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Understanding the biofortified cassava market in Nigeria: Determinants of consumer demand and farmer supply

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Abstract: Biofortified foods are smart and strategic nutritious foods which plays critical role in addressing global burden of micronutrients in many emerging economies. While there is more and more consensus about the potential benefits of biofortification, the challenge lies on how to scale up its consumption and market system. This requires understanding of the dynamics of the biofortified cassava consumer demand and producers supply. Therefore, the study aims to identify the demand and supply drivers for biofortified foods and how it affects the food security of households across Nigeria.. A survey was administered to 240 willing consumers and 90 producers of biofortified cassava. The results revealed that price, marketing orientation, institutional support, price of substitute and education had a significant influence on supply, while the price of substitute, expenses on nutritional products, awareness of benefits, income, recommendation from experts, and education had a significant impact on demand for biofortified cassava. Our study lends support to the important role of communication to improve awareness and increase adoption, and also recommends institutional and infrastructural support to encourage market orientation and investments in biofortified crops. Our study provided evidences that scaling up sustainable market growth for biofortified foods required the convergence of consumer knowledge, awareness and expert recommendations, as well as effective communication strategies. Our concluded that dynamics of demand and supply of food must be targeted at enhancing access, availability and utilization of food to achieve goal of the SDGs.

Subjects: Agriculture & Environmental Sciences; Rural Development; Economics; Business, Management and Accounting

Keywords: biofortification; cassava; consumer demand; food security; farmers' supply; Nigeria; Sustainable development

1. Introduction

Although, there have been several policies to strengthen food systems to deliver better food outcomes in Nigeria such as communication of nutrition information, supplementation, dietary diversification and commercial fortification (Labadarios et al., 2005; Onoja & Adione, 2019; Anjourin et al., 2019). Unfortunately, these have not yielded the desired outcome because most of these measures are unsustainable, unaffordable and inaccessible particularly to poor Nigerians that cannot afford more diverse food diets as a result, current nutrition trends call for potential change of strategy including increased, combined efforts to alleviate the burden of malnutrition sustainably, which is estimated to affect over 2 billion people (Gödecke et al., 2018), with Africa dominating the chart with nearly 1 out 5 Africans being undernourished (FAO et al., 2020). Therefore, captivating them with the idea of functional food is crucial for malnutrition reduction and improved nutrition in the region. Thus, biofortification, improving the micronutrient level of staple crops to close nutritional gaps in local food systems, represents a strategic nutritional intervention that could help in addressing poverty, hunger and malnutrition in developing countries (De Steur et al., 2017; Finkelstein et al., 2015; Lockyer et al., 2018; Saltzman et al., 2017).

Biofortified crops are released in more than 40 Low- and Middle-Income Countries (LMIC), including Nigeria, where Vitamin A cassava, maize and Orange-Fleshed Sweet Potato (OSFP) are available for production and consumption (CAST, 2020). Biofortified staple foods with vitamin A, iron or zinc in Nigeria are considered a valuable approach and could contribute to reaching the estimated average requirement for pro-vitamin A, iron and zinc by, respectively, 50%, 30% and 25% (Onuegbu et al., 2017). As a result, Nigeria has identified biofortification as a cog in the wheel of advancing nutrition through agriculture (GLOPAN, 2015) and has included biofortification into its overall food policy (CAST, 2020). Such a strategy could be especially relevant as consumers in poor, rural Nigeria often cannot afford industrially fortified foods (Chadare et al., 2019; Onuegbu et al., 2017).

As one of the main staple crops with cultural affinity in Nigeria, cassava was biofortified. Cassava is an essential staple and cash crop providing diets to about a billion people globally (Zhu et al., 2015), with Nigeria being the highest producer of cassava in the world (Ikuemonisam et al., 2020), because its agro-ecological terrain favors cassava production (Akinwale et al., 2010). In Africa and many developing countries, majority of these people depend and consume it to obtain their daily 40–50% calories (Oteh & Nwachukwu, 2014). As a food security crop (Wilson et al., 2017), cassava is produced widely by poor resource food producers in many rural areas of Nigeria (Adepoju & Oyewole, 2013), producing more than 60 million metric tons (FAO, 2022). Unfortunately, evidence shows that conventional white-fleshed cassava is not rich in pro-vitamin A, one of the target nutrients to address the double burden of malnutrition (Afolami et al., 2021; Talsma et al., 2016).

Cassava has been biofortified through conventional cross-breeding and is currently one of the key target crops of HarvestPlus, one of the key players in biofortification. Although Nigeria has opened up to Genetically Modified (GM) foods, but, it is still a subject of controversy (Bouis & Saltzman, 2017; Onuegbu et al., 2017; Onyeneke et al., 2019), by which the political agenda is currently less favourable to biofortified food based on GM technology, despite its potential benefits (De Steur et al., 2015). Extant literature further demonstrates that conventionally bred biofortified yellow cassava contains vitamin A that is bio-available (Bechoff et al., 2018), with public health gains (Talsma et al., 2016), particularly among children (Afolami et al., 2020; HarvestPlus, 2020). As a cost-effective intervention (CAST, 2020; Onyeneke et al., 2019), it could be a sustainable approach to addressing micronutrient malnutrition in Nigeria (Ayetigbo et al., 2018; Lockyer et al., 2018; Oparinde et al., 2014), and achieve food security goals.

