{i,h} + QS_{i,h} + G_{out,i,h} + QO_{i,h}) \text{-----1}$$

Where: the superscripts i and h represent the commodity/item index and household index, respectively

3.3.2. Estimation of Household Dietary Diversity Score (HDDS)

HDDS was calculated following FAO guidelines using a 7-day recall period. Food items were aggregated into 12 standard food groups (cereals, roots/tubers, vegetables, fruits, meat, eggs, fish, legumes/nuts, milk/milk products, oils/fats, sweets, spices/condiments/beverages). Each food group was assigned a score of 1 (if consumed over the previous 7 days) or 0 (otherwise). The household score ranges from 0 to 12 and is equal to the total number of food groups consumed by the household: Thus:

$HDDS_h = \sum (X_{i,h})$ where $X_{i,h} = 1$ if household h consumed food group i, else 0.

$$HDDS_h = \sum_{i=1}^{12} X_{i,h}$$

$$HDDS = \sum (A + B + C + D + E + F + G + H + I + J + K + L) \text{.....2}$$

3.4. Data Analysis

The data were analysed using descriptive and inferential statistics to address the research objectives, as outlined below:

Descriptive statistics, including means, proportions, and standard deviations, were used to quantify household food waste across various food groups. To identify

geographical disparities, the Student's t-test was employed to compare the mean food waste generated by rural versus urban households:

$$= \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}} \dots \dots \dots 3$$

Where:

$\bar{X}_1$ and $\bar{X}_2$ are the mean waste levels for rural and urban households, respectively

S_1^2 and S_2^2 represents the variances of the two groups,

n_1 and n_2 represents the sample sizes for rural and urban sectors, respectively.

Households were categorised into low (0-4), medium (5-8), and high (>8) diversity groups using tertiles. An Independent Samples t-test was used to determine if significant differences exist between rural and urban HDDS, while a Chi-square (χ^2) test was applied to compare the proportions of households within different dietary diversity categories:

$$\chi^2 = \sum \frac{(O_i - E_i)^2}{E_i} \dots \dots \dots 4$$

Where:

O_i = Observed frequency

E_i = Expected frequency under the null hypothesis

A multiple regression model was used to determine the drivers of food waste. Parameters were estimated using the ordinary least squares model with the functional form expressed as:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + + \mu_i \dots \dots \dots 5$$

Where:

Y is the dependent variable, which denotes the total value of food waste. The independent variables are age (years) of household head (X_1), sex of household head which is a dummy variable with the value 1 for male, otherwise 0 (X_2), Household size (X_3), food groups consumed (X_4), Extension access, (X_5), Primary education (X_6), Secondary education (X_7), and Tertiary education (X_8). $\beta_0 \dots \beta_8$ are the coefficients of the explanatory variables, and μ_i is the stochastic error term.

3.5 Endogeneity and Instrumental Variables

To evaluate the effects of food waste on HDDS between rural and urban households, an Instrumental Variable (IV) Regression Model was used, employing Two-Stage Least Squares (2SLS) estimation to address potential endogeneity, and estimate the causal effect of household food waste on dietary diversity. The IV regression model is expressed as: $HDDS_h = \beta_0 + \beta_1 FW_h + \beta_2 X_h + \varepsilon_h$ 6

Where:

$HDDS_h$ is the household dietary diversity score for household h (the dependent variable). FW_h is household food waste (in Naira), X_h is a vector of control variables (e.g., household size, income, education, gender, and market access), β_0 is the intercept term, β_1 is the marginal effect of food waste on dietary diversity, β_2 is the coefficient of the control variables, and ε_h is the error term.

Household food waste (FW_h) may be endogenous due to unobserved factors like household preferences, measurement errors, or reverse causality. An Instrumental Variable (Z_h) (harvest value) was introduced. To ensure instrumental variable suitability, the variable satisfied two basic assumptions: relevance and restriction exclusion (Wooldridge 2010) as expressed below:

- (i) Relevance – $Cov(Z_h, FW_h) \neq 0$: the instrument (harvestvalue) correlated with the endogenous explanatory variable (FW). Which means that harvestvalue have statistically significant relationship with FW
- (ii) Exogeneity – $Cov(Z_h, \varepsilon_h) = 0$. : The instrument (harvestvalue) is uncorrelated with the error term (ε) of the structural equation. This means the instrument affects the dependent variable (HHDD) **only** through its effect on FW, not through any other direct or indirect paths.

