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Article

Impact of Income Share on Dietary Diversity of Primary Actors in the Tomato Supply Chain in Nigeria

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Abstract: The tomato supply chain is not well depicted, which affects the income share of the farmers, as a result, they face difficulties in accessing food. Therefore, the study investigated the impact of the income share of primary actors on household dietary diversity in the tomato supply chain. A multistage sampling procedure was used to select 800 participants for this study. The data were analysed using a zero-one inflated beta regression model, the Herfindahl-Hirschman index (HHI), and the Household Dietary Diversity Score (HDDS). The findings revealed that marketers earn the most (84% of total income) in the supply chain. The remaining 16% of the income is split between farmers (15%) and transporters (1%). A larger percentage (63%) of the farmers consumed 3 food groups or fewer. It was further found that income share, along with other socioeconomic characteristics such as gender, age, formal education, farming experience, informal education, the average tomato yield, years of experience in tomato farming, number of working-class farm members, cooperative membership, access to credit service, and processing with various methods, had a significant impact on the probability and intensity of food security. The study indicated that greater revenue among tomato supply chain players enhances their households' food security.

Keywords: Earnings; Food security; Value chain; A zero-one inflated Beta regression model

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1. Introduction

Agriculture is the key source of revenue for many developing countries, including Nigeria, and will continue to account for a significant portion of GDP (World Bank, 2011; Abdullahi et al., 2015; Kehinde et al., 2022). The sector also has strong export revenue potential, which may greatly boost the country's foreign exchange revenues. Tomato farming is widely practised in Nigeria. Small-scale farmers account for 90% of production, planting on land ranging from 0.5 to 4 hectares, with commercial farmers accounting for the remaining 10% (Sahel study, 2015). Nigeria has the greatest area used to cultivate fresh tomatoes in Africa, with 541,800 ha, followed by Egypt at 214,016 ha (Mustapha et al., 2020). Nigeria is Africa's second-largest tomato grower and the world's 14th-largest tomato producer (FAOSTAT, 2019). The comparative advantage of tomatoes positions Nigeria to dominate global production and exports (Ugonna et al., 2015). Nigeria's annual tomato production is predicted to be around 1.8 million metric tons, accounting for approximately 68.4% of West Africa's output, 10.8% of total African production, and 1.28% of global production (FAO, 2020). Tomato production and marketing provide food and employment opportunities for both industry workers and tomato consumers (Oladapo et al., 2011), and its production, handling, shipping, distribution, and marketing involve a large number of people. Tomatoes can be processed and exported to other West African nations apart from being sold domestically. In addition to their economic advantages, tomatoes and foods containing them offer a variety of nutrients and numerous health advantages to people. In the region where it is grown and consumed, it is a vital component of the nutrition of the entire populace. Tomato is, therefore, of great value to human development and has the capacity for poverty alleviation (Kalidas and Sureka, 2014; Shuaibu and Mohammed, 2015).

Despite many advantages of the crop, production and marketing are unprofitable in most developing nations, including Nigeria, due to a variety of issues. Participants in the supply chain may experience challenges with marketing, post-harvest management, sustainable production, or any combination of these. Among these challenges, post-harvest issues are the most important (Obayelu et al., 2019). Many smallholder producers, processors, distributors, retailers, and exporters face post-harvest challenges as they manage food from harvest to the final client. Post-harvest difficulties in the tomato business might emerge on or off the farm. Farmers encounter a variety of challenges, including an inappropriate harvesting stage or period, ineffective harvesting machinery, high field heat, a lack of efficient storage and transportation facilities, ineffective packing materials, and inadequate field sanitation. Lack of access or poor road conditions, incorrect modes of transportation, a lack of processing facilities or factories, improper retail packaging, and a lack of reliable markets are all examples of off-farm concerns (FAO, 2020). The losses happen at every stage of the supply chain, including harvesting, packing, storing, transporting, retailing, and consuming (WFLO, 2010). Both developing and developed countries face substantial losses following the harvest of tropical fruits, which range from 10 percent to 80 percent. (FAO, 2006; Kitinoja et al., 2018). Poor handling, processing, and preservation methods result in the loss of 40–50% of the Nigerian tomato crop (Sahel research, 2015). The steps of processing, packaging, and distribution account for more than 45% (750,000 metric tonnes) of tomato waste. High post-harvest losses in the supply chain for tomatoes have been associated with poor infrastructure and transportation, poor farming techniques, a lack of expertise in post-harvest handling, and complicated marketing systems in the majority of developing nations (Obayelu et al., 2019). The primary causes of the loss are high rates of bruising, transpiration of moisture, and subsequent degradation during processing after harvest (Kaminski and Christiaensen, 2014). Before fresh tomatoes reach customers, the issues around post-harvest handling and storage may have an even greater impact on their quality.

All these concerns cause tomatoes to live shorter lives, resulting in lower quality and quantity of tomatoes on the market, forcing both farmers and traders to market their produce at low prices. Farmers' profits are reduced after harvest, which leads to supply chain inequality (Sablani et al., 2006; Babalola et al., 2010). Both rural and urban populations rely on tomato production and sale for income, thus, any drop caused by post-harvest loss will not only affect the income of the producers and traders but will also affect the income share between them. This shows that one way to boost income and eliminate income disparities is to reduce losses dramatically after harvest. A measurement of the distribution of income among supply chain participants is known as income inequality (Adeyemo and Kehinde, 2021). It is a comparative analysis of the income disparity within and between groups (Obayelu et al., 2019). However, the majority of tomato supply chain participants, particularly farmers, earn meagre wages that barely cover their subsistence needs. High inequality indicates that a group of supply chain actors will always be at a disadvantage (Kunawotor et al., 2020). Economic literature acknowledges that the poverty of the actors is significantly impacted by global income inequality (Donkor et al., 2022). Their low income, which limits their economic prospects, keeps them trapped in a vicious cycle of poverty (Kolawole et al., 2020; Kehinde and Ogundeji, 2022a; Adesiyan et al., 2023). Despite their low living standards, the investment patterns of participants in the tomato supply chain are heavily influenced by their socio-cultural origins. There is less research on the impact of losses following harvest on income and inequality among supply chain actors in Nigerian tomatoes. This differential between income shares among actors, most times, accounts for the food insecurity existing in the tomato supply chain (Donkor et al., 2022). This is because their current level of income has a significant impact on their food expenditure pattern.

According to several authors, improving supply chains is essential to boosting the quality-based competitiveness of domestic agricultural products, which will consequently promote food security and help eradicate poverty (FAO, 2014). Food insecurity is a widespread issue among tomato supply chain actors, caused by their inability to produce enough for the entire population due to low per capita income, a lack of social infrastructure and information flow, and high input costs, among other factors (Effiong and Enyia, 2022). This issue had resulted in malnutrition, which is an indicator of poverty (Adeyemi et al., 2020; Effiong and Enyia, 2022; Akande et al., 2023). This circumstance results in low levels of investments, savings, output, and a lack of demand for basic quality food; thus, the players continue to live in a vicious circle of poverty. The actors have persisted in coping with a range of economic circumstances that affect their standard of living and food security, resulting in gaps in resource distribution and a sizable discrepancy between household demand and supply of food. As a result, the food situation worsens, leading to increased food insecurity. It has not been proven that the actors' revenue alone is sufficient to cover household needs, particularly those related to food. This situation will continue uninterrupted until a conscious intervention is made to put an end to this unpleasant tendency. It is critical to ensure that the major actors in the tomato supply chain share the potential benefits of the market evenly. If only a few actors in the supply chain profit the most, income inequality is likely to worsen. Therefore, to make informed changes, it is necessary to understand how earnings are allocated among the actors of the chain as well as other factors that affect food security. Therefore, identifying and comprehending this fundamental part of the well-being of individuals and subgroups of individuals with extremely severe illnesses can be aided by monitoring food security (Kehinde et al., 2024). These contributions would lessen rural poverty and improve Nigeria's food security (Kehinde and Ogundeji, 2023; Ogunleye et al., 2024).

