











Food loss/waste (FLW) behaviour in the food-security transition nexus among farming households in the Southwest of Nigeria

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ABSTRACT: This study examines the dynamics of food loss/waste behaviour and its determinants among farming households in Southwestern Nigeria. A combination of cluster and systematic random sampling was used to select 160 households through primary data collected in two periods of late and early rain, respectively, over a period of 10 months. Data were analyzed using a simultaneous-equation model. Transition of food-security households to food-insecurity indicated a differential of 4.05% in the first season and a differential of 9.15% during the second. The probability of households escaping food insecurity was 0.23, and entering food insecurity was 0.37. Past studies of this nature only captured the food-insecurity status of households using a snapshot study. This study brought in innovation by examining the dynamics of FLW in two periods, during agricultural harvest, when more food waste/loss was recorded. Therefore, the question this study asks is: Can a farm household enhance food loss/waste reduction over a particular period of time and vice versa?

Keywords: community empowerment; social forestry; scale validation; psychometrics; factor analysis.

Comportamento de perda/desperdício de alimentos (PDA) no contexto da transição para a segurança alimentar entre famílias agrícolas no sudoeste da Nigéria

RESUMO: Este estudo examina a dinâmica do comportamento de perda/desperdício de alimentos e seus determinantes entre famílias agrícolas no sudoeste da Nigéria. Uma combinação de amostragem por conglomerados e amostragem aleatória sistemática foi utilizada para selecionar 160 famílias com base em dados primários coletados em dois períodos de chuvas tardias e precoces, ao longo de 10 meses. Os dados foram analisados com um modelo de equações simultâneas. A transição de famílias com segurança alimentar para famílias com insegurança alimentar indicou diferenças de 4,05% na primeira estação e de 9,15% na segunda. A probabilidade de as famílias saírem da insegurança alimentar foi de 0,23 e de entrarem nela, de 0,37. Estudos anteriores dessa natureza capturaram apenas o status de insegurança alimentar das famílias por meio de um estudo pontual. Este estudo inovou ao examinar a dinâmica do desperdício de alimentos em dois períodos, sendo que, durante a colheita agrícola, foi registrado maior desperdício e perda de alimentos. Portanto, a questão que este estudo busca responder é: uma família agrícola pode aumentar a redução de perdas e desperdício de alimentos em um determinado período de tempo e vice-versa?

Palavras-chave: empoderamento comunitário; silvicultura social; validação de escalas; psicometria; análise fatorial.

1. INTRODUCTION

In the context of the food security nexus, one of the primary sustainability issues that requires immediate attention is food loss and waste (SKAWI; ZLEWSKI, 2022; BOITEAU; PINGALI, 2023; SCHNEIDER et al., 2024; OLABODE et al., 2025). Policymakers, researchers, businesses, and civil society organizations have made food loss and waste a top priority in recent years, both globally and specifically in developing nations like Nigeria (AKERELE et al., 2017; BOITEAN; PINGALI, 2023). Food security and food loss or waste are related (CHABOUD, 2017; ZASADA

et al., 2019; CATTENEO et al., 2021; CAFIERO et al., 2024). Achieving zero food loss and waste as part of the strategy to end hunger can help overcome the Zero Hunger Challenge (UNEP, 2021; ROSEGRANT et al., 2024). Therefore, among other things, preventing or minimizing food loss and waste would be necessary to achieve zero hunger. A thorough understanding of the causal relationship between food loss and waste and the food security nexus is necessary (DELGADO et al., 2021; BARRERA; HERTEL, 2021; HOSSAIN et al., 2023). Food waste/loss is a global problem that is currently receiving more attention due to

issues with food security and associated environmental concerns (HUANG et al., 2020; CHAUHAN et al., 2021; ROSEGRANT et al., 2024).

Consumer behavior has been examined in household food waste studies in an effort to explain food security, poverty, and household food waste behaviors (PRINCIPATO, 2018; GALLI et al., 2019; QI et al., 2021). Reports from FAO (2019) and Fabi et al. (2021) indicated the need to reduce food loss, and waste is firmly embedded in the 2030 Agenda for Sustainable Development. These reports deduced that Food loss and waste reduction is considered important for improving food security and nutrition, promoting environmental sustainability and lowering production costs. However, efforts to reduce food loss and waste will only be effective if informed by a solid understanding of the problem. While in alignment with the global SDG 12.3 goals on food loss/waste, Target 12.3: The percentage of food lost globally after harvest on farm, transport, storage, wholesale, and processing levels, is usually attributed to structural inadequacies in the countries. Food loss and waste have been identified in the literature as a recurring problem in developing countries, yet little is documented (WANG et al., 2021; FAMI et al., 2019; APETI; EDOH, 2023). This continued improvement in food insecurity, which is more focused on low-level subsistence than was achieved 20 or 30 years ago, should raise serious concerns. This is the justification for conducting this study.

Food "loss" occurs before it reaches the consumer due to problems related to the stages of production, storage, processing, and distribution (CAITLIN et al., 2025). However, food that is fit for consumption but is purposefully prohibited during the selling or consumption stages is referred to as "waste" (GARRONE et al., 2021; PEREZ-ESCAMILLA et al., 2024; THORSEN et al., 2024). This distinction highlights the need for targeted interventions at various points in the food supply chain to reduce both loss and waste in the food-security nexus (AHMED et al., 2024). This study aimed to assess the factors influencing food loss and waste (FLW) in the food-security nexus among farming households in Southwest Nigeria and identify strategies for reduction.

Thus, knowing the relationship between food loss/waste and food security can improve micro-policy for household-level food waste reduction (ARAGIE et al., 2018; ANDERSON et al., 2023). By implementing targeted strategies that address the root causes of food waste, policymakers can enhance food availability and accessibility (SANTERANIO, 2021; SIDERIUS et al., 2024). Nigeria grapples with a significant food loss and waste challenge, with approximately 40% of its total food production lost annually (FAO, 2025). Report from FAO 2025 indicated that 33.2 million Nigerians are expected to be acutely food insecure during the June-August lean season in 2025, with nearly 1.8 million in emergency. The Southwest region is not the primary focus of the most urgent food insecurity concerns, but it is still affected, with about 5.4% post-harvest annual losses.

Hence, there is a need to build up resilience in the face of FLW prevalent in the Southwest region. The study was structured as follows: section one contains the introduction, and section two contains the theoretical framework that served as the study's driving force. The study's methodology is covered in section three and

followed by the results and discussions in section four, while section five concludes the study.

2. Theoretical Framework

According to Campoy-Munoz et al. (2017), the most frequently cited connection between food waste and food security is an implicit one. The number of hungry people worldwide is listed after the amount of food wasted worldwide, but food loss cannot be calculated at the micro level other than at the macro level (GALLI et al., 2019; CORRADO; PALUMBO, 2022; ZAHIDI et al., 2024).

The Food and Agriculture Organization (FAO) (2024) estimated that approximately 1.3 billion tons of edible food are lost or wasted annually worldwide. This staggering figure highlights the urgent need for systemic changes in food production, distribution, and consumption patterns. Addressing this issue not only requires innovative solutions but also a collective commitment from individuals, businesses, and governments to reduce food waste at every stage of the supply chain (GUNDERSEN; OLIVEIRA, 2001).