The first stage used the instrument Z_h (harvest value) to predict food waste, producing fitted values.

$$\text{Stage 1: } FW_h = \alpha_0 + \alpha_1 Z_h + \alpha_2 X_h + u_h \dots\dots\dots 7$$

Then, in the second stage, the predicted FW_h was substituted by the actual food waste ($\hat{Y}FW_h$) to estimate the causal effect of food waste on dietary diversity as expressed below:

$$\text{Stage 2: } HDDS_h = \beta_0 + \beta_1 \hat{Y}FW_h + \beta_2 X_h + \varepsilon_h \dots\dots\dots 8$$

$$\text{Additionally, we employed an interaction model defined as } HDDS_h = \beta_0 + \beta_1 FW_h + \beta_2 Urban_h + \beta_3 (FW_h + Urban_h) + \beta_4 X_h + \varepsilon_h \dots\dots\dots 9$$

Where, β_3 tests whether the effect of food waste on HDDS differs between urban ($Urban_h=1$) and rural ($Urban_h=0$) households.

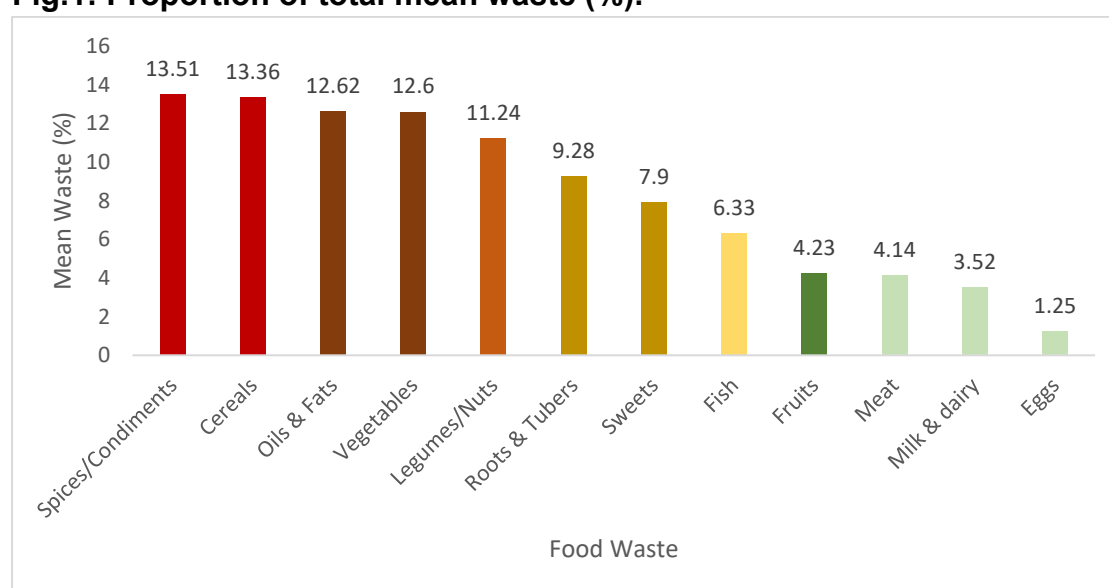
To ensure the reliability of our results, we conducted a series of diagnostic tests to confirm the instrument-variable approach in the household food waste sector. First, the multivariate F-test of the Sanderson-Windmeijer tool with the excluded instruments yielded a statistic of 1283.10 ($p < 0.0001$), well above the stock-jouge critical value of 16.38 for 10 per cent of the maximum IV size, thus refuting the null hypothesis of poor identification and confirming the strong correlation between the instrument and the endogenous variable. This is further supported by Kleibergen-Paap Rk Wald F of 1283.10 ($p < 0.001$).

3.0 Results

This section presents an analysis and discussion of the findings, structured systematically to address each of the specific objectives of the study.

3.1. Proportion Household Food Waste by Food Group

Fig.1: Proportion of total mean waste (%).



Source: Authors' computation using data from the Nigeria GHS-LSMS panel wave 5

The distribution of food waste across various food groups is illustrated in Figure 1, highlighting the distinct waste profiles observed in Nigerian farming households. The results show that spices and condiments (13.51%) and cereals (13.36%) were the largest contributors to household food waste. This was followed by oils and fats (12.62%) and vegetables (12.60%), which recorded similarly high waste shares. A moderate level of waste was observed for legumes (11.24%) and roots and tubers (9.28%). Lower proportions of food waste were recorded for sweets (7.90%), fish (6.33%), fruits (4.23%), and meat (4.14%). The least wasted food groups were milk and dairy products (3.52%) and eggs (1.25%). Overall, the distribution of food waste across food groups indicates considerable variation in household wastage patterns,

with higher waste proportions concentrated among staple and frequently used food items, and lower proportions among animal-source foods.

3.1.1 Mean Food Waste between Rural and Urban Households in Nigeria

The locational differential in food waste among farming households in Nigeria is presented in Table 1.