Even though there has been a lot of research on tomato products, most of it has concentrated on the production and economic analysis of certain supply chain members. However, in Nigeria, the supply chain as a whole received little or no attention. Even though smallholder farmers in the districts mostly grow tomatoes, it is unclear which actors benefit the most and who benefit the least from the product. To find potentially practical policy actions to be implemented to increase the income and well-being of tomato supply chain members, a study of this sort is required. This contrasts with previous initiatives that were unable to enhance the well-being of actors to a sustainable level because they did not account for their income sharing. So far, most studies undertaken on tomato supply chains have focused on postharvest losses. (Abay, 2007; Meaza et al., 2007; Adugna and Teka, 2009; Alemnew, 2010; Meseret, 2010; Temesgen et al., 2011; Birhanu, 2011). There has been no comprehensive research into the income shares of participants in the tomato supply chain and their impact on food security. This study addresses the following research questions: How are incomes distributed among the various stakeholders in the tomato supply chain in Nigeria? Does the income share of actors affect their food security? Using the novel inverse Herfindahl index and a zero-one inflated Beta regression model, our paper makes a significant contribution to the body of knowledge on supply chains by enhancing the knowledge of the distribution of income within the main actors (primarily farmers and markets) across the Nigerian tomato supply chain. The study gives insight into the factors influencing the food security of tomato supply chain participants. The findings of the study have policy implications for lowering income inequality and guaranteeing long-term sustainable food security for Nigerian supply chain actors. Policymakers can use the study's findings in the development of plans for the supply chain's sustainable production and marketing of tomatoes. Furthermore, the findings of the study would provide information that would be beneficial to Nigerian corporate groups, tomato producers and merchants. More specifically, policymakers would utilize the information to amend, create, or update current policies.

2. Literature review

The literature indicates an increasing interest in understanding household and individual dietary diversity, owing to its importance in achieving nutrient requirements (Labadarios et al., 2011) and nutrient adequacy (Swindale and Bilinsky, 2005; Kennedy et al., 2009). Dietary diversity could serve as a realistic proxy measure of household or individual food security due to its ease of measurement and reflection on major food security pillars (Thorne-Lyman et al., 2009; Vakili et al., 2013). With this backdrop, numerous socioeconomic characteristics (income, education, and age) may influence individuals' dietary diversity (Thiele and Weiss, 2003; Thorne-Lyman et al., 2009), which is important to understand for policy recommendations and food security interventions. Dietary diversity refers to the number of individual foods or food types ingested over a certain period. Dietary variety is typically quantified by adding the number of foods or, more commonly, by calculating the number of food types ingested over a given time (Ruel, 2002; Vakili et al., 2013). Vakili et al. (2013) proposed that dietary diversity can be utilized as a proxy indicator of household food access and a reflection of nutritional quality at the individual level. The reference time is typically one to three days, while seven days are also commonly used (FAO, 2011), and spans of up to 15 days have been documented. Household dietary diversity can be linked to food availability, access, and use, which are essential components of food security. Availability refers to the existence of food that may be obtained from its production or the market, whereas accessibility refers to households' ability to obtain diverse food in sufficient quantity and quantity, which is determined by household income and price.

Several researchers have noticed that there are few recommendations for measuring dietary diversity and propose that counting the number of different foods or food groups consumed could be a good indicator. It is a helpful measure of family food security because questions about dietary diversity can be posed at the household or individual level, allowing researchers to investigate food security at both the household and intra-household levels. Participants also find the questions simple to answer, and they do not take long. Third, consuming a variety of foods is an acceptable outcome. Fourth, a wider diversity of foods is linked to many favourable outcomes, including a lower risk of death from cardiovascular disease and cancer (Hoddinott and

Yohannes, 2002). Some researchers have investigated the relationship between the number of particular foods or food types and nutrient adequacy (Hatloy et al., 1998; Ruel 2002). Common dietary variety measures used in developing countries include those based on a basic count of foods or food groups, while others evaluate the number of servings of various food groups following dietary standards (Ruel, 2002). Several African studies employed food group counts in Ethiopia (Arimond and Ruel, 2002) and Niger (Tarini et al., 1999), as well as the number of specific foods consumed in Kenya (Onyango et al., 1998), Ghana, and Malawi (Ferguson, 1993).

Studies (Hatløy et al., 2000; Ogle et al., 2001; Hoddinott and Yohannes, 2002) suggest that dietary diversity can be measured using a combination of single and group meal counts. In Mali (Hatloy et al., 1998) and Vietnam (Ogle et al., 2001), researchers employed both single food counts, known as food variety scores (FVS), and food group counts, known as dietary diversity scores (DDS). The Mali study made a useful contribution by demonstrating that DDS (based on food groupings) was a stronger predictor of nutrient sufficiency than FVS (based on individual foods). Increasing the number of food groupings has a bigger influence on nutritional intake than increasing the number of individual foods. This is because the elements required to meet nutritional requirements are not contained in a single food item (excluding human breast milk in the first month of life) but rather in a diet that includes numerous food groups (Hsu-Hage & Wallqvist, 1996). HDDS is calculated by adding all of the food groups consumed within the family over 24 hours (FAO, 2020). HDDS is a systematic free recall of food items ingested by households in the previous 24 hours (Huluka et al., 2019). Following FAO (2022), this study employed HDDS as an indicator of family food security measures. This food security indicator evaluates food diversity based on dietary quality and adequacy. Dietary diversity has an advantage in validating the degree of heterogeneity in household dietary patterns as well as the households' economic capacity to consume a varied range of food items (Mango et al., 2018). To acquire dietary diversity data from the investigated families, a 24-hour food recall was used. Following (Mutengwa et al., 2023; Wekesa et al., 2018), numerous food products consumed in the research sites were listed, and respondents were asked to select the ones they had ingested within the previous 24 hours. Following (FAO, 2022; Huluka et al., 2019), the list of household food items consumed was then divided into twelve traditional categories.

3. **Materials and methods**

3.1. Study Area

The study was conducted in Nigeria. Tomatoes are grown in most of the Nigerian States. Tomatoes are grown largely in the northern region of the country. These states are among the top producers of tomatoes. The tomato-producing states of Nigeria are Kano, Taraba, Gombe, Bauchi, Kaduna, Sokoto, Zamfara, Katsina, Jigawa, Delta, Kwara, Oyo, Borno, Bauchi, and Plateau. These states included about five of Nigeria's six geopolitical zones. These states produce roughly 80% of the tomato crops in the nation. Kano has been the most successful in this area. Additionally, Nigeria accounts for 2% of global tomato production. In 2010, Nigeria had its highest tomato yield (20-25 t/ha) (FAOSTAT, 2014). They bloom at temperatures ranging from 25 to 34 degrees Celsius. Tomatoes are also highly susceptible to humidity and rainfall. The tomato growing season in these areas is from August to September. The tomato supply chain includes actors such as producers, traders, and transporters scattered across different states in Nigeria (Figure 1).