While wealthy households buy and cook more than they actually need, this ultimately leads to more food waste. Food-insecure households are thought to be more concerned about the financial volatility of food prices, which influences them to buy food ingredients in bulk. Though most food is not consumed in time, resulting in food waste (DEMORAES et al., 2020; FAO, 2020b; DHAR et al., 2024). Therefore, from the perspective of econometric estimation, it is necessary to ascertain the relationship between consumer attitudes and behaviors that result in food loss and waste. Understanding these dynamics can help develop targeted interventions aimed at reducing food waste, particularly among vulnerable populations. This can be achieved by promoting better purchasing practices and efficient food storage/usage strategies (CHALAK et al., 2019; MONTALVO et al., 2024).

2.1. Econometric estimation of food insecurity transition

A household is considered food secure if all of its members have access to enough safe, nourishing food to sustain an active and healthy lifestyle (BAYLISS-SMITH, 1991; HELLEGERS, 2022). This definition emphasizes not only the quantity of food available but also its quality (AREGAWI et al., 2024). Food security nexus is a dynamic issue rather than a static one (ZASADA et al., 2019; SANTERANIO, 2021; GILES et al., 2024). Thus, using the Markov chain model as a framework, this study investigated the transition to food security using food loss/waste as the driver. To fit the study's objectives, the Markov chain theory and methodology used by Nord et al. (1999) and Baulch; McCulloch (1998) were modified to fit the scope of the study.

In order to comprehend the correlates and causes of movement into and out of food insecurity, the Markov chain model was used to investigate the dynamics of food security. The number of households in and out of a food-secure situation during a specific time period, broken down by their food-security status, is displayed in the food-insecurity transition matrix. This matrix provides valuable insights into patterns of food security, revealing how various factors influence households' transitions between secure and insecure status. By analyzing these transitions, researchers can identify key determinants that may contribute to

improving food security interventions. As a result, it is simple to determine how many households have experienced food insecurity or not, as well as how many people have fled or fallen into it. The likelihood of entering and leaving between the two periods can then be computed from the matrix. In order to obtain the transition probability matrix displayed in Equation 01, the items in the transition matrix above are transformed into probability values of entering and leaving a situation of food insecurity. Each item is then divided by the corresponding row total.

The Markov food insecurity transition matrix would be derived as follows:

$$\begin{pmatrix} F_{11} & F_{12} & F_{13} \\ F_{21} & F_{22} & F_{23} \\ F_{31} & F_{32} & F_{33} \end{pmatrix} \quad (01)$$

Also, the vector of initial probability $P_H(0)$ will be obtained by dividing each column total by the total. Thereafter, the proportion of households that will be in each category in the subsequent periods can be known by using the following equation:

$$P_H(T) = P_H(0)P^T \quad (02)$$

where: T is the time period in years.

Long-term equilibrium (Le) would be derived from:

$$LeP_H = Le \quad (03)$$

As,

$$(Le_1 Le_2 Le_3) = \begin{pmatrix} F_{11} & F_{12} & F_{13} \\ F_{21} & F_{22} & F_{23} \\ F_{31} & F_{32} & F_{33} \end{pmatrix} = (Le_1 Le_2 Le_3) \quad (04)$$

The solution to the above matrix produced Le_1 , Le_2 , and Le_3 , which are the proportions of households that will be food secured, moderately food insecure and core food insecure at the equilibrium, respectively. Le_1 is the equilibrium state for core food secure; Le_2 is the equilibrium state for moderate food insecure, and Le_3 is the equilibrium state for food secure. From Table I, the simple probability of entry and exit of the food (in) secure is then derived. To obtain the food-secure/-insecure households, food-secure/-insecure line will be constructed to delineate the food-secure and insecure status of the households.

Table I. First-order Markov model of food insecurity transition. Tabela I. Modelo de Markov de primeira ordem da transição da insegurança alimentar.

Period I (early rain)	Period II (late rain)			Total
	Core Food Insecurity	Moderate Food Insecurity	Food Security	
Core Food Insecurity	CFIS	MFIS	FS	
Moderate Food Insecurity	CFIS	MFIS	FS	
Food Security	CFIS	MFIS	FS	
Total				300

Notes: CFIS, core food insecurity; MFIS, moderately food insecure; FS, food security.

Notas: CFIS, insegurança alimentar grave; MFIS, insegurança alimentar moderada; FS, segurança alimentar.

The study used the following specific steps in the delineation of food security/insecurity households (Greer and Thorbecke, 1986):

(1) The value of food ($VFhj^*$) consumed by each household, which is equal to the sum of the value of purchased food (Vhj^*) and the value of own production consumed (Chj^*) was determined by:

$$VFhj^* = Vhj^* + Chj^* \quad (06)$$

where: Vhj^* is deduced as,

$$Vhj^* = \sum Q_{ij}Ph_{ij} \quad (07)$$

where: Vhj^* is the value of purchased food consumed by the j th household; Q_{ij} is the quantity of the i th food item purchased by the j th household, and Ph_{ij} is the local price paid by the j th household for the i th food item. The value of own output or food consumed by the household Gh_{ij} is the product of own production (including gifts) (OP_i) and the local prices (P_{xi}). The quantity OP_{ij} is the imputed value of consumption:

$$Gh_{ij}^* = \sum OP_{ij}Ph_{ij} \quad (08)$$

(2) The adult equivalent H_j for each household was proxied by the household size.

(3) $VFhj^*$ was deduced by,

$$VFhj^* = \frac{VFh_{ij}^*}{H_j} \quad (09)$$

where: $VFhj^*$ is the total value of food consumed by the j th household; H_j is the adult equivalent for the j th household, and VFh_{ij}^* the total value of food consumed per adult equivalent units.

(4) The different types and quantities of foods consumed by the different households were converted to calories Ca_j using the calorie equivalents.

(5) A regression model was fitted to estimate parameters to determine the food insecurity threshold (line):

$$\ln Tfx_j = a + bCa_j \quad (10)$$

where: Tfx_j is the total food expenditure per adult equivalent by household j ; Ca_j is the total calorie consumption per adult equivalent by household j , and a and b are the parameters to be estimated.

(6) The food poverty line Z (which is the estimated cost of acquiring the calorie recommended daily allowance RDA) was estimated as:

$$Z = Le^{a+bRe} \quad (11)$$

where: Z is the food insufficiency threshold (line) and the recommended daily allowance of calories per adult equivalent of 2,350 (SCUBERT, 1994).

(7) The classifications of various measures of food insufficiency in households (P_α) were computed using the formula of Foster et al. (1984):

$$P_\alpha = \frac{1}{N} \sum_{i=1}^Q h \left(\frac{Z - Y_i}{Z} \right)^\alpha \quad (12)$$

where: Z is the food insecurity line; Y_i is the food expenditure measure in Naira (N) $_i$ ($i=1, 2, \dots, q$); q is the number of households below the food insecurity line (food poverty households); N is the total number of sampled households; α the parameters of the Foster Greer and Thorbecke index ($Ph\alpha$). $a \geq 0$ and it can take three values of 0, 1 and 2. These values give different implications. This formula was therefore used to decompose the farming households into classes of food-security/food-insecurity status.

2.2. Calculation of Food Loss and Waste

The value of food lost or wasted annually at the global level is estimated at US\$1 trillion (MONTALVO et al., 2024). Yet reliable numbers on specific instances of wastage are absent. Food is lost or wasted throughout various stages of the food supply chain. During agricultural production, crops and harvest can become damaged or spoiled, animals may die due to diseases, fish may be discarded during fishing, and milk could be lost due to cattle diseases (ZAHIDI et al, 2024). Crops, animals, fish or milk may be lost during post-harvest handling, storage and transportation. During processing, food may be lost or degraded during washing, peeling, slicing, canning, packaging, etc., or during slaughtering, smoking, freezing or pasteurizing. During distribution, food may be lost or wasted during transport, at wholesale markets, supermarkets, retailers, etc. Finally, consumers may waste food by throwing it away (MCDONALD; MOFFIT, 1980).

