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**Consumer Acceptance of Genetically Biofortified Food in Sub-Saharan Africa: Empirical  
Evidence from Nigeria**

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# Declaration

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Date

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Titilayo Akinwehinmi

# **Dedication**

I dedicate this work to my late father, Mr. Babatunde Oyeyinka, who deeply wished to witness this accomplishment but departed too soon.

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## **Zusammenfassung**

Mikronährstoffmangel, oft als „versteckter Hunger“ bezeichnet, bleibt eine erhebliche Herausforderung in Ländern mit niedrigem und mittlerem Einkommen und betrifft insbesondere Frauen im gebärfähigen Alter und kleine Kinder in Subsahara-Afrika. Jüngste Forschungsergebnisse zeigen, dass die Biofortifizierung von Grundnahrungsmitteln eine kosteneffiziente und skalierbare Strategie zur Bekämpfung dieser Mängel darstellt. Zwar wurde die konventionelle Pflanzenzüchtung erfolgreich zur Biofortifizierung einiger Grundnahrungsmittel eingesetzt, doch die agronomischen Einschränkungen dieser Methode haben bislang die Wirksamkeit der Biofortifizierung als Strategie zur Minderung von Mikronährstoffmangel in Subsahara-Afrika begrenzt. Im Gegensatz dazu bietet der Einsatz gentechnischer Verfahren zur Biofortifizierung von Grundnahrungsmitteln einen effizienteren Ansatz als die konventionelle Methode, da durch Gentechnik mehrere Mikronährstoffe gleichzeitig angereichert und höhere Nährstoffgehalte in kürzerer Zeit erreicht werden können. Dennoch bleibt die weit verbreitete Verbraucheraversion gegenüber gentechnisch veränderten Lebensmitteln eine Herausforderung.

Nur wenige Studien haben die Verbraucherakzeptanz gentechnisch veränderter Lebensmittel in Subsahara-Afrika untersucht, und ihre Ergebnisse zeigen, dass das Verbraucherbewusstsein für Gentechnik in der Region nach wie vor sehr gering ist. Gleichzeitig haben Präferenzstudien sich ausschließlich auf die Akzeptanz konventionell biofortifizierter Lebensmittel konzentriert. Zudem stützten sich die meisten Studien auf sensorische Eigenschaften zur Bewertung der Verbraucherpräferenzen und übersahen dabei oft, dass sogenannte Vertrauenseigenschaften, wie etwa die Methode der Biofortifizierung, die Präferenz maßgeblich beeinflussen können. Die Literatur deutet darauf hin, dass die Akzeptanz neuartiger Lebensmitteltechnologien durch Verbraucher nicht nur von der Wahrnehmung, sondern auch vom Verständnis der wissenschaftlichen Prozesse hinter den Technologien abhängt – was darauf

hindeutet, dass die Bereitstellung von Informationen die Akzeptanz erhöhen kann. Darüber hinaus legt die Literatur nahe, dass das Verständnis des Verbraucherverhaltens gegenüber neuartigen Lebensmitteltechnologien eine Untersuchung der kognitiven Prozesse erfordert, die dem Entscheidungsverhalten der Verbraucher zugrunde liegen.

Diese Dissertation leistet einen Beitrag zur bestehenden Literatur, indem sie die identifizierten Forschungslücken adressiert. Erstens liefern wir empirische Evidenz darüber, wie Informationen zu gentechnischen Prozessen die Verbraucherpräferenzen und die Zahlungsbereitschaft für genetisch biofortifizierte Lebensmittel in Subsahara-Afrika beeinflussen, wo Ernährungs- und Nahrungssicherheit drängende Probleme darstellen. Mittels eines Discrete-Choice-Experiments, das in Nigeria im Rahmen eines randomisierten experimentellen Designs durchgeführt wurde, wurden 352 Teilnehmende befragt. Von diesen wurden 235 Teilnehmende je einer von zwei Arten von Informationstreatments ausgesetzt: Das erste betonte die gesundheitlichen Vorteile eines ernährungsphysiologisch verbesserten Kassa-Produkts ("Gari"), während das zweite zusätzlich die wissenschaftlichen Prozesse hinter konventioneller Züchtung, Gentechnik und Genom-Editierung erklärte. Die Daten wurden unter Verwendung von Mixed-Logit-Modellen analysiert, wobei auch das Verhalten der Attribut-Ignoranz berücksichtigt wurde. Die Ergebnisse zeigen, dass Verbraucher bereit sind, einen Aufpreis für einen erhöhten Mikronährstoffgehalt zu zahlen. Allerdings führten Informationen zu den wissenschaftlichen Prozessen zu einer stärkeren Ablehnung gegenüber Gentechnik und Genom-Editierungs-Methoden. Besonders wichtig ist, dass die Bereitstellung von Prozessinformationen die Häufigkeit von Attribut-Ignoranz-Verhalten deutlich reduzierte, wobei Modelle unter expliziter Berücksichtigung der Attribut-Ignoranz die beste Modellgüte aufwiesen.

Zweitens untersuchen wir die Wahrnehmungen und Werte, die die Akzeptanz genetisch biofortifizierter Lebensmittel durch Verbraucher beeinflussen. Unser Hauptbeitrag zur Literatur

besteht in der Beschreibung des kognitiven Prozesses, der die Akzeptanz gentechnisch veränderter Lebensmittel in Nigeria bestimmt. Mithilfe eines Means-End-Chain-Frameworks identifiziert und beschreibt die Studie die Werte und Wahrnehmungen der Verbraucher in Bezug auf „Gari“, ein Kassava-Produkt, das in Nigeria durch konventionelle Züchtung, Gentechnik und Genom-Editierung mit Vitamin A und Eisen biofortifiziert wurde. Wir stellen fest, dass die Wahrnehmung von Natürlichkeit und der Wert, der einem langen Leben beigemessen wird, die Präferenz für konventionelle Methoden gegenüber gentechnischen Methoden bestimmen. Darüber hinaus wird Genom-Editierung als weniger riskant wahrgenommen, da es als frei von Fremdstoffen gilt, was es im Vergleich zu Gentechnik akzeptabler macht – wiederum beeinflusst durch den Wert eines langen Lebens.

Drittens untersuchen wir die Rolle der absoluten Ablehnung bei der Akzeptanz genetisch biofortifizierter Lebensmittel durch Verbraucherinnen und Verbraucher. Insbesondere bewerten wir, ob das Konzept der absoluten Ablehnung im Vergleich zum Risiko-Nutzen-Wahrnehmungsrahmen besser geeignet ist, die Verbraucherakzeptanz zu erklären. Unsere Studie liefert Nachweise für absolute Ablehnung sowohl anhand selbstberichteter Maße als auch eines wahlbasierten Ansatzes. Wir argumentieren, dass eine ausschließliche Betrachtung der selbstberichteten absoluten Ablehnung den Anteil der tatsächlich absolut Ablehnenden überschätzt. Durch die Anwendung einer neuartigen wahlbasierten Methode, die die tatsächlichen Entscheidungsmuster der Befragten ableitet, zeigen wir, dass frühere Studien die Verbreitung absoluter Ablehnung wahrscheinlich überbewertet haben, da viele Verbraucher entgegen ihren eigenen Angaben handeln. Darüber hinaus untersuchen wir die sozioökonomischen und verhaltensbezogenen Faktoren, die sowohl mit der selbstberichteten als auch mit der wahlbasierten absoluten Ablehnung zusammenhängen. Die Ergebnisse deuten darauf hin, dass negative Einstellungen gegenüber gentechnisch veränderten Lebensmitteln eher durch Risiko-Nutzen-Wahrnehmungen als durch absolute Ablehnung selbst beeinflusst werden.

Diese Dissertation kommt zu mehreren Schlussfolgerungen und politischen Implikationen. Die Ergebnisse zeigen, dass Verbraucher im Südwesten Nigerias mit gentechnischen Methoden nicht vertraut sind. Daher ist eine kontinuierliche Verbraucheraufklärung von entscheidender Bedeutung. Ebenso sind politische Maßnahmen erforderlich, die eine klare Kennzeichnung gentechnisch veränderter Lebensmittel vorschreiben, um fundierte Kaufentscheidungen zu unterstützen. Wichtig ist zudem, dass die Studie aufzeigt, dass Verbraucher eine deutliche Zahlungsbereitschaft für erhöhte Mikronährstoffgehalte aufweisen, was nahelegt, dass Marketingstrategien den Fokus stärker auf gesundheitliche Vorteile als auf Produktionstechniken legen sollten. Auffällig ist auch, dass Verbraucher Genom-Editierung deutlich weniger ablehnend gegenüberstehen als der Gentechnik, was auf ein vergleichsweise höheres Marktpotenzial für genomeditierte biofortifizierte Lebensmittel in Nigeria hinweist. Schließlich müssen Studien zur Zahlungsbereitschaft für neuartige Lebensmittel das Verhalten der Attribut-Ignoranz berücksichtigen, da ein Unterlassen zu verzerrten Schätzungen der Zahlungsbereitschaft führen kann.

Diese Forschung weist jedoch gewisse Einschränkungen auf. Die Verwendung eines hypothetischen Discrete-Choice-Experiments zur Erfassung von Verbraucherpräferenzen und Zahlungsbereitschaft könnte die Ergebnisse beeinflussen. Da die Anwendung gentechnischer Methoden für das in dieser Studie untersuchte Lebensmittelprodukt bisher nicht kommerzialisiert wurde, war der Einsatz realer Lebensmittelprodukte nicht möglich. In der Hoffnung auf eine zukünftige Kommerzialisierung könnten weitere Studien reale Produkte einsetzen, um belastbare Maße der Zahlungsbereitschaft von Verbrauchern für gentechnisch veränderte Lebensmittel in der Region zu ermitteln. Darüber hinaus sollten künftige Studien die Rolle der Kennzeichnung gentechnisch veränderter Lebensmittel auf die Zahlungsbereitschaft der Verbraucher untersuchen, wie dies in anderen Regionen bereits geschehen ist. Wir schlagen zudem die

Durchführung von länderübergreifenden Studien in Subsahara-Afrika vor, um die Generalisierbarkeit unserer Ergebnisse zu prüfen.

Ferner verhinderte beim Erkunden der kognitiven Strukturen, die die Verbraucherakzeptanz genetisch biofortifizierter Lebensmittel prägen, die relativ geringe Stichprobengröße eine Heterogenitätsanalyse anhand von Teilnehmermerkmalen. Zukünftige Arbeiten könnten dies aufgreifen, indem sie Unterschiede in den kognitiven Strukturen in Abhängigkeit von Stichprobenmerkmalen untersuchen und damit eine gezieltere und wirksamere Politikgestaltung ermöglichen.

## Summary

Micronutrient deficiency (MND), often referred to as “hidden hunger,” remains a significant challenge in low- and middle-income countries, particularly affecting women of reproductive age and young children in sub-Saharan Africa (SSA). Recent research shows that biofortification of staple crops is a cost-effective and scalable strategy to address these deficiencies. While conventional plant breeding methods have been used to successfully biofortify some staple crops, the agronomic limitations of the method have, up till now, limited the effectiveness of biofortification as a strategy to mitigate MND in SSA. Alternatively, the use of genetic engineering (GE) techniques to biofortify staple crops offers a more efficient approach compared to the conventional method, as GE can enhance crops with multiple micronutrients and achieve higher nutrient levels in a shorter time. Nonetheless, the widespread consumer aversion to GE foods remains a concern.

Only a limited number of studies have examined consumer acceptance of genetically engineered foods in SSA, and their findings indicate that consumer awareness of GE technologies in the region remains very low. At the same time, preference-elicitation studies have focused solely on consumer acceptance of conventionally biofortified foods. Moreover, most studies have relied on sensory attributes to assess consumer preferences, often overlooking how credence attributes, such as the biofortification method, can shape preferences. The literature suggests that consumers’ acceptance of novel food technologies hinges not only on awareness but also on their understanding of the scientific processes underlying these technologies, indicating that providing accurate information can enhance acceptance. In addition, the literature also suggests that understanding consumer behaviour regarding novel food technologies requires investigating the cognitive processes behind consumer choice behaviour.

This dissertation contributes to the existing literature by addressing the identified research gaps. First, we provide empirical evidence on how information on GE processes influences

consumer preference and WTP for genetically biofortified foods in SSA, where food and nutrition insecurity are pressing issues. Using a discrete choice experiment (DCE) and a randomized experimental design, 352 participants were sampled in Nigeria. Of these, 235 participants were subjected to two types of information treatments: one emphasizing the health benefits of a nutritionally enhanced cassava product ("gari") and another that also explained the scientific processes behind conventional breeding, genetic modification (GM), and gene editing (GED). The data were analyzed using mixed logit models while also accounting for attribute non-attendance (ANA) behaviour. The results show consumers are willing to pay a premium for enhanced micronutrient content.

However, information detailing scientific processes increased consumer aversion toward GM and GED methods. Importantly, providing process information significantly reduced instances of ANA behaviour, with stated ANA models offering the best fit to the data.

Second, we explore the perceptions and values influencing consumer acceptance of genetically biofortified foods. Our main contribution to the literature is the description of the cognitive process that determines consumers' acceptance of genetically engineered food in Nigeria. Through a means-end chain framework, the study identifies and describes consumer values and perceptions toward "gari", a cassava product biofortified with vitamin A and iron through conventional breeding, GM, and GED in Nigeria. We find that the perception of naturalness and the value placed on long life drive preference for conventional methods over GE methods. Additionally, GED is viewed as less risky due to its perception as free of foreign objects, making it more acceptable than GM, again influenced by the value of long life.

Third, we investigate if absolute opposition (AO) plays any role in consumers' acceptance of genetically biofortified foods. Specifically, we assess whether the framework of AO, compared to the risk–benefit perception framework, better explains consumer acceptance. Our study

provides evidence of AO using both self-reported measures and a choice-based approach. We argue that relying solely on self-reported AO overestimates the proportion of genuine absolute opponents. Instead, by applying a novel choice-based method that infers respondents' actual decision patterns, we show that prior research may have exaggerated the prevalence of absolute opponents, as many consumers act inconsistently with their stated AO. Furthermore, we examine the socio-economic and behavioural factors associated with both self-reported and choice-based AO. The findings suggest that negative attitudes toward genetically engineered foods are driven more by risk–benefit perceptions than by absolute opposition itself.

This dissertation offers several conclusions and policy implications. The findings indicate that consumers in southwestern Nigeria were unfamiliar with GE methods. As such, sustained consumer education is crucial. Policies mandating clear labelling of genetically engineered foods are also essential to support informed purchasing decisions. Importantly, the study reveals that consumers exhibit a significant WTP for enhanced micronutrients, suggesting that marketing should emphasize health benefits over production techniques. Consumers are notably less averse to GED than to GM, indicating a relatively greater market potential for gene-edited biofortified foods in Nigeria. Finally, studies on WTP for novel foods must account for ANA, as failing to do so can lead to biased consumer WTP estimates.

However, this research has certain limitations. The use of a hypothetical DCE to elicit consumer preferences and WTP may have influenced the results. The fact that the use of GE methods for the food product investigated in this study has not been commercialized does not permit the use of real food products. With the hope of commercializing these products, further studies can use real food products to provide robust WTP measures of consumers for genetically engineered foods in the region. Moreover, future studies should investigate the role of GE labelling on consumers' WTP, as has been done in other regions. We also suggest conducting multi-country studies across SSA to assess the generalizability of our findings.

Additionally, while exploring the cognitive structures shaping consumer acceptance of the genetically biofortified foods, the relatively small sample size prevented heterogeneity analysis across participant characteristics. Future work could address this by examining variations in cognitive structures based on sample characteristics, thereby informing more targeted and effective policy development.

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## **List of Abbreviations**

ABS	African Biofortified Sorghum
ANA	Attribute Non-Attendance
AO	Absolute Opposition
CRISPR	Clustered Regularly Interspaced Short Palindromic Repeats
DCE	Discrete Choice Experiment
EAR	Estimated Average Requirement
ECLC	Equality Constrained Latent Class
GAIN	Global Alliance for Improved Nutrition
GE	Genetic Engineering
GED	Gene Editing
GM	Genetic Modification
HVM	Hierarchical Value Map
IITA	International Institute for Tropical Agriculture
ISAAA	International Service for the Acquisition of Agri-biotech Applications
MEC	Means End Chain
MND	Micronutrient Deficiencies
MNL	Multinomial Logit
NAFDAC	National Agency for Food and Drug Administration and Control
NBMA	National Biosafety Management Agency
PV	Protected Values
RP	Revealed Preference
RPL	Random Parameter Logit
RUT	Random Utility Theory
SP	Stated Preference
SSA	Sub-Saharan Africa
UNICEF	United Nations Children Emergency Fund
VA	Vitamin A
WHO	World Health Organization
WTP	Willingness to Pay

# CHAPTER ONE

## INTRODUCTION

### 1.1. Background

Globally, micronutrient deficiencies, particularly in vitamin A (VA) and iron, contribute to severe health consequences, including increased susceptibility to infections, impaired physical and cognitive development, and higher mortality rates (Stevens et al., 2015; Harika et al., 2017; Abolurin et al., 2018). Women of reproductive age and children under five in sub-Saharan Africa (SSA) are among the most affected groups (Bailey et al., 2022). For instance, Africa has the highest prevalence of iron deficiency among women of reproductive age (38.9%), with rates reaching 52% in Western Africa (FAO, 2023).

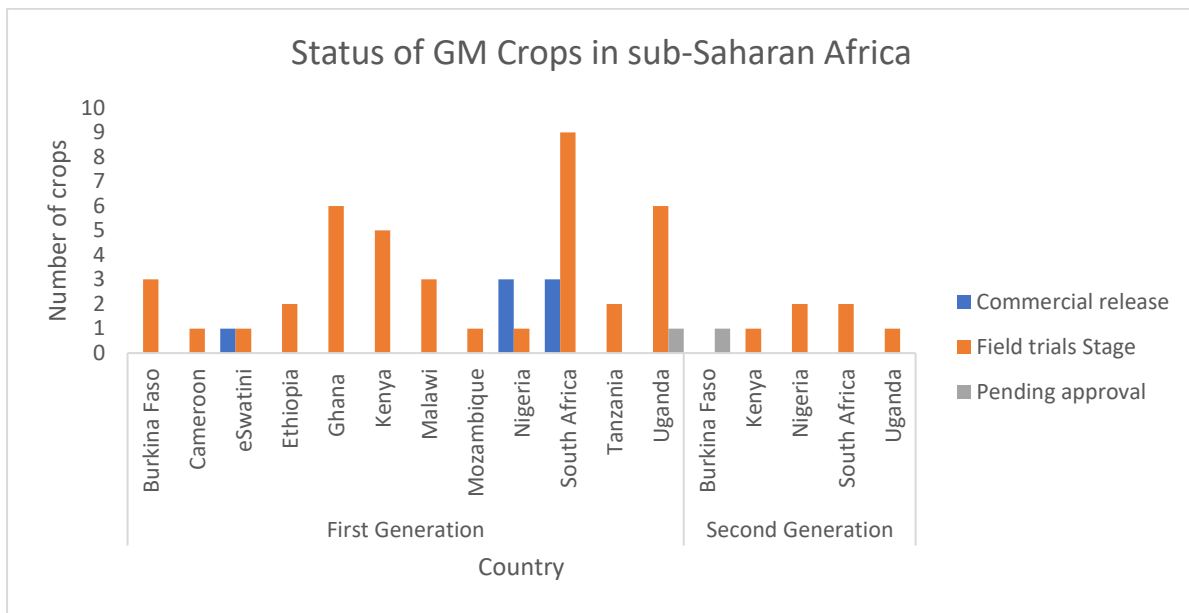
The primary causes of micronutrient deficiencies include a heavy reliance on low-quality staple foods, inadequate consumption of fruits and vegetables, high costs of nutrient-rich foods, limited knowledge of food processing, and a general lack of awareness regarding nutritious diets (Onuegbu et al., 2017; Okwuonu et al., 2021). Low-income households are particularly micronutrient-deficient because their diets are predominantly composed of staple crops that provide essential calories but insufficient vitamins and minerals (Onuegbu et al., 2017). Consequently, enhancing the micronutrient content of staple foods through biofortification has received particular attention in low-income countries (Bouis et al., 2011; Bouis and Saltzman, 2017). Biofortification, among other interventions, is cost-effective and offers the highest potential to reduce micronutrient deficiencies among poor and nutrient-deficient rural populations (Qaim et al., 2007; Meenakshi et al., 2012; Bouis and Saltzman et al., 2017).