Building upon HarvestPlus and other organizations, biofortified cassava has been commercialized and found its way into the mainstream food systems and markets in Nigeria. In 2019, about 1.6 million Nigerians were already growing Vitamin A cassava varieties (Foley et al., 2021; Ilona et al., 2017), with several extension service agents delivering biofortified planting materials to farmers in rural communities (CAST, 2020). However, despite Nigeria having the largest Vitamin A cassava promotion program (CAST, 2020), there is still limited presence of biofortified foods in most of the local markets in Nigeria, thus creating artificial scarcity in demand with spillover impact on price and consumption thus fueling malnutrition crisis. A plausible explanation may be due to the inability to scale-up production (Ilona, 2014), coupled with challenges in terms of consumer perception and governmental registration (Onuegbu et al., 2017), or poor delivery of seeds (Foley et al., 2021). Consumer demand is further affected by the poor awareness of the nutritional value of biofortified cassava (Bouis & Saltzman, 2017). For instance, about 53% of Nigerians in Abia State were not aware of the nutritional benefits of biofortified cassava over conventional "yellow" *garri* (Oteh et al., 2020). Consequently, only 10% of the total estimated production of 7,000 tons of Vitamin A cassava roots harvested were sold in local markets (Ilona, 2014). This low level of sales has created challenges to ensure a sustainable market for both seeds and products. As biofortified seeds are not yet available to farmers on the open market (Foley et al., 2021; Onuegbu et al., 2017), BoP farmers are facing difficulties to access these seeds without established economic and social networks, regardless of the support of Nigeria, universities and agricultural research institutions for seed multiplication and utilization of biofortified crops (GLOPAN, 2015). These difficulties limit access to quality seeds, which has severe consequences on productivity and leads to poor market income and profits. This consequently negatively impacts food and nutrition security, which is already under high pressure in Nigeria (FAO et al., 2020). More than 60% of Nigerians live below the poverty line (WEF, 2020) and cannot afford commercial food fortification (Joel et al., 2019). With the Nigerian population projected to rank third after China and India by 2050, a home-grown, agriculture-based strategy like biofortification could be a valuable alternative to existing micronutrient strategies, but only if it is available and affordable to its key beneficiaries. Given its position as the world's largest producer of cassava, Nigeria offers large potential for producers to market and invest in biofortified cassava (Bouis & Saltzman, 2017; Okwuonu et al., 2021).

While there is more and more consensus about the potential of biofortification, the challenge lies in how to scale up biofortified crops to reach millions of people (GLOPAN, 2015) and this requires an improved understanding of the dynamics of the biofortified food demand and supply in Nigeria. Therefore, as it is crucial to understand the dynamics of building demand as well as supply, this study aims to examine the key factors influencing consumer demand and farmer supply of biofortified cassava in Nigeria. Despite the growing evidence of biofortified crops as a pro-poor, cost-effective micronutrient strategy, many countries, including Nigeria, have yet to fully adopt biofortified seeds and products (Foley et al., 2021). By studying demand and supply factors in the same setting simultaneously, this approach is expected to improve the understanding of the current challenges towards scaling up biofortification.

2. Literature review

2.1. Demand and supply challenges of biofortification

Consumer demand is a vital cornerstone of agricultural and food markets (Isenhour, 2011; Lusk & McCluskey, 2018) and results from the interplay between social, economic and environmental factors (Monterrosa et al., 2020). As food is a complex phenomenon and goes beyond the fulfilment of human, cultural and social needs (Aycan et al., 2005; Nwachukwu et al., 2010), consumer and producer food decisions vary and are influenced by a diversity of factors. For instance, the decision of consumers to accept or adopt biofortified foods varies depending on their socio-economic demographic factors (De Steur et al., 2015), sensory evaluation (Birol et al., 2015; Talsma et al., 2016), expert information, nutrition knowledge and awareness of benefits (Birol et al., 2015; Bouis & Saltzman, 2017; Reyes et al., 2021). Price and price of substitutes are also critical components of demand and supply. Non-staple food prices have continued to rise, making it difficult to afford a diverse diet (Bouis & Saltzman, 2017), while biofortified crops are promoted as a cost-effective alternative nutrition strategy (Onuegbu et al., 2017). Despite this, evidence shows that consumers are willing to pay 60–70% more for biofortified cassava (Gonzalez et al., 2009). Price is a critical component of consumers' acceptance and adoption (Baker et al., 2022) and impacts food security (FAO et al., 2020). Progress in scaling up the consumption of biofortified foods must not focus only on demand. Supply is critical and affects both demand and policy (Bouis & Saltzman, 2017). Supply is complex and is known to be influenced by various factors, which determine the success of commercialization (Oteh & Nwachukwu, 2014). A better understanding of the determinants of farmer adoption is crucial for scaling up biofortification production. Literature indicates that farmers are generally willing to adopt the biofortified crops, but they are constrained by several factors such as the premium price (Talsma et al., 2017), price fluctuations and marketing costs (Onyeneke et al., 2019), farm size (e.g. the average yield of vitamin A cassava varieties is higher than conventional) (Foley et al., 2021). Also, factors related to farmers' characteristics, such as education (Jogo et al., 2021; Onyeneke et al., 2020), knowledge and perceptions of technology (Jogo et al., 2021; Lividini & andFiedler, 2015) are expected to affect the adoption and, hence, supply (Muthini et al., 2019). Small-scale farmers in many developing countries face several barriers, such as low market orientation (Ilona, 2014; Oteh & Nwachukwu, 2014), which limits production and investments (Bouis & Saltzman, 2017; Bouis et al., 2011), and a lack of adequate infrastructural facilities (Foley et al., 2021). Addressing the latter would help to stimulate production and improve biofortified market access (Oteh et al., 2020). Furthermore, knowledge gaps, poor information dissemination and the absence of appropriate policies to encourage the production and utilization of biofortified foods are often postulated as key challenges hampering widespread commercialization of biofortified foods (Oteh et al., 2020).