The mass balance method designed by Calderia et al. (2019) was used in this research. This method calculates the amount of FLW as the difference between inputs and outputs of food, their stock variations, and weight changes during the process (HARTIKAINEN et al, 2018). This method presents several advantages, as it allows calculating the FLW of liquid and solid food at each stage of the food supply chain (FSC). Moreover, the data required are often easily accessible and readily available, e.g., in national statistics (ENDALEW et al., 2015). For this research, the mass balance method is found to be appropriate. It covers the FSC worldwide, in all stages, and includes a wide range of food products. In addition, the amount of FLW estimated for each study area was associated with its level of food security, using the four clusters formed by the Global Food Security Index (GFSI) designed by The Economist Intelligence Unit. These clusters are “very good”, “good”,

“moderate”, and “weak”, and a set of indicators calculates them based on four categories related to food security: affordability, availability, quality, and safety, and natural resources and resilience. The GFSI is calculated for 113 countries, while FLW is estimated for 171; therefore, the rest of the countries were classified in a “without EUI index” cluster. The accounting approach to estimate FLW is described in Figure 1. The following equations represent the estimation of FLW and pooling that is adopted for this study.

$$FLW_{xi} = \sum_{i=1}^n \delta A_{ij} x; \alpha B_{ij} x; \beta C_{ij} x; D\gamma_{ij} x; E\theta_{ijx}; \epsilon \tag{13}$$

$$FLW_{xi} = a_0 + a_1 \delta A_{ij_1} + a_2 \alpha B_{ij_2} + a_3 \beta C_{ij_3} + a_4 D\gamma_{ij_4} + \dots . a_5 E\theta_{ij_5} + \epsilon \tag{14}$$

where,

$$FLW_x = FLW_{xi} \tag{15}$$

where:

1. i is the food group: fruit, cereals, milk, fish and seafood, meat, eggs, starchy roots, oil crops, and vegetables;
2. j is the stage of the FSC: agricultural production, post-harvest, storage, processing and packaging, distribution, and consumption;
3. k is the food insecurity status;
4. l is the level of food insecurity categorized as Chronic, Moderate and Good.
5. δA_{ij} is the domestic food supply quantity, which is the quantity of food available in the food group i in stage j .
6. αB_{ij} is the food loss and waste rate (FLWR) in the food group i in stage j , where k , defined as the ratio of food loss and waste to the total amount of food production;
7. βC_{ij} is the allocation factor in the food group i in stage j , where k , which defines the proportion of the food meant for human consumption.
8. $D\gamma_{ij}$ is the conversion factor in the food group i in stage j , where k , which defines the proportion of edible food;
9. $E\theta_{ijx}$ is the conversion factor in the food group i in stage j , where k , which defines the proportion of non-edible food;
10. FLW_{kl} is the food loss and waste in the country k with the level l of security.

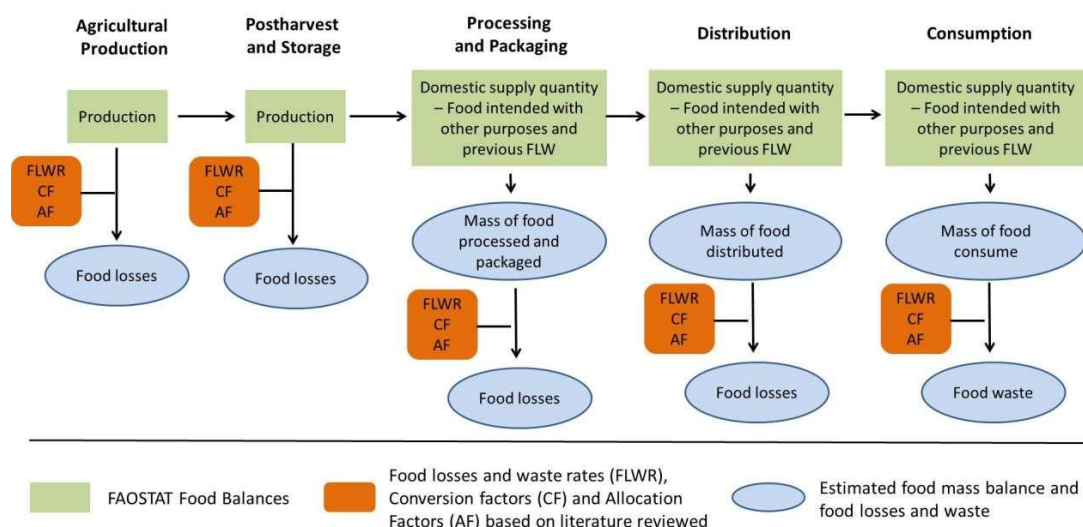


Figure 1. Accounting approach to estimate FLW. (FAO, 2021).

Figura 1. Abordagem contábil para estimar FLW (Fase de Orçamento Familiar). (FAO, 2021).

The mass balance method distinguishes between edible and non-edible food. Regarding FLW, quantification only considers edible food and discordance in the FLW estimation. Several causes contribute to decreased edible food mass in FSC stages (ENDALEW et al., 2015). In this regard, food loss occurs at all stages except consumption, when food waste occurs (HARVEY et al., 2020). Therefore, the FLW is calculated by multiplying the amount of food available at each step of the food chain (FLWR) by the conversion factors. Finally, the FLW considers the country's level of food security (FAO, 2020a). Thus, the following equation was used to calculate the per capita FLW

$$FLW_{PC} = \frac{FLW_x}{Phn} \quad (16)$$

where: *FLW_{PC}* is the per capita food loss and waste, and *Phn* is the population/sample size (n)

3. METHODOLOGY

3.1. Area of Study

One of Nigeria's six main regions is the southwest. The states in the southwest region are Lagos, Oyo, Ogun, Ondo, Osun, and Ekiti. Three states (Lagos, Ogun, and Ondo) were randomly chosen from the six states in southwest Nigeria. Ondo State is primarily an agricultural state with plenty of job opportunities in both the public and private sectors. Moreover, the state has a reputation for being conservative when it comes to FLW. Ogun State is a commercial and agricultural state where FLW is prevalent and under control in certain areas. On the other hand, FLW is visible in Lagos, the region's commercial center and a multicultural city.

3.2. Sampling Techniques

The sampling frame adopted for this study is obtained from the respective agricultural development programme (ADP) of each location. In each of the respective ADPs, 1600 registered farmers were obtained (sampling frame) (Table 2). The study adopted stratified random sampling to select four rural/semi-urban local government areas (LGAs) from each state, for a total of twelve LGAs. These four rural/semi-urban local government areas (LGAs) were randomly selected based on the information sourced from the Nigeria Bureau of Statistics (NBS, 2023).

A systematic random sampling was used to select 40 households from each of the selected twelve rural/semi-urban communities. Thus, a total of 160 households per state (selection of the 160 households per state is a result of the 10% taken from the sampling frame of each of the selected states) and 480 households in all were selected during the first data collection (Table 2).