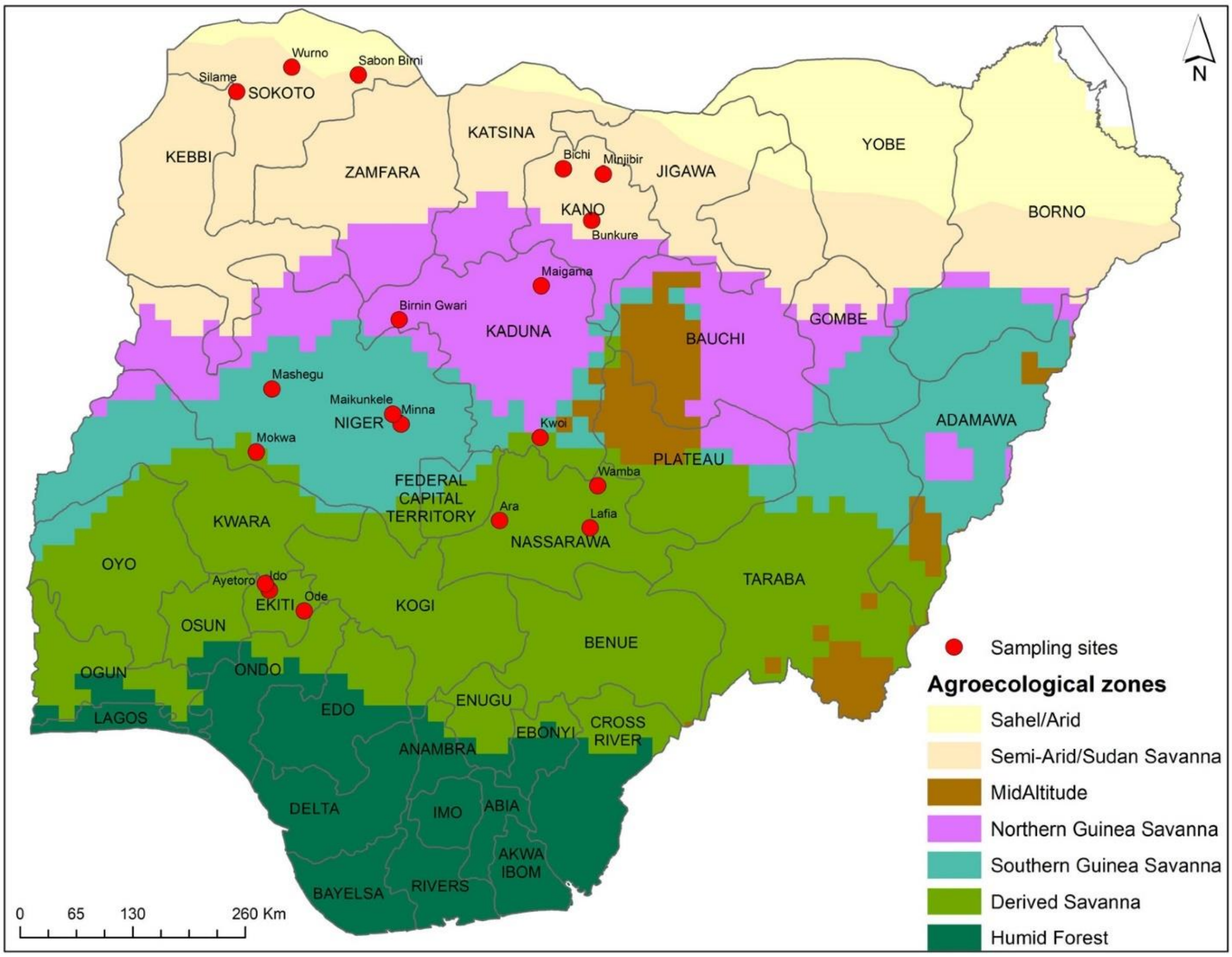

Figure 1: Tomato-producing States in Nigeria.

Source: Google map, 2019 Accessed from https://www.researchgate.net/publication/314174390_Report_Horticultural_Study_Nigeria/figures?lo=1 at 4/10/2024.

3.2. Sampling procedure

A multistage sampling procedure was used to select respondents for the study. This paper is based on a farm household survey, and the data collected were for the 2021/2022 cropping season through personal interviews. Each geopolitical zone of the country was assigned a state based on the predominance of production and consumption in the supply chain. Participants were drawn from the producers/farmers, traders, and transporters across the selected States.

The number of respondents for the study was obtained using Yamane's Formula for sample size (Eq 1)

$$n = \frac{N}{1 + N(e)^2}$$

Where n = sample size, N = population size, e = level of precision or sampling error (5%). After determining the sample size required for the study, Participants for this study were drawn from the tomato supply chain using a multistage sampling technique. In total, 800 participants (tomato producers, marketers and transporters) along the supply chain were selected.

Producers- Tomato producers were selected across the six geo-political zones in Nigeria to ensure wider coverage for the study. About 80% of the farmers chosen for this study were from the North because the North accounts for 80% of tomato output. Two states were purposefully chosen from each of the three geopolitical zones in the North based on tomato production volume, with one state from each of the remaining geopolitical zones. The list of tomato producers in the chosen state was collected from the State Ministry of Agriculture. A random sample technique was used to select 300 tomato farmers from the selected states.

Marketers- Tomato traders were selected across eight (This figure is based on the total number of states chosen for tomato producers in this study) major tomato markets within the six geo-political zones in Nigeria to ensure wider coverage for the study. Tomato marketplaces were purposively chosen based on the number of tomatoes sold in each market. The list of tomato traders in each market was obtained from the tomato traders' association in each market. 50 traders from each market were chosen using a random sampling procedure. A total of 400 traders were selected for this study across major tomato markets in Nigeria.

Transporters- Tomato transporters were selected across eight (This figure is based on the total number of states selected as tomato producers in this study) major tomato markets within the six geo-political zones in Nigeria. Between 10 and 15 transporters from each market were chosen using a random sampling technique. This survey included a total of 100 transporters from across Nigeria.

3.3. Analytical Techniques

First, descriptive statistics and independent sample t-tests were employed to analyze the data and describe the socioeconomic characteristics of farmers. The income shares of players in the tomato supply chain were then calculated using the inverse Herfindahl index and the household dietary variety score to determine the food security status of the actors. The maximum likelihood distribution of a zero-one inflated Beta regression was used to quantify the impact of income share on food security among tomato farmers along the supply chain.

3.3.1. The test statistic: t-test

This involved an independent sample t-test as shown in equation 1.

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}} \quad (1)$$

$\bar{x}_1$ = The mean value of the socio-characteristics of the farmers.

$\bar{x}_2$ = The mean value of the socio-characteristics of the traders

S_1 = Standard deviation of farmers,

S_2 = Standard deviation of traders,

n_1 = sample of farmers.

n_2 = sample of traders.

3.3.2. Herfindahl-Hirschman index (HHI)

The income shares of major actors in the tomato supply chain were determined using an inverse Herfindahl index, often known as the Herfindahl-Hirschman index (HHI).

This is expressed in Equation (2):

$$HHI = 1 - HI = 1 - \sum_{i=1}^{n} P^2 \quad (2)$$

where p is the proportion of each income of the actor to the overall income of the tomato supply chain.

3.3.3. Household dietary diversity score (HDDS)

It is feasible to inquire about dietary variety at the household or individual levels. This is the total quantity of different food groups consumed throughout a specific period. This refers to the number of different food categories consumed throughout a certain period. Food is divided into twelve categories: cereals, tubers and roots, fruits, vegetables, meats, eggs, fish, shellfish, legumes, nuts and seeds, milk and dairy products, oils and fats, sweets, spices, sauces, and beverages. The household over the 24-hour recollection period either ingested "1" or did not consume "0" the responses (FAO, 2012). The dietary diversity score of households ranges from 0 to 12, depending on how all the food groups are added together.

According to Kennedy et al. (2010), there are no predetermined cut-off criteria for the number of food groups that represent enough or insufficient dietary diversity for the HDDS. Equation (3) was used to calculate the household dietary diversity index (HDDI), which categorizes families as having low (≤3), medium (4-6), or high (≥6) dietary diversity.

$$\text{HDDS} = \frac{Number\ of\ food\ groups\ consumed\ by\ household}{Total\ number\ of\ food\ groups\ (12)} \quad (3)$$

3.3.4. The zero-inflated beta regression model

Let f_i be the HDDs of household i, c_i be the income share of the household head, and then $y_i = c_i - f_i$ is the capacity of the household to be food secure. Define the fraction of HDDs (h) required for a home to be food secured, as $v_i = \frac{h_i}{y_i} \in (,1)$, then household food security is not guaranteed if $\mathrm{t}v_i > z$,where $z \in (,1)$ a threshold at which food security is deemed out of bounds. The present literature uses either the binary logit or the probit to model the factors influencing food security. To address the previously identified difficulties with this technique, we simulated the factors that directly influence food security utilizing the variable f_i as a dependent variable. Because the proportion of food-secure households can have a point mass of zero, we adopt a sequential model that distinguishes between the extensive margin (whether the HDDs of specific houses are 0 or nonzero) and the intensive margin. The presence of zeros implies that some HDDs of households have both continuous and discrete components, and their density can be represented as a discrete-continuous density as follows in equation 4: (Ospina and Ferrari, 2012; Cook et al., 2008).

$$g(v;\mu,\emptyset,\pi) = \begin{cases} 0 & if\ v < 0 \\ \pi & if\ v = 0 \\ (1-\pi)f(v;\ \mu,\emptyset) & if\ 0 < 0 < 1 \end{cases} \quad (4)$$

$$\text{Where } f(v;\ \mu,\emptyset) = \frac{\Gamma(\phi)}{\Gamma(\mu\emptyset)\Gamma((1-\mu)\phi)} v^{\mu\phi-1}(1-v)^{(1-\mu)\phi-1} \quad (5)$$

is an illustration of a two-parameter beta distribution (Ferrari and Cribari-Neto, 2004, Smithson and Verkuilen, 2006) that gives the probability density of v on the interval (0, 1) and $\Gamma(.)$ represents the gamma function.

The gamma function is represented as a two-parameter beta distribution (Ferrari and Cribari-Neto, 2004, Smithson and Verkuilen, 2006) with probability density of v on the interval (0, 1) and $\Gamma(.)$. For the mixture density,$E(v) = (1-\pi)\mu$ and $(v) = \sigma^2 = (1-\pi)V(\mu) + \pi(1-\pi)\mu^2$, where $V(\mu) = \frac{(1-\mu)}{1+\phi)}$ is a variance equation in equation 5.