Biofortification can be achieved using selective or conventional breeding, agronomic practices, and genetic engineering (GE) methods, including genetic modification (GM) and gene editing (GED) (Van Der Straeten et al., 2020; Kumar et al., 2022). Unlike conventional breeding, which depends on natural genetic variation and selection, GM involves transferring specific traits between organisms, while GED directly modifies an organism's genetic material to enhance desired characteristics (McFadden et al., 2020).

While the conventional breeding method has contributed significantly to biofortification in SSA (Birol et al., 2015; Oparinde et al., 2016a), there are several limitations. The limitations include the lengthy time required for breeding, loss of hybrid vigour leading to reduced yields, inability to introduce micronutrients that are absent in a crop's genetic pool, and reduced expression of desirable traits due to uncontrolled gene interactions. Additionally, farmers must purchase new hybrid seeds each planting season, which can be a financial burden (Garcia-Casal et al., 2017). On the other hand, GE methods are considered more efficient for biofortification because they allow for the simultaneous enhancement of multiple micronutrients and can achieve desired nutrient levels more rapidly than conventional breeding (Naqvi et al., 2009; De Steur et al., 2012; Van Der Straeten et al., 2020). Given the advantages of the GE methods, achieving comprehensive biofortification objectives may only be feasible through GE approaches (Onuegbu et al., 2017; Bouis and Saltzman, 2017).

Although global debates on genetically engineered foods have been ongoing for many years, the issue is relatively new in SSA. This is largely because the region has long faced food and nutrition insecurity (Gbashi et al., 2021; Mmbando et al., 2023). Recently, however, policies in SSA have become more supportive, with an increasing number of genetically modified crops approved for commercialization (Ngongolo and Mmbando, 2025). Despite this progress, research shows that most people in SSA remain largely unfamiliar with GE technologies (Ewa et al., 2022; Mustafa et al., 2023). Figure 1 shows the current state of GM and GED crops development in SSA. The

first-generation genetically modified crops address agronomic challenges such as pest resistance, herbicide tolerance, and disease resistance, aiming to improve yields and benefit farmers. In contrast, second-generation genetically modified crops are developed to benefit consumers by offering improved nutrition and longer shelf life (Chapman and Burke, 2006; Gonzalez et al., 2009).

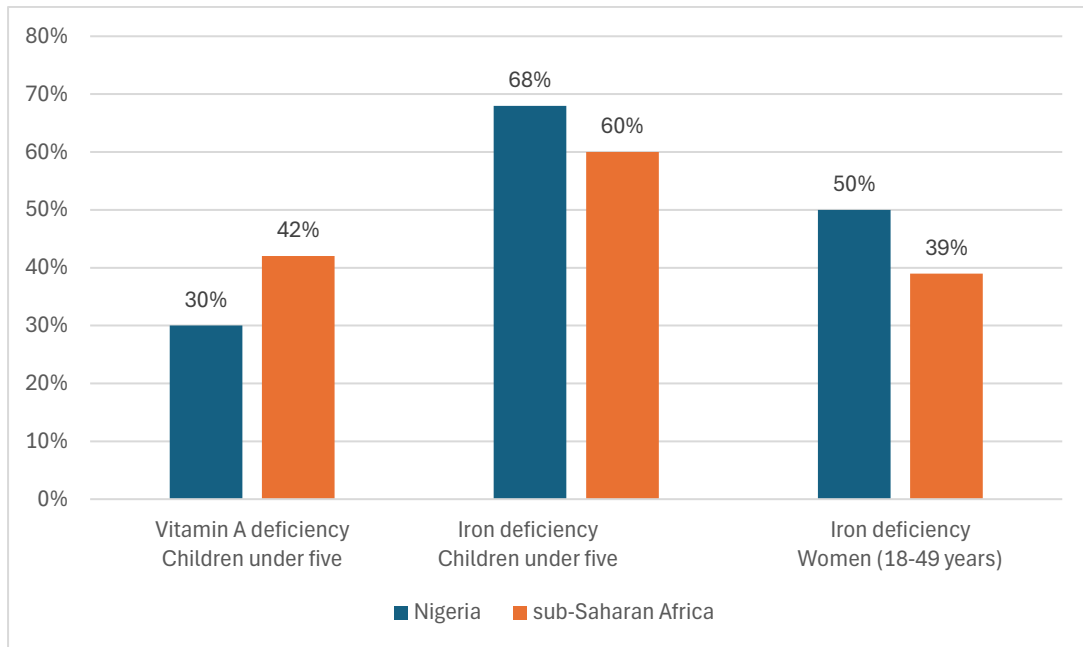


**Figure 1: Status of GM and GED Crops Development in SSA**  
**Source: (ISAAA, 2019; ISAAA, 2024)**

## 1.2. Micronutrient Deficiencies and Biofortification in Nigeria

Nigeria is the most populous country in SSA and West Africa. Micronutrient deficiencies remain a major public health issue in the country, particularly affecting women of reproductive age and children under five (Abubakar et al., 2022). VA and iron deficiencies are among the most widespread micronutrient deficiencies in the country (Maziya-Dixon et al., 2006; Harika et al., 2017; Obasohan et al., 2022). Approximately 30% of children under five in Nigeria suffer from VA deficiency (The World Bank, 2023). Additionally, around 68.9% of children and 50% of pregnant women experience iron deficiency (The World Bank, 2023). Figure 2 shows that iron

deficiencies in Nigeria among the women of reproductive age and children under five are higher than the average in SSA.



**Figure 2: Current Prevalence of VA and Iron Deficiencies in SSA and Nigeria**  
Source: (World Bank, 2023)

Several interventions have been implemented to address these deficiencies. These interventions include supplementation programs, food fortification, nutrition education campaigns, and biofortification of staple crops to enhance micronutrient content (WHO, 2020; GAIN, 2020; UNICEF, 2021; Bouis and Saltzman, 2017). Despite their potential effectiveness, the interventions face significant challenges. For instance, supplementation programs, while efficient in the short term, require sustained funding, logistical infrastructure, and strong government commitment (Ekesa et al., 2017). Food fortification primarily benefits urban populations who consume industrially processed foods, whereas rural communities largely depend on unprocessed, locally produced staples that are not fortified (GAIN, 2022; Ogunmoyela et al., 2023). Furthermore, the effectiveness of nutrition education efforts is hampered by a lack

of trained extension workers and nutrition officers, restricting outreach to vulnerable rural populations (Thomas and Uwandu, 2019; Sani, 2024).

However, studies have demonstrated the effectiveness of biofortification in reducing micronutrient deficiencies in Nigeria (Afolami et al., 2021; Ofori et al., 2022). For example, Afolami et al. (2021) found that consuming VA cassava improved serum retinol levels in preschool children (3–5 years old) in Nigeria. Regarding genetically biofortified foods, two genetically modified biofortified staple crops have been introduced to Nigeria through the African Biofortified Sorghum (ABS) project and the Bio-Cassava Plus project. The ABS project aims to develop transgenic sorghum with increased levels of lysine, VA, iron, and zinc (<https://www.biosorghum.org>; Zhao et al., 2019). The Bio-Cassava Plus (Sayre et al., 2011) initiative focuses on developing cassava varieties enhanced with virus resistance, zinc, iron, protein, and VA. However, these genetically modified biofortified crops have not yet been approved for commercialization by the Nigerian government.

### **1.3. Statement of the Problem**

Novel food technologies, particularly GE, are being advanced globally to address persistent challenges such as food and nutrition insecurity by improving crop yields, enhancing nutritional quality, and increasing resilience to environmental stresses (Qaim and Kouser, 2013; Aziz et al., 2022). In SSA, these technologies are increasingly being implemented to improve food attributes and combat regional food and nutrition insecurity (Gbashi et al., 2021; Mmbando et al., 2023). For instance, confined field trials and commercialization of genetically modified crops are expanding (Kedisso et al., 2022), and significant investments are being made in GED applications for key staple crops such as maize, cassava, sorghum, and millet to meet specific food security needs (Syombua et al., 2021; Bicko et al., 2021; Sprink et al., 2022). Despite these

advancements, the public acceptance of these technologies remains unknown (Gbadegesin et al., 2022).

Public acceptance of genetically engineered foods is shaped by awareness, knowledge, and concerns related to health and safety (Kikulwe et al., 2011; Kedisso et al., 2022). In SSA, empirical evidence consistently shows low levels of consumer awareness and knowledge about genetically engineered foods (Kimenju et al., 2005; Dovey et al., 2020; Oladipo et al., 2020). Widespread knowledge deficits contribute to misinformation, fear, and information asymmetry, potentially resulting in market inefficiencies (Caswell and Mojduszka, 1996; Olynk et al., 2010; Gbadegesin et al., 2022).

Studies have examined consumers' acceptance of conventionally biofortified foods in SSA and have found that consumers are often willing to pay a premium, even without detailed nutrition information (Chowdhury et al., 2011; Meenashki et al., 2012; Oparinde et al., 2016a). However, estimating the market potential for genetically biofortified foods remains difficult due to the persistent lack of consumer awareness and understanding of the underlying technologies. Given the increasing relevance of genetically biofortified foods in addressing micronutrient deficiencies, especially in SSA, bridging these knowledge gaps is critical.

Therefore, this dissertation seeks to investigate the effect of providing information on the scientific processes behind conventional, GM, and GED food production on consumer preferences and WTP for genetically biofortified foods in Nigeria. Additionally, it aims to understand the cognitive and mental processes that shape consumer attitudes and decision-making related to these technologies. By examining how information affects consumer purchasing behaviour and their cognitive processes, this research offers insights into the market prospects of genetically biofortified foods and informs strategies to enhance consumer acceptance of food biotechnology in SSA.

#### **1.4. Research Questions**

Therefore, this study seeks to answer the following research questions:

1. What is the role of process information in consumer preferences for genetically biofortified food?
  - a. What are consumers' initial levels of awareness, knowledge, and risk-benefit perception of genetically biofortified food?
  - b. How do different information treatments affect consumer preferences and willingness to pay for genetically biofortified food?
  - c. How does attribute non-attendance (ANA) affect the effect of the information?
2. What are the cognitive processes that determine consumer acceptance of genetically biofortified food?
3. Does Absolute Opposition (AO) play any role in consumer acceptance of genetically biofortified food?
  - a. Do consumers' self-reported measures of AO to GE food overestimate their actual behavioural opposition?
  - b. Which factors predict the manifestation of AO toward GE?

#### **1.5. Research Objectives**

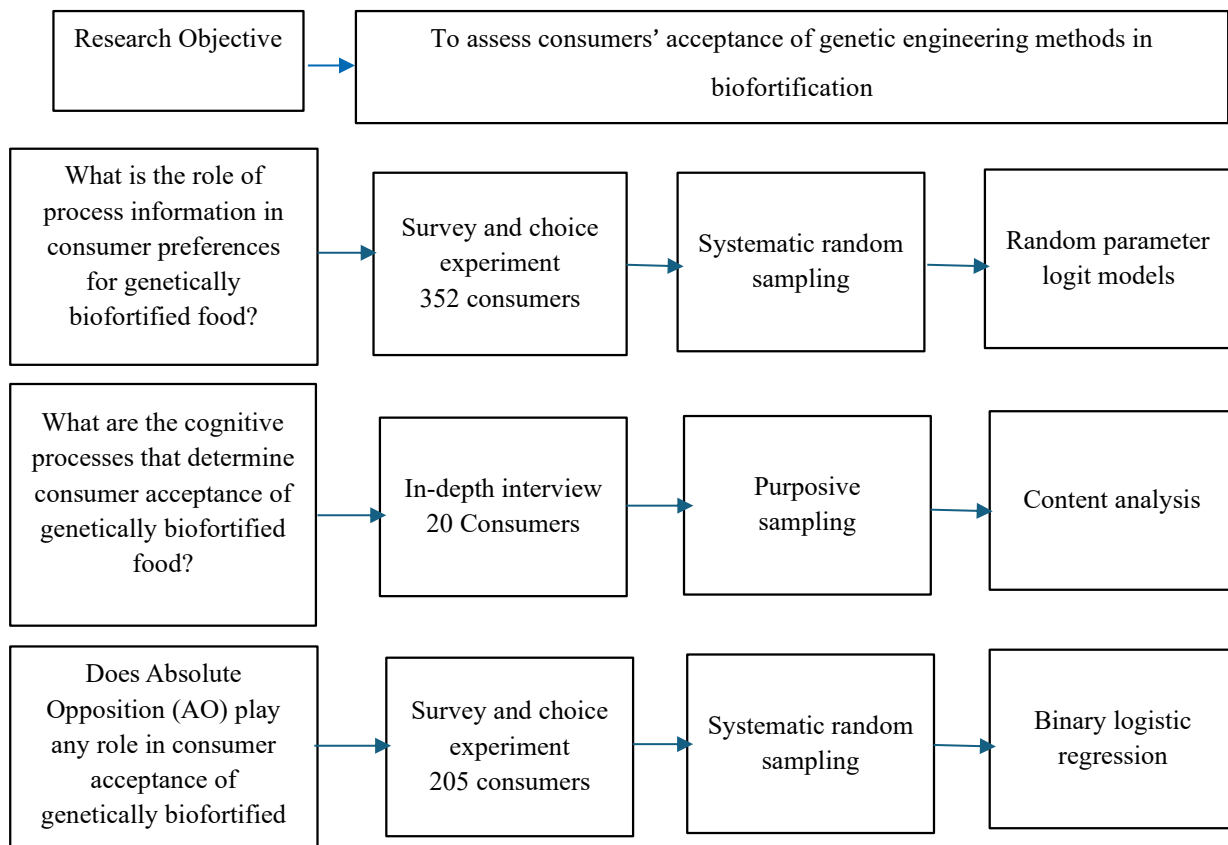
The main objective of this study is to assess consumers' acceptance of GE methods in biofortification in Nigeria. The specific objectives were to:

- i. Examine the effect of information about the scientific process behind transgenic GM and GED technologies on consumers' preferences and WTP for genetically biofortified food.
- ii. Explore the cognitive processes that determine consumer acceptance of genetically biofortified food.

- iii. Assess if AO to GE plays a role in consumers' acceptance of genetically biofortified foods.

## **1.6. Research Design**

Figure 3 illustrates the research design of the study. This dissertation employs a mixed-method design that integrates both quantitative and qualitative approaches to provide a comprehensive understanding of consumer acceptance of genetically biofortified foods in Nigeria. The quantitative approach was employed to assess how production process information provision influences consumers' preference and WTP for genetically biofortified foods, and the role of absolute opposition in consumer acceptance of genetically biofortified foods in Nigeria. The qualitative approach explores the cognitive processes that underlie consumer attitudes toward the use of GE methods in biofortification. It uncovers the personal values and perceptions that influence consumer behaviour and product choice. By combining these methods, the study not only measures how much consumers are willing to pay but also explores why they make such decisions.



**Figure 3: Research Design**

### 1.7. Dissertation Outline

The dissertation is structured into eight chapters. Chapter One presents the introduction section of this dissertation. It outlines the background information on MND and the use of GE methods in biofortification. Moreover, it describes the research problem, research questions, the study’s objectives, and an overview of the research design.

Chapter Two presents the theoretical framework of the study and an empirical review of the literature, focusing on studies related to consumer acceptance of conventionally biofortified foods in SSA, the influence of production process information on consumers’ WTP for novel food technologies globally, consumer acceptance of genetically engineered foods, and absolute opposition.

Chapter Three outlines the research methodology. It presents the quantitative and qualitative methods used in this dissertation. It provides the details on the study area, sampling techniques, and data collection procedures. The chapter discusses the conceptual framework, econometric framework, and data analysis procedures employed.

Chapters Four to Six present the results of the three main analyses of this dissertation. The analyses focus on the role of information in consumer preferences and WTP for genetically biofortified food, consumers' perception of genetically biofortified food, and the role of absolute opposition in consumer acceptance of genetically biofortified food.

Chapter Seven provides the discussion, integrating and interpreting the results obtained from the analyses described in Chapters Four to Six.

Chapter Eight summarizes the key findings, discusses practical implications, and outlines directions for future research.

## **CHAPTER TWO**

### **LITERATURE REVIEW**

#### **2.1. Chapter Overview**

Micronutrient deficiencies are prevalent in SSA, and biofortifying the staple foods primarily consumed by low-income populations could help alleviate these health challenges. Research indicates that using GM and GED in biofortification can be more effective than conventional methods. Consequently, consumers' knowledge and perceptions of these production techniques, as well as the nutritional benefits they provide, are likely to influence their food choices. This chapter presents the theoretical framework relating to consumer choices, and the empirical review of literature on consumer acceptance of conventional biofortified foods, Consumers' WTP for novel food technologies and production process information, consumer acceptance of GE methods in food, and attribute non-attendance in food choice experiment.

#### **2.2. Theoretical Foundation: Consumer Choices**

The theoretical foundation for consumer choice begins with the representation of preferences over feasible alternatives and the assumptions under which those preferences can be used to derive a utility function. Depending on the nature of the decision situation, choice can be discrete, continuous, or ordinal in nature. A discrete choice situation is defined as one in which the respondent faces a choice among a set of alternatives meeting the following criteria: the number of alternatives in the set is finite; the alternatives are mutually exclusive; and the set of alternatives is exhaustive (Train, 2009). Discrete choice models are theoretically rooted in Lancaster's Theory of Consumer Demand (Lancaster, 1966) and Random Utility Theory (McFadden, 1974).

### ***2.1.1. Lancaster's Theory of Consumer Demand***

Lancaster (1966) introduced a "new theory of consumer demand" by revising the standard neoclassical consumer theory to suggest that utility is derived from the attributes of a product, not the product itself. In this framework, each good is seen as a fixed bundle of attributes, and a combination of goods generates a vector representing the quantities of these characteristics. As a result, consumers evaluate goods based on the specific characteristics (attributes) they offer, rather than viewing them as a single, uniform entity.

The assumptions of the theory, marking a departure from the traditional consumer theory, are that:

- The good, per se, does not give utility to the consumer; it possesses characteristics, and these characteristics give rise to utility.
- In general, a good will possess more than one characteristic, and many characteristics will be shared by more than one good
- Goods in combination may possess characteristics different from those of the goods separately (Lancaster, 1966).

Consequently, the utility function to be maximized can be rewritten as  $\mu = \mu (Z)$ , where  $Z$  is a vector of characteristics rather than  $\mu = \mu (X)$ , where  $X$  is a vector of goods.

### ***2.1.2. Random Utility Theory***

Random Utility Theory (RUT) originates from Thurstone's (1927) Law of Comparative Judgement. In this framework, an alternative  $i$  has a true stimulus level  $V_i$ , which is perceived with an error, represented as  $V_i + \varepsilon_i$ . Thurstone proposed that individual choice can be modelled as a process in which a random variable is associated with each alternative, and the option with the highest realized value is selected (Kjær, 2005). When these perceived stimulus levels are

interpreted as representing satisfaction or utility, the model becomes one of economic choice, where individuals select the alternative that yields the highest realized utility (McFadden, 2001). RUT assumes that individuals make rational choices by selecting the alternative that provides them with the highest perceived utility. When faced with multiple options, decision-makers weigh the attributes of each alternative and choose the one that maximizes their overall satisfaction. The Random Utility Model posits an indirect utility function that decomposes the utility function of a decision maker into deterministic and stochastic parts, such that for an individual  $n$  with the choice of alternative  $i$  in a choice set, utility  $U$  becomes:

$$U_{in} = V_{in} + \varepsilon_{in}$$

$U_i$  is the true but unobservable (latent) utility for alternative  $i$ ,  $V_i$  is the observable systematic component of utility, and  $\varepsilon_i$  is the factor unobservable to the researcher and treated as a random component (Hanemann 1984). Therefore, individual  $n$  chooses alternative  $i$  over  $j$  if the utility derived from this alternative, ( $U_{in}$ ), is greater than the alternative  $j$ , ( $U_{jn}$ ), among  $I$  alternatives.

$$\text{i.e. if } U_{in} > U_{jn} \forall i \neq j.$$

The RUT accommodates Lancaster's theory of demand when we assume that preferences are attribute-based, meaning each alternative is characterized by a vector of attributes. Therefore, the attributes, the characteristics of the decision maker, or a combination of both, usually define the deterministic part ( $V_{in}$ ).