On visiting the same households during the second data collection, only 300 households' data were useful for data analysis. The unused data of 180 households had incomplete information and missing data in the questionnaire, which could not provide sufficient information for data analysis. The needed information was collected through the use of piloted interview schedules/questionnaires. Food price data were obtained through community market surveys. Both primary and secondary data were used for this study. Based on the specific nature of the data requirements for this study, panel data were adopted, and they were collected in two periods. Data were collected during the late and early rain, respectively, over a period of ten months (October 2022 – July 2023).

Table 2. Distribution of the selection procedure of the sample size from the sampling frame.

Tabela 2. Distribuição do procedimento de seleção do tamanho da amostra a partir do quadro de amostragem.

State	Zones (75%)	LGAs/Blocks (75%)	Cells/Towns (50%)	Registered contact farmers/Sampling frame	10% selection of the registered contact farmers	
Ondo	Zone 1					
	Akure south	Akure south	Akure	200	20	
			Oda road	200	20	
	Owo	Owo	Owo	200	20	
			Ipele	200	20	
	Irele	Irele	Irele	200	20	
			Sabomi	200	20	
	Zone III					
	Idanre	Idanre/ Ileoluji	Idanre	200	20	
			Ileoluji	200	20	
Lagos	Badagry	Badagry	Gayingbo	200	20	
			Iworo	200	20	
	Epe	Epe	Araga	200	20	
			Igboye	200	20	
	Ikorodu	Ikorodu	Agbowo	200	20	
			Igbodu	200	20	
	Mushin	Mushin	Ojuiwoye	200	20	
			Isolo	200	20	
Ogun	Ijebu	Odogbolu	Odogbolu	200	20	
		Ijebu ode	Ijebu	200	20	
	Remo	Ikenne	Ikenne	200	20	
		Sagamu	Sagamu	200	20	
	Egba	Abeokuta north	Abeokuta	200	20	
		Ewekoro	Ewekoro	200	20	
	Yewa	Yewa south	Ayetoro	200	20	
		Ado odo/Ota	Ota	200	20	
Total				480		

Source: Registered arable crop farmers from the ADP List (2023).

Fonte: Agricultores de culturas aráveis registrados na Lista ADP (2023).

Primary data were collected with the aid of a well-structured and tested questionnaire, administered on farming households in the area of study. Secondary data came from the Central Bank of Nigeria and the National Bureau of Statistics. Food consumption and FLW information/data were collected on an individual basis from the households. Magnitudes of daily food intake were collected for each member of the household, using a 48-hour recall method. Each household was visited at least once every two weeks in the months of March and November. Thus, daily food intake quantities for each individual in the household and FLW were collected twice in March and twice in November. The analysis reported here was based on per capita daily food consumption averaged over the ten months of data collection. This is designed to reduce measurement errors in food consumption by smoothing day-to-day fluctuations in food intake. These quantities were then converted into kilogram units. Income and expenditure information, as well as FLW data, were obtained on a fortnightly basis for a period of ten months.

The study requested information about respondents' amount of food waste generation (order starting from 1= very low, less than 5%; to 5= very high, more than 50%) in different categories that include fruits and vegetables, tubers, dairy, chicken, meat, seafood, processed food and cooked food, among others. Data were also collected on food preparation and eating habits.

3.3. Estimation techniques

The structural form equation adopted as a framework for this study is the simultaneous equation model. The use of the Simultaneous model enables all the available information from the explanatory variables to be used in the equation as a single model (Simultaneous model) (GASCON et al., 2022). The idea of this model is that FLW has a significant role in the food security nexus. The study deduced that the food insecurity gap (which serves as the percentage insecurity gap), as one of the dependent variables, has an amended distribution as:

The food insecurity gap,

$$(FISG_i) = \left(\frac{Z - Y_i}{z} \right) \tag{17}$$

where: $FISG_i$ (food insecurity gap) is the latent economic quantity of interest:

- (1) If $Z > Y_i$, $FISG_i$ is positive. This means that the household records a food spending level that is lower than the food security threshold (line) and is regarded as falling into a food insecurity situation.
- (2) If $Z < Y_i$, $FISG_i$ is negative. It has a superior food spending level to the food insecurity line and is regarded as falling into a food security situation

The implication is that for food-insecure households, the $FISG_i$'s are positive, while for food-secure households, they are negative. This situation calls for a simultaneous equation. Hence, in our model specification, FLW_{xi} is used as a dependent variable. Hence, the model is expressed as:

$$FLW_{xi} = a_0 + a_1X_1 + a_2X_2 + a_3X_3 + a_4X_4 + \dots a_{20}X_{20} + \varepsilon \tag{18}$$

where one of the X_i is FLW_{xi} extracted from equations 18 to 19

Hence, the estimating equation is:

$$FHI_j = a_0 + a_1X_1 + a_2X_2 + a_3X_3 + a_4X_4 + \dots a_{20}FLW_{xi} + \varepsilon \tag{19}$$

where,

FHI_j = Food insecurity statu

$FHI_j = 1$, If $D_i > D_{0i}$

$FHI_j = 0$, If $D_i < D_{0i} \dots 300$

The four categories of food insecurity transitions are stated below:

1. $FH_{11} = 1$ if never food insecurity, 0 if otherwise;
2. $FH_{12} = 1$ if gratifying food insecurity, 0 if otherwise;
3. $FH_{13} = 1$ if exiting food insecurity, 0 if otherwise;
4. $FH_{14} = 1$ if always food insecurity, 0 if otherwise;

a = coefficients; β = vector of respective parameters;

X_1 - X_{20} = independent variables, while ε = distributed error term;

The independent variables are socio-economic and demographic and are captured as: X_1 = household size (number), X_2 = level of education (years), X_3 = age (years); X_4 = marital status of household head; X_5 = gender of household head; X_6 = farming/ fishing experience (Naira); X_7 = hired labor (Naira); X_8 = dependency ratio (No.); X_9 = expenses on food (Naira); X_{10} = farming/fishing income (Naira); X_{11} = farm size (Ha); X_{12} = expenses on non-food items (Naira); X_{13} = expenses on inputs (Naira); X_{14} = non-farm rural activities income (Naira); X_{15} = income consumed outputs (Naira); X_{16} = access to extension facilities (dummy), if access = 1, otherwise = 0; X_{17} = access to credit facilities (dummy), if access = 1, otherwise = 0; X_{18} = market facilities (dummy), if access = 1, otherwise = 0; X_{19} = asset status (measures in Naira); X_{20} = Estimates of FLW_{pc} (measures in Naira).

3.4. Simultaneous equation model

To establish linkages (or interactions) between FLW and the food insecurity transition nexus, a Simultaneous equation model was adopted. The effects of the FLW and food insecurity transition nexus on agriculture and other variables on economic growth were examined by regression analysis, where a two-stage methodology was used. This is necessary because the food insecurity transition nexus and FLW are jointly dependent on similar household socio-economic variables (GASCON et al., 2022). Moreover, FLW has been used previously as a dependent variable in Equation (18). Hence, in equation (19), FLW was then used as part of the independent variables that predicted the food insecurity transition nexus. Hence, the study used a 2-stage least squares (2SLS) estimation method.

Thus, this calls the test for model fitness, and it was done through the use of the Durbin-Wu-Hausman test to test for endogeneity, tests for overidentification, and the likelihood ratio. These tests were used to assess the model's assumptions, whether it can satisfy the parameters that are statistically significant or not. The study used the Stata 19 statistical package, which helped the study in estimating

simultaneous equation models using two-stage least squares (2SLS) as the estimation technique. The use of 2SLS has the advantage of estimating all parameters of the structural equation in the model simultaneously (GASCON et al., 2022). The objective of using 2SLS is to facilitate the use of the Ordinary Least Squares (OLS) method for each equation of the structural model.