When looking at consumer and farmer research, several studies have investigated attitude formation and (intended) behaviour. These studies typically examined the role of different consumer and farmer characteristics to explain consumer either demand or farmer supply of biofortified cassava. At the consumer level, for instance, measurement of consumer demand is linked to consumer adoption (Oteh et al., 2020, Oparinde et al., 2014; Oparinde et al., 2016), consumption (Afolami et al., 2021), willingness-to-pay (Kolapo & Abimbola, 2020; Oparinde et al., 2016) or preference (Kolapo et al., 2020; Okwuonu et al., 2021). At the farmer level, research has targeted the adoption of biofortified cassava (Onyeneke et al., 2020; Ayinde et al., 2017), with specific emphasis on its economic benefits and productivity issues (Adeola et al., 2017; Kolapo et al., 2021), or gender-related constraints (Olaosebikan et al., 2019). While the results show no "one size fits all" for stimulating consumer demand and farmer supply, none of these studies has examined determinants of supply and demand simultaneously. Therefore, the study analyses will focus on demonstrating the demand and supply factors that influence biofortified cassava market system.

2.2. Theoretical background

Our study theoretical framework was hinged on the food system approach, which describes the various elements and trade-offs between these elements in our food systems (Van Berkum et al., 2018). We believe this is suitable for this study for some reasons. First, it captures the complex interaction of elements and trade-offs which focused on food demand and supply, which from the perspective of economic system is referred to as market forces. Demand and supply are central to the food systems as they determine both production, consumption and food prices. Food demand intensifies connections in the food systems towards meeting consumer need by advancing food production, value addition and food security (Staatz & Hollinger, 2016). Van Berkum et al. (2018) explained that food system approach offers a guidance for managing food supply dynamic. Generally, food and agriculture involve a complex interaction of factors, market forces and systems (Nayak & Waterson, 2019). Second, the food system approach is fundamental to enhancing food security component of the SDGs (see Ingram, 2011). Therefore, food system transformation can impact food production and diets (Dwivedi et al., 2017), thus impacting on food security (WHO, 2021).

Based on the framework, we suggest that a system-based approach is critical to connecting the dot between food supply, food demand and achieving food security (Capone et al., 2014), thus providing insights into food production, what shape consumer demand and how to scale up supply. We believe that the interaction of demand and supply is critical in building an economic system that delivers value to both consumers and the market (Zhou & Staatz, 2016), and thus requires understanding of factors that trigger changes in the deeper layers of demand and supply-side. Because of these consequences for the food market and prices, market forces are best seen from the lens of food systems approach.

From this approach, it is plausible to notice a correlation and trade-offs in the variables that influence consumer demand and producers' supply, particularly the intervening factor of price, which suggests structural equation model. Price is a critical endogenous factor in food choice intervening on food production and consumption (Cornelsen et al., 2015), and its changes reflect the food systems and impact on food security (Troell et al., 2014). To properly estimate demand and supply, we believe that Two-Stage Least Square (2SLS) is the best estimation of structural equation (Liu et al., 2022). This method is necessary to accommodate omitted variables and solve problem of endogeneity due to measurement errors and simultaneity. Therefore, we hypothesize that price does not affect the market system of biofortified cassava in Nigeria. We believe that consumers and producers may be more inclined to demand and supply biofortified cassava due to convergence of other factors.

3. Methodology

3.1. Study context

This study targeted biofortified cassava producers and consumers in Abia state, South-East Nigeria. Due to its large interest in cassava cultivation and marketing, as well as the presence of the National Root Crops Research Institute (NRCRI) Umudike, this region is considered an important state in the Nigerian cassava masterplan. The NRCRI was one of the Nigerian agricultural institutes that were responsible for the field trials of pro-vitamin A and biofortified iron crops (Sayre, 2011). Moreover, the region of Umudike in Abia state was one of the first six locations in Nigeria where pro-vitamin A cassava varieties were approved by the Nigerian National Variety Release Committee in 2011. The relevance of this study location is further illustrated by the importance of cassava products to the high prevalence of micronutrient deficiencies (Ejike, 2016).