Finally, assumptions can only be made about the distribution of the stochastic part ( $\varepsilon_{in}$ ) of the utility function, giving rise to a probabilistic model that captures the probability of choice.

### **2.1.3. Preference Elicitation**

Consumer preferences can be elicited either through a revealed or stated approach. While revealed preferences (RP) derive from actual observed behavior in market or non-market settings (Samuelson, 1938), by contrast, stated preferences (SP) elicit hypothetical choices in controlled

survey settings, allowing researchers to manipulate attributes and scenarios beyond those observed in markets (Hensher et al., 2000). SP methods include contingent valuation (Mitchell and Carson, 1989) and discrete choice experiments (Adamowicz et al., 1998), both of which can estimate willingness to pay for non-market goods, forecast demand for new products, and examine preferences for rarely traded attributes.

In a DCE, respondents are presented with repeated hypothetical choice tasks, each comprising a finite set of alternatives described by varying attribute levels, and are asked to select their preferred option. The DCE has been favoured in the literature for several methodological and analytical advantages. First, DCE is based on Lancaster's (1966) characteristics theory of demand, enabling the estimation of marginal utilities for individual attributes and allowing decomposition of WTP for specific product features. Second, by presenting respondents with repeated, structured trade-offs between alternatives, DCE better mimics actual market decision-making and reduces some forms of strategic or yes-saying bias that can occur in the Contingent Valuation Method (Louviere et al., 2000). Third, the experimental design in DCE allows the inclusion of hypothetical products and attribute levels not observed in the market, enhancing its flexibility for policy or innovation scenarios, while still facilitating estimation of substitution patterns and cross-elasticities (Caputo and Lusk, 2022).

## **2.3. Review of Empirical Literature**

### ***2.3.1. Consumer Acceptance of Conventionally Biofortified Crops in SSA***

The biofortification process has largely relied on the conventional plant breeding approach. The approach involves selecting and cross-breeding plants with naturally higher levels of essential micronutrients. Successes have been documented using conventional breeding methods for biofortification. For instance, biofortified varieties of maize, cassava, beans, and sweet potato have been developed and distributed in several SSA countries (Birol et al., 2015; Talsma et al.,

2017; Birol and Bouis, 2023). However, studies have identified that the success of biofortification initiatives depends on both economic viability for farmers and consumer acceptance (Qaim et al., 2007; Chowdhury et al., 2011; Birol and Bouis, 2023).

Consumer acceptance of conventionally biofortified crops has been extensively studied in SSA, where field experiments and sensory evaluations have been employed to assess WTP and perceptions of organoleptic characteristics. These evaluations compare biofortified foods with commonly consumed varieties, offering insights into consumer preferences and potential market demand. Further, the role of nutrition information in shaping consumer acceptance of these foods has been a focus of these studies.

Stevens and Winter-Nelson (2008) examined consumer acceptance of VA-biofortified maize through sensory evaluation and a framed field experiment in Mozambique. The results show that on average, participants rated the taste, texture, and appearance of local white maize higher than biofortified orange maize. However, a significant proportion of participants were willing to trade their local white maize for biofortified maize. Factors such as household size, the presence of young children, dietary diversity, and perceived taste influence consumer acceptance. The findings suggest that while white maize remains the preferred choice, it does not prevent the acceptance of orange biofortified varieties, highlighting the potential for VA-biofortified maize as a self-targeting nutritional intervention, particularly with appropriate pricing strategies.

Naico and Lusk (2010) assessed consumer preferences for biofortified orange-fleshed sweet potato with nutritional benefits compared to the traditionally consumed white varieties in Mozambique. Data from a choice experiment were used to estimate conditional logit models, which provided consumers' WTP across eight treatments. These treatments represented scenarios in rural and urban areas, with and without information on nutritional value, and included both visual/incentivized and hypothetical frameworks. The findings show that consumers are willing to pay a premium for orange-fleshed sweet potato if they possess eating qualities like traditional

varieties. Dry matter content emerges as the most important quality attribute, with marginal WTP for high versus low dry matter content remaining consistent across rural and urban areas. Moreover, the WTP for high dry matter content was nearly twice that of pulp colour, even when nutritional information was provided. This highlights the importance of improving dry matter content in orange-fleshed sweet potato varieties to increase acceptance. Additionally, the results indicate that preferences for orange-fleshed sweet potato are influenced by information about their nutritional benefits, the questioning format, which encourages participants to carefully consider their answers, and whether the individuals resided in urban or rural areas.

Chowdhury et al. (2011) investigated consumer acceptance of conventionally bred vitamin A-rich orange-fleshed sweet potato in Uganda. The study focused on sensory perception and the effect of nutrition information on WTP for orange-fleshed sweet potato compared to non-biofortified alternatives. Sensory evaluations were conducted using a nine-point hedonic scale to assess taste and colour, as the presence of vitamin A alters the colour of the sweet potato from white or yellow to orange. The study employed a between-subject design, dividing participants into four groups based on different nutrition information treatments, followed by a DCE. The results indicate that consumers found the taste and colour of orange-fleshed sweet potato acceptable compared to non-biofortified varieties. Moreover, without nutrition information, consumers are willing to pay for orange-fleshed sweet potato just like the traditional (white varieties). However, information provision led to consumers' willingness to pay a premium for an orange-fleshed sweet potato variety.

DeGroot et al. (2010) investigated consumers' WTP for yellow and fortified maize through experimental auctions conducted in Kenya. The findings revealed that consumers were willing to pay a 24% premium for maize fortified with essential minerals and vitamins. While white maize remained the preferred variety, yellow maize was still accepted, albeit only at an 11%

discount. These results suggest that although colour preferences influence consumer choices, the yellow colouration does not pose a significant barrier to the acceptance of biofortified maize.

Meenakshi et al. (2012) examined the effect of nutrition information on consumers' WTP for biofortified orange maize in rural Zambia. Sensory evaluations of three maize varieties: non-biofortified white and yellow, and biofortified orange, were conducted using a five-point hedonic scale. To measure the effect of nutrition information, the study implemented five treatment groups, comparing the effectiveness of simulated radio broadcasts and community leaders in delivering nutrition messages. The results suggest that consumers can distinguish between the maize varieties, and biofortified orange maize has the potential to compete with non-biofortified white maize even in the absence of a nutrition campaign. Furthermore, providing nutrition information significantly increases WTP for biofortified orange maize, with both radio broadcast and community leader-led nutrition messaging having similar effects on consumer acceptance.

DeGroot et al. (2014) assessed consumers' acceptance and WTP for quality protein maize in rural Tanzania. Sensory evaluations were conducted to compare quality protein maize with the traditional maize variety in terms of texture, taste, and overall quality, while WTP was measured using the Becker-DeGroot-Marschak experiment. Participants were categorized into two groups based on whether they received nutrition information. The results show that consumers preferred quality protein maize to the traditional maize due to its sensory attributes, as reflected in higher ratings for texture, taste, and overall qualities. Moreover, without nutrition information, consumers were willing to pay a 16% premium for quality protein maize, while those who received information were willing to pay a 39% premium.

Oparinde et al. (2016a) analyzed the effect of nutrition information campaigns and the nature of planting material delivery institutions on consumers' WTP for biofortified VA cassava in Nigeria. Sensory evaluations were conducted using a cassava variety known as 'gari,' with participants assessing its colour, texture, and taste on a five-point hedonic scale. Participants

were divided into three groups based on the type of nutrition information they received, and the Becker-DeGroot-Marschak experiment was used to elicit their WTP. The results showed that participants preferred the taste and colour of the biofortified gari. Furthermore, consumers were willing to pay a premium for the biofortified cassava, even in the absence of nutrition information. However, providing nutrition information significantly increased the price premium for biofortified cassava, while the method of information delivery had no significant effect.

Oparinde et al. (2016b) examined the impact of nutrition information, information framing, and the frequency of information delivery on consumers' WTP for iron bean varieties in Rwanda, specifically red iron bean and white iron bean. Participants were divided into five groups based on the type of nutrition information they received and were asked to assess the sensory attributes of three bean varieties: red mottled local, red iron bean, and white iron bean. The Becker-DeGroot-Marschak experiment was used to elicit WTP for each variety. The findings indicate that without nutrition information, consumers were willing to pay a significant premium for red iron bean but not for white iron bean. However, providing nutrition information led to a substantial increase in WTP for both varieties. The framing of the information did not have a statistically significant effect, but delivering nutrition information three times, rather than once, significantly boosted consumer demand for white iron bean.

Lagerkvist et al. (2016) studied the effects of VA biofortification information on consumers' sensory evaluations and emotions related to orange-fleshed sweet potato consumption. The study consists of a field experiment combining information treatments with sensory testing of VA-biofortified orange-fleshed sweet potato. The participants were divided into three groups based on the information treatments. Findings suggest that while detailed nutrition information reduced consumer acceptance, information on potential drawbacks affected expected taste and perceived texture, but had a limited overall impact. These results highlight critical considerations for how

nutrition information should be communicated to enhance consumer acceptance of orange-fleshed sweet potato.

Murekezi et al. (2017) employed cluster analysis to identify distinct consumer segments for four biofortified iron bean varieties in Rwanda. Consumer preferences for different sensory attributes of the beans were assessed using a seven-point hedonic scale, with home-use and central location tests conducted in both rural and urban areas. The cluster analysis revealed several distinct consumer segments within the study population. Additionally, multinomial probit and logit models were used to predict segment membership based on consumer characteristics. The results show that consumer preferences for iron bean varieties were influenced by factors such as geographic location, income source, and exposure to nutrition information.

These studies highlight the critical role of sensory attributes and nutrition information in influencing consumer acceptance and WTP for biofortified crops in SSA. Except for Lagerkvist et al. (2016), findings indicate that changes in sensory attributes, particularly the colour changes associated with vitamin A biofortified crops, as well as variations in taste and texture, was not an impediment to consumers being willing to purchase and consume the biofortified varieties. Further, nutrition information plays a significant role in shaping WTP. While consumers demonstrate a willingness to pay for biofortified foods even in the absence of information, the provision of health benefit information significantly increases their WTP. These findings reinforce the importance of consumer education in promoting biofortified crops. Overall, the studies point to market prospects for conventionally biofortified foods in SSA.

### ***2.3.2. Consumers' WTP for Novel Food Technologies and Production Process Information***

The limited effectiveness of conventional agronomic practices in improving crop performance has prompted the development and application of novel food technologies, such as genetic engineering. To evaluate the market potential of these technologies, research has increasingly

focused on examining consumer preferences for such technologies. Empirical evidence often indicates consumer aversion, citing limited consumer understanding of the underlying technologies identified as a key contributing factor (e.g., Nayga et al., 2005; Kahan et al., 2009; Fernbach et al., 2019). Consequently, several studies have explored how providing information about these technologies influences consumer acceptance of novel foods (Bieberstein et al. 2012; McFadden and Huffman, 2017; Zhang et al. 2020; Caputo, 2020; Kilders and Caputo, 2021; Marette et al., 2021). Overall, these studies find that consumers' reaction to these technologies varies across regions. In the following sections, I present the findings of these studies.

In Europe, Bieberstein et al. (2012) provided information on the process of nanotechnology to test its impact on WTP for an orange juice fortified with vitamin D and the packaging for the preservation of nutrients through the technology. In addition, specific information on health, society, and environmental benefits and risks was provided. Health information, which is most important to consumers, and the process information led to a decrease in WTP for the orange juice produced through the technology.

McFadden and Huffman (2017), focusing on the use of biotechnology in food, examined consumer WTP to reduce carcinogenic-forming potential in potatoes through information provision in the United States. Perspectives from science in terms of health risks from acrylamide exposure, industry relating to the benefits of targeting low acrylamide levels in food products, and the environment detailing the negative perspectives were considered in the study. The authors indicated that without any information, consumers' WTP for biotech methods was similar to that of the conventional methods. However, the effects of information varied across perspectives. While environmental information decreased consumers' WTP, scientific perspective, and scientific plus industry perspectives increased consumers' WTP for the biotech potatoes and reduced WTP for the conventional method.

A similar study on biotechnology (Kilders and Caputo, 2021) from the United States evaluated consumers' WTP for milk produced from a cow dehorned using GED methods. Information provision targets the process of GED, how it differs from GM, and its benefits for animal welfare. Findings indicate an increase in consumers' WTP for the GED method when the benefit, i.e., animal welfare, is considered. However, information on how GED differs from GM decreases consumers' WTP for GED and GM methods noticeably more for the GM method.

Further, Marette et al. (2021) examined consumers' WTP for apples that do not go brown using biotechnology in France and the USA. Information provision targets the benefits and biotechnology used while comparing WTP for GM and GED technologies. Findings indicate consumers' disutility for both the GM and GED methods in the two countries, with a larger discount for the GM method.

In a study on the effect of production process information on consumers' acceptance of cultured meat in China, Zhang et al. (2020) found that technology information emphasizing how and why it is made increases WTP by 2.2% more than the price of conventional meat. Likewise, in Asia, Caputo (2020) examines consumers' acceptance of food irradiation through the labelling system. Information provision focused on food safety and irradiation. Specifically, general information on food-borne diseases was presented, followed by positive and negative information about irradiation technology. Findings indicate that food safety information accompanied by positive information highlighting the benefits of irradiation led to an increase in WTP for irradiated beef in the study area.

Findings from these studies show mixed results on the effect of information on consumers' WTP in different regions of the world. We find no empirical evidence in Africa where consumers still have a limited understanding of GE technologies (Ewa et al., 2022; Gbadegesin et al., 2022). Additionally, food labelling to help consumers make informed choices is still largely absent in domestic food markets of countries in the region (Gbadegesin et al., 2022). Therefore, our study

investigates how information on the process of conventional, genetic modification, and gene editing technology might affect their preferences and WTP for genetically engineered foods.

### ***2.3.3. Information and Consumers' Acceptance of Genetically Modified Foods***

Several studies have examined consumer acceptance of genetically modified foods, with a particular focus on the role of different types of information. The following studies examine how different types of information affect consumer acceptance of genetically modified foods.

Lusk et al. (2004) investigated the effects of information about the potential benefits of biotechnology on consumer acceptance of genetically modified foods in the United States, England, and France. Using an incentive-compatible auction mechanism, the study elicited consumers' willingness to accept compensation for consuming a genetically modified cookie in comparison to a non-genetically modified alternative. The results indicate that the information led to a significant decrease in the compensation demanded by consumers in the United States and England, suggesting increased acceptance of genetically modified foods. In contrast, the information resulted in increased compensation demands for French consumers, indicating opposition to genetically modified foods.

Deodhar et al. (2008) evaluated consumers' WTP for genetically modified foods in India, providing participants with information on the advantages and disadvantages of GM technology. The findings revealed that over 70% of consumers were willing to consume genetically modified foods even when non-genetically modified alternatives were offered at the same price. Further, consumers are willing to pay a premium of 19.5% for golden rice and 16.12% for genetically modified edible oil, indicating consumer acceptance of genetically modified foods in the study area.

Depositario et al. (2009) investigated consumers' acceptance of golden rice in the Philippines, focusing on how different types of information influence WTP using a uniform-price auction

method. The results showed that the mean WTP was highest when participants received positive information, followed by the no-information condition, then negative information, with the lowest WTP observed under two-sided (both positive and negative) information. These findings suggest that when exposed to mixed messages, consumers may place greater emphasis on negative information, leading to reduced valuation of the product.

Gonzalez et al. (2009) examined consumers' WTP for genetically modified cassava biofortified with genetically modified in Brazil. Participants were informed about both the health benefits of VA and the use of GM in the biofortification process. The study found that the mean WTP was approximately 60–70% higher than the market price for traditional cassava. However, the findings also suggest that consumer acceptance would be even greater if the biofortification were achieved through conventional breeding methods rather than GM technology.

Corrigan et al. (2009) estimated consumers' WTP for golden rice in the Philippines and how it is influenced by different types of information about GM. Participants were divided into eight groups exposed to no information, positive, negative, or two-sided (both positive and negative) information. The results showed that WTP was highest among participants who received positive information, followed by those given no information. Two-sided information led to lower WTP, while negative information produced the lowest WTP estimates, highlighting the strong influence of message framing on consumer acceptance.

Colson et al. (2011) investigated consumers' WTP for foods nutritionally enhanced with vitamins and antioxidants using transgenic and intragenic GM methods, while accounting for the effect of different types of information. The study found that pro-biotechnology information alone significantly increased WTP. However, this effect reduced when positive, negative, and verifiable information were presented simultaneously. Further, consumers are willing to pay more for foods developed through intragenic modification, which are perceived as more similar

to conventional breeding, compared to transgenic methods involving the transfer of genes across species.

De Steur et al. (2012) examined the effect of information on consumers' WTP for folate biofortified rice in China. The study found that information highlighting the product's enhanced vitamin content led to substantial WTP, which significantly increased when participants were further informed about the associated health benefits. However, when information regarding the use of GM in the development of folate biofortified rice was introduced, WTP values reduced. Despite this reduction, the perceived health benefits appeared sufficient to partially offset consumers' negative perceptions of genetically modified foods.

Kajale and Becker (2014) assessed students' WTP for golden rice using the double-bounded contingent valuation method in India. Findings from the study revealed that approximately 55% of participants were willing to purchase golden rice at the same price as conventional rice, while about 85% were willing to do so if offered at a discount. The estimated mean WTP corresponded to a 4% price premium. Moreover, perceptions of global benefits, such as food security and personal health benefits, had a significant positive effect on WTP. In contrast, risk perceptions and sociodemographic factors were not found to significantly influence students' willingness to pay.

Lee et al. (2018) examined the effects of positive vs negative information on consumer valuation of genetically modified edamame in the United States. The results suggest that negative information significantly reduced the WTP for the genetically modified food, while positive information had little effect. Specifically, while positive information about GM technology did not significantly enhance consumer valuation of genetically modified food, negative information substantially decreased it. Moreover, the order in which the information was presented had no significant effect, given the stronger effects of negative information.

Edenbrandt et al. (2018) studied how information about the breeding techniques affects consumers' WTP for genetically modified foods in the United States. The study found that while consumers prefer the traditional breeding methods to GM, they are willing to pay more for genetically modified grapes developed through cisgenics, where gene transfer occurs between sexually compatible species, compared to transgenics, which involve gene transfer across species. Furthermore, providing additional information, including specific examples of the breeding techniques, enhanced consumer acceptance of cisgenic products. Nonetheless, a general aversion to GM persisted despite the information treatment.

Valente and Chaves (2018) studied the perceptions and economic valuation of GM and exposed participants randomly to three information treatments concerning genetically modified organisms' impacts (negative, positive, or mixed). Findings indicate that while negative information affects economic valuations, positive or mixed information has no effect.

Wuepper et al. (2019) investigated how information about risks and benefits influences German consumers' WTP for bread made with genetically modified wheat. The study found that opposition to GM increases among consumers after receiving information. Further, the information had a small negative effect on consumers' WTP.

The findings on the effect of information from these studies are mixed, while some studies report a positive influence, others indicate a negative effect. Although this research has been conducted in various parts of the world, no such studies have been carried out in SSA. This is significant, as scientists are advocating for the adoption of GE to address the high levels of food and nutrition insecurity in the region. Moreover, consumer awareness and knowledge of GE remain generally low in SSA.