3.5. Econometrics estimation issues

Even though the structural equation presented in equation 19 is theoretically valid. But estimating the model by a single equation of ordinary least-squares (OLS) regression procedure would likely result in biased estimates of elasticity coefficients (KHALID et al., 2019). Theoretically, both non-farm income and farm income share are considered endogenous to the food insecurity model for two reasons. First, since the income variable used in this model is basically labor income (both for non-farm and farm), its value is largely an outcome of labor supply choices. Second, reverse causality is a potential source of bias in the OLS estimate of the coefficients of the food insecurity household model and income share. Furthermore, given the difficulty in getting accurate information on the income of individuals and households in developing countries, classical measurement error bias (or dwindling bias) may also be a very important source of bias in this modelling.

Therefore, several steps were taken to address the potential biases of the estimates of the insecurity status of farm-household income and non-farm income share elasticity. First, the study adopted the maximum likelihood estimates (MLE) method on the dependent variable. MLE was used to estimate population parameters from a random sample. Secondly, in order to reduce the classical measurement error bias, per capita income on food expenditures and income data were used. Also, the study was conducted on multiple visits and 48-hour memory recall over the period of data collection (10 months).

Furthermore, the instrumental variable of the two-stage least-squares estimation procedure was used to address the problems of bias due to measurement error, omitted variable and reverse causality. The robust check of instrumental variable was used as a variable to proxy all income sources data, comprising non-farm and farm income variables. This variable is correlated with the endogenous regressor but uncorrelated with the error in the structural equation.

4. RESULTS

4.1. Preliminary statistics

The study revealed that the mean age in Lagos is 10.49, Ogun is 47.86, and Ondo is 47.27 (Table 3). This is an active age group that can support the adoption of progressive technology. The study also indicated a fairly literate group where information dissemination can easily be accessed and used appropriately. However, the dependency ratio in the study is 4, and this has an implication on the resources of the household (Table 3). The average monthly income in Lagos is higher by 24%, for Ogun state 23.3% and 26.7% in Ondo state. Similarly, sustenance allowance for food in Ogun state is higher by 3.32% in Lagos and 4.42% in Ondo state.

Moreover, Table 3 indicates that the monthly income was higher during the first data collection with a differential of 30%. Allowances for food upkeep with a differential of 1.2% over the 2nd data collection. The study indicated that during the second data collection, there was a significant contribution of non-farm income to household income, thus increasing disposable income. Moreover, respondents from Ogun and Ondo states consumed more (15.5%) of farm produce than Lagos households. Likewise, farm income increases by 10.01 percent during the second data collection; however, a decrease was recorded in Ogun 4% and Ondo (4,85%) (Table 3). Thus, sustenance allowances are more in Lagos, with a difference of 6.03 percent and 6.46% in Ogun.

Table 3. Fundamental statistics and variables that influenced food security status and the FLW transitions matrix.
Tabela 3. Estatísticas fundamentais e variáveis que influenciam o estado de segurança alimentar e a matriz de transição FLW.

s/n	Selected Household Characteristics	Lagos		Ogun		Ondo		All group	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
1.	Age	46.10	10.49	47.86	12.25	47.37	12.42	47.11	11.74
2.	Household size	6.10	2.51	7.40	1.82	7.13	1.92	6.91	2.16
3.	Dependency ratio	3.28	1.73	4.45	1.59	3.75	1.68	3.83	1.73
4.	Educational level	3.29	0.87	2.56	0.61	2.74	0.79	2.86	0.82
5.	Income (Monthly) ₦ (1 st Data collection)	394040	155363	301070	118478	211750	57221	302286	138858
6.	Income (Monthly) ₦ (2 nd Data collection)	275830	108754	210750	82935	148220	40085	211600	97200
7.	Expenses on food (₦) 1 st Data (%)	126090 (32.00)	97160	106343 (35.32)	37913	65759 (31.06)	38857	96732	44434. -
8.	Expenses on food (₦) 2 nd Data (%)	104810 (38.00)	41327	80085 (24.03)	31515	56325 (37.97)	15221	80408	36936
9.	Income Monthly (farm) ₦ 1 st data (%)	36.40`		55.38		72.26			
	Non-farm income (%)	38.01		45.49		13.07			
	Gifts income (%)	10.05		4.00		4.85			
	Farm produce (income) (%) consumed at home (%)	15.54		11.00		9.82			
10	Income Monthly (farm) ₦ 2 nd - data (%)	31.82`		43.62		63.06			
	Non-farm income (%)	47.91		34.19		12.34			
	Gifts income (%)	8.92		11.27		7.22			
	Farm produce (income) (%) consumed at home (%)	11.35		10.92		17.38			

Source: Author's calculation from computer printout results.
Fonte: Cálculo do autor com base nos resultados de impressões de computador.

4.2. Income distribution and differentials during the transition

The study deduced that income distribution played a significant role in food security and the FLW transition model. Table 4 revealed that there were more households in the low-income category, as the study indicated a differential

of 46.43%. Other income categories are Intermediate 19.01% and high-income category 33.67% (Table 4). This income distribution and categorization helped the study in generating a chain that aided the use of the Markov-Chain model that engaged in the simulation of Food security and the FLW transition matrix.

Table 4. Income distribution and differentials during the transition.

Tabela 4. Distribuição de renda e diferenciais durante a transição.

s/n	Income category	1 st Data Collection (n)	2 nd Data Collection (n)	Differentials (%)
1	75,001 – 100,000	0	14	14.0
2	100,001 – 125,000	3	41	93.0
3	125,001 – 150,000	24	54	55.6
4	150,001 – 200,000	51	59	13.56
5	200,001 – 250,000	80	33	58.75
6	250,001 – 300,000	25	36	30.56
7	300,001 – 350,000	16	29	50.0
8	350,000 – 400,000	27	16	40.7
9	400,001 – 500,000	40	18	55.0
10	500,001- 1,000,000	34	0	34.0

Summary: Lower-income group; (75,001 – 200,000.00) 46.43%
 Intermediate-income group; (200,000.00 – 350,000) 19.01%
 High-income group; (350,001 – 1,000,000.00) 33.67%

Source: Author's calculation from computer printout results.

Fonte: Cálculo do autor com base nos resultados de impressões de computador.

4.3. Food security status transition matrix from October 2022 to July 2023

The preliminary statistics of households' food security status and food expenses in Table 5 revealed that households spend ₦1,439.38 per person for daily food expenses during the 1st data collection, while the 2nd data collection indicated

food expenses of ₦1,020.81 per person for daily food expenses. Hence, the study revealed that food-secured households usually have larger food expenditures per capita than other groups (Table 5), and the minimum food spending needs per capita are relatively lower in the food-secured households.

Table 5. Food security status transition matrix from October 2022 to July 2023.

Tabela 5. Matriz de transição do status de segurança alimentar de outubro de 2022 a julho de 2023.

1 st data collection matrix (October, 2022)	2 nd data collection matrix (July, 2023)			Row (Total)
	Food non-poor - % (n)	Food poor (moderate) - % (n)	Food poor - % (n)	
Food non-poor - % (n)	18.33 (55)	13.66 (41)	23.67 (71)	55.67 (167)
Food poor (moderate) - % (n)	5.67 (17)	7.00 (21)	11.00 (33)	23.66 (71)
Food poor - % (n)	7.67 (23)	4.33 (13)	8.67 (26)	20.67 (62)
Column (Total)	31.67 (95)	24.99 (75)	43.34 (130)	

Source: Author's calculation from the computer print-out.