3.2. Sampling procedure

In close consultation with the Agricultural Development Programme (ADP), a cross-sectional research design was developed for target BoP producers and consumers. Therefore, a multistage sampling procedure was used in the selection of the both types of respondents and locations. There are three agricultural and senatorial zones in each states in Nigeria. With regard to the producers, the first stage involved a purposive selection of three Local Government Areas (LGAs) from Abia stateagricultural zones. These LGAs included the Aba zone (Ugwunagbo, Obingwa and Isiala-Ngwa North), Ohafia zone (Arochukwu, Isuikwuato and Bende) and Umuahia agricultural zone (Umuahia south, Isialangwa south and Ikwuano). The choice of these zones is because they are major cassava farming communities in the zones. In the second stage, one autonomous community from each selected LGAs was randomly selected. The third stage included a purposive selection of 10 biofortified cassava farmers, with 30 respondents for each zone to ensure a suitable sample size in all zones. The survey was sent to 90 producers, of whom 71 (83.3%) answered all questions.

For consumers, the first stage involved a purposive selection of eight LGAs in the state (Aba south, Aba North, Umuahia south and north, Osisioma, Bende, Ikwuano and Isiala-Ngwa North). The choice of LGAs was driven by data on consumption trends and expert advice from the ADP. The second stage involved a random selection of 30 respondents from each LGA. A total number of 240 respondents were targeted, of which 201 respondents (83.7%) completed the survey.

3.3. Survey

The data collection method consists of two structured surveys that were used to collect data from producers and consumers and consisted of questions on respondents' socio-demographic profile, food security level, knowledge of nutrition and biofortified foods, and demand and supply factors. These questions were adopted or adapted from the scientific literature on biofortified food in Nigeria (such as Agwu et al., 2017; Bouis & Saltzman, 2017; Ekwe et al., 2010; Jhingan & K, 2010; Ojiako et al., 2017; Oteh et al., 2017). At the consumer level, price and the price of substitute refer to the amount paid for either biofortified cassava products or its substitutes (conventional cassava products) and were measured in Naira (Nigeria's local currency), i.e. "How much do you pay for biofortified cassava products and/or conventional variants (Andreyeva et al., 2010; Waterlander et al., 2020).

With regard to awareness of product benefits, consumer responses were measured using a dummy variable (no = 0, yes = 1). This is supported by Timpanaro et al. (2020). While researchers have focused on improving awareness (Ilona, 2014; Okello et al., 2017), the information source, especially access to expert advice, is also considered to be crucial (Reyes et al., 2021). Therefore, we measured source of consumer knowledge in terms of whether consumers received professional recommendations (no = 0, yes = 1). To ascertain the cost-effectiveness of biofortified food, we measured the monthly household expenditures on nutritional products, such as commercial fortified products (Marinos Elia et al., 2018; Sue, 2006). This was measured in terms of the amount spent monthly on nutritional supplements in local currency (Naira). Concerning the socio-demographics of consumers, questions dealt with age (years), the highest level of education attained (years) and the size of the household (number). Taste refers to the flavour ability of biofortified cassava and was measured based on a 10-point scale (1 = extremely poor to 10 = good taste) (Nwachukwu et al., 2010).

With regard to the producers' survey, the study measured food price and the price of substitute in terms of monetary value (Naira) paid for biofortified cassava, its derivatives or its substitutes (conventional cassava products) by asking suppliers, i.e. "How much do you supply a specified quantity of biofortified cassava and/or conventional variants (Andreyeva et al., 2010; Waterlander et al., 2019). Producers' acceptance of innovations is often influenced by their perceptions of costs and benefits, often reinforced by incentives (Olum et al., 2020; Shikuku et al., 2019). The producer survey measured perceptions of institutional support ("Have you received any form of incentives/support from government or its agencies") as a dummy (no = 0, yes = 1) variable (Oteh et al., 2017). Market orientation was assessed as the level of market participation/commercialization (low, medium, high), following Banterle et al. (2009). Also, marketing cost was questioned and was measured as the total cost of selling biofortified cassava. Other variables dealt with socio-demographic (education, age, income, household size), in addition to farm-related characteristics (farm size). Regarding food security, three key questions on affordability ('How would you rate your ability to afford biofortified cassava products'), access ('How would you describe your household's ability to have biofortified cassava products from the market in the right quantities and the right time') and utilization/consumption ('How would you describe your understanding of the nutritional value of biofortified products, food safety and use of biofortified foods') were included, using a 5-point scale ("1" = extremely low to "5" = very high). This is in line with Na and West (2015) and Bryant and Stevens (2006), who used a Likert scale to measure food access and availability at home.

3.4. Statistical analysis

All statistical analyses were performed with STATA. To understand the extent of deviation between respondents, this study measured and classified consumers into food secure and food insecure households, in line with Omonona and Agoi (2007) and Oteh and Nwachukwu (2014). After reliability analysis of the food security-related constructs indicates high Cronbach's alphas (0.77 and 0.80, respectively), the index was measured as follows:

$$F_I = \frac{per\ capita\ food\ expenditure\ for\ the\ household}{\frac{2}{3}\, mean\ per\ capita\ food\ expenditure\ of\ all\ household} \quad (1)$$

Where F_i = food security index; When $F_i \geq 1$ = food secure i^{th} household; $F_i \leq 1$ = food insecure i^{th} household.