#### ***2.3.4. Studies Comparing Consumers' Preferences and WTP for GM and GED***

With the recent emergence of GED methods, studies have assessed consumers' preferences and WTP for gene-edited foods compared to those produced using GM or conventional methods. The following is a summary of findings from studies conducted in other regions of the world.

Shew et al. (2018) conducted a multi-country study to evaluate consumer willingness to consume and WTP for foods produced using clustered regularly interspaced short palindromic repeats (CRISPR) technology, in comparison to both conventional and genetically modified foods. The study surveyed participants in the United States, Canada, Belgium, France, and Australia, where 56%, 47%, 46%, 30%, and 51% of participants, respectively, indicated a willingness to consume both genetically modified and CRISPR-derived foods. Familiarity with biotechnology and perceptions of food safety emerge as the primary factors influencing willingness to consume both CRISPR and genetically modified products. Findings reveal that consumers valued CRISPR and genetically modified foods similarly, yet significantly lower than conventional foods.

Muringai et al. (2019) examined the determinants of consumer acceptance of genetically modified potatoes, emphasizing three key factors: the introduced trait (e.g., health or environmental benefits), the type of breeding technology employed, and the identity of the product developer. The study revealed that consumers are willing to pay a premium for potatoes offering health and environmental benefits. However, consumers generally required a price discount to consider purchasing potatoes developed through either GM or GED, with a steeper discount applied to genetically modified products. These findings suggest a relatively higher level of consumer acceptance for GED compared to GM technologies.

Marette et al. (2021) compared consumers' WTP for apples developed using GM and GED in the United States and France. The study provided information on both the social and private benefits of the apples, as well as the technologies employed. Findings revealed that consumers in both countries applied price discounts to apples produced through GM and GED relative to

conventionally bred alternatives, with the largest discount observed for GM apples, followed by those developed through GED.

Ortega et al. (2022) investigated consumers' acceptance of gene-edited foods and assessed how information about the differences between transgenic GM and GED methods influences consumer preferences in China. Results from the study indicate that while consumers are averse to the use of biotechnology, they are more accepting of the GED method compared to GM.

Hu et al. (2022) examined how different methods of information delivery affect consumers' preference for orange juice produced using various technologies, including GM and GED (CRISPR). The results indicate that consumers were generally less familiar with CRISPR compared to GM technology. However, as information increased, consumers showed a higher WTP for orange juice produced using CRISPR relative to GM.

Hao et al. (2024) estimated the WTP for a price premium for GED rice compared to GM and conventional rice in Vietnam under different information treatments. Findings from the study suggest that consumers will widely accept quality-improved gene-edited foods targeted at consumer preferences.

Most of these studies indicate that, while consumers generally prefer conventional methods, they are more willing to pay for gene-edited food products than for genetically modified food products.

### ***2.3.5. Attribute Non-Attendance in Food Choice Experiments***

Attribute Non-Attendance (ANA) has become an important area of research in food choice experiments, particularly in stated preference studies using DCEs. These studies present consumers with hypothetical food product choices that vary based on different attributes. The neoclassical economic theory assumes that consumers possess complete information and engage in full compensatory behaviour, meaning they evaluate all available alternatives and

systematically trade off attribute levels to maximize their overall utility. However, it has been observed that in practice, decision-makers may not consider all the information provided about the attributes of the available alternatives (Hensher, 2006; Alemu et al., 2013).

Studies have shown that when the assumption of full compensatory behaviour is violated, consumers may ignore certain attributes in their decision-making process. This behaviour, referred to as ANA, has been widely discussed in the literature (e.g., Hensher et al., 2005; Campbell et al., 2008; Ryan et al., 2009). ANA is rooted in the fields of behavioural economics and cognitive psychology, which suggest that individuals rely on heuristics and simplification strategies when faced with complex decisions (Tversky and Kahneman, 1974). In the context of DCEs, ANA occurs when participants either consciously or unconsciously disregard certain attributes while making their choices (Scarpa et al., 2013).

The DCE literature identifies two general approaches for obtaining ANA information. These are the stated and inferred ANA methods. In the stated ANA approach, participants explicitly indicate which attributes they ignored while completing the choice tasks. This involves asking participants a follow-up question while attending to the DCE. Within the stated ANA, there are two main approaches. The serial stated ANA requires participants to report ignored attributes only once, after completing all choice tasks (e.g., Hensher et al., 2005; Scarpa et al., 2009; Balcombe et al., 2011; Alemu et al., 2013; Kragt, 2013; Bello and Abdulai, 2016). Choice task stated ANA, on the other hand, asks participants to specify which attributes they ignored at the end of each choice task (e.g., Puckett and Hensher, 2009; Scarpa et al., 2010; Caputo et al., 2017). The Inferred ANA methods rely on econometric models to identify ANA behaviour based on choice data. These methods use probabilistic models to identify ANA by classifying participants into distinct groups. The main inferred methods include the coefficient of variation method (Hess and Hensher, 2010; Ortega and Ward, 2016); The Equality Constrained Latent Class model

(ECLC) is an approach to modelling ANA and has been widely used by studies (e.g., Scarpa et al., 2009; Scarpa et al., 2013; Kragt et al., 2013; Caputo et al., 2017).

The following studies provided empirical evidence for the prevalence of ANA in DCE and underscored the importance of accounting for ANA to enhance the reliability of preference estimates. In light of these ANA measurement approaches, Caputo et al. (2017) observed that, before their study, there was still no consensus on the most appropriate method for modelling ANA behaviour, particularly within choice experiments. Below are the studies that account for ANA in food choice modelling:

Scarpa et al. (2013) reviewed the existing ANA literature in stated choice experiments and analyzed data from beef and chicken choice experiments. The study compared stated and inferred ANA methods in terms of model fit and mean WTP estimates. The inferred methods included the individual-specific posterior means and variances (Hess and Hensher, 2010) and the ECLC model (Scarpa et al., 2009), while the serial stated approach was used for stated ANA. The ANA behaviour was modelled using MNL models. The findings revealed discrepancies between the inferred and stated ANA methods, with the ECLC model offering a better fit and yielding lower mean WTP estimates.

Caputo et al. (2013) investigated consumer preferences for two types of labelling information related to food transport. The first label provided information on carbon dioxide emissions, while the second detailed the distance and time the food travelled. Using the ECLC approach, the study found that 58% of participants exhibited ANA, demonstrating that consumers may ignore certain information when presented with the DCE.

Bello and Abdulai (2016) examined the impact of consumer non-attendance behaviour on hypothetical bias mitigation strategies, relying solely on the serial ANA approach. Participants were divided into three groups: a control group with no mitigation strategy, a group exposed to a cheap talk script, and a group receiving honesty priming. The study found significant variations

in ANA rates across the groups, with the honesty priming strategy resulting in the lowest ANA incidence and WTP estimates. These findings suggest that mitigation strategies can influence attribute attention and, consequently, preference estimations in DCEs.

Caputo et al. (2017) assessed how incorporating serial versus choice task stated ANA affected mean WTP estimates and whether estimates from both stated ANA methods aligned with those from the inferred method. The study used empirical consumer data from a DCE on poultry meat with sustainability labels. ANA behaviour was modelled using a random parameter logit model, while the inferred method was implemented using the ECLC method. The findings reveal differences in mean WTP estimates between the serial and choice task ANA approaches. At the choice task level, fewer participants consistently applied the same attribute processing strategies across all choice tasks compared to the serial level. This suggests that ANA data collected at the serial level may fail to capture shifts in attribute processing behaviour throughout the experiment. When comparing serial ANA, choice task ANA, and the inferred method, results indicated that accounting for ANA at the choice task level provided the best model fit.

Gonçalves et al. (2020) examined consumer preferences for wine by comparing stated and inferred modelling approaches to accounting for ANA in a DCE. The study assessed the concordance between stated ANA and inferred ANA while also evaluating differences in model fit and mean WTP estimates. ANA behaviour was modelled using a RPL model, with the inferred ANA identified through the ECLC approach and contrasted with serial stated ANA. Results revealed a high incidence of ANA for all attributes except price. Moreover, there was little concordance between the stated and inferred methods, with the inferred method yielding a better model fit and lower mean WTP estimates.

### ***2.3.6. Studies on Consumers' Absolute Opposition to GE***

People hold certain values, which cause them to absolutely resist trade-offs when they are urged to choose a course of action. This is because they rate such values higher than compensatory or economic values of the proposed action (Baron and Spranca, 1997). These values, referred to as protected values (PVs), make such persons insensitive to consequentialist considerations – that is, they will not consider the consequences or benefits of courses of action proposed to them. Rather, they are guided by deontological rules, making them only concerned about the actions and not the consequences of those actions. Those who hold PVs manifest AO in the proposed course of actions that violate their PVs.

The implications of AO have been investigated in different contexts. Most relevant to the present study is the role that AO plays in economic decisions in the context of controversial food technologies, especially the GE of food. Generally, the morality or ethicality of the application of GE to food has been found to underlie AO to GE food (Scott et al., 2016). Particularly, the beliefs that the naturalness or sanctity of food should be preserved have been strongly associated with AO (Rozin et al., 2012; Siegrist et al., 2016; Roman, 2017; Mallison et al., 2018). Early studies in this domain attempt to provide evidence of AO in GM food. Rozin et al (2012) assessed the attitude of consumers toward natural foods and genetically modified organisms in Europe and the USA. The authors report that most of the respondents were opposed to GE food because of their preference for natural food. Similarly, Siegrist et al. (2016) find that German-speaking consumers in Switzerland disregarded the benefits communication of food technology when it is perceived as unnatural. Scott et al (2016) also report that 64% of the participants in the USA manifest absolute moral AO to genetically modified food while linking opposition to disgust. Mallison et al (2018) conclude that UK consumers are insensitive to rationality arguments about GM mainly because of a belief that GM technology compromises the sanctity of food.

There are two connected issues relating to investigating consumers' acceptance/rejection of food biotechnologies using the framework of AO. First is the question of whether consumer behaviour towards controversial food biotechnologies should only be viewed as a risk-benefit perception issue or whether there are instances where the framework of AO better explains consumer behaviour. Second is the issue of how to validly identify absolute opponents in empirical studies. These two issues are closely linked, and addressing one may provide insights into the other issue. This connectedness is apparent in the debate sparked by Scott et al. (2016). As previously noted, the study reports that 64% of participants expressed aversion toward GM foods, primarily driven by feelings of disgust. This suggests that risk-benefit perception did not explain their opposition to GM food. In response, Gray and Schein (2016) argued that the data used by Scott et al. (2016) do not support their evidence of AO; disconfirming moral absolutism and conclude that perceived risks rather than disgust predict moral judgements of self-claimed absolute opponents. In contrast to Scott et al. (2016), Royzman et al. (2017) replicated their study and concluded that AO is better explained by individuals' tendency to feel "creeped out" by strange or subtly deviant situations rather than by feelings of disgust. Subsequently, Inbar and Scott (2018) identified a methodological limitation, specifically, ambiguity in how emotions linked to AO were measured due to the use of different scales. They argued that this issue renders the empirical evidence theoretically and empirically questionable, suggesting that Royzman et al.'s (2017) conclusions may have been premature.

#### **2.4. Chapter Summary: Gaps in the Literature**

Although previous studies provide valuable insights into consumer acceptance of conventionally biofortified foods in SSA, several gaps remain. Existing research has largely focused on consumer responses to conventional biofortification methods, with limited attention to genetically modified and gene-edited approaches, despite evidence that these methods may be

more effective in addressing micronutrient deficiencies. Consumer awareness and understanding of GE technologies remain low in SSA, and food labelling systems that could support informed decision-making are still underdeveloped. This highlights the importance of examining how information about different biofortification methods, conventional, GM, and GED, affects consumer acceptance and WTP.

Furthermore, while previous studies consistently emphasize the role of sensory attributes and nutrition information in shaping acceptance, the effect of information provision on WTP shows mixed results globally and has not been empirically tested in SSA. This gap is particularly relevant given ongoing debates about how consumers might respond to GE-based biofortification when provided with benefit and process-related information.

In addition, research comparing consumer acceptance of GM versus GED foods remains scarce, especially in SSA, where GED technologies are emerging as promising tools to combat food and nutrition insecurity. Understanding how consumers in the region perceive and differentiate between these technologies is therefore critical for designing appropriate policy and communication strategies.

We find no study to date that has explicitly accounted for ANA in analysing consumer preferences for biofortified foods in SSA. Considering that consumers may be unfamiliar with GE methods, ignoring ANA could lead to biased conclusions about their choices. Addressing this methodological gap is essential for generating more reliable insights into consumer behaviour and market prospects for biofortified foods.

Previous studies have shown that consumers' perceptions of the risks and benefits of GE food affect their acceptance of it. Moreover, these perceptions are the result of their subjective evaluation of the GE method used. To the best of the author's knowledge, no study in SSA analyzes the cognitive processes involved in the evaluation of the application of GE methods in foods.

Finally, no study in SSA has identified whether consumers' behaviour towards controversial food biotechnologies should only be viewed as a risk-benefit perception issue or whether there are instances where the framework of AO better explains consumers' behaviour.

## CHAPTER THREE

### METHODOLOGY

#### 3.1. Chapter Overview

As outlined in Chapter 1, this dissertation employed both qualitative and quantitative approaches. Accordingly, this chapter details the methodological procedures used, including the study area, the qualitative and quantitative research designs, the conceptual framework, sampling techniques, data collection methods, the econometric framework, and the empirical strategies applied.

#### 3.2. Study Area

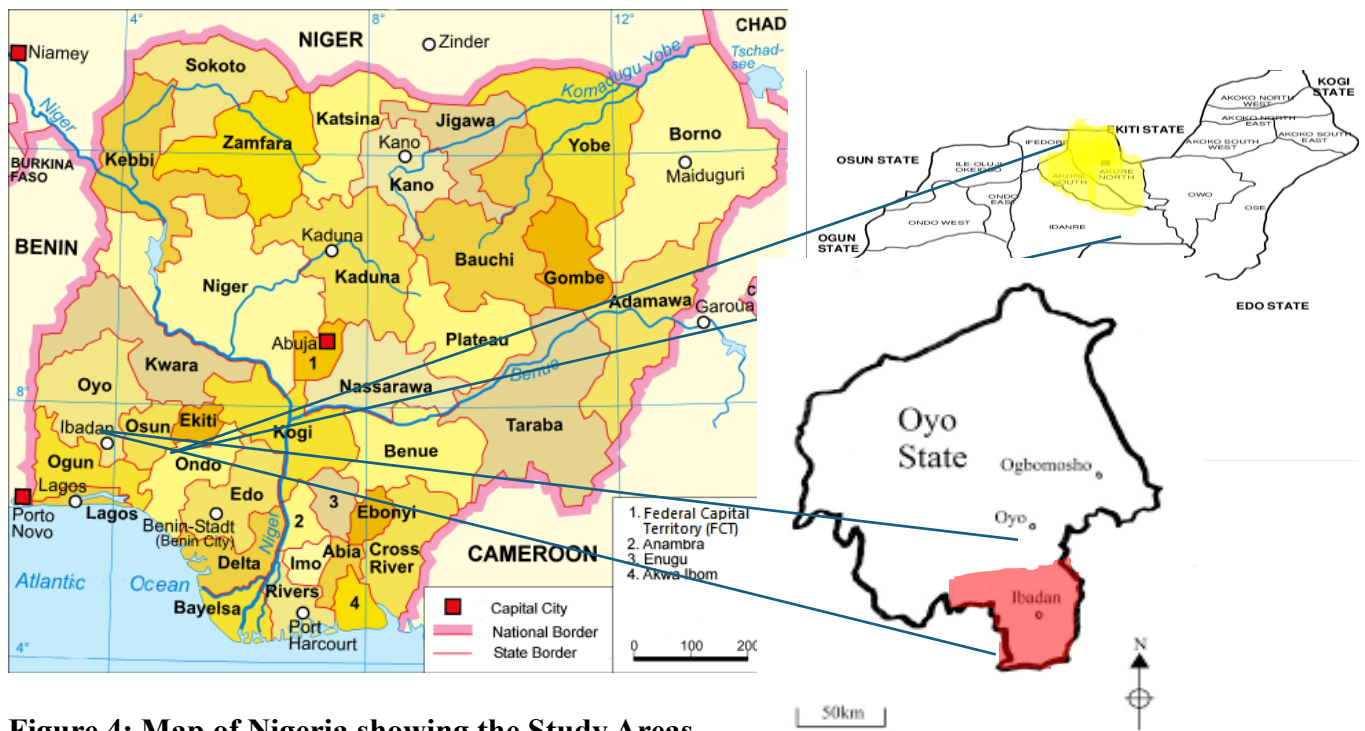
Nigeria is located on the Gulf of Guinea in West Africa, bordered by Benin to the east and Cameroon to the west. With a population of 195.9 million as of July 2018, Nigeria is Africa's most populous country. It covers a total land area of 910,800 km<sup>2</sup>, yielding a population density of 215 people per km<sup>2</sup> (<http://www.worldometers.info/>). Approximately 50% of Nigerians live in rural areas, many of whom are subsistence farmers or local traders (Reed and Mberu, 2013). Like many countries in SSA, Nigeria experiences high rates of VA and iron deficiencies, which are linked to diets that rely on staples lacking these essential micronutrients (Harika et al., 2017; Abubakar et al., 2017). The prevalence of iron deficiency in Nigeria ranges from 19% to 80% among preschool children under five years old, and from 20% to 60% among pregnant women (Ekwochi et al., 2014; Akodu et al., 2016). A study conducted in southwestern Nigeria found that 15.9% of children under five were VA-deficient, with 1.8% experiencing severe deficiency (Abolurin et al., 2018).

Research into biofortification, particularly through the conventional breeding of staples, has made progress in Nigeria, driven by the efforts of HarvestPlus. Some of the biofortified crops available in the country include VA cassava, VA maize, VA orange sweet potato, iron-zinc

sorghum, and iron pearl millet (HarvestPlus, 2021). In recent years, genetically modified crops have been cultivated on approximately 700 hectares in Nigeria, with Bt cowpea, Bt cotton, and genetically modified maize approved for commercialization (ISAAA, 2019; ISAAA, 2024). However, second-generation GM crops, such as genetically modified biofortified cassava developed under the Bio-Cassava Plus Program, have not yet received approval for commercialization.

As for gene-edited crops, Nigeria has implemented guidelines for case-by-case reviews, but no African country has yet approved gene-edited crops, though some are currently in trials.

The map of the study area is presented in Figure 4. For this study, Oyo and Ondo States in southwestern Nigeria were purposively selected because biofortified cassava developed through conventional breeding is readily available, processed into gari, and sold in local markets.



**Figure 4: Map of Nigeria showing the Study Areas**

### **3.3. Qualitative Study**

For the qualitative data, key informant interviews with experts and in-depth interviews with consumers were conducted in the study area between February and May 2022. Details of the data collection processes are provided below.

#### ***3.3.1. Key Informant Interview***

Biofortification of crops typically involves multiple stakeholders across the value chain. These include breeders who conduct research and develop new biofortified crop varieties, seed companies and institutions that handle seed multiplication and distribution, farmers, processors responsible for processing and storage, marketers, and consumers (Dalberg et al., 2019). To achieve the objective of this study, key informant interviews were conducted with breeders, processors, traders, and consumers. Notably, in the study area, processors also serve as traders. The International Institute of Tropical Agriculture (IITA) is one of the key institutions involved in breeding biofortified crops in Nigeria. As such, the first phase of the interview was conducted with a breeder at IITA to gain insights into the biofortification process and the application of GE techniques in developing biofortified crops. The purpose of the interview was to:

- Understand the process of cassava biofortification
- Explore the use of GE in cassava biofortification
- Assess the impact of GE on the colour changes associated with VA and iron enrichment in cassava
- Identify the key attributes and levels of biofortified cassava to be used in the DCE for this study

The second phase involved interviews with processors and marketers of biofortified foods. These interviews focused on the following topics:

- The bioavailability of nutrients in biofortified foods after processing

- The availability of conventionally biofortified cassava
- The price comparison between conventionally biofortified gari and non-biofortified gari
- Perceptions regarding the sales performance of conventionally biofortified gari
- Sources and points of sale for conventionally biofortified gari

### ***3.3.2. In-depth Interviews***

In-depth interviews were conducted with 20 gari consumers in the southwestern part of Nigeria. Participants were also sampled through household visits in the urban and rural areas of Ondo and Oyo states. The interviews aimed to gain an in-depth understanding of consumers' perceptions of genetically biofortified gari. Using a semi-structured questionnaire, they enabled flexible probing of individual beliefs while maintaining consistency across participants.