Fonte: Cálculo do autor, com base na impressão do computador.

Therefore, the ratio of the minimum food spending to usual food expenditure is around unity (0.94) for the food-secured household but higher (1.37) for the food-insecure group (Table 5). This evidence indicates that experiencing greater food insecurity is also expected to be significantly higher than their available resources. However, households' ability to manage resources may contribute to differences between food insecurity levels and vice versa. However, there might be other factors responsible for the food insecurity status of the household.

The study examined the seasonal variation and influence on food-secure households and found that during the on-farm period (harvesting season), 59.1% households are food-secure compared to 46% during the off-farm season (planting period). Hence, many households progressed into food-secure status during the harvesting season with a difference of 12.9%. Therefore, the study deduced the use of probabilities to ascertain the probabilities of households transitioning into food secured (non-poor) or not (Table 6).

Table 6. Modest entry and exit probabilities.

Tabela 6. Probabilidades modestas de entrada e saída.

Year (2022-2023)	Probability of entering FLW	Probability of existing FLW	Households moving out of FLW	Headcount (%)
October	0.23	0.37	39.6	40.8
July	0.31	0.33	31.7	35.3

Source: Author's calculation; Notes: N= 300. Headcount is for the second data collection.

Fonte: Cálculo do autor; Observações: N = 300. A contagem refere-se à segunda coleta de dados.

The results of this analysis revealed that the probability of households becoming food insecure, given that such households were food secure in the first period, was 0.23, and the probability of escaping food insecurity, given that such households were food non-poor, was 0.37. Similarly, the earlier methodological discussion showed the relationship between entry and exit probabilities and the steady-state food-insufficient headcount using the Markov model (with the ratio of the entry into and exit probabilities being equal

to the ratio of the proportion of food insecure, food poor and food secure, food non-poor). Therefore, the dynamic nature of the food secured status as evidenced in this study, interpreted by the use of panel data. The results of the analysis revealed the importance of examining factors influencing entries into and exits from a food security (non-poor) situation.

4.4. Determining food waste and factors influencing outcome

The study categorizes characteristics that can influence food waste and also the factors that triple this effect. The results of this analysis are presented in Table 7. The priority impact of determining food waste is keeping foodstuffs for long, and unfit to eat/expired foodstuffs (18.19%). Moreover, other factors determining food waste are as follows: Food stored is

unfit to eat 26% - 50%, Food stored is unfit to eat 1% - 10%, relying on Food gifts as a coping strategy, storing food cooked manually, among others (Table 7).

4.5. Food Loss Waste (FLW), Food Security Status Transition Matrix

The study examines Food Loss Waste (FLW) and Food Security Status Transition Matrix in the study areas, and the results are presented in Table 8. The study revealed that the category of respondents in the food non-poor and with Low FLW are 13.67%. Similarly, respondents with food poverty and with high FLW are 29.67% (Table 10). Hence, this study establishes that there was a relationship between FLW and Food security. High FLW is common among the food poor as 30% differentials from food-non-poor households.

Table 7. Determining food waste and factors influencing the outcome.

Tabela 7. Determinação do desperdício alimentar e dos fatores que influenciam o resultado.

s/n	Food waste characteristics	Classes of Food						Cooked food	Processed food	Row Total
		Cereals /Tubers	Protein	Fats & Oils	Minerals	Vitamins				
1.	Food cooked and finished with the family	51	33	39	24	45	84	75	351	
2.	Food cooked, remaining frozen	40	48	25	28	39	23	20	223	
3.	Food cooked, remaining stored manually	42	34	42	30	42	63	57	310	
4.	Food stored is available to eat 0%	15	18	26	35	15	35	48	192	
5.	Food stored is unfit to eat 1% - 10%	26	20	14	29	26	25	37	177	
6.	Food stored is unfit to eat 11% - 25%	18	14	5	12	12	0	0	61	
7.	Food stored is unfit to eat 26% - 50%	10	24	11	6	19	0	0	70	
8.	Food stored is unfit to eat above 50%	18	20	10	0	18	0	0	66	
9.	Food gifts about 1%- 10%	0	6	18	27	6	22	0	79	
10.	Food gifts about 11%- 25%	12	10	17	15	8	0	0	62	
11.	Food gifts about 26%- 50%	15	8	5	12	12	0	0	52	
12.	Food gifts are about above 50%	13	20	6	0	13	0	0	52	
13.	Food gifts none	4	2	4	9	4	0	0	23	
14.	Keep foodstuffs for long, and unfit to eat/expired foodstuff	36	43	78	73	41	48	63	382	
	Column Total	300	300	300	300	300	300	300	2100	

Source: Author's calculation from the computer print-out.
Fonte: Cálculo do autor, com base na impressão do computador.

Table 8. Food Loss Waste (FLW), Food security status transition matrix.

Tabela 8. Perda e Desperdício de Alimentos (PDA), Matriz de transição do status de segurança alimentar.

Food Loss Waste (FLW) Transition Matrix	Food Security Status Transition Matrix			Row (Total)
	Food non-poor - % (n)	Food poor (moderate) - % (n)	Food poor - % (n)	
FLW Low - % (n)	13.67 (41)	7.67 (23)	9.00 (27)	30.33 (91)
FLW Moderate - % (n)	7.33 (22)	1.67 (05)	4.67 (14)	13.67 (41)
FLW High - % (n)	10.67 (32)	15.67 (47)	29.67 (89)	56.00 (168)
Column (Total)	31.67 (95)	24.99 (75)	43.34 (130)	

Source: Author's calculation from the computer print-out.
Fonte: Cálculo do autor, com base na impressão do computador.

4.6. Determinants of food loss and waste in the food security nexus

Table 9 reveals that 13 of the 20 independent variables measured had their coefficient values significant at different levels. Fundamental variables that significantly stimulate food insecurity gap are as follows: X₁ = household size, X₂ = level of education (years), X₆ = farming/ fishing experience, X₇ = hired labor, X₈ = dependency ratio, X₉ = expenses on food, X₁₀ = farming/ fishing income, X₁₂ = expenses on non-food items, X₁₃ = expenses on inputs, X₁₄ = non-farm rural activities income, X₁₈ = market facilities, X₁₉ = asset status, X₂₀ = Estimates of FLWpc.

The explanatory variables that influence the FLW are as follows: X₁ = household size, X₂ = level of education,

dependency ratio, X₉ = expenses on food, X₁₀ = farming/fishing income, X₁₄ = non-farm rural activities income, X₁₈ = market facilities, and X₁₉ = asset status. The study deduced that socio-economic variables jointly depend on FLW and Food insecurity. Thus, implies that the marginal effects of variables that measure well-being (food spending needs) differ among households. Hence, this outcome can be a basis for forecasting the food security risk, particularly those in the moderately and core food-poor households. However, studies contended that poor households influenced by FLW can also enhance food insecurity (CAFIERO et al., 2024; SCHNEIDER et al, 2024). The marginal effects predicting food insecurity and FLW results are presented in Table 10.

Table 9. Determinants of FLW reduction practices among farming households.
Tabela 9. Determinantes das práticas de redução de desperdício de alimentos entre famílias agrícolas.