By definition, a food secure household is one whose per capita monthly food expenditures fall above or are equal to two-thirds ($\frac{2}{3}$ of the mean per capita food expenditure).

To further describe the context, an independent sample t-test was used to analyze differences in food expenditure between food insecure and secure households.

The choice of the food security index as a separate analysis was considered as further analysis of the food demand. Including the construct of the food security in the regression was not necessary, given that the main threats and determinants of food security were included in the regression model such as price, education, income, gender and increase demand for food (See, Zhou et al., 2019).

Two-Stage Least Square (2SLS) regression analysis was used to analyze the relationships existing between the explanatory variables and demand or supply. The implicit form of biofortified cassava food demand function is specified as follows.

$$Qd = f(P, PS, T, ED, AG, INC, HS, RD, EX, AWB) \quad (2)$$

Where;

Qd = Quantity demanded (Naira), P = price, PS = price of substitute, T = taste, ED = education, AG = Age, INC = Income, HS = Household size, Rd = Recommendation from experts, Ex = Expenditure on nutritional products and AWB = Awareness of benefits

The implicit form of the biofortified cassava food supply function is specified as:

$$Qs = f(P, MO, PS, MC, FS, PT, INSP, INC, ED) \quad (3)$$

Where,

Qs = Quantity supplied, P = Price, MO = Market orientation, PS = Price of substitutes, MC = Marketing cost, FS = Farm size, PT = perception of technology, INSP = Institutional support, INC = Income, ED = Education

From Equations 2 and 3, there is only one endogenous variable (P), while the other variables are predetermined. Therefore, the endogenous variables were expressed as a function of the predetermined variables as shown in Equations 4, 5 and 6

$$P_i = \pi_{10} + \pi_{11}PS + \pi_{12}T + \pi_{13}EX + \pi_{14}AWB + \pi_{15}INC + \pi_{16}RD + \pi_{17}AG + \pi_{18}ED + \pi_{19}HHS + \pi_{20}MO + \pi_{21}MC + \pi_{22}FS + \pi_{23}PT + \pi_{24}INSP + V_1 \quad (4)$$

$$Q_d = \pi_{10} + \pi_{11}PS + \pi_{12}T + \pi_{13}EX + \pi_{14}AWB + \pi_{15}INC + \pi_{16}RD + \pi_{17}AG + \pi_{18}ED + \pi_{19}HHS + \pi_{20}MO + \pi_{21}MC + \pi_{22}FS + \pi_{23}PT + \pi_{24}INSP + V_2 \quad (5)$$

$$Q_S = \pi_{10} + \pi_{11}PS + \pi_{12}T + \pi_{13}EX + \pi_{14}AWB + \pi_{15}INC + \pi_{16}RD + \pi_{17}AG + \pi_{18}ED + \pi_{19}HHS + \pi_{20}MO + \pi_{21}MC + \pi_{22}FS + \pi_{23}PT + \pi_{24}INSP + V_3 \quad (6)$$

In estimating the parameter of the price variable ($\hat{P}$), Ordinary Least Squares (OLS) regression was applied to the form equation. In the structural equation, the original price (P) was replaced with the estimated price to get consistent and unbiased estimates, as shown in Equations 7 and 8:

$$Q_d = f\left(\hat{P}, PS, T, EX, AWB, INC, Rd, AG, ED, HS\right) \quad (7)$$

$$Q_s = f\left(\hat{P}, MO, PS, MC, FS, PT, INSP, INC, ED\right) \quad (8)$$

The OLS regression was applied to these Equations (7) and (8) respectively to obtain the final coefficients of the variables.

4. Results

4.1. Sample characteristics

Table 1 presents the respondents' socio-demographic and farm-related characteristics of both surveys. The results demonstrate that the majority of the respondents (40.4%) fall within the age group of 26–35 years, with a mean age of 31 years (consumers) and 44 years (producers). The sample also has more female consumers and producers, i.e. 51.2% and 54.7%, respectively. Given their role in household food production and preparation, female consumers are often the decision-makers when it comes to the purchase of cassava products. Further, the majority of consumers and producers are literate as shown by the average years spent in school, i.e. 16 years (consumers) and 14 years (producers). This is important, as education generates consumer knowledge, which drives brand preference for healthy foods (Bornkessel et al., 2014). The mean income level was NGN 139,185 ($180.80) for consumers and NGN 174,136 ($226.20) for producers, pointing to a relatively reasonable monthly income to cater to basic household needs. The household size typically ranges between 1 and 3 persons (71.1%), with two an average. The producers further differ in their experience with producing cassava and biofortified cassava. About 89% have less than 5 years of experience with biofortified cassava. The average farm size amounts to 3 hectares, which is relatively large but often not large enough to drive commercial production to a level that allows substantial scaling up of the supply of cassava products. Interestingly, most of these producers belong to an agricultural group or cooperative, in which they share experiences.