Participants were purposively selected to include adult consumers of gari (aged 18 and above), women of reproductive age, and caregivers from households with children under five years old. These groups were prioritized due to their nutritional vulnerability and relevance to the biofortification intervention (Bouis et al., 2011).

Key areas explored during the interviews included:

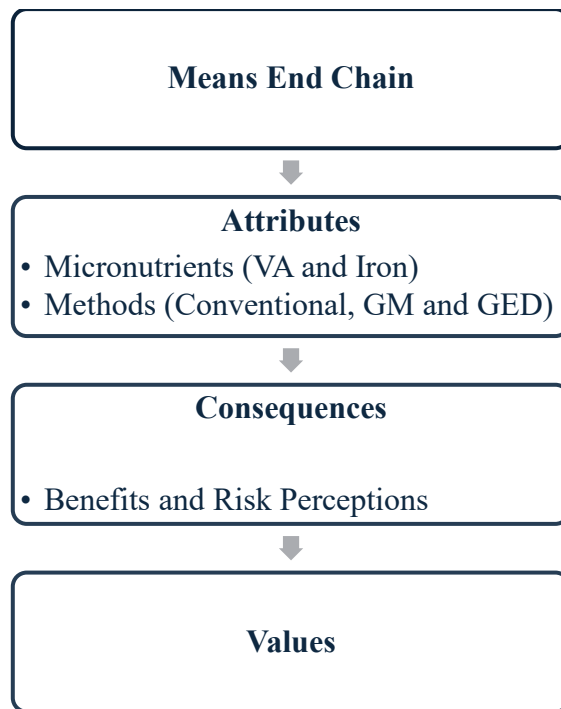
- Awareness and knowledge of biofortified gari and GE
- Consumer preferences, particularly attributes of biofortified gari considered most important to consumers
- Identification mechanisms, or how consumers distinguish between biofortified and non-biofortified gari
- Perceptions of the use of GE in food biofortification

### *3.3.2.1. Conceptual Framework*

The Means-end chain (MEC) framework provides an adaptable framework to investigate the mental constructs underlying consumer decision-making. The framework posits that consumers' evaluation of a product follows a hierarchical structure in which consumers associate a product's characteristics with self-relevant consequences that reflect their broader value system (Gutman, 1982). In other words, the MEC describes a cognitive process often referred to as attribute-consequence-value linkage in the literature (Olson, 1989).

For the qualitative research, we adapted the MEC framework to describe how consumers will evaluate genetically biofortified gari, as shown in Figure 5. According to this framework, we assume that consumers subjectively evaluate product attributes that align with their personal values as beneficial and those that compromise their personal values as risky (Slovic, 1987). Consequently, higher benefit (risk) perception will increase (decrease) product acceptance. Indeed, much of the literature on consumer evaluation of genetically engineered food concedes that consumers basically weigh benefits versus risks of such food to make their choices (Frewer et al., 2013; Grunert et al., 2003).

Finally, it is important to know that the formation of the perception depends on how much consumers know about the product attributes (Grunert, 2005). Therefore, in this context where consumers lack the objective knowledge of GM and GED, they will only be able to correctly perceive and evaluate genetically biofortified food when they are first given basic facts on how the GE methods are applied (Sturgis and Allum, 2004; Kahan et al., 2011).



**Figure 5: Means End Chain for Evaluating Genetically Biofortified Food**  
**Source: Author’s own compilation**

### 3.3.2.2. Selection of Product and Attributes

The selected product for this study is gari, a widely consumed staple food in Nigeria made from processed cassava (Ndjouenkeu *et al.*, 2020; Okwuonu *et al.*, 2021). The choice of gari is based on the fact that most cassava varieties grown in the country are deficient in essential micronutrients (Okwuonu *et al.*, 2021). According to the Nigerian Food Composition Table (2017), 100 grams of white roasted gari provides approximately 363.19 kcal of energy, with 86.89 grams of carbohydrates, just 0.16 grams of protein, negligible fat content, and very low levels of micronutrients.

To identify relevant attributes for this study, we first conducted a comprehensive review of the literature on biofortification, GE, and key micronutrients in Nigeria and SSA (Bouis *et al.*, 2011; Sayre *et al.*, 2011; Birol *et al.*, 2015; Oparinde *et al.*, 2016a; Van der Straeten *et al.*, 2020). In addition, we conducted expert interviews with cassava breeders involved in biofortification

efforts in IITA, Ibadan, Nigeria. This deepened our understanding of the biofortification process and the role of GE in enhancing the nutrient content of gari. Our findings reveal that VA and iron are recognized as key targets in addressing micronutrient deficiencies in Nigeria (Harika et al., 2017; Okwuonu et al., 2021).

Regarding the method attributes, the conventional breeding method has successfully been used to enhance the VA content of cassava in Nigeria (Birol et al., 2015; Oparinde et al., 2016a). However, to improve VA bioavailability and introduce iron, the Bio-Cassava Plus Program developed genetically biofortified cassava, though it is not yet approved for commercialization (Sayre et al., 2011; Oparinde et al., 2016b; Onuegbu et al., 2017). Further, the GED method is emerging as a promising alternative to GM for nutrition enhancement (Kumar et al., 2022). Therefore, in line with our study objectives, we selected the micronutrient attributes of VA and iron, and the plant breeding method attributes of conventional, GM, and GED.

### *3.3.2.3. Interview Technique*

We used the laddering technique for an in-depth interview with the study participants (Reynold and Gutman, 1988). This technique is based on the personal construct theory that individuals perceive the world through a unique set of personal constructs, essentially mental frameworks used to understand and interpret reality. Further, the constructs shape how people perceive events, objects, situations, and other people in their lives (Kelly, 1955). This technique has been widely used in numerous empirical studies in SSA employing the means–end chain framework. (e.g., Lagerkvist et al., 2012, Okello et al., 2013; Okello et al., 2017; Pambo et al., 2017; Kilwinger & Dam, 2021). The technique can be implemented using either a soft or hard approach (Grunert & Grunert, 1995). Hard laddering provides a more structured process, whereas soft laddering encourages open discussion in a less structured format (Grunert et al., 1995). Given the exploratory nature of this study, we adopted the soft laddering approach (Costa et al., 2004).

We started the data collection process by presenting the participants with samples of two types of gari: the non-biofortified type, which is white, and the conventionally biofortified gari with VA, which is yellow. The participants were informed that the colour change was due to the addition of VA to the cassava used for processing the gari. A sample of genetically biofortified gari was not presented to consumers because it is not yet available. Therefore, we informed the consumers that the use of GE methods to add VA and iron may not result in any change in colour from yellow since the addition of minerals like iron does not result in any colour change or appearance of the crop (Banerji et al., 2016). Then, each participant was provided informed consent, and it was explained that they could withdraw from participation at any time.

The laddering interview was conducted in two phases, focusing on the micronutrient and method attributes. Each phase of the interview consisted of three stages. In the first phase, participants were provided with <sup>1</sup>information on the health risks associated with VA and iron deficiencies, as well as the benefits of consuming foods biofortified with these micronutrients. Secondly, we presented the micronutrient attributes to the participants and asked them specifically, “*Why would you be interested in eating ‘gari’ nutritionally enhanced with VA and Iron?*” Lastly, we asked them to state what comes to mind when considering each attribute. We asked a series of “*Why is that important to you?*” follow-up questions to generate individual attribute–consequence–value linkages for the micronutrient dimension.

Following the initial responses, we proceeded to the second phase of the interview. In the first stage of this phase, participants were presented with a <sup>2</sup>second information treatment that

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<sup>1</sup> Both sets of information were delivered through video clips, shown to participants in either English or the local language (Yoruba), according to each participant preference. Using video as the communication medium aligns with previous research showing it is more effective at conveying information about GE than text- or image-based formats (Kilders and Caputo, 2021; Yang et al., 2022). Full details of the information treatments are provided in the appendix.

<sup>2</sup> Please note that we did not include information on the potential risks associated with GE methods, as there is currently no scientific consensus regarding their adverse effects on human health or the environment (Smyth et al., 2021; Stanton et al., 2021; Lynas et al., 2022).

explained the scientific processes underlying the conventional, GM, and GED methods. Subsequently, they were asked, “*How do you perceive the use of these methods for the nutritional enhancement of vitamin A and iron?*” We then asked a series of follow-up questions, “*Why is that important to you?*” to elicit individual attribute-consequence-value constructs associated with the method attributes. The interview was audio-recorded. Afterwards the interviewers reviewed the “attribute–consequence–value” linkages generated to ensure they were complete.

#### *3.3.2.4. Sample Characteristics*

Table 1 summarizes the sample characteristics. Participants ranged in age from 18 to 70, with the majority between 30 and 49 years old. Most of the participants were female, married, and resided in rural areas. About half of the participants have a secondary level of education or lower. 60% of the females are in their reproductive age, while 45% of the households have children aged five or below. Before receiving any information, half of the participants were aware of VA gari produced through the conventional breeding method, while awareness of GM and GED methods was generally low. However, a greater proportion of participants were familiar with GM compared to GED.

**Table 1: Summary Statistics of the Laddering Interview Participants (N=20)**

Variable	N = 20	Percentage
<b>Age</b>		
18-29	7	35%
30-49	10	50%
50-70	3	15%
<b>Gender</b>		
Female	13	65%
Male	7	35%
<b>Education</b>		
None	1	5%
Secondary or Lower	9	45%
Graduate	6	30%
Postgraduate	4	20%
<b>Marital Status</b>		
Single	4	20%
Married	16	80%
<b>Residential Area</b>		
Urban	9	45%
Rural	11	55%
<b>Awareness</b>		
Heard about VA gari	10	50%
Heard about GM	5	25%
Heard about GED	2	10%
<b>Others</b>		
Women of reproductive age	12	60%
Households with children aged 5 or below	9	45%

### 3.3.3. Data Analysis

We follow the procedure outlined by Reynolds and Gutman (1988) to conduct the analysis. First, all attributes, consequences, and values mentioned by respondents were coded. The coding was

done to allow for the replication of the “attribute–consequence–value” linkages among the participants (Reynold and Gutman, 1988). These coded elements are then used to create an implication matrix, which records how often one element (e.g., an attribute) is followed by another (e.g., a consequence or value) in the responses. From this matrix, a Hierarchical Value Map (HVM) is generated to visually represent the most common linkages between elements. Only linkages occurring more frequently than a specified threshold are included in the map, emphasizing the key means-end chains. For this study, the threshold was set at three, meaning that only associations mentioned by at least three participants were included, allowing for a broad display of construct linkages. The analysis was performed using an Excel calculator file developed by Foolen-Torgerson and Kilwinger (2021). Using the software, the direct linkages of the individual coded “attribute–consequence–value” linkages were aggregated in the implication matrix. After this, the HVM was built and generated using the Excel add-in NodeXL.

### **3.4. Quantitative Study**

Two sets of quantitative data were collected for this study through a cross-sectional survey and a DCE conducted in southwestern Nigeria between February and May 2022. The first dataset, comprising 352 respondents, was used to address the first research objective, which examined how information influences consumers’ preferences and WTP for genetically biofortified foods in Nigeria. Sample statistics for this dataset are presented according to the information treatment groups.

The second dataset consisted of 205 respondents and was used to address the third research objective, which investigated the role of AO in consumer acceptance of genetically biofortified foods in Nigeria. This sample included 117 respondents from the control group of the first dataset and an additional 88 newly collected responses. The characteristics of this sample are summarized in Table 2.

### ***3.4.1. Sampling Technique***

A multi-stage sampling approach was used to select households for the quantitative data collection. In the first stage, Oyo and Ondo States in southwestern Nigeria were purposively selected due to the availability of conventionally biofortified gari being sold in the market. Within each state, both urban and rural areas were included. The urban areas selected were the state capitals: Ibadan (Oyo) and Akure (Ondo). These cities were stratified into three residential zones representing low-, middle-, and high-income groups (Adeoye, 2016; Sanni and Akinyemi, 2017), and two residential areas were randomly selected from each zone. In the rural areas, data were collected from two villages located in Ayede-Ogbese (Ondo) and Ido (Oyo) Local Government Areas. Unlike the urban areas, rural communities did not have clearly defined residential zones. So, no stratification was done in the villages. In both urban and rural locations, a systematic random sampling method was used, selecting every fourth household. In each selected household, the respondent was either the household head or an adult primarily responsible for food purchases.

### ***3.4.2. Household Survey***

The household survey included a structured questionnaire and the DCE. Before the survey, several preparations were made. First, enumerators were recruited and trained to conduct the survey. Then, the questionnaire and the DCE were pre-tested in forty-eight households, after which corrections were made. Through the structured questionnaire, data were collected on consumer purchasing and consumption patterns, awareness of biofortified gari, awareness and objective knowledge of GM and GED, attitude toward the use of GM and GED in food, risk and benefit perceptions of genetically modified and gene-edited food, food choice behaviour, and their demographic characteristics.

The DCE was used to collect data on individual preferences for genetically biofortified foods by presenting participants with a series of hypothetical choice scenarios. In each scenario, participants were asked to choose their preferred option from a set of alternatives, each described by a combination of attributes with varying levels.

**Table 2: Sample Sociodemographic Characteristics of Absolute Opposition Data (N=205)**

Variable	Description	Mean (S.D)/%
Age	Age of participants in years	41.26 (12.68)
Years of Education	Number of years spent in formal education	11.61 (4.83)
Trust Government	Trust in government, from 0 (no trust at all) to 5 (complete trust)	0.50 (0.40)
Trust Scientists	Trust in scientists, from 0 (no trust at all) to 5 (complete trust)	0.59 (0.63)
<b>Percentage</b>		
Male	1 if the participant is male, 0 otherwise	31.71%
No Knowledge	1 if participant does not know GE, 0, otherwise	5.85%
Urban	1 if participant lives in urban, 0 rural	47.18%
Risk Perception	1 if perceived GM has a higher risk, 0, otherwise	20.00%
Christian	1 if Christian, 0, otherwise	80.00%

### **3.4.3. Experiments and Procedures**

#### *3.4.3.1. DCE: Selection of Attributes and Attribute Levels*

Table 3 outlines the attributes and corresponding levels of the gari products shown to consumers during the DCE.

**Table 3: Attributes and Levels of Experiment**

Variables	Description	Levels	Reference Level
<b>VA</b>	Percentage of estimated average body requirement for VA	60, 100	60
<b>Iron</b>	Percentage of estimated average body requirement for Iron	0, 25, 50	0
<b>Starch Content</b>	Cassava Starch Content	Low, High	High
<b>Plant Breeding Method</b>	Breeding Method used for the Cassava	Conventional, GM, GED	Conventional
<b>Price (Naira)</b>	Price per 1kg of Gari	<sup>3</sup> 300, 500, 700	

**VA and Iron:** VA and Iron were selected as the main micronutrient attributes because most cassava varieties grown in Nigeria lack these essential micronutrients to combat the hidden hunger resulting from insufficient micronutrients in the diet (Okwuonu et al., 2021). Thus, we included VA and Iron as part of the attributes of our DCE design because these are the main targets of efforts to address MND in the study area. The conventionally bred cassava is observed to contain a maximum of 60% of the estimated average requirement (EAR) for VA for a cassava meal of 200g per day for children and 400g for adults (Bouis et al., 2011; Oparinde et al., 2016a). The iron present in cassava, based on consumption patterns in West Africa, provides only 5–8% of EAR for iron for children 2–5 years old (Stephenson et al., 2010). In this study, a situation in which GE methods are used to add VA and iron to gari was modelled. This gari delivers 100% of the EAR for VA in cassava and up to 50% of the EAR for iron (Sayre et al., 2011). Therefore, the levels for VA and Iron in gari were presented as percentages, relative to the EAR for these micronutrients. The status quo alternative is 'white gari', which has not been biofortified with micronutrients and is currently sold in the market. So, a value of 0% has been assigned to the VA and iron content for the status quo alternative.

<sup>3</sup> Price is measured in Naira. ₦416 ≈ US1\$ at the time of the survey

**Plant breeding methods:** Previously, the conventional method of breeding, which does not involve the use of GE methods, was applied to increase micronutrients in cassava. Specifically, scientists employed the conventional method to successfully enhance cassava by adding VA (Birol et al., 2015; Oparinde et al., 2016a). However, due to the need to ensure the bioavailability of higher levels of VA and also enhance cassava with iron, the Bio-Cassava Plus Program developed genetically modified cassava, which is yet to be approved for commercialization (Sayre et al., 2011; Oparinde et al., 2016b; Onuegbu et al., 2017). Elsewhere, GED is becoming a promising alternative to GM, as certain studies have shown that micronutrient densities of some crops are being increased through the GED method (Kumar et al., 2022; Kadam et al., 2023). In line with the objectives of this study, we included the conventional, GM, and GED attributes as part of the attribute levels for the plant breeding method in our DCE design.




**Starch Content:** An important sensory attribute of cassava that is affected by VA enhancement is starch content (Beyene et al., 2017; Oluba et al., 2017). It has been shown in previous studies that the starch content of cassava can be an important attribute in determining the choice of gari in Nigeria (Dalberg, 2019). Modifying cassava for elevated levels of VA either through conventional or GE methods is associated with a lower level of starch content in the final cassava variety (Bayene et al., 2017). Hence, it becomes essential to see how this attribute, along with the enhancement of the micronutrients, can determine the choice of consumers. We only included this attribute in a binary form of "High starch content vs Low starch content," with the former as the base level. The underlying reasoning is that the "white gari," which represents the status quo in our design, has high starch content, while the nutritionally enhanced gari has low starch content.

**Price:** The price attribute was included as part of the DCE design since we intended to estimate consumers' WTP to indicate their reaction towards using GE in gari. The range of price levels chosen for our DCE design spans from the average minimum price of "white gari" in the markets

up to the price of the gari enhanced with VA using the conventional method that is available for sale in the market at the time of the study. The selected attributes and levels were combined to form an unlabelled DCE.

#### *3.4.3.2. DCE Design and Survey Procedure*

The full factorial design, which contains all combinations of selected attributes for this study, yields 216 profiles. Using this considerably large number of profiles will be cognitively demanding for the participants. Therefore, to make a fractional DCE design, the Bayesian efficient fractional design approach was employed to generate the alternatives and choice tasks used. The Bayesian design, like other fractional designs, aims at taking a fraction of profiles that will produce preference data with minimal standard errors for the estimated parameters, given a specific sample size (Scarpa and Rose, 2008). The R software version 4.2.0 with the *idefix* package was used (Traets et al., 2020) for the experimental design. As a requirement for Bayesian design, a pilot study was first conducted with 48 participants, setting the prior estimates for our model parameters at zero. Then, a Bayesian design was made for the main study using parameter estimates generated from the pilot study. Finally, the design produced an unlabelled DCE of 16 choice tasks of two alternatives of nutritionally enhanced gari and a status quo alternative representing a gari sold in the market. The choice tasks were further divided into two blocks to reduce the cognitive burden of the choice tasks on participants. Figure 6 provides a sample of the choice task presented to respondents.