Particulars (Variable)	Estimates	t-values
X ₁ = household size (number)	0.043	2.430**
X ₂ = level of education (years)	0.004	4.873***
X ₃ = age (years)	0.352	0.814
X ₄ = marital status of household head	0.583	1.258
X ₅ = sex of household head	0.818	0.913
X ₆ = farming/ fishing experience (Naira)	0.072	2.143*
X ₇ = hired labor (Naira)	-0.053	-2.185*
X ₈ = dependency ratio (No.)	-0.002	-5.823***
X ₉ = expenses on food (Naira)	-0.018	-3.818***
X ₁₀ = farming/fishing income (Naira)	0.013	2.281*
X ₁₁ = farm size/fishing pond size (Ha)	0.137	1.673
X ₁₂ = expenses on non-food items (Naira)	0.037	3.015***
X ₁₃ = expenses on inputs (Naira)	0.002	7.235***
X ₁₄ = non-farm rural activities income (Naira)	0.003	6.928***
X ₁₅ = income consumed outputs (Naira)	-0.081	0.813
X ₁₆ = access to extension facilities (dummy), if access = 1, otherwise = 0	0.178	0.0738
X ₁₇ = access to credit facilities (dummy), if access = 1, otherwise = 0	0.083	0.1878
X ₁₈ = market facilities (dummy), if access = 1, otherwise = 0	0.002	4.836***
X ₁₉ = asset status (measures in Naira)	0.073	2.328**
X ₂₀ = Estimates of FLWpc (measures in Naira).	-0.004	-11.853***

Source: Computer-generated results. Notes: ***, **, *Significant at 1, 5, 10 percent, respectively.
Fonte: resultados gerados por computador. Notas: ***, **, * Significativo a 1%, 5% e 10%, respectivamente.

Model Results of OLS estimates of the simultaneous equation model.
Resultados do modelo de estimativas OLS do modelo de equações simultâneas.

Source	SS	Df	MS	Diagnostic
Model	224.819549	4	112.409794	No of Observation = 3
Residual	144.797694	296	314.777896	F(4, 296) = 418.58
Total	369.617243	300		Prob. > f = 0.000
				R. Squared = 0.6079
				Adjusted r – Square = 0.5836
				Root MSE = 1.7741

Table 10. Marginal effects of selected variables in the simultaneous equation model of FLW status.
Tabela 10. Efeitos marginais de variáveis selecionadas no modelo de equações simultâneas do status FLW

Particulars (Selected Variables)	Estimates		
	FLW Low (Food non-poor)	FLW Moderate (Food poor)	FLW High (Food poor)
Constant			
X ₁ = household size (number)	0.07*	0.018**	0.031***
X ₂ = level of education (years)	0.149***	0.012	0.023
X ₆ = farming/ fishing experience (Naira)	0.119**	0.372**	0.475*
X ₈ = dependency ratio (No.)	0.018*	0.0341	0.697***
X ₉ = expenses on food (Naira)	0.0089*	0.0049***	0.0019
X ₁₀ = farming/fishing income (Naira)	0.18*	0.12*	0.28**
X ₁₂ = expenses on non-food items (Naira)	0.013	0.09	-0.037***
X ₁₄ = non-farm rural activities income (Naira)	0.078*	0.024	0.022**
X ₁₅ = income consumed outputs (Naira)	0.0018	-0.0185	- 0.0217
X ₁₈ = market facilities (dummy), if access = 1, otherwise = 0	0.038*	0.0184	0.0241

Source: Computer-generated results. Notes: n = 300. ***, **, *Significant at 1, 5, 10 percent, respectively.
Fonte: resultados gerados por computador. Observações: n = 300. ***, **, *Significativo a 1, 5 e 10 por cento, respectivamente.

The study established the linkage between the FLW and the food security (Food non-poor) nexus. The results of this analysis are presented in Table 10. Table 10 revealed the odds ratios (OR) of various independent variables. Household size and income variables indicated a very strong influence of FLWs in the food security nexus. Although education, dependency ratio and income from secondary sources had significant variables across some categories. The study deduced that an additional increase of 10 percent in household size (X₁) enhanced food poverty by 0.73%, and an increase in moderately food poor by 0.18% and food non-

poor by 0.007 %, respectively. Similarly, the estimated marginal effects of a 10 percent increase in the dependency ratio would enhance food poverty by 0.7%, which is not significant for the moderately food poor. Still, they would enhance the food non-poor by 0.11%. Moreover, 10% increase in farm/fish income would enhance 0.28% for food-poor, 0.12% for moderate food-poor and 0.48% 0.12 for food-non-poor. The estimated marginal effects of a 10% increase in food expenses enhances 0.89% for food non-poor and 0.49% in moderately food non-poor. In addition, the effects of a 10 percent increase in the income consumed

outputs (X_{15}) have an opposite effect to that of an increase in minimum spending needs, particularly in the moderately and food-poor households.

This result is consistent with the earlier findings of past studies (KAFA; JAEGLER, 2021; CELA et al., 2024). These studies argued that the marginal propensity to consume food marketable outputs at home (that could have earned income) is higher than exchange farm outputs for income. The marginal effects are of larger magnitude for the food-poor groups. This result suggests that income earned from the sales of marketable surplus outputs has a relatively larger effect on reducing food-insecure situations among the core food-insecure category. The contribution of non-farm income (X_{14}) to food nonpoor is significant at a 1 percent level. Therefore, evidence is being established here that more participation in non-farm activities is likely to be in food non-poor and Low FLW. The positive correlation indicates that they are affected in the same direction by random shocks. The results also show that household size (X_1), dependency ratio (X_8), income consumed outputs (X_{15}) and farming/fishing income (X_{10}) influenced food insecurity positively, i.e., the higher these variables, the poorer the food insecure situation.

4.7. Hausman Specification Test (HST)

The Hausman specification test was conducted to test the simultaneity in the relationship between the FLW and food insecurity (food poverty). The endogenous variables in the model, such as compounded Household Income (food insecure) and the FLW, are analyzed individually in relation to the rest of the predetermined variables by using the Ordinary Least Squares (OLS) method. The unstandardized predicted value and residuals are saved. Once this is accomplished, another endogenous variable is created from the residuals and included in the analysis as an explanatory variable. If the t-value for this variable is statistically significant and greater than or equal to 2, then it can be concluded that there is simultaneity (MILLS; ZANDVAKILI, 1997; PAUDEL, 2004).

The following are the results after performing the HST.

$$\Delta V_t = 12.247 - 0.326\Delta G^* + 0.145\epsilon^* \tag{20}$$

t - value -5.147 2.17

$$\Delta G \{y(t)\} = 28.146 - 1.583\Delta t^* + 0.126\epsilon^* \tag{21}$$

t-value -5.101 -1.583 2.46

where: ΔV_t = FLW reduction, $\Delta G \{y(t)\}^*$ = estimated unstandardized predicted value of growth of real output from reduced-form equation by OLS, ϵ^* = saved residual value while estimating unstandardized predicted value of compounded LDI, $\Delta G \{y(t)\}$ = computed household income, ΔV_t^* = estimated unstandardized predicted value of compounded ΔV_t from the reduce-form equation by OLS, and ϵ^* = saved residual value while estimating unstandardized predicted value of compounded household income. These estimated coefficients for the ϵ^* variables are statistically significant and greater than 2 in both equations, implying that there is simultaneity between compounded changes in V_t and agricultural/economic growth. Equations 20 and 21 present the results from the reduced-form equation (as in $\Delta G \{y(t)\}^*$ and ΔV_t^*), expressing endogenous variables as functions of exogenous or predetermined

variables only. Their parameters measure both the direct and indirect influence of exogenous variables on endogenous variables. These reduced-form parameters are composed entirely of structural parameters (GASCON et al., 2022). The reduced-form parameter is a combination of some structural parameters.