Given that, given a fixed μ, the larger the value of ϕ, the smaller the variance of v, the parameter μ is a location parameter, and the parameter ϕ is a precision parameter. The beta density takes on a variety of shapes based on the values of the factors. μ *and* ϕ.

Cook et al. (2008) proposed a zero-inflated beta regression based on the previously reported zero-inflated density, which was then generalized by Ospina and Ferrari (2012). The modification permits the modelling of the variance of v_i and the potential for one inflation. We employ the model by Ospina and Ferrari (2012) because it enables the handling of extra zeros in proportions as well as the modelling of the proportion's variance. The zero-one-inflated beta regression model is defined as follows. Assume that each v_i As a probability density function that is independently and identically distributed as in equation (6), the zero-inflated beta regression model is given by

$$f(v_i|x) = 1 - \Lambda(x_i'\alpha) \;\; if\, v_i{=}0 \qquad (6)$$

and

$$f(v_i|x) = 1 - \Lambda(x_i'\alpha) \;\; \left[\frac{\Gamma(\phi_i)}{\Gamma(\mu_i\phi_i)\Gamma((1-\mu_i)\phi_i)} v_i{}^{\mu_i\phi_i-1}(1-v_i)^{(1-\mu_i)\phi_i-1}\right] if\ 0 < v_i < 1 \qquad (7)$$

Where $\Lambda(.)$ is the strictly monotonic, twice-differentiable cumulative density function of a logistic distribution, α is a compatible variable vector, and x_i is a vector of exogenic regressors. The unconditional mean is represented as $E(v_i|x) = \Lambda(x_i'\alpha)\mu_i = \Lambda(x_i'\alpha)E(v|v\epsilon(0,1), x) = \Lambda(x_i'\alpha)\Lambda(x_i'\beta)$, where α and β are compatible variable vectors in equation 7. The unconditional mean is calculated using the chance that a household is food secure and the conditional mean of the degree of food security for the households. Predicted values of v_i are guaranteed to be bounded between zero and one by $\Lambda(x_i'\beta)$. If β_j is positive, then the covariate of income share x_j increases the food security of households.

We choose logit link functions for both equation (6) and the conditional mean $E(v_i|v_i\epsilon(0,1), x)$since they are compatible with previous research (Smithson and Verkuilen (2006) and Cook et al. (2008), which use proportional data).

A log-log link, a complementary log-log link, and a probit link are all possible link functions. For further details on link functions, see Smithson and Verkuilen (2006) and Ospina and Ferrari (2012). To determine if a variable contributes to the variance of v_i beyond its influence on the mean, the conditional precision parameter ϕ_i is represented as follows.

$$\phi_i = \exp\,(x_i'\theta) \qquad (8)$$

Where θ is a compatible variable vector. A positively signed θ_j *the* value indicates more precision, which reduces the variance or risk of food insecurity for the households. The log link function, consistent with previous research (Smithson and Verkuilen, 2006; Cook et al., 2008), was used to maintain the restriction of negative variances. Another alternative is the square root link function.

With precision, the zero-inflated beta regression is reduced to beta regression when $\Lambda(x_i'\alpha) = 1$, and without precision when $\Lambda(x_i'\alpha) = 1$ and $= \exp(x_i'\theta) = 1$. In a nutshell, the zero-inflated beta regression utilized in this study contains three sub-models. Equation (7), the first sub-model, captures the likelihood that a household is food secure on x. The second model, $\mu_i = \Lambda(x_i'\beta)$, is a location sub-model that examines how the average degree of food security varies with x about the income share. The third model, represented by equation (8), is a precision sub-model that allows one to assess if, given the mean, changes in x result in an improvement or deterioration of the food security of a household: The vector of exogenous variables for the three sub-models does not have to match, meaning that the exogenous variables may partially or completely overlap. The zero-one inflated beta regression parameters are estimated using maximum likelihood methods (Ospina and Ferrari, 2012). Data were gathered by the researchers and processed using social science package software (SPSS) version 23 and STATA software (ver. 18, College Station, TX).

The inclusion of these independent variables in the model was based on a previous expectation of the variable used and a review of the literature. These independent variables are expected to influence food security (Table 1).

Table 1. The prior expectation for the explanatory variables for the Probit model

Variables	Unit	Expected sign	Description	Studies
Gender	Dummy	+	1= male 0= female	Visser and Wangu (2021)
Marital Status	Dummy	+	1= if a farmer is married 0= otherwise	Lee et al. (2023)
Age	Year	+	Measured in years	Tambe et al. (2023)
Years of formal education	Year	+	Measured in years spent in school	Wudil et al. (2023)
Years of informal education	Year	+	Measured in years spent seeking informal education	Mutisya et al. (2016)
Main occupation	Dummy	+	1= agriculture 0= otherwise	Obayelu and Akpan (2021)
Farm size	Hectares	+	Measured in hectares	Edafe et al. (2023)
Farming experience	Years spent in farming	+	Measured in years spent in farming	Villacis et al. (2022)
Average tomatoes yield	Continuous	+	Measured in output	Wudil et al. (2023)
Tomatoes farming experience	Years spent in farming	+	Measured in years spent in farming	Garba (2024)
HHsize 6-14	Number of persons between 6-14 years	-	Measured in the number of household members between 6-14 years	Amao et al. (2023)
HHsize 15-64	Number of persons between 6-14 years	+/-	Measured in the number of household members between 6-14 years	Wudil et al. (2023)
HHsize above 65	Number of persons above 65 years	-	Measured in the number of household members above 65 years	Tamiru et al. (2016)
Membership in an agricultural cooperative	Dummy	+	1= if the farmer belongs to a cooperative 0= otherwise	Kehinde and Kehinde (2020)
Distance to market	Distance	-	Measured in Kilometre	Wudil et al. (2023)
Access to credit	Dummy	+	1= Access; 0= otherwise	Kehinde and Ogundeji (2022b)
Costing of processing	Continuous	-	Measured in Naira	Olugbire et al. (2016)
Income	Continuous	+	Measured in Naira	Orjiakor et al. (2023)

Sundry processing	Dummy	+	1= if, yes 0=otherwise	Tigabu and Gebeyehu (2018)
Access to extension service	Dummy	+	1= if, yes 0=otherwise	Aremu and Reynolds (2024)

4. Results and Discussion

4.1. Socioeconomic characteristics of the actors in the tomatoes supply chain

Table 2 shows the socioeconomic characteristics of the participants in the tomato supply chain. According to the HHI analysis, there are two primary actors in the tomato supply chain in this study.

Table 2: Socioeconomic characteristics of the actors in the tomatoes supply chain

Variables	Farmers	Traders	T-test
Age	42.76(10.98)	37.96(10.82)	3.08**
Experience	21.00(10.65)	13.18(9.08)	4.62***
Year of education	2.95(1.22)	2.80(1.05)	2.28**
			X^2-value
Main occupation	90.46	81.60	0.01**
Gender (Male) (%)	96.20	86.28	0.01***
Married (%)	93.85	78.84	0.02**
Observations	300	400	

Statistics in parenthesis are standard deviation *, ** &* represent significance levels at 1%,5% & 10%, respectively**

Source: Field Survey (2021).

The primary actors are farmers and traders because they bear all the financial responsibility in the supply chain. There is a considerable disparity in the mean age of farmers (42.76±10.98years) and traders (37.96 ±10.82 years) farmers in the study. This suggests that the farmers were relatively older than the traders in the supply chain. The years of academic achievement of actors are very different from one another. The years of schooling by farmers (2.95±1.2 years) were higher than the traders (2.80±1.05 years). This could indicate that farmers spent more time in school than traders in the tomato supply chain. The results showed that farmers (21±10.88 years) have more years of experience than traders (13.18±9.08). The majority (96%) of farmers are male though 86 % of traders are also male. The majority (93%) of farmers are married though 79 % of traders are also married. Most farmers (90%) have tomato production as their main occupation, while 82 % of traders market tomatoes as their main occupation. The result indicated a significant distinction in the primary occupation, gender and marital status of actors in the tomato supply chain. This result indicates the presence of selection biasedness and endogeneity in the selected sample.

4.2. Income of the various actors in the tomato supply chain

Figure 2 shows the income share of the supply chain's actors of tomatoes using the inverse Herfindahl index.