Table 2 shows the food security status of the households. There is little difference between food secure and food-insecure households. On average, an individual household consumes food worth NGN 17,460 in a month, although this does not entirely reflect the increasing and alarming incidence of food scarcity in Nigeria. Table 3 shows the test of independent sample test of the food secure and food-insecure households. The analysis shows that food secure households spend significantly more [27168.29 ± 18456.11] than food insecure households [5949.94 ± 3236.41], t(198)10.83, $P < 0.001$.

4.2. Consumer demand for biofortified cassava products

The role of determinants of consumer demand for biofortified cassava was evaluated through 2SLS regression. The findings are presented in Table 4. The F-statistic was statistically significant, implying that the model performs well in estimating consumer demand for biofortified cassava products.

The coefficient of multiple determination (R^2) implies that about 37% of the total variation in the quantity demanded could be explained by the variables included in the model. Though this is relatively low, it can be considered a moderately good model in social sciences (Dhakal, 2018; Ferenc, 1999). The coefficients represent the variables' main effects on the demand for biofortified cassava products. Table 4 reveals that expenditures on nutritional products, awareness of the nutritional benefits of biofortification, income and expert recommendations to adopt and consume biofortified foods are significantly and positively influencing consumer demand. In contrast, the price of the substitute and education have an inverse relationship with the demand for biofortified cassava products. Price, taste, age and household size do not appear to play a role in influencing consumer demand for biofortified cassava.

4.3. Producer supply of biofortified cassava products

The estimated results of the 2SLS regression on the determinants of the supply of biofortified cassava are presented in Table 5. The significant F-ratio confirms the model fit, while the R^2-value of 88.04% implies that the total variation in quantity supplied is largely explained by the variables included in the model.

The findings further demonstrate that price and the substitute price are both positively associated with the supply, while market orientation, institutional support and education have a significant, negative influence. As shown in Table 5, a one-thousand unit increase in the price of biofortified

Table 1. Socio-demographic and farm-related characteristics

Variables	Consumers		Producers	
	Freq.	%	Freq.	%
Age category (years)				
16–25	55	27.3	1	1.3
26–35	81	40.4	16	21.4
36–45	55	27.3	22	29.3
46+	10	5.0	26	48.0
Mean	*31.0*			*44.0*
Gender				
Male	98	48.8	34	45.3
Female	103	51.2	41	54.7
Education				
Primary	0	0.0	8.0	10.6
Secondary school	8	4.0	24	32.0
Tertiary education	113	56.2	38	50.7
Post-tertiary education	80	39.8	5	6.7
Mean	*16.6*		*14.0*	
Monthly income (NGN)				
0–80000	96		51	68.0
80001–160000	81		21	28
160001–240000	9		1	1.3
240001–320000	6		-	-
320001-above	9		2	2.7
Mean	*139185*		*174136*	
Household Size				
1–3	143	71.1	59	78.7
4–6	49	24.4	13	17.3
7–9	7	3.5	3	4.0
10–12	2	1.0	0	0.0
Mean	*3 persons*		*3 persons*	
Farm experience (years)				
0–4			67	89.3
5–8			8	10.7
Mean				*3.3 years*
Farm size (hectares)				
1–4			56	74.7
5–8			11	14.6
9-above			8	10.7
Mean				*3.1*
Group membership				
Yes			48	64.0
No			27	36.0

Table 2. Summary statistics of household food insecurity indices

Food security indicators	Food secure households		Food insecure households	
	Freq.	**Percent (%)**	**Freq.**	**Percent (%)**
Per Capita Expenditure				
<10,000	0	0	69	75
>10,000	110	100	23	25
Total	110	100	92	100
Mean PCE	27106.75		5957.73	
2/3 MPCE = 11640 **Average MPCE** = 17460 **% of food secure** = 54%				

MPCE, Monthly per capita expenditure; PCE, Monthly per capita expenditure.

cassava products will result in a 3.6% increase in supply and a 5.9% increase in the substitute price. Other variables do not significantly influence the supply of biofortified cassava products.

5. Discussion

Biofortified foods must be successfully marketed to ensure their status as a valuable intervention. Our study builds upon the views of Andrew et al. (2008) and Beierlein et al. (2014) that, to enhance the welfare and ensure food and nutrition security, BoP producers must take advantage of the projected domestic demand growth by supplying consumers with low-cost foods such as biofortified cassava. This study aimed to analyse the determinants of demand and supply of biofortified cassava. On the demand side are the consumers, who drive both demand and production, while on the supply side are producers as key actors of the supply chain.