	<b>Gari 1</b>	<b>Gari 2</b>	<b>Gari 3 (Status quo)</b>
			
Vitamin A	Contains 60% of the average Vitamin A required by the body.	Contains 60% of the average Vitamin A required by the body.	Does not contain Vitamin A required by the body.
Iron	Does not contain Iron required by the body.	Contains 25% of the average Iron required by the body.	Does not contain Iron required by the body.
Starch Content	High Starch Content	High Starch Content	High Starch Content
Breeding Method	Conventional Method	Gene-Editing Method	
Price per Kg	₦ 300	₦ 500	₦ 300
I will buy	( )	( )	( )

**Figure 6: Sample of Choice Task from Experiment**

#### 3.4.3.3. Information Treatment and Survey Procedure

During the survey, participants received two targeted information treatments in order to evaluate how it influences their choices of genetically biofortified foods. The first information treatment was on the risks of micronutrient deficiencies and the benefits of biofortification, while the second information treatment was on the scientific process of the conventional, GM, and GED methods. Participants received the information through video clips in either English or the local language (Yoruba), depending on their preference. The choice of video as the communication medium aligns with previous studies that show the use of video to be more effective in communicating information on genetic engineering compared to text-only or text with still pictures (Kilders and Caputo, 2021; Yang et al., 2022).

**Table 4: Layout of the Information Treatments**

	<b>Control</b>	<b>Nutrition</b>	<b>Nutrition + Method</b>
<b>No information</b>	✓		
<b>Micro-nutrient and health information</b>		✓	✓
<b>Conventional, GM, and GED scientific process information</b>			✓

The “Nutrition” treatment video starts by informing participants about the importance of VA and iron in the body, and that many of the staple foods that consumers eat in Nigeria are deficient in VA and iron. Next, participants were informed about the health risks of VA and iron deficiencies in adults, children, and pregnant women, while they also saw the statistics of children and women suffering from VA and iron deficiencies in Nigeria. Lastly, participants were informed that some cassava varieties with enhanced VA content but deficient in iron were already available in the market, but because of the insufficient VA in the varieties and lack of iron, the government was planning to release new varieties that would not only have a sufficient amount of VA but also have sufficient iron content. In the “Nutrition + Method” treatment, participants watched the same video as the “Nutrition” treatment and were additionally informed about the scientific processes behind three methods that can be used to enhance cassava.

First, participants were informed that the enhanced cassava varieties in the market were developed using the conventional breeding method, which could only add an insufficient amount of VA to cassava and could not enhance the Iron content. Next, they were informed that the GM (transgenesis) method had also been used to develop new varieties of cassava, but with sufficient VA and Iron content. Afterward, participants were informed that varieties developed with the conventional method were already tested and released into the market and that those developed with GM were only tested and approved as not harmful to the environment and consumers’

health, but not yet commercialized by the government. Next, participants were informed that the GED method is only being proposed but not yet tested and approved by scientists or the government.

In contrast to some studies that provide information on both the risks and benefits of genetically engineered foods (Kimenju and DeGroot, 2008; Gbegbelegbe et al., 2015), information about risks associated with the use of GE methods was not provided since there is currently no consensus among scientists concerning the scientific evidence of the adverse effects on health and the environment (Smyth et al., 2021; Stanton et al., 2021; Lynas et al., 2022). Details of the information treatments are provided in the appendix.

The DCE was designed with the three information treatments using a between-subject approach. The treatments are labelled “Control”, “Nutrition,” and “Nutrition + Method” as presented in Table 4. During the survey, participants were randomized at two levels:

First, they were randomly assigned to the two experimental information treatment groups. The “Nutrition” group received information on the risks of micronutrient deficiencies and the benefits of biofortification, while the “Nutrition + Method” group received the first information and information on the scientific process of conventional, GM, and GED.

Second, they were assigned to the DCE versions of Block 1 and Block 2. Specifically, the enumerator assigns participants from the first two households, respectively, to Block 1 and Block 2 within the “Nutrition” group. Then, the next two households are respectively assigned to Block 1 and Block 2 within the “Nutrition + Method” group. So, each participant faced eight repeated choice tasks. After each choice task in the DCE, participants were asked to state which of the attributes they ignored. This approach allows us to obtain stated ANA information at each choice task level, as demonstrated in Caputo et al. (2017). The choice tasks used for the survey are also provided in the appendix.

#### *3.4.3.4. Sample Characteristics and Balance Test*

The results of the socioeconomic characteristics, presented by information treatment groups as shown in Table 5, indicate that most participants were female, married, with an average age of approximately 41 years, and residing in rural areas. About 60% of the participants had only attained the secondary level of education, and a majority earned less than 150,000 naira (\$360) at the time of the study. About half of the female participants are women of reproductive age, while participants with children aged 5 or below constitute about 45% of the sample. In terms of purchasing preferences, most of the participants purchase white gari and also purchase from the open market. The balanced test results show no significant difference between the treatment groups in terms of their socioeconomic and purchasing characteristics.

**Table 5: Sample Characteristics based on Information Treatment Groups (N=352)**

Variable	Control (n=117)	Nutrition (N=116)	Nutrition +Method (N=119)	Pooled	P-Value
	Mean (SD) / %	Mean (SD) / %	Mean (SD) / %	Mean (SD) / %	
Female	69.23%	67.24%	65.55%	67.38%	0.83
Married	84.62%	86.21%	84.87%	85.53%	0.64
Age	41.71 (11.72)	43.63 (13.00)	44.68 (12.06)	41.52 (12.66)	0.12
Live in a rural area	61%	63.79%	57.98%	60.92%	0.36
<b>Formal education</b>					
None	5.55%	5.17%	4.20%	4.97%	0.51
Secondary or lower	57.26%	63.80%	56.31%	59.12%	
Graduate	23.93%	21.55%	31.09%	25.52%	
Post-graduate	10.26%	9.48%	8.40%	9.38%	
<b>Income Group (Naira)</b>					
< 30,000	27%	25%	29%	27%	0.36
30,001 – 70,000	17%	20%	18%	18%	
70,001 – 150,000	17%	15%	16%	16%	
> 150,000	39%	40%	37%	39%	
Women of reproductive age	44%	41.38%	52.10%	45.82%	0.10
With Children age 5 or below	42.75%	44.83%	48.74%	45.44%	0.54
<b>Purchasing characteristics</b>					
<b>Favorite purchase location</b>					
Open Market	81%	75.86%	83.19%	79.57%	0.22
From Processor	19%	24.24%	16.81%	20.43%	
<b>Gari type frequently bought</b>					
White	91%	89.66%	90.76%	90.21%	0.59
Yellow	0.60%	0.86%	0.00%	0.43%	
Both	8.40%	9.48%	9.24%	9.36%	

*Note: P-value from the ANOVA test between the means and the Chi-square test of difference in distribution*

#### 3.4.3.5. Research Hypotheses

Four hypotheses were tested in this study based on the information provision. The first hypothesis relates to the role of the information treatments in influencing ANA behaviour. In this regard, we expect consumers in the “Nutrition” group to have a significantly higher propensity to ignore method attributes compared to consumers in the “Nutrition + Method” group. Although consumers in both groups were initially unfamiliar with the method attributes before information provision, we expect that the scientific process information given to the method group should increase the knowledge of consumers in the group, thereby reducing their ANA rates.

Second, we hypothesize that models that account for ANA will explain the data better than models that assume full attendance.

The third hypothesis relates to how consumers in both treatments respond to micro-nutrient and health benefits information. Consistent with previous studies (e.g. Chowdhury et al., 2011; Meenakshi et al., 2012; Oparinde et al., 2016a; Lusk et al., 2018), we expect that consumers in both treatments will be willing to pay a premium for enhancement in all the micronutrient attributes. To test the hypothesis, we estimated marginal WTPs for the micronutrient attributes for both experimental groups and tested if the estimates are statistically different from zero.

The fourth hypothesis relates to the role that process information will play in consumers' preferences for the method attributes. We expect that consumers in the method group will prefer the conventional method to GE methods, consistent with most similar studies reported in other regions (Van Loo et al., 2020; Marette et al., 2021). Also, we expect that consumers are likely to have lower disutility for the GED method compared to the GM method.

#### **3.4.4. Econometric Framework**

##### *3.4.4.1. Multinomial Logit (MNL) Model*

In choice modelling, the MNL model, also referred to as the conditional logit model, is widely employed due to its simplicity in both estimation and interpretation of choice probabilities and elasticities. Based on RUT (McFadden, 1974), the utility that an individual derives from choosing an alternative can be generally expressed as:

$$U_{ijt} = \beta' x_{ijt} + \varepsilon_{ijt} \quad (1)$$

where  $x_{ijt}$  is a vector of explanatory variables, including the characteristics of products and interactions between product attributes and/or participants' socioeconomic characteristics. The term  $\varepsilon_{ijt}$  represents unobserved utility and is assumed to follow a Type I Extreme Value

distribution.  $\beta_i$  is a vector of utility weights (parameters) that capture the importance the respondent assigns to each explanatory variable.

The MNL model assumes that the random error terms  $\varepsilon_{ijt}$  are independently and identically distributed as extreme value type I, and that preferences for the observed attributes are homogeneous, that is, the vector  $\beta_i$  is the same across all participants. This assumption about the distribution of the error terms leads to the independence of irrelevant alternatives property (Kassie et al., 2017), a restrictive condition implying that the relative odds of choosing between any two alternatives remain unaffected by the presence or attributes of other alternatives.

While the MNL model is widely used, its underlying assumptions, particularly those of independence of irrelevant alternatives and preference homogeneity, often do not reflect real-world decision-making. As a result, the model has been continuously extended to relax these limitations and better capture the complexity of choice behaviour.

#### *3.4.4.2. Random Parameter Logit (RPL) Model*

The RPL model is one of the key extensions of the MNL model and addresses the restrictive independence of irrelevant alternatives assumption. A central focus in discrete choice modelling has been to account for taste heterogeneity across individuals (Train, 2009). Among the various models developed for this purpose, the model is particularly valued for its flexibility in accommodating different forms of parameterization (McFadden and Train, 2000). RPL model allows for random variation in preference parameters by assuming a continuous distribution of taste heterogeneity across individuals, while the MNL model assumes that the error terms are independently and identically distributed extreme value type I. The individual-specific utility weight ( $\beta_i$ ) for a given attribute is specified as:

$$\beta_i = \beta + \Gamma v_i \quad (2)$$

In this specification:

- $\beta$  is the vector of mean utility weights in the population,
- $\Gamma$  is a diagonal matrix containing standard deviations ( $\sigma$ ) of the random parameters around the population mean,
- $v_i$  is a vector of unobserved, individual-specific random components, assumed to be standard normal with mean zero and standard deviation one (Kassie et al., 2017).

This structure enables the estimation of individual-level utility parameters by conditioning on observed choices. Additionally, RPL supports correlation in unobserved factors over time, allows for unrestricted substitution patterns, and, unlike the multinomial probit model, it is not limited to normally distributed taste parameters (Train, 2009).

### ***3.4.5. Estimation Strategy***

To test the research hypotheses, models that assumed full attendance and models that accounted for ANA were estimated using the DCE data. For the full attendance model, the estimation was based on utility weights for the gari attributes using data from each treatment group (segmented data). In this study, the choice-task stated the ANA approach as employed by Caputo et al. (2017) was employed.

For all the models, the DCE data were fitted to random parameter logit models (McFadden and Train, 2000). In specifying the random parameter logit models, it is common to assume that consumers are rational utility maximizers as described in the RUT (McFadden, 1986). According to the RUT, we assume that the indirect utility of respondent  $n$  for gari option  $j$  in choice situation  $t$  can be specified as:

$$U_{njt} = V_{njt} + \varepsilon_{njt} \quad (1)$$

Where  $V_{njt}$  represents the deterministic part of utility and  $\varepsilon_{njt}$  represents the stochastic random portion of the utility assumed to follow the Type 1 Generalized Extreme Value distribution

(McFadden, 1986). In many econometric specifications, a common assumption is that  $V_{njt}$  is determined only by the attributes of the product alternatives that consumers face. However, it is also common to assume that consumers have full information about the alternatives and attend to all the attributes to make full trade-offs among the attributes. Alternatively, the random parameter logit model can be specified to accommodate ANA behaviour. For this study, we specified full attendance and the ANA (non-compensatory) model. For the full attendance specification, we specify:

$$V_{njt} = \beta_{va}VA + \beta_{ir}Ir + \beta_{ls}LS + \beta_{gm}GM + \beta_{ged}GED + \beta_{nb}ASC + \beta_{price}Price \quad (2)$$

where  $VA$ ,  $Ir$ ,  $LS$ ,  $GM$ ,  $GED$ ,  $ASC$  and  $Price$  respectively denote VA, iron, low starch, genetic modification, gene editing method, alternative specific constant (ASC), and Price, and their respective parameters are denoted with  $\beta_{va}, \beta_{ir}, \beta_{ls}, \beta_{gm}, \beta_{ged}, \beta_{asc}$  and  $\beta_{price}$ .  $VA$ ,  $Ir$  and  $Price$  are coded as continuous variables while  $GM$ ,  $GED$  and  $ASC$  are included as dummy variables, which are coded as 1 when the attribute is present and 0 otherwise. All parameters were specified as normally distributed random parameters, while also allowing for correlation among the parameters (Train, 2009). However, as recommended in a recent review by Caputo & Scarpa (2022),  $\beta_{price}$  was specified to follow a triangular distribution as an alternative to overcome known problems with a normally distributed price parameter when computing WTP.

For the ANA model specification, we specify:

$$V_{njt} = (\beta_{va}^{att} + \beta_{va}^{natt})VA + (\beta_{iron}^{att} + \beta_{iron}^{natt})Iron + (\beta_{ls}^{att} + \beta_{ls}^{natt})LS + (\beta_{gm}^{att} + \beta_{gm}^{natt})GM + (\beta_{ged}^{att} + \beta_{ged}^{natt})GED + \beta_{asc}^{att}ASC + (\beta_{price}^{att} + \beta_{price}^{natt})Price \quad (3)$$

In equation 3,  $\beta_{va}^{att}$ ,  $\beta_{iron}^{att}$ ,  $\beta_{ls}^{att}$ ,  $\beta_{gm}^{att}$ ,  $\beta_{ged}^{att}$ ,  $\beta_{asc}^{att}$ ,  $\beta_{price}^{att}$  respectively represent utility estimates of respondents who attended the VA,  $Ir$ ,  $LS$ , GM, GED, ASC, and  $Price$ , while  $\beta_{va}^{natt}$ ,  $\beta_{iron}^{natt}$ ,  $\beta_{ls}^{natt}$ ,  $\beta_{gm}^{natt}$ ,  $\beta_{ged}^{natt}$ ,  $\beta_{price}^{natt}$  respectively represent the utility estimates for the respondents who ignored the attributes. Only parameters for attenders in equation (3) were specified as normally distributed

random parameters, allowing for correlation among the parameters (Train, 2009). Price parameters and all parameters for non-attenders were specified as fixed.

The choice probability of the mixed logit model can only be estimated using simulated log-likelihood over a series of iterations that require several draws (Train, 2009). In all the specifications, 500 Sobol draws were used. Using the model fit statistics, the log-likelihood, and BIC, we selected the model that best fits the data.

The second stage empirical strategy involved the determination of whether to pool the data of the treatments together based on the best-fit model selected in the first stage. Following the practice in the literature (e.g. Matthews, et al., 2017; Van Loo et al., 2020; Caputo, 2020), the test of the hypothesis of equality of coefficients between the segmented models and the pooled model was carried out. The test is based on the log-likelihood values of the segmented and joint models, and it is calculated as:  $-2[L_{pooled} - (L_{nutrition} + L_{method})]$  where  $L_{pooled}$ ,  $L_{nutrition}$  and  $L_{method}$ . These are the respective log-likelihood values for the pooled, nutrition, and method models. The test is chi-square-distributed with degrees of freedom equal to  $K(T - 1)$ , where  $K$  is the number of restrictions and  $T$  the number of treatments.

All models were estimated using the simulated maximum likelihood estimation with the Apollo package in the R Statistical environment (Hess and Palma, 2019). The utilities of the models were all specified in the preference space. Thereafter, estimates of the finally selected models were used to compute WTP estimates that are interpretable in monetary terms, as done in other food choice studies (e.g., Van Loo et al., 2020; Sanou et al., 2021).

#### ***3.4.6. Measurement of Awareness, Knowledge, Perception, and Absolute Opposition***

Concerning awareness of the methods, participants stated whether they had previously heard the terms “genetic modification” and “gene editing.” Only participants who stated “Yes” attended to questions relating to subjective and objective knowledge subsequently. For the subjective

knowledge, participants were asked, “How much do you know about genetically modified food or gene-edited foods?” with the possibility to answer on a rating scale ranging from 1 (Very low knowledge) to 5 (Very high knowledge), Moreover, for their objective knowledge, we included two items to which they were to respond ‘YES,’ ‘NO,’ or ‘DO NOT KNOW’ (Gaskell et al., 2006). These items were (i) “Genetically modified foods contain genes while non-genetically modified foods do not contain genes” and (ii) “Human genes can change through consuming genetically modified foods.” We categorized participants who answered ‘NO’ to both questions as having objective knowledge.

Respondents were categorized as having complete knowledge if they answered ‘NO’ to both questions, while those who answered twice ‘YES’ or ‘DON’T KNOW’ to both questions were categorized as having no knowledge. The remaining respondents were categorized as having partial knowledge.

To measure the perception of GM and GED, we adopted the approach used by Yang and Hobbs (2020), posing this question: Which of the following represents your view on the impact of genetically modified and gene-edited food on health? The responses include (i) “Equal health risks and benefits,” (ii) “Health risks are higher than the health benefits,” (iii) “Health benefits are higher than health risks,” and (iv) “I do not know”.

To measure AO, we followed the approach of previous literature (Baron and Spranca, 1997; Scott et al, 2016) by presenting two items to the participants, to which they must agree or disagree by indicating a YES or NO response. The items were (i) “I oppose genetic engineering of plants” and (ii) “Genetic engineering of plants should never be allowed, no matter how great the benefits and minor the risks associated with it.”

Following a uniform approach employed in previous studies, we classified those who responded YES to items (i) and (ii) as self-reported absolute opponents; those who responded NO to items (i) and (ii) were categorized as supporters, while those who indicated YES to item (i) and NO to

item (ii) were classified as non-absolute opponents. In addition, and different from the approach employed in previous studies, we further classified these self-reported absolute opponents as choice-based absolute opponents if, in addition to their statements, they consistently choose non-GE products in their purchase decisions in the DCEs. Otherwise, they remain only self-reported absolute opponents and not choice-based absolute opponents.

### **3.5. Chapter Summary**

Chapter Three outlines the qualitative and quantitative methodologies employed in the study. It begins by describing the study area, followed by an account of the qualitative and quantitative research approaches.

The qualitative component details the in-depth interviews conducted within the framework of the MEC theory, which conceptualizes consumer decision-making as a structured cognitive hierarchy linking product attributes to anticipated consequences and, ultimately, to personal values that drive behaviour. It further explains the laddering technique used to elicit consumers' perceived consequences and values associated with the consumption of gari nutritionally enhanced with VA and iron, as well as their perceptions of the breeding methods. In addition, the chapter presents the socio-demographic profile of the interview participants and outlines the procedures applied for data analysis.

The quantitative component presents the details of the DCE, including its design, the attributes incorporated, and the survey implementation procedure. It further outlines the information treatments, research hypotheses, variable measurement, econometric framework, and estimation strategy applied to the data. In addition, the chapter reports the socio-economic characteristics of the survey participants.

The following chapter presents the results on the role of process information in consumer preferences for genetically biofortified gari in Nigeria.

## CHAPTER FOUR

### THE ROLE OF PROCESS INFORMATION IN CONSUMER PREFERENCES FOR GENETICALLY BIOFORTIFIED FOOD IN NIGERIA

#### 4.1. Chapter Overview

This chapter presents the results of the analysis on the role of production process information on consumer preferences and WTP for genetically biofortified food in Nigeria. The chapter starts by assessing the level of consumers' awareness, knowledge, and perceptions of the GE technologies involved before information provision. Subsequently, on how production process information affects consumers' preferences for genetically biofortified foods. Data from 235 consumers in the nutrition group and the nutrition + method group were used for the analysis.