Table 1. Combined summary statistics and independent samples t-test comparing mean food waste between rural and urban households in Nigeria

Group	Obs (n)	Mean Food Waste (₦)	Std. Dev. (₦)	Mean Difference (Urban – Rural)	t-value	Df	p-value (2-tailed)
Urban households	324	113,019.9	126,445.4				
Rural households	1,629	148,580.1	140,436.7	– 35,560.24	– 4.5362	495.03	0.0000
Combined sample	1,953	142,680.7	138,814.8				

Source: Authors' computation using data from the Nigeria GHS-LSMS panel wave 5

The result shows a statistically significant difference between rural and urban households in household food waste in Nigeria, with rural households having a significantly higher average waste (148,580.1) than urban households (113,019.9). The independent-samples t-test ($t = -4.5362$, $df = 495.03$, $p < 0.001$) confirmed that this difference reflects a true structural and behavioural difference rather than sampling variability. The large standard deviations observed in both rural (140,436.7) and urban (126,445.4) households show a significant variability within the group, which underlines that the behaviour of food wastage cannot be fully explained by location alone.

3.2 Food Group Consumption Patterns by Location

Table 2 presents the distribution of food group consumption among rural and urban households. Consumption of cereals and spices and condiments was nearly same across both locations, with no statistically significant rural–urban differences ($p > 0.05$). Similarly, the consumption of milk and sweets did not differ significantly between rural and urban households.

Table 2: Mean number and type of food groups consumed

Food Group	Rural Consumption (%)	Urban Consumption (%)	χ^2	p-value
Cereals	99.3	99.7	0.74	0.387

Spices & Condiments	99.4	99.7	0.32	0.574
Milk	35.2	39.5	2.13	0.144
Sweets	65.1	61.7	1.37	0.242
Roots & Tubers	78.3	93.5	40.27	<0.001***
Vegetables	96.7	100.0	11.05	0.001**
Oils & Fats	95.5	99.4	11.13	0.001**
Fish	58.6	77.5	40.63	<0.001***
Meat	36.2	53.4	33.49	<0.001***
Eggs	15.3	24.7	16.81	<0.001***
Fruits	41.9	50.9	8.91	0.003**
Legumes & Nuts	89.9	93.8	4.80	0.028*

Source: Authors' computation using data from the Nigeria GHS-LSMS panel wave 5

*p < 0.05; ** p < 0.01; *** p < 0.001

In contrast, statistically significant differences were observed for several food groups. Roots and tubers were consumed by a significantly higher proportion of urban households (93.5%) compared to rural households (78.3%) ($\chi^2 = 40.27$, $p < 0.001$). Urban households also reported significantly higher consumption of vegetables (100.0% vs. 96.7%), oils and fats (99.4% vs. 95.5%), and legumes and nuts (93.8% vs. 89.9%), with p-values below 0.05. Animal-source foods showed pronounced rural–urban differences. Consumption of fish, meat, and eggs was significantly higher among urban households, with differences statistically significant at the 1% level ($p < 0.001$). Fruit consumption was also higher in urban areas (50.9%) than in rural areas (41.9%), with the difference statistically significant ($\chi^2 = 8.91$, $p = 0.003$). Overall, while staple food consumption was similar across locations, notable rural–urban differences exist in the consumption of roots and tubers, vegetables, fats, fruits, legumes, and animal-source foods.

3.3 Dietary Diversity Status of Farming Households

Table 3 summarizes the dietary diversity status of farming households based on the Household Dietary Diversity Score (HDDS).

Table 3: Dietary diversity status of farming households

HDDS Category	Frequency (n)	Percentage (%)	Cumulative (%)
Low (1-4)	93	4.76	4.76
Medium (5-8)	1,024	52.43	57.19
High (>8)	836	42.81	100.00
Total	1,953	100.00	

Source: Authors' computation using data from the Nigeria GHS-LSMS panel wave 5

The majority of households fell within the medium dietary diversity category (5–8 food groups), accounting for 52.43% ($n = 1,024$) of the sample. A substantial proportion of households also achieved high dietary diversity (>8 food groups), representing 42.81% ($n = 836$). In contrast, only a small fraction of households exhibited low dietary diversity (1–4 food groups), comprising 4.76% ($n = 93$) of the total sample.

Cumulatively, households with medium to high dietary diversity accounted for 95.24% of the respondents. Generally, the distribution indicates that most farming households consumed a relatively diverse diet, with more than two-fifths achieving high dietary diversity.

3.3.1 Differences in Mean HDDS between Rural and Urban Households

Table 4 presents the results of the comparison of mean Household Dietary Diversity Scores (HDDS) between rural and urban households in Nigeria.