5.1. Food security status of biofortified households

Based on the food security index adopted by Omonona and Agoi (2007), our study showed a slightly higher level than in an earlier study in Abia State (Oteh, 2017). Income status might be a key variable accounting for these differences, as a higher income eventually leads to higher profits and improves the standard of living and, hence, food security (Agwu et al., 2017). In our study, an individual household consumes food worth NGN 17,460 per month. If we factor in the current inflation rate in Nigeria, this amount is not considered adequate for a family to address basic needs and obtain a diversity of foods. Not surprisingly, there is a significant difference in the food expenditure between food secure and insecure households, in line with the findings of Dare (2015) and Andrés et al. (2016). A small shift in the price of food could further increase availability. While evidence shows that about 56.4% of household income is spent on food in Nigeria (WEF, 2016), poor households continue to remain food insecure because of their economic circumstances (Webb et al., 2018) and its impact on food accessibility and availability (Jafri et al., 2021) and food consumption and choice (Capone et al., 2014). Given the link between poverty and food and nutrition security (FAO et al., 2020; Siddiqui et al., 2020), triggered by the current pandemic (Pereira & Oliveira, 2020), biofortification as a cost-effective pro-poor, pro-rural strategy (CAST, 2020) could be considered as a valuable, complementary micronutrient strategy in Nigeria. As such, our findings on food security in Nigeria can be linked to the marketing of biofortification. First, it advances the argument in favour of the effect of an individual household's purchasing power on its ability to purchase affordable foods. As such, economic considerations might make it difficult for a typical household to obtain industrially fortified food, opening up opportunities for agriculture-based nutritious foods. Secondly, it creates an incentive for investing in the production of biofortified cassava, because its cost-effectiveness creates economic opportunities at the household level. This will improve supply, with the capacity to enhance food availability and utilization.

5.2. Determinants of consumer demand for biofortified cassava

Our findings show that the price of the substitutes (conventional cassava or its variants), expenses on supplements, awareness of health benefits, income, expert recommendations and education were

Table 3. Independent sample test for food secure and food insecure households

	Levene's test for equality of variance		t-test for equality of means						
			t	df	Sig. (2-tailed)	Mean difference	Std. error difference	95% confidence interval of the difference	
	F	Sig.						Lower	Upper
Equal variance assumed	56.6	.000	10.825	198	.000	21218.35124	1960.17503	17352.8518	25083.8506
Equal variance not assumed			11.788	115.914	.000	21218.35124	1800.03629	17653.1245	24783.5779

Table 4. Estimates of the determinants of bio fortified cassava demand

Variables	Coefficient	Std. error	t-ratio
INTERCEPT	3633.942	2877.888	1.26
Price	−.0440594	.2934461	−0.15
Price of conventional product variants	−.2429981	.1465753	−1.66*
Taste	−21.34681	73.34557	−0.29
Expenditures on supplements	.3811091	.1222878	3.12***
Awareness of health benefit	492.7659	256.0918	1.92*
Income	.0318676	.0041196	7.74***
Recommendation from experts	802.9144	381.2711	2.11**
Age	17.75429	19.51612	0.91
Education	−112.1162	63.57933	−1.76*
Household size	18.66033	54.64319	0.34
R^2	0.3789		
Adj R-squared	0.3462		
F-ratio	11.36***		

Note:
* Significant 10%
** Significant 5%
*** Significant at 1%.

positively associated with consumer demand for biofortified cassava. The inverse relationship with the substitute price confirms economic theory (Jhingan & K, 2010) and this is expected given that cassava is a staple food in Nigeria with little market differentiation. As evidence has shown that biofortified crops are cost-effective (Bouis & Saltzman, 2017), this study demonstrates that it could be a viable alternative to food fortification and supplementation in Nigeria, especially when health benefits would be communicated (Nguema et al., 2011; Uchendu, 2013). Several studies (Ilona, 2014; Okello et al., 2017; Uchendu, 2013) highlighted the need for enhanced awareness and communication effectiveness to improve biofortified product acceptance (Foley et al., 2021). To achieve this, recommendations from experts are considered to be important. As illustrated in our study, there is nexus between expert recommendations and the consumer demand for biofortified cassava products. Experts are seen as a credible source of information and a vital link in consumers' learning, as shown in previous literature on biofortification (Foley et al., 2021; HarvestPlus, 2020; Solomon, 2011). Somewhat surprisingly, our study found a significant effect of education on consumer demand, but with negative coefficient. Generally, consumers with a high education level are typically expected to evaluate food products based on specific attributes, such as nutritive quality rather than price and availability alone, though the not clear nutritional benefits appear to have reversed the direction of the effect. This result is consistent with Ezeh et al. (2012), who observed that consumers' monthly spending on the consumption of *garri*, i.e. a by-product of cassava, has an inverse relationship with their education level. Two important views can explain the inverse effect of education on demand. First, cassava is a staple food with cultural affinity and is consumed by both educated and non-educated consumers. Second, over the years, people with higher education in Nigeria do not seem to be earning high income and as such cannot afford commercially diverse foods. Therefore, higher educated individuals may be spending more on non-food items (Zani et al., 2019).