#### 4.2. The Role of Consumer Knowledge in Influencing Attitudes toward Genetically Engineered Foods.

Genetically engineered crops were first introduced in SSA in 1996 with the commercialization of genetically modified insect-resistant maize in South Africa. Since then, a range of genetically modified crops has been developed across the region. However, the success of commercialization efforts largely depends on consumer acceptance of GE technologies (Frewer et al., 2013). Consumer awareness and knowledge are fundamental to the acceptance of genetically engineered foods (Wunderlich and Gatto, 2015; Zhang and Liu, 2015). Moreover, previous research identifies consumer knowledge as a key factor influencing perceptions and attitudes toward genetically engineered foods (House et al., 2004; Fernbach et al., 2019). Findings from these studies show that subjective knowledge, that is, what consumers think they know, and their objective knowledge, knowledge based on scientific facts, can differentially mediate through their risk and benefit perceptions to determine acceptance/opposition of GE applications to food.

Therefore, to assess consumers' attitudes toward genetically biofortified foods before receiving information, this chapter evaluates their initial awareness of GE technologies, their subjective and objective knowledge of GE, and their perceptions of GE methods.

### **4.3. Process Information, ANA, and Consumer Preference for Genetically Biofortified Food**

The limitations of the conventional method have necessitated the need for the use of GE methods in biofortification. However, as novel food products are being introduced into the markets, studies show that consumers demand information about how their food is produced (Caswell, 1998; Galati et al., 2019; Zhang et al., 2021). Specifically, the use of GE in food production represents a "process attribute" potentially resulting in information asymmetry and market failure if there is no signalling of the attribute (Caswell and Mojduszka, 1996; Olynk et al., 2010). This raises questions about whether consumers' reluctance to novel food technologies is driven by a limited understanding of the process behind novel food technologies and whether there is a need to provide 'process' information about novel food technologies to consumers (e.g., Nayga et al., 2005; Kahan et al., 2009; Fernbach et al., 2019). While previous studies (e.g., Bieberstein et al., 2012; Van Loo et al., 2020; Zhang et al., 2021) have investigated the effect of information on consumer acceptance of novel food technologies, we do not know how consumers in SSA will respond to process information about GE technologies that promise to elevate the micronutrient content of their staple foods.

This chapter also examines how information on GE processes influences consumers' preferences and WTP for genetically biofortified food. Through a DCE conducted in Nigeria and a randomized experimental design, participants were subjected to two types of information treatments. Further, empirical evidence has suggested that there is a tendency for participants to ignore certain attributes when going through the DCE (Hensher and Rose, 2009; Kehlbacher et al., 2013), a behaviour referred to as ANA. Empirical studies have demonstrated that failure to

account for ANA in choice models may lead to inaccurate estimation of preferences and WTP measures and consequently wrong policy conclusions (Scarpa et al., 2010; Kragt, 2013; Caputo et al., 2017).

Therefore, given that this study focuses on a context in which consumers have a low level of knowledge about genetically engineered food technologies, one can expect a high level of non-attendance to GE attributes in the DCE. For instance, Sandorf et al. (2017) find that a low level of knowledge is associated with a higher propensity to ignore attributes for which consumers did not have knowledge. Thus, the focus of this chapter is on how information provided influences ANA behaviour and whether this influence affects WTP estimates.

#### **4.4. Results**

##### ***4.4.1. Awareness and Knowledge of Genetically Biofortified Foods***

Table 6 presents the findings on consumers' awareness and knowledge of GE technologies for the overall sample before information provision. The results indicate that approximately half of the participants reported having heard of nutritionally enhanced gari produced using conventional methods. Moreover, the results show that about 30% of participants were aware of GM methods, while 18% were aware of GED methods. Although overall awareness of GE methods was low, a greater proportion of participants were familiar with GM than with GED.

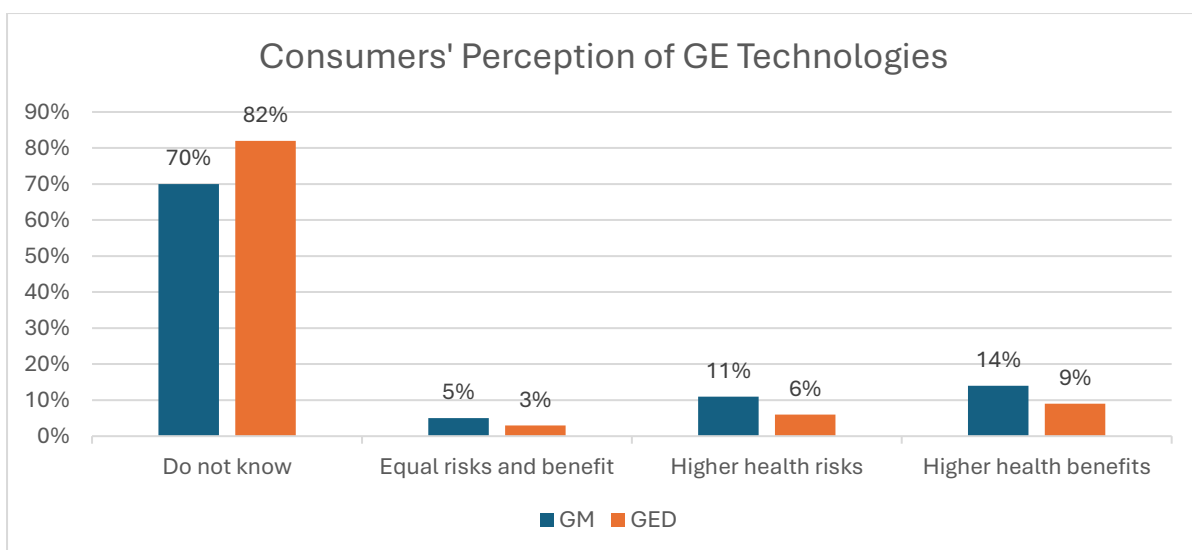
In terms of subjective knowledge, participants rated their familiarity with GM and GED on a scale from 1 (very unknowledgeable) to 5 (very knowledgeable). The average score was 1.40, suggesting that participants generally considered themselves to have limited knowledge of these technologies. Among those who reported being aware of GM or GED, only about 8% demonstrated objective knowledge of GE.

**Table 6: Awareness and knowledge of GE technologies**

Awareness and Knowledge	Mean (SD) / %
<b>Conventionally biofortified gari</b>	47.23%
<b>GM</b>	30%
<b>GED</b>	18%
<b>Subjective knowledge of GM</b>	1.40 (1.02)
<b>Subjective knowledge of GED</b>	1.17 (0.82)
<b>Objective knowledge of GE</b>	8.09%

#### 4.4.2. Consumers' Perception of GE Technologies

Figure 7 presents the results of consumers' perceptions of GM and GED technologies before receiving any information. The findings show that most of the participants, 70% and 82% respectively, had no prior opinion about GM and GED technologies. This is followed by a smaller proportion of participants who perceived greater health benefits associated with these methods. The smallest proportion comprised those who perceived GM and GED technologies as offering equal health risks and benefits.



**Figure 7: Consumers' Perception of GM and GED**

#### 4.4.3. Rate of Attribute Non-Attendance

Table 7 shows the rate at which the participants ignored the attributes in each treatment group for the stated ANA approaches. The results reveal a high incidence of ANA, reaching up to 60% for method-related attributes, while nutrient-related attributes showed considerably lower ANA rates. Differences in ANA between groups were examined using independent-sample t-tests. The results indicate that only the method attributes exhibited statistically significant differences between groups, confirming our first hypothesis: respondents in the “nutrition” group were significantly more likely to ignore the method attribute than those in the “nutrition + method” group. These findings highlight the importance of accounting for ANA in estimating preference parameters.

**Table 7: Proportion of Attribute Non-Attendance by Experimental Group**

	<b>Nutrition</b>	<b>Nutrition + Method</b>	<b>P-value</b>
	<b>N=928</b>	<b>N=952</b>	
<b>VA</b>	5.72%	4.62%	0.28
<b>Iron</b>	16.74%	16.81%	0.97
<b>Low starch</b>	16.74%	16.81%	0.97
<b>Methods</b>	60.48%	55.57%	0.03
<b>Price</b>	24.95%	26.57%	0.42

#### 4.4.4. Preference Estimates

Table 8 presents the preference estimates for each treatment group based on full attendance and stated ANA models. For each attribute, we present the estimate of the mean and the standard deviation below. The full estimation results of the ANA models include estimates for both

attenders and non-attenders. However, as many of the estimates for the non-attenders are not statistically significant, we do not present them here. Based on the log likelihood and BIC of the models, the results show that for both treatment groups, the ANA models fit the data better than the full attendance model. This confirms our second hypothesis that models that account for ANA will fit the data better than models that do not account for ANA. There is therefore a need to account for ANA behaviour in estimating preferences for both treatment groups.

From the results, ANA models across both groups, as presented in Table 8, coefficients for all micronutrient attributes are positive and statistically significant. Particularly, consumers exhibit the strongest preference for gari that provides 50% of the EAR for iron. For biofortification method attributes, results differ by group. In the “Nutrition” group, coefficients for both GM and GED gari are negative but statistically insignificant, suggesting indifference between genetically engineered and conventionally biofortified gari. In contrast, in the “Nutrition + Method” group, both GM and GED coefficients are negative and statistically significant, with stronger disutility compared to the “Nutrition” group. These findings support our fourth hypothesis: consumers exposed to information about methods are more likely to discount genetically engineered options.

In both groups, the coefficient for low starch is positive and statistically significant, indicating a consistent preference for gari with reduced starch content. Price coefficients are negative and statistically significant in both groups, reflecting disutility from higher prices, as expected.

Regarding unobserved preference heterogeneity, we observe significant variation in preferences for the non-biofortified gari across both groups. Additionally, in the “Nutrition + Method” group, significant heterogeneity is also found for gari, providing 50% EAR for iron.

Table 9 reports the log-likelihood ratio (LR) test for coefficient equality across groups. It reveals that the LR statistic is statistically insignificant. Thus, we fail to reject the null hypothesis

of equal coefficients, implying no statistically significant differences in attribute preferences between the groups. However, the pooled model shows that the scale parameter for the “Nutrition + Method” group is both statistically significant and relatively larger, indicating differences in error variance across the groups.

**Table 8: Preference Estimates for Full Attendance and ANA**

		Nutrition		Nutrition + Method		Pooled
Attribute		Full Attendance	ANA	Full Attendance	ANA	ANA
<b>VA (100% EAR)</b>	Mean	0.41* (0.16)	0.49* (0.2)	1.00* (0.22)	1.38* (0.38)	0.76* (0.16)
	Std. dev	0.30 (0.29)	0.22 (0.14)	0.45 (0.40)	-0.26 (0.2)	-0.01 (0.43)
<b>Iron (25% EAR)</b>	Mean	1.54* (0.22)	2.19* (0.42)	2.13* (0.32)	3.62* (0.87)	2.39* (0.29)
	Std. dev	0.41 (0.39)	0.09 (0.46)	0.98* (0.45)	1.29* (0.61)	0.31 (0.44)
<b>Iron (50% EAR)</b>	Mean	2.18* (0.30)	3.07* (0.54)	2.72* (0.42)	4.41* (1.08)	3.08* (0.36)
	Std. dev	0.00 (0.48)	0.22 (0.15)	1.24* (0.43)	0.49 (0.84)	-0.02 (0.42)
<b>GM</b>	Mean	0.30 (0.34)	-0.91 (0.47)	-0.85 (0.50)	-1.99* (0.75)	-1.35* (0.4)
	Std. dev	0.75 (0.41)	0.04 (0.36)	0.79 (0.58)	1.42* (0.72)	0.16 (1.42)
<b>GED</b>	Mean	-0.10 (0.21)	0.57 (0.43)	-0.76* (0.29)	-1.63* (0.67)	-0.86* (0.31)
	Std. dev	10.07* (2.54)	0.19 (0.46)	0.36 (0.35)	0.04 (0.48)	0.03 (0.52)
<b>ASC</b>	Mean	-8.11* (2.11)	-7.44* (1.65)	-5.32* (0.95)	-11.63* (2.77)	-8.66* (1.65)
	Std. dev	1.37* (0.24)	6.03* (1.45)	6.39* (1.05)	10.31* (3.24)	7.35* (1.28)
<b>Low starch</b>	Mean	-0.44 (0.75)	1.83* (0.36)	1.72* (0.34)	2.82* (0.96)	1.83* (0.27)
	Std. dev	0.41* (0.16)	0.54 (0.6)	2.12* (0.38)	2.85* (0.71)	0.23 (0.47)
<b>Price</b>	Mean	-0.00* (0.00)	-0.00* (0.00)	-0.00* (0.00)	-0.00* (0.00)	-0.00* (0.00)
	Std. dev	0.00* (0.00)	0.00* (0.00)	0.00* (0.00)	0.00* (0.00)	0.00* (0.00)
<b>Scale (Nutrition)</b>	Std. dev					1
<b>Scale (Nutrition + Method)</b>	Std. dev					1.13 (0.18) **
<b>Model Statistics</b>						
<b>N Parameters</b>		30	43	30	43	45
<b>N Respondents</b>		116	116	119	119	235
<b>N Observations</b>		928	928	952	952	1878
<b>Log Likelihood</b>		-563.03	-451.96	-581.30	-455.90	-922.22
<b>BIC</b>		1331.04	1197.65	1368.35	1206.73	2146.22

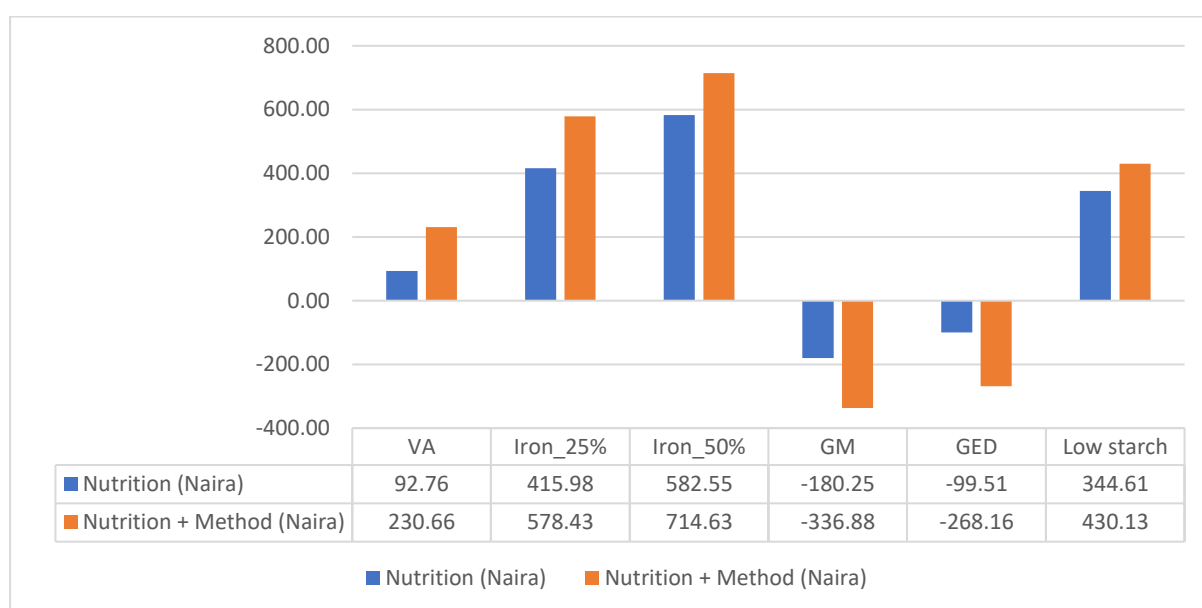
Note: \*\*, \*, Significant at 1%, 5% level; standard errors are in parenthesis

**Table 9: Log-Likelihood Ratio Test based on Stated ANA Models**

Models	N	Log Likelihood	LR test statistic	Degrees of Freedom	P-Value
<b>Nutrition</b>	928	-451.96			
<b>Nutrition + Method</b>	952	-455.9			
<b>Pooled</b>	1878	-921.08	26.44	43	0.98

#### 4.4.5. Mean WTP Estimates

Figure 8 presents the mean marginal WTP estimates for both groups using the stated ANA model. Generally, we observe that consumers in the nutrition + method group have relatively higher premiums for the micronutrient attributes and higher discounts for the GM and GED attributes.



**Figure 8: Mean Marginal WTP Values based on ANA Model**

#### 4.5. Chapter Summary

This chapter highlights a gap in consumer awareness, knowledge, and perception of genetically engineered foods in Nigeria. It further examined how scientific process information influences

consumer preferences, WTP, and ANA in the context of genetically biofortified foods in Nigeria, where awareness of GE technologies remains low. Our findings indicate a high incidence of ANA when consumers are faced with unfamiliar attributes like the GE attributes. Further, the results also reveal a strong WTP for enhanced micronutrient content and aversion to the GE methods after the scientific process information provision. This suggests that consumers value health benefits over how the food is produced when those benefits are evident. Moreover, we find greater aversion to the GM method when compared to the GED method.

**CHAPTER FIVE**

**CONSUMER PERCEPTION OF GENETICALLY BIOFORTIFIED FOOD IN  
NIGERIA: A MEANS-END CHAIN ANALYSIS**

**5.1. Chapter Overview**

This chapter presents the results of the analysis of consumer perceptions and values that shape the acceptance of genetically biofortified foods in Nigeria. With GE technologies becoming increasingly important for addressing nutrition insecurity in SSA, understanding how consumers cognitively perceive these technologies in food is crucial. Focusing on Nigeria, where VA and iron deficiencies are prevalent, this chapter examines the cognitive factors influencing consumer perceptions of genetically biofortified foods.

**5.2. Consumer Perceptions and Values for Genetically Biofortified Food in Nigeria**

To examine how consumers in Nigeria perceive the attributes of genetically biofortified foods and the values shaping these perceptions, the means–end chain (MEC) framework (Gutman, 1982) is employed to illustrate how consumers connect product attributes to personal values through a structured cognitive hierarchy, thereby influencing their acceptance decisions.

Previous studies in SSA have analysed consumer preferences for biofortified foods developed through conventional breeding methods (Chowdhury et al., 2011; Meenakshi et al., 2012; Lagerkvist et al., 2016; Oparinde et al., 2016), they have largely overlooked the perceptions and values of consumers underlying these preferences. An exception is Okello et al. (2017), who used the MEC to examine the cognitive factors behind preference for conventionally biofortified orange-fleshed sweet potato. Findings from this study indicate that nutrition information significantly increased the proportion of consumers who perceived the product as nutritious, thereby enhancing its acceptance. However, to the best of our knowledge, no studies in SSA have investigated consumer perceptions and values regarding genetically engineered

foods developed using GM and GED techniques. This chapter builds on this literature by explicitly investigating both the perceptions and values that drive consumer acceptance of genetically biofortified food.

By integrating the MEC framework, our study contributes to the broader literature by offering insights into the cognitive and value-based mechanisms underlying consumer choices for genetically engineered foods in Nigeria.

### **5.3. Results**

In this section, we present two HVMs illustrating participants' attribute–consequence–value linkages for micronutrients (VA and iron) and methods (conventional, GM, and GED), respectively. In each HVM, attributes are highlighted in pink, consequences in blue, and values in green. The thickness of the connecting lines indicates the strength of the associations between elements within the attribute–consequence–value linkages; thicker lines indicate relationships frequently mentioned by participants during the interviews.

#### ***5.3.1. HVM of Motivations for Consuming Biofortified Gari***

Figure 9 presents the HVM, illustrating participants' motivations for consuming biofortified gari. The resulting HVM captures 93.9% of the direct links reported by participants, exceeding the 70% threshold recommended by Gengler et al. (1995) for meaningful representation. The HVM reveals that the two micronutrient attributes, VA and iron, are connected to ten perceived consequences (benefits) and three personal values.