Table 4: Differences in mean HDDS between rural and urban households in Nigeria

Metric	Rural Group	Urban Group	Difference (Rural – Urban)
Observations (N)	1,629	324	
Mean HDDS	8.116	8.938	–0.822
Standard Deviation	1.994	1.804	
95% Confidence Interval for Difference	(–1.042, –0.603)		
t-Statistic	–7.3599		
Satterthwaite's Degrees of Freedom	493.343		
p-value (Two-tailed)	**0.0000 ***		
Decision on H_0 ($\alpha = 0.05$)	Reject H_0		

Source: Authors' computation using data from the Nigeria GHS-LSMS panel wave 5

The mean HDDS for rural households was 8.116 (SD = 1.994), while urban households recorded a higher mean HDDS of 8.938 (SD = 1.804). The observed mean difference of –0.822 indicates that rural households had, on average, lower dietary diversity than their urban counterparts. The difference in mean HDDS was statistically significant, as shown by the t-statistic of –7.36 with Satterthwaite's degrees of freedom of 493.34 and a two-tailed p-value < 0.001. The 95% confidence interval for the mean difference (–1.042, –0.603) does not include zero, further confirming the statistical significance of the observed difference. Based on these results, the null hypothesis of no difference in mean HDDS between rural and urban households was rejected at the 5% significance level, indicating a significant rural–urban disparity in dietary diversity.

3.4 Determinants of Household Food Waste: Log-Linear Regression Results

Table 5 presents the log-linear regression estimates of factors associated with household food waste for rural, urban, and pooled samples. All three models are statistically significant at the 1% level ($p < 0.01$), suggesting that the selected independent variables have a combined significant impact on household food waste.

Table 5: (Log-linear models; Dependent variable: $\ln(\text{Food Waste})$)

Variable	Rural (β)	Urban (β)	Pooled (β)	Direction & Consistent Effect
Age	-0.0099 (ns)	0.0086 (ns)	-0.0074 (ns)	No linear age effect
Age ²	0.00003 (ns)	-0.00002 (ns)	-0.000006 (ns)	No life-cycle effect
Sex (1 = Male)	0.4425 ***	0.1735 (ns)	0.4184 ***	Gendered effect (context-dependent)
Household size	0.0549 ***	0.0202 (ns)	0.0499 ***	Scale effect dominant in rural & pooled
Groups consumed	-0.1170 ***	-0.0770 *	-0.1175 ***	Strong waste-reducing factor
Extension access	-0.3675 **	0.2956 (ns)	-0.2417 *	Information reduces waste
Primary education	0.2515 ***	0.5789 ***	0.2914 ***	Higher waste at basic education
Secondary education	-0.1288 (ns)	0.3280 (ns)	-0.0652 (ns)	No systematic effect
Tertiary education	-0.0083 (ns)	0.4913 (ns)	0.0831 (ns)	No systematic effect
F-stat	25.42	2.43	26.62	All models jointly significant ($p < 0.01$)

Source: Authors' computation using data from the Nigeria GHS-LSMS panel wave 5

Age ($\beta = -0.0074$; $p = 0.561$) and Age² ($\beta = -0.000006$; $p = 0.959$) were not statistically significant across all models, indicating no linear or life-cycle effect on food waste. Sex of household head had a statistically significant positive effect on food waste in the rural and pooled models ($\beta = 0.4184$; $p < 0.001$). Household size showed a positive and statistically significant association with food waste in the rural and pooled samples, while the effect was not significant for urban households. The number of food groups consumed ($\beta = -0.1175$; $p < 0.001$) was consistently negative and statistically significant across all models, indicating a robust association with lower levels of food waste. Access to extension services is weakly but negatively associated with food waste ($\beta = -0.2417$; $p < 0.10$). Education effects varied across levels. Primary education is associated with a significantly higher rate of food wastage ($\beta = 0.2914$; $p < 0.001$), while secondary ($\beta = -0.0652$; $p < 0.001$) and tertiary education do not have a significant effect ($\beta = 0.0831$; $p < 0.5$).

3.5 Impact of Food Waste on Household Dietary Diversity

The study provides substantial causal evidence that household food waste in Nigeria is structurally driven by production glut, rural post-harvest inefficiencies and household management, rather than by demographic characteristics as such.