5.3. Determinants of producer supply for biofortified cassava

Our study identified several factors that determine the supply of biofortified cassava products, such as price, substitute price, market orientation, institutional support and education. First, the price of biofortified cassava generated a significant positive effect on its supply. Higher price levels appear to motivate

Table 5. Estimates of the determinants of biofortified cassava supply

Variable	Coefficient	Std. error	t-ratio
Intercept	3716.384	757.3286	4.91***
Price Price of substitute	.0003621 .0000594	.000017 0000321	21.26*** 1.85*
Market orientation	−592.0002	241.893	−2.45**
Marketing cost	.0000708	.000804	0.09
Farm size	−19.30261	82.37294	−0.23
Perception of technology	26.68734	47.92456	0.56
Institutional support	−266.0423	110.8724	−2.40**
Income	−2.38e-06	.0001439	−0.02
Education	−123.776	33.64179	−3.68***
R-squared	0.8804		
Adj R-squared	0.8638		
F-ratio	60.37		

producers and can unlock supply (Lundahl & Ndulu, 2022). The positive value of the substitute price of cassava products was significant, though only at 10%, reflecting a marginal effect on the shift in quantity supplied. Although this was not expected, it reflects the current situation in Nigeria, where cassava is an important food product for household consumption and industrial processes. Another reason could be attributed to the lack of clear differences in labelling between biofortified cassava and conventional white cassava, by which the former is also sometimes sold as a generic brand.

The role of market orientation contradicts previous literature postulating that an increase in market orientation should increase the supply of biofortified foods. Our results might be linked to a reality of market constraints related to the land tenure system, policies, institutional support and market infrastructure, which limit the competitiveness and applicability of producers to think and act commercially (Oteh & Nwachukwu, 2014; Bouis & Saltzman, 2017). Ordinarily, institutional support ought to have a positive significant effect on the likelihood to supply. However, local factors such as the elite hijack of agricultural input materials, diversion of project funds and politicization of projects may have been responsible for the inverse effect. In Nigeria, there are many inconsistencies in policy implementation, as illustrated by the lack of commitment to support agriculture based on budgetary allocation and administration of funds (Eze et al., 2010).

Although access to education improves household farming productivity (Habtamu, 2019) and enhances the acquisition of food-related knowledge (Bornkessel et al., 2014), education in our study had a significant, negative effect on the supply, similar to consumer demand. Our result is surprising given that education is known to be a driver of behavioural change in favour of new technologies and innovations (Kamrath et al., 2019). The nature of cassava as a food security crop, with high demand and high market potential and planted by smallholder farmers with little education could explain this inverse effect of education.

5.3.1. Theoretical and practical implication

The present study provides some important information that will help in advancing the food system conversation in Nigeria. It demonstrated that food system approach can help to conceptualize food security for biofortified foods over time by understanding the expectation of market and consumers. Theoretically, this study contributes to food system approach beyond the agri-food marketing field, as it improves understanding of the dynamics of consumer demand and producer supplier using a local food by emphasizing the crucial role of adopting deep communication machinery to improve demand. To the best of the knowledge of the researchers, the study is the first to empirically consider the demand and supply of biofortified foods using food system approach and 2SLS.

Based on findings, this study makes three important contributions. Our study is the first to conceptualize the demand-supply dynamics of the biofortified food in Nigeria. By so doing, it provides insight into the critical issues of demand and supply that determine consumer and producer responses to changes in the cassava market system, because it provides input for supply development that advance the fulfilment of market demand for biofortified cassava products. Secondly, our study provides empirical evidence on the conversation of considering the food systems from the lens of system theory (Alarcon et al., 2021). Advancing better food outcome requires interaction of food demand and food supply, given that the interconnected systems and processes influence rational choice. Importantly, this paper provides insight on how these interacting factors of demand and supply can be built into key strategies that advance the marketing systems. Finally, the study extended argument on critical role of supply chain management in food systems. From farm to fork create economic opportunities for actors in the supply chain. Therefore, building a stable supply of biofortified crops must address key issues that bridge production.

5.3.2. Limitation and future research direction

Inspite of large empirical evidences and approaches adopted, the study has some limitations. One obvious limitation is the sample size and frame. The sample was drawn from only Abia state consumers and producers. The diversity of Nigeria may make it impossible to generalize the finding as variances may arise. The study also highlighted the extreme and complex challenge of quantifying food insecurity. The approach adopted in analyzing the food security status may pose some challenges based on context and environment. This may have also affected weak estimates of demand and supply in the study. Therefore, future researchers on this subject may choose a different route and enlist more variables such as incorporating the food security elements into the regression model. Since the issue of food security is complex and multidimensional, it would be useful to try a variety of methods or approach it from a qualitative approach.

6. Conclusions

This study examined the critical role of supply and demand factors to transition biofortified cassava food systems in Nigeria. Therefore, this study considered two stakeholders linked to the pull (consumers) and push (producers) strategy, to identify the factors that hinder the production and consumption of biofortified cassava. Our findings show that consumer knowledge, awareness and expert recommendations, as well as effective communication strategies, can help scale up demand and supply. Our evidence further suggests that both consumers and producers must be coupled with the right incentives and targeted communication to ensure sustainable market growth. Although the government has shown commitment through policies that encourage agricultural transformation, institutional support is highly needed to scale up biofortification. This lends support for addressing the current institutional challenges limiting agricultural productivity, through bridging infrastructural gaps and stimulating market orientation and demand, while avoiding adverse impacts of price increases of biofortified cassava.

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