4. DISCUSSION

4.1. Policy implications of the findings

The study deduced that FLW occurs across the entire food supply chain, where higher rates of food loss (reduction in quantity or quality from production to distribution) were indicated. This study deduced that FLW was due to factors like inadequate infrastructure and post-harvest handling. In contrast, developed countries, particularly those with high urbanization, experience higher levels of food waste at the retail and consumer levels. This is often linked to consumer behavior, aesthetic standards for produce, and overproduction (THORSEN et al., 2024).

Reports from FAO 2025 estimates indicated that roughly 14% of food is lost from harvest to retail, excluding retail losses, while a recent UN report highlighted that 17% of food is wasted at the retail and consumer levels (OECD/FAO 2025). These reports documented that a more FLW has significant environmental and economic consequences. Hence, reducing FLW can improve food security, reduce greenhouse gas emissions, and improve resource utilization.

Review of past studies revealed that addressing food waste requires changes in consumer behavior, supply chain optimization, and policy interventions (OLABODE et al., 2025; OECD, 2025). Therefore, investing in agricultural extension services to educate farmers on best practices for harvesting, handling, and storage can significantly reduce losses. In addition, developing and improving cold-chain infrastructure, including refrigeration and storage facilities, can help maintain food quality and reduce spoilage, especially in regions with limited access to reliable electricity. Hence, policies that can facilitate food redistribution from surplus to those in need, such as tax incentives for food donation, can reduce waste and address food insecurity. In addition to boosting public awareness campaigns programmed aimed at changing consumer behavior, promoting responsible food consumption, and reducing household waste are crucial.

The study revealed the extent of FLW, identified its causes and its influence on food security, economic well-being, and environmental sustainability. Food loss and waste (FLW) studies in Nigeria are crucial for understanding and improving household food systems. Hence, policies that will strengthen the development and adoption of technologies like smart inventory management systems, energy-efficient processing, and packaging solutions can also play a role in reducing food loss and waste. This suggests that a policy that can influence income increase can also do the same to improve FLW reduction. Thus, the study finding revealed that reducing FLW has a significant effect on food non-poor (Low FLW). The results suggest that there is a curvilinear relationship between the course of the FLW reduction and food security enhancement.

5. CONCLUSIONS

"Do food waste interventions hold the potential of making an effective contribution to the food security nexus?" was the question that the study attempted to answer. By

examining the shift between food loss and waste reduction in the food-security relationship among farming households in Southwest Nigeria, the study provides an answer to this query. The study findings supported the notion that food waste is a major issue and hardship for households in southwest Nigeria. According to the study, micro-scale food security circumstances may be directly and temporarily impacted by FLW reduction initiatives. Although the study is only a pilot study, it can have a substantial impact when incorporated into a larger value chain or food system approach. According to the study's findings, in certain situations, food insecurity may also be largely caused by FLW. However, there is no one solution that can be used to reduce food waste in general. Reducing waste can help achieve the goal of improving food security, especially when it comes to increasing the food supply in a reasonably efficient manner, but additional steps will be required. This is especially true since efforts to reduce food waste typically concentrate on just one aspect of food security - food availability. Future research may address the relative undervaluation of access, utilization, and stability in waste interventions and related literature.

Using two seasons, this study introduced a novel way to investigate the relationship between food security status and FLW in transition. In order to explain the generation of food waste, a model was subsequently developed that integrated the transition to food insecurity with conventional consumer waste-related behaviors. But even though this paper adds something new to the discussion, there is still a lot to learn about this topic. This paper emphasizes the incentives to reduce food loss and waste as well as the significant connection between FLW reduction and the food security nexus. According to the study, there is still a high prevalence of food poverty among farming households in southwest Nigeria. Large household sizes, high dependent ratios, income-consumed outputs, and non-food expenditures have all been found to be contributing factors to temporary food insecurity. Food security (not food poverty) is a feature of households of a reasonable size. The majority of families experiencing food insecurity were primarily farmers, had a high dependency ratio, and had low levels of education.

Transition households experiencing food insecurity had a strong correlation with low FLW, income generation and seasonal agricultural harvest fluctuations. As income generation declines over time, food security (or food non-poor) households experience an increase in food insecurity (FLW). Thus, a policy on FLW reduction and a more varied occupational structure that can add value to labor time for reasonable income support are recommended. Additionally, compared to households in the food sufficiency class, food-insecure (food-poor) households spend less per person to meet their basic needs, have a higher rate of non-participation in non-farm activities, and thus experience a larger gap between their perceived (subjective) minimum food spending needs and their available resources. Increases in educational attainment have a comparatively greater impact on altering the status of food insecurity, and the marginal effects of FLW and the degree of food insecurity are positively connected. The food security status of households and the FLW of the identified households were simultaneously calculated, and the results showed a simultaneity. Therefore, policies that have an impact on income growth can also have an impact on FLW reduction. Therefore, this result showed that food non-poor (low FLW) is significantly impacted by lowering

FLW. The findings imply that the improvement of food security and the duration of the FLW reduction have a curvilinear relationship.

The study has provided a deeper understanding of FLW within the context of Nigeria's household food systems. The study also identified gaps in knowledge and research priorities, guiding future research efforts to address further the challenges of food loss and waste in Nigeria's household food systems. This is essential for developing effective strategies to enhance food security, improve livelihoods, and promote sustainable development. Fallout from this study revealed that the understanding of the FLW issue moves beyond simply quantifying loss to analyzing its causes and potential solutions. Hence, there is a need for newer research to focus on specific commodities, regional differences, and the effectiveness of interventions, including those addressing post-harvest handling, storage, and processing, particularly in developing countries like Nigeria. Although several studies now recognize the stark differences between food-producing and food-consuming regions, such as the north and south of Nigeria. This will help to tailor interventions to specific contexts, such as addressing conflict and infrastructure challenges in the north. A significant shift is towards understanding and addressing post-harvest losses, including those occurring during handling, storage, and processing in the south. This is crucial in regions where these losses are particularly high, as highlighted in studies on Sub-Saharan Africa. While global estimates of FLW are important, newer studies emphasize the need for localized solutions and interventions that consider the specific context of each region, like Nigeria. There's growing recognition of the role of consumer behavior and awareness in reducing food waste at the retail and household levels. In essence, recent studies on FLW in Nigeria and globally are moving beyond simple quantification to a more in-depth understanding of the issue, its causes, and potential solutions tailored to specific contexts.

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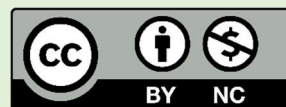
Authors' contributions: T.G.A. and K.O.: conceptualization, defining the research question and objectives; O.O. and M.O.A.: data curation, managing and organizing data; A.T.G. and A.A.: formal analysis, applying statistical or computational methods; A.T.G. and T.O.O.: writing, creating the initial draft or revising the manuscript; A.T.G. and A.A.: supervision, providing guidance and oversight; A.T.G. and O.K.: funding acquisition, securing financial resources for the research. All authors have read and agreed to the published version of the manuscript.

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Conflict of interest: The authors declare that they have no conflict of interest.



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