Table 6: (Dependent Variable: Dietary Diversity Score, DDS; Instrument: $\ln_harvestvalue$)

Variable	Coefficient (β)	Robust Error	Std. t- statistic	p-value
ln_food_waste (ln_fw)	-0.118	0.015	-7.87	0.000***
Age of household head	0.004	0.002	1.92	0.055*
Years of education	0.021	0.009	2.33	0.020**
ln_income	0.037	0.026	1.42	0.156
Extension access	0.089	0.041	2.17	0.031**
Rural sector	-0.142	0.052	-2.73	0.006***
Constant	3.214	0.382	8.41	0.000***

Source: Authors' computation using data from the Nigeria GHS-LSMS panel wave 5

Table 6 presents the instrumental variable regression estimates of the determinants of household dietary diversity, with dietary diversity score (DDS) as the dependent variable and ln(harvest value) used as the instrument. Log food waste exhibits a negative and highly statistically significant association with dietary diversity ($\beta = -0.118$, $p < 0.001$), indicating that higher levels of food waste are associated with lower dietary diversity. The age of the household head shows a weak positive effect on dietary diversity, significant at the 10% level ($p = 0.055$). Years of education have a positive and statistically significant effect on dietary diversity ($\beta = 0.021$, $p < 0.05$). Household income, although positive, is not statistically significant. Access to extension services is positively and significantly associated with dietary diversity ($\beta = 0.089$, $p < 0.05$). The rural sector dummy is negative and statistically significant ($\beta = -0.142$, $p < 0.01$), indicating lower dietary diversity among rural households relative to urban households. The constant term is positive and statistically significant. The results indicate a strong inverse association between food waste and dietary diversity after controlling for household characteristics.

Discussion

Proportion Household Food Waste by Food Group

This finding both supports and contradicts the prevailing narrative of food wastage. While cereal waste has long been recognised as a major problem due to storage losses and over-preparation, the prominence of spices and condiments in Nigeria presents a relatively unexplored aspect of the household food wastage behaviour and a novel contribution to literature. Evidence from previous studies confirms that cereal waste persists, with cereals accounting for 27.97% of total food waste in Abeokuta and rice alone accounting for 36.45% of household waste in Lagos [20]. The waste rates recorded for oil and fats (12.62%) and vegetables (12.60%) reflect the interaction between perishability and infrastructure constraints common in developing countries. Vegetable spoilage in Nigeria is well documented and is fuelled by limited refrigeration, unreliable power supply and weak cold chain systems [21]. The high moisture content and rapid respiration make vegetables particularly vulnerable to microbial decomposition, particularly where the product has already suffered from improper

handling and high-temperature transport [22]. Although oils and fats are not conventionally considered perishable, waste in this category results from rancidity caused by improper storage and disposal of reused or contaminated cooking oils.

The moderate level of waste observed for legumes and roots and tubers is in line with their relatively long shelf life in the raw form. At the household level, spoilage mainly affects cut or cooked tubers, which rapidly spoil without refrigeration, and legumes, which are exposed to pests and humid storage conditions. On the other hand, animal-based foods - fish, meat, milk and eggs - show the lowest waste rates, reflecting the patterns observed in low and middle-income countries where high-value foods are consumed with great care and attention because of their economic and nutritional value [23]. The negligible waste generated by eggs further emphasises their perceived value and ease of rationing. Generally, these findings both support and challenge the global narrative of food waste. While developed countries report high levels of waste at the consumer stage, dominated by fruit, vegetables and bakery products [14, 12], the situation in Nigeria reveals a significant level of food waste concentrated in cereals, condiments, oils and fats, which account for more than half of the total.

Mean Food Waste between Rural and Urban Households in Nigeria

The higher level of rural waste is consistent with [24], who reported that reliance on traditional storage systems exposes food - especially cereals, pulses, roots and tubers - to moisture, pests and microbial contamination in low- and middle-income countries. Urban households, on the other hand, benefit from cooling, improved storage conditions, and increased consumption of processed and packaged foods, which, in turn, reduce the risk of spoilage and waste. The large standard deviations observed in both rural (140,436.7) and urban (126,445.4) households show a significant variability within the group, which underlines that the behaviour of food wastage cannot be fully explained by location alone. The high variability suggests that food waste is driven more by individual household characteristics and personal behaviours, such as income, habits, and household size, rather than whether a family lives in a rural or urban environment.

Food Group Consumption Patterns by Location

The consumption patterns of food groups differ between rural and urban households, with staple foods such as cereals and spices consumed almost the same way in both contexts. The absence of statistically significant rural-urban differences in cereals, spices, milk and sweets suggests that the basic requirements are largely met at the national level and that these foods are culturally rooted and widely available [25, 26]. Although milk consumption is slightly higher in urban areas, the total intake remains low, reflecting the persisting economic, cultural and dietary constraints that restrict the use of milk in Nigeria [27].

On the other hand, for eight food groups, most of which are nutrient-rich or highly market-dependent, a strong urban consumption advantage is apparent. Urban households report significantly higher intakes of roots and bulbs, vegetables, oils and fats, fish, meat, eggs, fruit, beans and nuts, with the biggest differences in the food from animals (77.5 % versus 58.6 %), meat (53.4 % versus 36.2%) and eggs (24.7 % versus 15.3 %). It is noteworthy that roots and tubers, traditionally part of rural households' diets, are consumed by a much higher proportion of urban households (93.5% versus 78.3 %). These differences reflect the structural advantages of urban households, such as higher incomes, more diversified and reliable food markets, and better storage facilities that make it easier to have consistent access to perishable and nutrient-rich food [28].