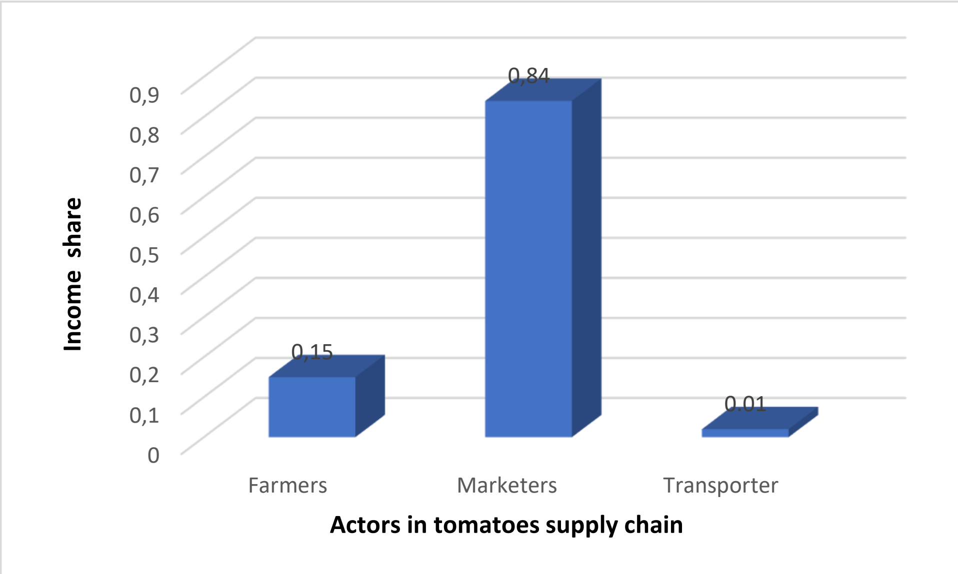

Figure 2: Income of the various actors in the tomatoes supply chain

Source: Field Survey (2022)

The inverse Herfindahl index, also known as the Herfindahl-Hirschman index, is the most appropriate statistic since it considers both the number of actors in the supply chain and their contributions to overall household income. Based on this, it classifies the actors into stakeholders and facilitators. The Nigerian tomato supply chain consists of two main actors and one facilitator. The actors are farmers and traders, while the facilitators are the transporters. The main activity of the facilitators is to ensure the movement of tomatoes from one point of the chain to another without any financial commitment. It can be deduced that traders have the largest share of income along the supply chain. They enjoy about 84% of the income flow along the tomato supply chain. While the remaining 16% of the income is shared among the farmers (15%) and transporters (1%). This result indicates that the traders have enough money to afford anything they want including food. According to the respondents during the field study, farmers are primarily responsible for the transportation of tomatoes. From the findings of the result and our observation during the field survey, we observed that the problem of food insecurity is intense among tomato farmers. Therefore, we further investigated the food security situation of tomatoes farmers.

4.3. Food security status of the farmers in the tomatoes supply chain

Further, the distribution of HDDs of tomato farmers in the supply chain is presented in Figure 3 using bar chat.

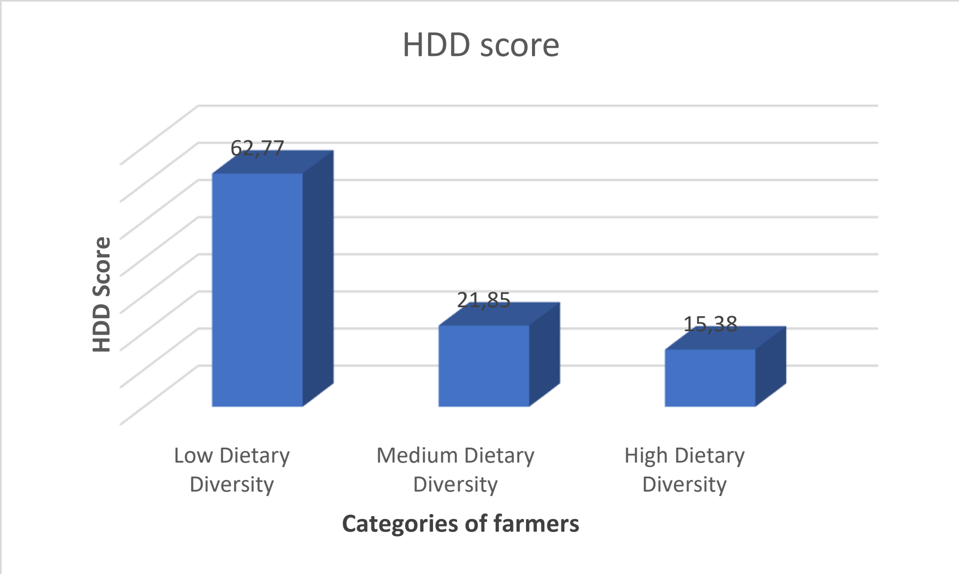

Figure 3: Food security status of the farmers in the tomatoes supply chain

Source: Field Survey (2022)

Dietary diversity measure of food security reflects nutrient adequacy and the financial capacity of a household to access a variety of food. Nutrient adequacy and dietary diversity score are directly correlated (Kennedy et al., 2010). Higher socioeconomic standing, particularly among farmers, is linked to greater dietary diversity. The HDDS ranged from 0 to 12. Cereals; roots and tubers; vegetables; fruit; meat, poultry, and offal; eggs; fish and sea foods; legumes, nuts, and seeds; milk and milk products; oils and fats; sugar/honey; sauces and beverages (FAO, 2007; 2008). These food groups were utilized to better depict the high-quality diets found in the study area's homes. This was accomplished using the 24-hour recall approach. The chart showed that a larger percentage (63%) among the farmers consumed 3 food groups and below. Also, within medium HDDS, 22% of the farmers consumed between 4 to 6 food groups, and among the high HDDS category, 15% of respondents consumed over 6 food groups. This implies that a larger percentage of farmers are food insecure. This further implies that the low-income share along the supply chain might have been one of the contributory factors to the low HDDs.

4.4. Impact of income on household dietary diversity of farmers along the tomato supply chain using the maximum likelihood of a zero-one inflated Beta distribution.

The maximum probability distribution of a zero-one inflated beta regression model was used to investigate the impact of income on household dietary diversity of farmers across the tomato supply chain. Table 3 displays the results of the double hurdle regression, which investigated the effect of income on the likelihood and intensity of household dietary diversity of farmers. The DH model's significance tests (log-likelihood = -122.902) support its use because they show that it is the best match. This shows that the probability and intensity of household dietary diversity of farmers are driven by two distinct processes and should thus be examined independently. The Double-Hurdle model has a Wald chi2 value of 184.10, a zero inflate constant of 5.560, and a Ln_phi of 0.968, indicating an excellent fit and statistical significance (p=0.000). The second hurdle employs a zero-one inflated Beta regression model to emphasize the factors that influence the intensity of household dietary diversity of farmers, while the first hurdle reveals the factors that influence the probability of household dietary diversity of farmers.

The first hurdle regression results show that among the socioeconomic characteristics of the farmers included in the model, gender, age, income, years of formal education, years of informal education, average tomato yield, years of experience in tomato farming, number of working-class members, cooperative membership, access to credit service, and processing with sun-dry methods all have a significant impact on the probability of household dietary diversity of farmers. Gender, age, income, years of formal education, average tomato output, years of tomato growing experience, cooperative participation, and access to finance are all positive and significant determinants of the household dietary diversity of farmers. On the other hand, the coefficient of the number of working-class individuals, tomato processing using sun-dry techniques, and years of informal schooling all had a substantial negative impact on the likelihood of household dietary diversity in the research area. Furthermore, the data show that increasing age, years of formal education, average tomato yield, years of experience in tomato farming, cooperative membership, and access to financial services improves household dietary diversity of farmers. While the increase in years of informal schooling, the number of working-class members, and processing with sun-dry methods would have an adverse influence on the household dietary diversity of farmers.

In the second hurdle, socioeconomic characteristics such as income, gender, age, years of formal education, years of farming experience, years of informal education, the average yield of tomatoes, years of experience in tomato farming, number of working-class members, cooperative membership, access to credit service, and processing with various methods have a significant impact on the intensity of household dietary diversity (Table 3).