Dietary Diversity Status of Farming Households

The low, medium and high categories show a generally positive dietary profile for farming households. The result suggests that the vast majority of households are consuming a diet that goes beyond the staple diet. The very low proportion of low-nutrition diets group is particularly noteworthy, as diets consisting of three or fewer food groups are often associated with severe food insecurity and micronutrient deficiencies [26]. This pattern indicates that most of the sampled households have relatively reliable access to a wide range of food through their own production, market purchases or a combination of both. This finding is in line with evidence that moderate dietary diversity is common in agricultural communities characterised by partial access to the market and modest purchasing power [8]. On the other hand, the high HDDS group, which represents a significant 42.81% of the sample, reflects a high dietary adequacy and is indicative of favourable socio-economic conditions, diversified livelihood strategies and stable income streams, which promote consistent access to a wide range of dietary groups. Similarly, empirical studies across Sub-Saharan Africa have shown that high dietary diversity is closely associated with better nutrition outcomes, higher household income and greater market integration [28]

Differences in Mean HDDS between Rural and Urban Households

A comparison of the mean household dietary diversity score reveals a statistically significant difference between rural and urban areas. The result confirmed that the difference is systematic and not random, which implies persistence of spatial inequalities in access to a variety of foods, even in predominantly agricultural economies. The finding is consistent with [29] who found that Urban households showed higher dietary diversity scores (mean 9.57) compared to rural households (mean 8.76), with diets dominated by cereals and tubers in both settings. This result also confirms the assertions of [10] that growing one's own food is generally not necessary for dietary diversity in Nigeria. In fact, households producing a greater share of their food often had lower dietary diversity scores compared to those who primarily purchased food from markets.

Determinants of Household Food Waste: Log-Linear Regression Results

The study provides strong empirical evidence that household food waste in Nigeria is not driven by age or life-cycle dynamics, but rather by behavioural, structural, and information factors that span different demographic groups. The result reveal that food waste is strongly influenced by household size, dietary diversity, gender roles in food management, the quality of education and access to extension services. In rural areas, the lack of adequate refrigeration and inconsistent electricity supply heightens the chances that any leftover food will spoil before it can be utilised again. [30] indicates that in sizable households, particularly in southern Nigeria, food that remains after meals is often thrown away within a day due to the risk of spoilage. Consequently, larger household sizes exacerbate food waste in contexts where storage and coordination capabilities are limited. The result is consistent with [31], which showed that larger family units were associated with higher levels of coordination and waste.

Dietary diversity (number of groups consumed) has a negative, highly significant relationship with household food waste. This means that dietary diversity significantly reduces food waste. households that consume a more varied diet, including proteins, fruits, and vegetables, attribute greater economic and nutritional significance to food, leading to more rigorous management and preservation practices. Thus, dietary diversity is indicative not only of nutritional quality but also of organisational capability and consumption discipline. This finding is consistent with the evidence from Tanzania and Uganda that a varied diet is associated with more efficient food use and reduced food waste [32, 33].

The analysis also reveals a knowledge gap: primary education is associated with a significantly higher rate of food wastage while secondary and tertiary education do not have a significant effect. This indicates a considerable "discrepancy between awareness and practice," where individuals recognise the adverse effects of food waste but are hindered by structural obstacles and time due to extended working hours, rendering effective food management nearly unrealistic. This implies that formal education alone does not guarantee efficient food management and that functional food literacy - practical knowledge of meal planning, portioning, and storage- remains crucial. Similar patterns were observed in urban South Africa and Egypt, where primary education increased food waste due to limited food-planning skills, despite increased purchasing power [34. 35].

Gender is a significant determinant of food waste ($\beta = 0.4184$; $p < 0.001$), reflecting the unequal roles of the sexes in food preparation and disposal. This is because food management in Nigeria is predominantly associated with women, who generally exhibit greater "food literacy," which includes skills in planning, shopping, and effectively utilising leftovers. Research conducted by [36] substantiates that these gender-specific roles contribute to increased waste in households led by men, where there is considerably less focus on meal planning and the strategic use of leftovers. This finding consolidates findings from South African research, which show that the central role of women in food production often leads to lower waste levels than men's

practices [37]. In addition, access to extension services is weakly but negatively associated with food waste ($\beta = -0.2417$; $p < 0.10$). This negative correlation indicates that as households gain greater access to external information and agricultural extension services, their waste levels tend to decrease, although the relationship is only slightly statistically significant. In the rural areas, this exposure leads to essential technical knowledge related to preservation, including the utilisation of hermetic storage bags that inhibit the spoilage of grains and legumes. Conversely, for urban residents, access to extension services cultivates an understanding of the environmental and economic implications of waste, prompting behavioural shifts towards more sustainable consumption practices. [38] discovered that environmental awareness serves as a significant differentiator in waste behaviour in Southwestern Nigeria, highlighting that individuals with access to waste-reduction information reduced their waste by as much as 20% through the application of inventory management strategies such as "First-In, First-Out" (FIFO).

Impact of Food Waste on Household Dietary Diversity

Instrumental variable estimates provide strong causal evidence that household food waste is a significant barrier to dietary diversity in Nigeria. The food waste coefficient ($\beta = -0.118$; $p < 0.001$) shows that a 1% increase in household food waste reduces the dietary diversity score by approximately 0.12, while the other factors remain constant. This implies that inefficiencies in food use are not only an economic or environmental problem but also directly affect nutritional outcomes. This could be because the majority of Nigerian households function within strict food budgets, and when food is wasted, the financial investments associated with those items are permanently lost. Consequently, households find themselves unable to replace the wasted nutrient-rich foods such as meat, fish, fruits, and vegetables, and are compelled to turn to less expensive, calorie-rich staples like gari, rice, or tuwo. This transition emphasises immediate caloric adequacy over nutritional diversity, resulting in a significant reduction in the variety of food groups consumed. Furthermore, animal-derived foods and fresh produce are more susceptible to spoilage, and repeated losses foster a risk-averse mentality, prompting households to intentionally limit their purchases of perishable goods to prevent future waste. This observation corroborates the assertion made by [39] that food waste functions as a "hidden tax" on impoverished populations, where the calories lost due to spoilage or excessive preparation are frequently the most costly, thereby compelling a retreat into a mono-diet consisting of cheaper, less nutritious staples such as cassava or maize.

Age of the head of household has a modest positive effect ($\beta = 0.004$; $p = 0.055$), suggesting that experience gained may slightly improve dietary choices. This can be attributed to the accumulation of traditional knowledge regarding indigenous food varieties and seasonal availability, which allows older heads to source a broader range of nutrients even under budget constraints. Furthermore, older heads often prioritise household health over convenience, a stark contrast to younger, urban-dwelling heads who may favour processed, single-category convenience foods. [40] corroborates this

by noting that "age-based food wisdom" in Nigerian rural settings often leads to better utilisation of forest-sourced foods and traditional leafy vegetables, which significantly boosts the Dietary Diversity Score (DDS) compared to younger cohorts.

The result underscoring that formal education equips households with nutrition knowledge and food management skills that support a more varied diet. This relationship can be explained by the role of formal education as both a cognitive and economic equaliser within the family unit. Education enhances the allocative efficiency of a household head, thereby improving their capacity to process nutritional information, assess food options, and convert knowledge into healthier and more varied purchasing decisions. Also, educated individuals are more inclined to participate in formal or semi-formal employment that offers structured schedules. This facilitates intentional meal planning and frequent, small-scale purchases of perishable items, which are crucial for maintaining a higher Dietary Diversity Score (DDS).

Moreover, education broadens social capital and access to information, especially through digital platforms and informal knowledge networks. Educated heads of households are more likely to utilise mobile applications, online media, and health-related resources to acquire new recipes, comprehend food preservation methods, and prolong the shelf life of various food groups. This perspective reduces dependence on cheap, starch-heavy staples and encourages a greater allocation of budget towards micronutrient-rich foods, as educated households recognise that the costs associated with dietary diversity are significantly lower than the long-term economic and health repercussions linked to malnutrition and diet-related non-communicable diseases. This result aligns with the findings of [41], who observed that in North-Central Nigeria, every additional year of formal schooling increased the likelihood of a household meeting the minimum dietary diversity threshold by approximately 5%, as education reduces the reliance on calorie-dense but nutrient-poor food choices. Access to extension programme also increases dietary diversity, indicating that rural advisory systems, when focused on nutrition and post-harvest management, may effectively improve the quality of household diet. Extension agents often provide training on home gardening and the cultivation of diverse crops beyond traditional cash crops. This direct access to varied food sources at the production level naturally increases the variety available at the consumption level. Moreover, extension services provide the technical skills needed to reduce spoilage, ensuring that diverse food groups actually reach the plate.

Implications for Interventions and Policy

The reduction of food waste should be formally integrated into Nigeria's national frameworks for food and nutrition security, which encompass agricultural, nutrition, and social protection policies. Existing strategies are predominantly focused on production, neglecting inefficiencies at the household level regarding food handling, storage, and utilisation. By recognising food waste as a challenge sensitive to nutrition,

615 policymakers can tackle both dietary quality and food access concurrently, especially
616 in the context of escalating food prices and fluctuating incomes.