Table 2: Impact of income on the food security of farmers along the tomato supply chain using the maximum likelihood of a zero-one inflated Beta distribution

Variable	**First hurdle** (probability of food security)	**Second hurdle** (the incidence of food security)
	Coefficient (Z value)	**Coefficient (Z value)**
Gender	0.119***(3.33)	4.310***(5.20)
Marital status	0.311(0.11)	0.457(0.54)
Age	0.587***(5.14)	0.722***(5.05)
Years of formal education	0.685**(3.33)	0.764**(2.15)
Years of informal education	-0.232**(-2.31)	-0.279***(-3.17)
Main occupation	0.154(0.48)	0.382(0.13)
Years of farming experience	0.141(1.37)	0.284**(2.25)
Farm size	0.193(0.05)	0.889(0.12)
Average tomatoes yield	0.108***(3.60)	0.313***(4.28)
Years of tomatoes farming	0.274***(2.61)	0.342**(2.42)
HH size 6-14 years	0.901(0.45)	0.904(0.00)
HH size 15-64 years	-0.441**(-2.21)	-0.139***(-3.16)
HH size above 64 years	0.264(0.05)	0.860(0.86)
Cooperative membership	0.408***(2.91)	0.758***(3.56)
Distance to market	-0.264(-0.06)	-0.448(-1.21)
Access to credit service	0.684***(5.46)	0.428***(6.86)
Cost of processing	0.239(0.27)	0.236(0.13)
Income	0.886**(2.33)	0.619**(2.00)
Sundry processing	-0.494***(-3.15)	-0.967***(-2.67)
Access to extension service	0.150(0.95)	0.462(0.05)
Constant	0.855***(5.38)	0.625***(9.92)
No of Obs	300	300
Waldchi^2 (20)	184.10	
Prob>chi^2	0.000	

Loglikelihood	-122.902
Zero inflate constant	5.560***(5.54)
Ln_phi	0.968***(16.37)

****, ** &* represent significance levels at 1%,5% & 10%, respectively*

Source: Field Survey (2022)

However, the coefficients of gender, age, income share, years of formal education, years of agricultural experience, the average tomato production, years of experience in tomato growing, cooperative membership, and access to credit services all showed positive outcomes. This suggests that increasing age, income share, years of formal education, average tomato output, years of experience in tomato farming, cooperative membership, and access to credit services will raise the intensity of household dietary diversity in the research area. The coefficients of years of informal education, number of working-class individuals, and tomato processing using sun-dry methods all showed negative results. This suggests that increasing years of informal education, the number of working-class members, and processing using non-traditional ways would reduce the intensity of household dietary diversity in this study area.

Years of education had an enormous effect on the household dietary diversity of the tomato farmers in the study. This shows that an increase in farmers' years of formal education will most likely improve their household dietary diversity. Previous studies, such as Bamire (2010), Eicher-Miller et al. (2011), Bawadi et al. (2012), and Mutisya et al. (2016), discovered a positive relationship between higher household education attainment and an increase in the likelihood of food security. Understanding these food groups influences dietary decisions, increasing family members' intake of high-quality meals. This is due to the potential that the household head's level of education is influenced by awareness of the food types essential for human growth and development. The same plausible explanation applies to the negative association between years of informal schooling and household dietary diversity. Years of expertise in agricultural production, particularly tomato farming, had a substantial impact on the household dietary diversity of the tomato producers in the study. This implies that a unit increase in agricultural farming experience, particularly tomato cultivation, will most likely improve household dietary diversity of the tomato producers. This is because lengthy years of agricultural experience raise farm output, which improves household dietary diversity of the tomato producers (Kehinde et al., 2021). Average tomato yield also significantly influenced household dietary diversity of the tomato producers in the study. The result of this is that a unit increase in tomato yield would probably improve the household dietary diversity of the tomato producers. This is since higher farm yields will raise the amount of money that households have available to them to spend on food whenever they like, which will always boost propensity of farming households to consume and household dietary diversity of the tomato producers (Kehinde et al., 2021).

Food security and access to credit services are positively correlated. This is due to the fact that having access to credit services greatly increases one's ability to obtain loans for both production and consumption, improving one's level of household dietary diversity (Kehinde and Kehinde, 2020; Adesiyan and Kehinde, 2024). Membership in a cooperative and household dietary diversity of the tomato producers are positively correlated. This is likely a result of cooperative members who consistently attended meetings acquired strong better farming and business skills, which in turn increased output and enhanced food security status. The gender of the farmers and their level of household dietary diversity of the tomato producers are positively correlated. The results show that having a male household head enhances the probability of being food secure. Although this contradicts the findings of Obayelu and Orosile (2015) and Awotide et al. (2011), it does corroborate the conclusion that female-headed households in Africa had a lower incidence of food insecurity. The farmers' age and level of food security are strongly connected. According to Zhu et al. (2012), elderly farmers are more likely to profit from remittances from their migrating children and family members. This could be because elderly farmers are more economically engaged and may pursue profitable livelihood opportunities (Umeh et al., 2012; Matchaya and Chilonda, 2012).

Several studies (Agboola, 2005; Ayantoye, 2009; Ibrahim, Uba-Eze, Oyewole, and Onuk, 2009; Ayanwale et al., 2024) have found a negative correlation between the number of working-class farm members in a household and household dietary diversity of tomato producers. This is most likely because larger households have more consumer household resources, particularly food, and vice versa. Additionally, households with a high working-class membership are more likely to experience food insecurity (Ayantoye, 2009). Also, there is a negative relationship between tomato processing with sun-dry methods and the household dietary diversity of tomato producers. This is because tomato processing with sun-dry methods does not command a good market price and this therefore has an adverse effect on the household dietary diversity of the tomato producers.

5. Conclusions

The study analyzed the income share of the primary players in the tomato supply chain and how it impacted their household dietary diversity. For this study, 800 participants were selected from the tomato supply chain using a multistage sampling technique. The data was analyzed using descriptive statistics, a zero-one-inflated Beta regression model, the Household Dietary Diversity Score (HDDS), and the Inverse Relative Important Index (commonly known as the Herfindahl-Hirschman Index, or HHI). The study revealed that traders have the largest share of income along the supply chain. They enjoy about 84% of the income flow along the tomato supply chain. The study also observed that a larger percentage (63%) of the farmers consumed 3 food groups and below. The first hurdle regression results show that income share along with the socio-economic, institutional and farm characteristics of the farmers such as gender, years of formal education, average tomato yield, cooperative membership, access to credit service, and processing with various methods have a significant impact on the probability of household dietary diversity of the tomato producers. While, in the second hurdle, income share along with the socio-economic and institutional characteristics of the farmers such as gender, years of formal education, cooperative membership, and access to credit service are significant in influencing the intensity of household dietary diversity of the tomato producers. It was also concluded that income along with other socio-economic, institutional and farm characteristics of the farmers influenced the probability of household dietary diversity of the tomato producers as well as its intensity. Hence, policies that can promote increased access to income for the farmers on the tomato supply chain should be promoted.

The study suggests recommended actions should be taken to reduce or close the income gaps among the participants in the tomato supply chain. Since farmers are the least privileged participants in the supply chain, concerted efforts such as government policies and programs should be made to raise their income and help close the income gap. Another recommendation would be that agricultural policy initiatives encourage the development of cooperative societies, particularly among farmers, as well as the strengthening of existing cooperative societies, so that they can become more active and assist the commercial endeavours of members. We advocate that farmers create cooperatives because it will allow resource-poor individuals to not only obtain loans but also pool their resources and overcome the lack of capital. The implementation of initiatives to educate people about nutrition, particularly regarding different food categories and diversifying their eating practices among low-income actors, such as farmers, will also be necessary. This will assist actors in changing their daily dietary habits to include a wider variety of foods. Also, the government should devote enough time to educating the actors about proper family planning. This will assist in restricting household size to promote a healthy lifestyle and all household members' well-being. The policy on food security should also prioritize providing the ageing population with the opportunity to develop their human capacity. Human capacity development can be achieved by educating farmers about better farm management techniques through adult education programs. The study has some shortcomings, and they include the following. First, financial constraints limited us to only four (4) States in Nigeria. This calls for sample size expansion by future researchers. Future researchers can look at other supply chains or conduct comparative studies on perishable crop supply chains to broaden our understanding of the relationship between income share and food security. We also suggest that further studies consider rigorous interaction effect analysis for a deeper understanding of the relationship between income share and food security.