617 It is essential to strategically invest in rural storage and preservation infrastructure to
618 mitigate both post-harvest and household-level food losses. Enhancing access to
619 affordable, climate-appropriate technologies such as hermetic storage bags, solar
620 drying systems, improved granaries, and community-based cold storage would
621 significantly decrease spoilage of cereals, vegetables, oils, and condiments. These
622 measures are particularly vital in rural regions, where structural limitations, rather than
623 behavioural issues, primarily influence food waste patterns.

624 Agricultural extension services that are sensitive to nutrition should be restructured to
625 include education on behavioural food management. Extension programs must extend
626 beyond mere production advice to encompass guidance on meal planning, portion
627 control, stock rotation, safe storage practices, and the repurposing of leftovers.
628 Communication should be rooted in behavioural change frameworks, such as the
629 Theory of Planned Behaviour, to effectively alter attitudes, social norms, and perceived
630 control over food management. Special emphasis should be placed on involving male
631 heads of households and enhancing women's decision-making roles in food
632 provisioning, given their significant impact on dietary outcomes.

633 Policies ought to collaboratively encourage dietary diversity and waste reduction by
634 enhancing market access and food purchasing flexibility. Investments aimed at
635 lowering transaction costs, such as improved rural roads, market infrastructure, and
636 digital market platforms, can empower households to frequently purchase small
637 quantities of perishable foods, thus preserving diverse diets while reducing spoilage
638 risks. Income diversification initiatives can further bolster households' ability to
639 maintain balanced diets throughout the year.

640 Urban food policy must tackle dietary quality in conjunction with waste reduction by
641 cultivating healthier food environments. Strategies such as transparent food labeling,
642 public nutrition campaigns, support for urban and rural agriculture, and incentives for
643 fresh food retailing can enhance dietary diversity while discouraging excessive
644 purchasing and wasteful consumption behaviours.

645 **Conclusion**

646 This study offers strong empirical evidence that household food waste is a
647 considerable yet often overlooked barrier to dietary diversity and nutritional security in
648 Nigeria. The findings contextualizes food waste reduction as a strategy sensitive to
649 nutrition development, rather than merely an issue of environmental concern or
650 efficiency. Evidence indicates that behavioural elements such as planning portions,
651 rotating stock, implementing proper storage practices, and attitudes towards leftovers
652 are crucial, aligning with the Theory of Planned Behaviour. Even food products
653 generally regarded as low-risk, such as spices, condiments, and oils, are particularly
654 susceptible to spoilage in Nigeria's humid climate when not stored correctly, resulting
655 in preventable nutritional and economic losses.

656 The study therefore concludes that successful food waste reduction necessitates a
657 shift in policy focus from demographic profiling to behavioural, educational, and

structural interventions. Incorporating food waste awareness into nutrition programs, extension services, and community education while enhancing functional food literacy, especially among women, provides a cost-effective and scalable approach to improving dietary diversity, household nutrition, and the sustainability of Nigeria's food system.

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Statements and Declarations

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Conflict of Interest

The authors declare no conflict of interest

Data Availability

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

Disclaimer (Artificial Intelligence)

Author(s) hereby state that no generative AI tools such as Large Language Models (ChatGPT, Capilot etc) and text-to-image generators were utilized in the editing of this manuscript

Authors' Contributions:

Nwafor Solomon conceptualized the study, designed the review protocol, carried out data extraction and analysis, and drafted sections of the results. **Ayoade Adetoue** supervised the overall research process, contributed to methodological refinement, and reviewed manuscript for intellectual content and provided critical revisions. **Oladokun Yetunde reviewed empirical literature, drafted theoretical framework, and reviewed the manuscript.** All authors read and approved the final manuscript.

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Informed Consent

Consent to participate

Because the study relied exclusively on anonymized secondary data that are publicly available for research purposes, no additional ethical approval or informed consent was required for the present analysis. The original data collection procedures for the Nigeria General Household Survey–Panel were conducted by the responsible institutions in accordance with applicable ethical guidelines and standards governing human participant research, including the protection of respondent confidentiality and voluntary participation.

All analyses conducted in this study complied with the data usage regulations and ethical standards associated with secondary data analysis.

Ethics and Consent to Publish

Ethics statement

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843 This study did not involve the direct collection of primary data from human participants.
844 The analysis was based entirely on secondary microdata obtained from the Nigeria
845 General Household Survey–Panel (GHS-Panel, Wave 5), a nationally representative
846 dataset collected by the National Bureau of Statistics in collaboration with the World
847 Bank under established national and international research protocols. Therefore, no
848 additional ethical approval was required for the present analysis.

849