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6. References

1. Abay AW (2007): Vegetable Market Chain Analysis in Amhara National Regional State: the Case of Fogera Woreda, South Gonder: A Thesis. Haramaya University, Ethiopia.
2. Abdullahi M, Hamza AM, Isyaku MS, Abbas SAB (2015): *The potential of under-utilized plants in improving food security and economic of Sudan Sahelian region of Nigeria.* Proceedings of the 29th Annual national Conference of Farm Management Association of Nigeria, held at Federal University Dutse, Jigawa State on 23rd -26th November 2015. Pp.83-94.
3. Adesiyan AT, Olaniyan IR, Gaya HI, and Kehinde AD, (2023): A gendered approach to determinants of adoption of cassava-legume intensification technology and its impact on households' poverty status in innovation platforms of Southwestern Nigeria. *African Journal of Science, Technology, Innovation, and Development*, DOI: 10.1080/20421338.2023.2220637.
4. Adesiyan AT, Kehinde AD (2024): Is there a linkage between credit access, land use, and crop diversification in achieving food security? Evidence from cocoa-producing households in Nigeria. *Heliyon*, *10*(16), e35844
5. Adeyemi EB, Adeyemo R, Kehinde AD, Famuyini CA (2020): Effects of Fadama III User Group Participation on Food Security of Rural Households in Benue State, Nigeria. *Ife Journal of Agriculture*, 32(3), 85-97.
6. Adeyemo R, Kehinde AD (2021): Community Driven Development: The case of FADAMA II Cooperatives in Alleviating Poverty in a Developing Country. *Contemporary Agriculture*, 70 (1-2), 46-53.
7. Adugna G (2009): Analysis of Fruit and Vegetable Market Chains in Alamata, Southern Zone of Tigray: the Case of Onion, Tomato and Papaya. A Thesis Paper. The Department of Agricultural Economics, Haramaya University, Ethiopia.

8. Akande YB, Tijani AA, Kehinde AD, Oyenpemi LO (2023): Impact of Compliance with European Union (EU) Regulations on the Income of Actors along the Cocoa Supply Chain in Osun State, Nigeria. *Sustainable Futures*, 6, 100120.
9. Alemnew A (2010): Market Chain Analysis of Red Pepper: the Case of Bure Woreda, West Gojjam Zone, Amhara National Regional State, Ethiopia: A Thesis Paper. School of Agricultural Economics and Agribusiness Management, Haramaya University, Ethiopia.
10. Amao IO, Ogunniyi AI, Mavrotas G, Omotayo AO (2023): Factors affecting food security among households in Nigeria: the role of crop diversity. *Sustainability*, *15*(11), 8534.
11. Aremu T, Reynolds TW (2024): Welfare benefits associated with access to agricultural extension services in Nigeria. *Food Security*, *16*(2), 295-320.
12. Awotide BA, Awoyemi TT, Diagne A, Ojehomon VT (2011): Impact of access to subsidized certified improved rice seed on income: Evidence from rice farming households in Nigeria. *OIDA International Journal of Sustainable Development*, *2*(12), 43-60
13. Ayantoye K (2009): Food Insecurity Status and Transitions Among Rural Households in Southwestern Nigeria. *Unpublished* Ph.D Thesis, Department of Agricultural Economics, University of Ibadan, Ibadan.
14. Ayanwale AB, Adekunle AA, Kehinde AD, Fatunbi OA (2024): Networking and Training for Improvement of Farm Income: A Case of Lifelong Learning (L3F) approach in West Africa. *Heliyon*, 10, e23263.
15. Babalola DA, Makinde YO, Omonona BT Oyekanmi MO (2010): Determinants of post-harvest losses in tomato production: A case study of Imeko-Afon Local Government Area of Ogun state. Acta SATECH Journal of Life and Physical Sciences, 3(2), 14-18.
16. Bamire AS (2010): Effects of Tenure and Land Use Factors on Food Security among Rural Households in the Dry Savanna of Nigeria." *Africa Journal of Food, Agriculture and Nutrition Development,* 10 (1), 1982-2000.
17. Bawadi HA, Tayyem RF, Dwairy AN, Al-Akour N (2012): Prevalence of Food Insecurity among Women in Northern Jordan. *Journal of Health Population*
18. Birhanu MB, (2011): Avocado Value Chain Analysis in Jimma Zone: A Thesis Paper. The Department of Rural Development and Agricultural Extension, Haramaya University, Ethiopia.
19. Cook DO, Kieschnick R, McCullough BD (2008): Regression analysis of proportions in finance with self-selection. Journal of Empirical Finance 15, 860-867.
20. Donkor E, Onakuse S, Bogue J, Carmenad IR (2022): Income inequality and distribution patterns in the cassava value chain in the Oyo State, Nigeria: a gender perspective. British Food Journal. 24(13), 254-273.
21. Edafe OD, Osabuohien E, Matthew O, Olurinola I, Edafe J, Osabohien R (2023). Large-scale agricultural land investments and food security in Nigeria. *Heliyon*, *9*(9).
22. Effiong JAL, Enyia CO (2022): Analysis of Income Distribution Within Aquaculture Value Chain In Afikpo North L.G.A., Ebonyi State. *International Journal of Scientific Engineering and Applied Science (IJSEAS) –* 8(5), 371-387
23. Eicher-Miller HA, Mason AC, Weaver CM, McCabe GP, Boushey CJ (2011): Food insecurity is associated with diet and bone mass disparities in early adolescent males but not females in the United States. *The Journal of nutrition*, *141*(9), 1738-1745.
24. Etebu E, Nwauzoma AB, Bawo DDS (2013): Postharvest spoilage of tomato (Lycopersicon esculentum Mill.) and control strategies in Nigeria. *Journal of Biology, Agriculture and Healthcare*, 3(10), 51-61.
25. FAO (2014): The State of Food Insecurity in the World: Strengthening the Enabling Environment for Food Security and Nutrition, Food And Agriculture Organization of The United Nations Rome, 2014, 2014.
26. FAO Food and Agricultural Organization, in: Special Report – (2019): FAO Crop and Food Supply Assessment Mission to the Sudan, 2020, https://doi.org/10.4060/ ca7787en. Rome.
27. FAO (2008): State of food security report, Food and Agricultural Organization (FAO), Italy Rome *Nutrition,* 30 (1), 49-55.
28. FAO (2012): Gender and nutrition. Gender and Nutrition Issue paper (Draft). Food and Agriculture Organization. Rome, Italy.
29. Ferrari SLP, Cribari-Neto F (2004): Beta Regression for Modelling Rates and Proportions. Journal of Applied Statistics 31, 799-815.
30. Food and Agriculture Organization (2006): Post-harvest management of fruit and vegetables in the Asia-Pacific Region. APO, 2006, ISBN:92-833-7051.
31. Garba K. (2024): Food security for Nigerians through sustainable agriculture. *Nutrition & Food Science*, *54*(2), 269-284.

32. Grema HA, Jacob K, Mohammed B, Umaru OH (2020): Understanding Fish Production and Marketing Systems in North-western Nigeria and Identification of Potential Food safety Risks Using Value Chain Framework. *Preventive Veterinary Medicine*, 105038.
33. Ibrahim H, Uba-Eze NR, Oyewole SO, Onuk EG (2009): Food security among urban households: A case study of Gwagwalada Area Council of the Federal Capital Territory Abuja, Nigeria. *Pakistan Journal of Nutrition, 8*(6), 810-813
34. Kalidas KJS, Sureka M (2014): Supply chain management in vegetables. *Paripex Indian journal of Research*, 3(2), 315-316.
35. Kaminski J, Christiaensen L (2014): Post-harvest loss in sub-Saharan Africa. What do farmers say? World Bank Policy Research Paper 683, 1-34.
36. Kehinde AD, Ogundeji AA (2022a): The simultaneous impact of access to credit and cooperative services on cocoa productivity in South-western Nigeria. *Agriculture & Food Security*, *11*(1), 11.
37. Kehinde AD, and Ogundeji AA (2023): Distributive Impacts of Non-Farm Income on Output and Farm Income of Cassava Farmers in Southwestern Nigeria. *Scientific African*, e01535.
38. Kehinde AD, Kehinde MA (2020): The Impact of Credit Access and Cooperative Membership on Food Security of Rural Households in South-Western Nigeria. *Journal of Agribusiness and Rural Development* 57(3), 255-268.
39. Kehinde AD, Ogundeji AA (2022b): Social Capital Networks (SCNs) Reducing the Poverty in Cocoa Producing Households: Evidence from Osun and Ondo States of Southwestern Nigeria. *Tropical and Subtropical Agroecosystems* 25: #082.
40. Kehinde, M.A., Akinola, A., Kehinde, A.D**.** and Ogundeji, A.A. (2022). Agricultural Organisations and Adoption of Soil Conservation Practices among Smallholder Farmers in Oyo State, Nigeria. *Tropical and Subtropical Agroecosystems* 25: #125
41. Kehinde AD, Adeyemo R, Ogundeji AA (2021): Does Social Capital improve Farm Productivity and Food Security? Evidence from Cocoa-based Farming households in South-western Nigeria. *Heliyon*, 7(3), e06592
42. Kehinde AD, Ojo TO, Ogunleye AS, Ogundeji AA (2024): Impact of Access to Cash Remittances on Cocoa Yield in Southwestern Nigeria. *Sustainable Futures*, 7, 100168.
43. Kennedy G, Ballard T, Dop M (2010): Guidelines for measuring household and individual dietary diversity Rome: Nutrition and Consumer Protection Division, Food and Agriculture Organization of the United Nations; 2010. Available from: http://www.fao.org/3/a-i1983e.pdf
44. Kitinoja L, Torala VY, Brondy A (2018): Challenges and opportunities for im-proved post-harvest loss measurements in plant-based food crops. *Journal of Post-harvest Technology*, 6(4):16-34
45. Kunawotor ME, Bokpin GA, Barnor C (2020): Drivers of income inequality in Africa: does institutional quality matter?", African Development Review, 32, 718-729.
46. Lee CC, Zeng M, Luo K (2023): Food security and digital economy in China: A pathway towards sustainable development. *Economic Analysis and Policy*, 1106-1125.
47. Macheka L., Spelt E., van der Vorst JG, Luning PA (2017): Exploration of logistics and quality control activities in view of context characteristics and postharvest losses in fresh produce chains: A case study for tomatoes. *Food Control*, *77*, 221-234.
48. Matchaya G, Chilonda P (2012): Estimating effects of constraints on food security in Malawi: policy lessons from regressions quantiles. *Applied econometrics and international development*, *12*(2), 165-191.
49. Meaza M, Seyoum T, Woldetsadik K (2007): Effects of preharvest treatments on yield and chemical composition of tomato. Afr. Crop Sci. J. 15 (3), 149–159. ISSN 1021- 9730/2007, African Crop Science Society, Uganda.
50. Meseret DR (2010): Evaluation of Tomato (Lycopersiconesculentum Mill.) Varieties for Fruit Yield, Quality and Shelf Life. Jimma University, Jimma, Ethiopia
51. Mustapha AT, Zhou C, Amanor-Atiemoh R, Ali TA, Wahia H, Ma H, Sun Y (2020): Efficacy of dual-frequency ultrasound and sanitizers washing treatments on quality retention of cherry tomato. *Innovative Food Science & Emerging Technologies*, 62, 102348.
52. Mutisya M, Ngware MW, Kabiru CW, Ngianga-Bakwin K (2016): The Effect of Education on Household Food Security in Two Informal Urban Settlements in Kenya: A Longitudinal Analysis. *Food Security*, 8, 743-756.
53. Negi S, Anand N. (2015): Issues and challenges in the supply chain of fruits & vegetables sector in India: a review. *International Journal of Managing Value and Supply Chains*, *6*(2): 47-62.

54. Obayelu AE, Ogbe AO, Edewor SE (2019): Gender gaps and female labour participation in agriculture in Nigeria, African Journal of Economic and Management Studies, 11, 285-300.
55. Obayelu OA, Akpan E. I. (2021): Food insecurity transitions among rural households in Nigeria. *Studies of Applied Economics*, *39*(2).
56. Obayelu OA, Orosile OR (2015): Rural livelihood and food poverty in Ekiti State, Nigeria. *Journal of Agriculture and Environment for International Development (JAEID)*, *109*(2): 307-323
57. Ogunleye A, Akinloye MO, Kehinde AD, Ajayi OM, Wongnaa CA (2024): Impacts of credit constraints on adoption of risk management strategies and income of maize farmers in Northern Nigeria. *Agricultural Finance Review*. DOI 10.1108/AFR-11-2023-0152.
58. Oladapo A, Borokini EA, Oladipo AA, Nupo SS (2011): Economics of tomato production in rural households of Ogun State: production in rural households of Ogun State. Proceedings of the 25th Annual conference of Farm Management Association of Nigeria (FAMAN), held at the Federal College of Agriculture, Akure Ondo State on 5th - 8th September. Pp.195-200.
59. Olugbire OO, Aremu FJ, Opute OH, Ojedokun CA, Olawale OO, Adisa A (2016): Determinants of household cooking energy choice in Oyo State, Nigeria. *Russian Journal of Agricultural and Socio-Economic Sciences*, *52*(4), 28-36.
60. Orjiakor EC, Adediran A, Ugwu JO, Nwachukwu W (2023): Household living conditions and food insecurity in Nigeria: A longitudinal study during COVID-19 pandemic. *BMJ open*, *13*(1), e066810.
61. Ospina R, Ferrari SLP (2012): A general class of zero-or-one in.ated beta regression models Computational Statistics and Data Analysis 56:1609-1623.
62. Palmisano GO, Capone R (2020): Information and Communication Technologies for Smart and Sustainable Agriculture. In *30th Scientific-Experts Conference of Agriculture and Food Industry: Answers for Forthcoming Challenges in Modern Agriculture* (Vol. 78, p. 321). Springer Nature.
63. Sablani SS, Opara LU, Al–Balushi K (2006): Influence of bruising and storage temperature on vitamin C content of tomato. Journal of Food, Agriculture and Environment, 4(1), 54-56.
64. Sahel Research (2017): The Tomato Value Chain in Nigeria. *Catalysing Sustainable Agriculture and Nutrition*, *15*. Retrieved from http://www.sahelcp.com/wpcontent/uploads/2017/07/Sahel-Newsletter-Volume-15_Tomato.pdf
65. Serrat O (2017): The sustainable livelihoods approach. In *Knowledge solutions* (pp. 21-26). Springer, Singapore.
66. Shuaibu AU, Mamman AP (2015): Profitability of Lettuce (lectucesativa,) production using Water in dry lands: Acase study of Metropolitan Jakara River in Kano State, Nigeria. Proceedings of the 29thAnnual Conference of farm Management Association of Nigeria, held at General Studies- Auditorium. Federal University Dutse, Jigawa State, Nigeria on 23rd -26thNovember, 2015:.49-55.
67. Smithson M, Verkuilen J (2006): A better lemon squeezer? Maximum likelihood regression with beta-distributed dependent variables. Psychological Methods 11: 54-71.
68. Tambe BA, Mabapa NS, Mbhatsani HV, Mandiwana TC, Mushaphi LF, Mohlala M, Mbhenyane XG (2023): Household socio-economic determinants of food security in Limpopo Province of South Africa: a cross sectional survey. *Agriculture & Food Security*, *12*(1), 19.
69. Tamiru D, Argaw A, Gerbaba M, Ayana G, Nigussie A, Belachew T (2016): Household food insecurity and its association with school absenteeism among primary school adolescents in Jimma zone, Ethiopia. *BMC public health*, *16*, 1-8.
70. Temesgen M, Workneh TS, Bultossa G (2011): Effect of tomato cultivars, honey finisher and processing methods on quality of tomato ketchup: full-length research paper. Afr. J. Biotechnol. 10 (80), 18516–18527, 14 December 2011 ISSN 1684–5315.
71. Tigabu DG, Gebeyehu MF (2018): Agricultural extension service and technology adoption for food and nutrition security: Evidence from Ethiopia. *FARA Research Report*, *3*(4).
72. Ugonna CU, Jolaoso MA, Onwualu AP (2015): Tomato value chain in Nigeria: Issues, challenges and strategies. *J. Sci. Res. Rep*, *7*(7), 501-515.
73. Villacis AH, Mayorga J, Mishra AK (2022): Experience-based food insecurity and agricultural productivity in Nigeria. *Food Policy*, *113*, 102286.
74. Visser J, Wangu J (2021): Women's dual centrality in food security solutions: The need for a stronger gender lens in food systems' transformation. *Current Research in Environmental Sustainability*, *3*, 100094.

75. World Bank (2011): Community Driven Development in Africa, a Vision Poverty Reduction through Empowerment. www.worldbank.org.
76. World Food Logistics Organization (2010): Identification of Appropriate Post-harvest Technologies for Improving Market Access and Incomes for Small Horticultural Farmers in Sub-Saharan Africa and South Asia. WFLO Grant Final Report to the Bill & Melinda Gates Foundation, March 2010. 318 pp.
77. Wudil AH, Ali A, Aderinoye-Abdulwahab S, Raza HA, Mehmood HZ, Sannoh AB (2023): Determinants of food security in Nigeria: Empirical evidence from beneficiaries and non-beneficiaries rice farmers of the Kano River Irrigation Project. *Frontiers in Sustainable Food Systems*, *7*, 999932.
78. Zhu Y, Wu Z, Wang M, Du Y, Cai F (2012): Do migrants really save more? Understanding the impact of remittances on savings in rural China. *Journal of Development Studies*, *48*(5), 654-672.