The HVM shows that at the base level, a high proportion (85%) of the participants linked the VA with health benefits of disease prevention and good eyesight. Moreover, the same proportion strongly linked iron to the provision of energy. Insights from the soft laddering interviews further indicate that participants perceive the inclusion of vitamin A and iron in gari

as contributing to its nutritional value, due to the recognized importance of these micronutrients for overall health.

As one participant explained:

*“I think it is good, especially for eyesight. You know, people do have this opinion about gari that it affects the eyes, and since it includes vitamin A, I know it will be nutritious for the body, and it will not even affect the eyes because vitamin A is good for the eyesight, so I believe it should be okay for the body”* (Participant 4)

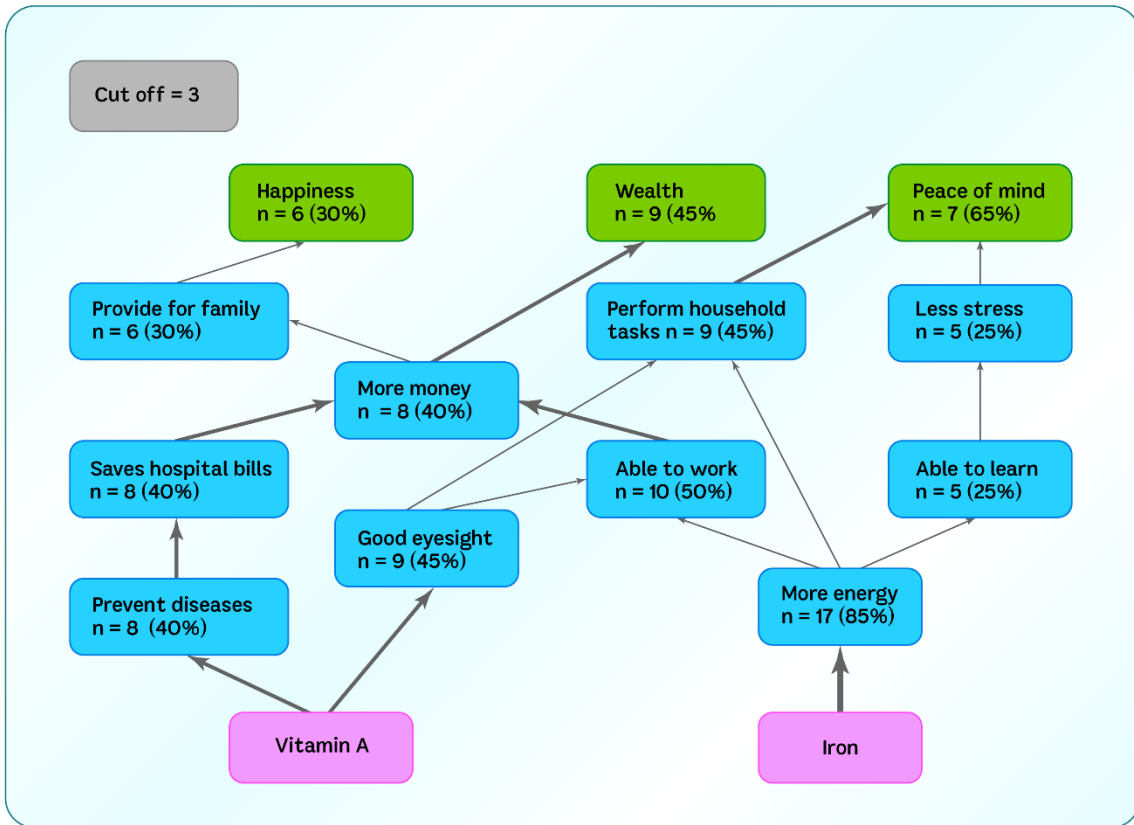
Another participant emphasized the role of iron in maintaining physical strength and daily functionality:

*“I love to be strong all the time. It is important so that I will be able to take care of my children, I will be able to go out, and I will be able to do the things I’m supposed to do* (Participant 13)

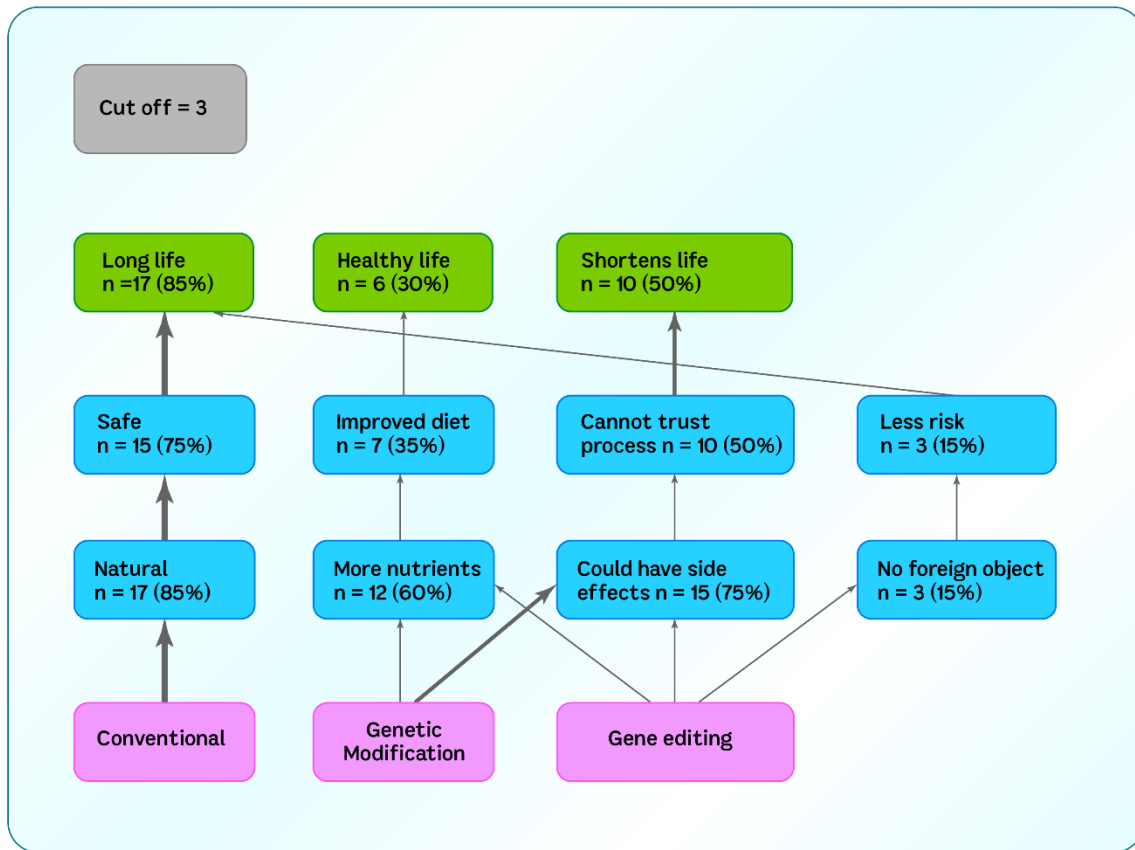
Moving up the ladder, disease prevention was further linked to financial gain (“more money”) through healthcare cost savings (“save hospital bills”), while good eyesight was linked to “more money” through improved ability to work and carry out household tasks. The central association for the VA and iron attributes was the ability to work and perform household tasks. One participant explained:

*“I feel it is important because it actually saves me money from having to go to maybe falling sick or anything, having to go to the hospital”* (Participant 6).

Overall, a high proportion of the participants (65%) associated consuming gari biofortified with VA and iron with the value of peace of mind, followed by wealth (45%) and happiness (30%), respectively.



**Figure 9: HVM of Motivation for Consumption of VA and Iron Attributes**



**Figure 10: HVM presenting Consumer Perceptions of Biofortification Production Methods**

### 5.3.2. HVM illustrating consumer perceptions of the GE methods

Figure 10 presents the HVM illustrating consumers' perceptions of applying conventional, GM, and GED. The HVM captures 88.7% of the direct links cited by participants. The map reveals that the three production method attributes are connected to eight consequences and three personal values. Consumers' perceptions are framed in terms of both positive and negative consequences: while GM and GED methods are associated with a mix of positive and negative outcomes, the conventional method is perceived solely in terms of positive consequences.

A high proportion of participants (85%) associated the conventional methods with naturalness, which they further linked to safety.

As one participant explained:

*“The conventional method is a natural way of cultivation and producing food crops. This is because something natural is how God made it, and it is safe to eat”* (Participant 6)

Regarding GE methods, 60% associated GM and GED with the potential to produce more nutrient-rich food, which they believed could improve diets.

One participant noted:

*“I think that it is good as it will help to augment the nutrients that are lacking in common food”* (Participant 2)

However, about 75% expressed concerns about potential side effects, largely stemming from a lack of trust in the production process. Participants’ perceptions of risk were primarily shaped by a lack of trust in the production process, with some voicing skepticism about the role of scientists. This distrust also extended to government institutions, as several participants questioned the government’s ability to regulate effectively and ensure that harmful products did not enter the market.

One participant explained:

*“Personally, to me, anything that they want to present to the public, the only issue I have about it is that they should test it very, very well to ensure it is not dangerous to our health. There are so many people out there that are producing things, presenting them to the public”* (Participant 1).

Others raised concerns about safety and uncertainty:

*“I’ve not seen people eat it; it may have side effects on the body. You know, one has to be careful with a new product like that”* (Participant 13).

*“It is not completely new but ... just like I said, if the purpose and the goal are to improve wellbeing, I think it’s good. If there is no ulterior motive behind it. Don’t forget that I’m still*

*an African and we have our sentiments. But if it is basically meant to help people, I think it's worth it"* (Participant 3).

Additionally, 15% perceived GED as less risky than GM because they believed no external elements were being added.

*"With genetic modification, I think there might be some risk. But with gene editing, the fact that nothing is being added, so I don't perceive any risk"* (Participant 8)

The HVM further reveals that a high proportion of the participants (85%) linked the value of a long life to conventional methods. Conversely, half viewed GE methods as potential obstacles to achieving this value, citing perceived health risks that could shorten lifespan. Overall, the HVM indicates that the primary value the majority (85%) associated with different production methods is long life, followed by healthy living (30%).

#### **5.4. Chapter Summary**

This chapter explored consumers' perceptions and values that underlie preferences for genetically biofortified foods in Nigeria, using the MEC framework. The analysis reveals that consumers associate the genetically biofortified foods with personal values of happiness, peace of mind, wealth, healthy life, and long life. Moreover, while consumers perceive the micronutrient attributes as beneficial, they have a strong preference for the conventional method due to its perceived naturalness and safety. However, consumers expressed concerns about GE methods, primarily citing potential health risks and a lack of trust in the production process.

While consumers recognized the nutritional benefits of GE technologies, a higher proportion perceived them as risky. Importantly, the relative preference for GED over GM suggests that consumers differentiate between GE techniques based on perceived risk and benefit trade-offs.

The findings indicate that the acceptance of genetically biofortified foods is shaped not only by consumers' awareness of their nutritional benefits but also by the extent to which these benefits and the underlying production methods are cognitively connected to deeply held personal values.

## CHAPTER SIX

### THE ROLE OF ABSOLUTE OPPOSITION IN CONSUMER ACCEPTANCE OF GENETICALLY BIOFORTIFIED FOOD IN NIGERIA

#### 6.1. Chapter Overview

Absolute opposition to controversial food biotechnologies, i.e., an injunction held by certain consumers that makes them insensitive to risk and benefit, is assumed to be a crucial barrier to addressing global food insecurity using genetically engineered foods. However, there is an ongoing debate as to the extent to which the AO framework, relative to the risk-benefit perception framework, can explain consumers' acceptance of GE foods. In this chapter, we provide evidence on the likely role of AO in consumers' acceptance of GE foods in Nigeria.

#### 6.2. Self-reported and Choice-Based Absolute Opposition to Genetic Engineering

Consumers' opposition to certain food biotechnologies, such as GE, has been recognized as a crucial barrier to scaling such innovations (Frewer et al., 1998; De Steur et al., 2022). Moreover, opposition among consumers to the use of GE in food is widely reported in the literature (e.g., Rozin et al., 2012; Frewer et al., 2013; Scott et al., 2016; Royzman et al., 2017; Fernbach et al., 2019). Such opposition can be due to a low level of objective knowledge (Fernbach et al., 2019), preference for naturalness (Rozin et al., 2012; Roman et al., 2017), perception of risks greater than benefits, low trust in institutions (Frewer et al., 2013), and moral (Scott et al., 2016) or ethical considerations (Kimenju and DeGroot, 2008; Ly et al., 2021). A dominant argument is that consumers' acceptance or opposition to GE is based on their risk-benefit perception of GE food, meaning consumers will accept GE foods with perceived positive net benefits (e.g., Kimenju and DeGroot, 2008; Lusk et al., 2015).

Conversely, some consumers are insensitive to the risks and benefits of GE food, making them absolutely opposed to the technology (Baron & Spranca, 1997; Scott et al., 2016).

This chapter aims to provide evidence on self-reported and choice-based AO to GE among consumers of biofortified gari in Nigeria. It is common for most of the studies to label respondents as absolute opponents based on the respondents' stated responses to certain questions. However, Baron and Leshner (2000) suggest that such self-reported claims may not be reliable when alternative approaches are used to determine the proportion of the population that manifests AO. The authors found that the share of respondents showing AO dropped from 48% to 34% once they considered counterexamples before making their final decision. Likewise, Royzman et al. (2019) discovered that absolutism was further reduced when participants who initially claimed AO to GM were further allowed to explain or give reasons for their decision. Therefore, in this chapter, we rely on respondents' choice patterns to validate their self-reported AO to GE food. Further, we investigated the socio-economic and behavioural determinants of AO.

### **6.3. Result**

#### ***6.3.1. Objective Knowledge and Opposition***

Our results from Table 10 show that while a few respondents in the sample had complete knowledge of the GE concept, the majority of the respondents have partial knowledge of GE. Concerning opposition, we find that a higher proportion of the respondents are supporters of GE. However, in terms of the self-reported absolute opponents, 16.10% were absolutely opposed to GE, but the proportion reduces to 4.88% for the choice-based absolute opponents.

**Table 10: Proportion of Respondents by Objective Knowledge and Opposition**

Variable	Description	Percentage
<b>Complete Knowledge</b>	Percentage of participants who have complete knowledge	6.34%
<b>No Knowledge</b>	Percentage of participants who have no knowledge	5.85%
<b>Partial Knowledge</b>	Percentage of participants with partial knowledge	87.80%
<b>Stated GE Supporters</b>	Percentage of participants who stated they support GE	76.56%
<b>Stated GE Non-Absolute Opposition</b>	Percentage of participants who stated non-absolute opposition	4.39%
<b>Self-reported GE Absolute Opposition</b>	Percentage of participants who reported absolute opposition	16.10%
<b>Choice-based GE Absolute Opposition</b>	Percentage of participants who have true absolute opposition	4.88%

### ***6.3.2. Predictors of Absolute Opposition***

We analyze how consumers' sociodemographic and behavioural characteristics influence their likelihood of exhibiting self-reported and choice-based AO to GE using binary logistic regression models. The results, as presented in Table 11, allow for a comparison between predictors of self-reported and choice-based AO. We observe that distrust in scientists and perception of higher risks with the use of GE were common positive predictors of both measures of AO. Furthermore, living in rural areas increases the likelihood of exhibiting choice-based AO. The 'No Knowledge' variable was excluded from the choice-based absolutism model because it perfectly predicted the absence of choice-based AO to GE; that is, all respondents who lacked knowledge of GE did not display choice-based AO.

**Table 11: Predictors of Self-reported and Choice-based Absolute Opposition to GE**

Variable	Self-reported AO		Choice-based AO	
	Coefficient	Std. Error	Coefficient	Std. Error
Male	0.27	0.51	0.07	0.83
Age (in years)	0.02	0.02	0.05	0.03
Education (in years)	0.14**	0.07	0.21*	0.12
Trust government	0.06	0.12	0.10	0.19
Trust scientists	-0.59***	0.14	-0.65***	0.22
Urban	-0.30	0.61	-2.15**	1.13
Perceives GM as having a higher risk	1.96***	0.52	1.69**	0.77
Christian	-0.24	0.58	1.08	1.19
Constant	-2.35		-5.98	
Loglikelihood	60.70		27.26	
Chisquare	0.00		0.00	
Pseudo R <sup>2</sup>	0.30		0.30	

*\*, \*\*, \*\*\*, Significant at 10%, 5%, 1%-level*

#### 6.4. Chapter Summary

This chapter investigated whether a self-reported measure of AO is reliable to predict consumer behaviour toward GE. We also investigated whether AO will be a crucial barrier to scaling GE foods in SSA. Although our findings reveal that there are some consumers who are absolutely opposed to the use of GE foods, there is a significant difference between the self-reported and choice-based AO measure. Moreover, consumers' perception of risks remains a strong predictor of both measures of AO to the use of GE. Therefore, the chapter concludes that consumer behaviour towards GE in Nigeria should be viewed as a risk-benefit perception issue.

The next chapter provides the discussion section of the dissertation

## CHAPTER SEVEN

### DISCUSSION

#### 7.1. Chapter Overview

This chapter presents the discussion section of the dissertation. The section is outlined based on the study's three main research objectives, with a specific focus on the research questions addressed.

#### 7.2. Discussion on the Role of Information on Consumer Preference and WTP for Genetically Biofortified Food

*Research question 1(a): What are consumers' initial level of awareness, knowledge, and risk-benefit perception of genetically biofortified foods?*

The findings reveal that awareness and knowledge of GE technologies among consumers remain low. Furthermore, most consumers lack clearly defined perceptions regarding the risks and benefits associated with GE methods. These findings are consistent with previous research in the region (Kimenju et al., 2005; Kimenju and De Groote, 2008; Mustafa et al., 2023), which repeatedly highlight limited public familiarity with GE technologies. For example, Kimenju et al. (2005) reported that only 38% of Kenyan consumers were aware of genetically modified foods, while Mustafa et al. (2023) found that just 39.1% of Ugandans had ever heard of genetically modified crops. In Nigeria, Oladipo et al. (2020) noted that only 26% of respondents rated their knowledge of GE as high, though the study did not evaluate consumers' objective knowledge. Even in South Africa, where GE crops have been commercialized for years, Dovey and Ntuli (2020) found that only 30% of consumers demonstrated accurate, objective knowledge of GE technologies.

However, some progress has been noted. Gastrow et al. (2018) observed a rise in awareness of GE biotechnologies in South Africa, with the proportion of informed individuals increasing

from 21% in 2004 to 54% in 2015. This increase is attributed to the commercialization of genetically engineered products, suggesting that the commercialization of genetically engineered crops may contribute to greater public awareness across the continent as more countries adopt these technologies. Dovey and Ntuli (2020) argue that consumer perceptions in Africa are still developing and are likely to continue evolving as knowledge improves. It remains difficult to assert that consumers have fully formed perceptions of genetically engineered foods when their understanding is limited. Indeed, the widespread lack of awareness and knowledge has been identified as a major barrier to the acceptance of GE technologies in the region (Gbadegesin et al., 2022). This knowledge gap restricts consumers' ability to make informed decisions about genetically engineered foods.

***Research question 1(b):** How do different information treatments affect consumer preferences and WTP for genetically biofortified food?*

The results show that consumers are willing to pay significant premiums for higher levels of micro-nutrients, regardless of whether they are informed only about the health benefits of GM and GED technologies or are additionally informed about the process behind these technologies. This result is consistent with previous studies (e.g., Oparinde et al., 2016a; Kolapo et al., 2023).

Regarding the WTP for the methods, the finding that consumers who were not informed about them showed no preference for any of the methods compared to the conventional method further confirms their unfamiliarity with these attributes. However, for those who were informed about the methods and attended to the method attributes, we find a similar pattern of aversion for GE attributes observed in previous studies (Muringai et al., 2019; Kilders and Caputo, 2021; Murette et al., 2021).

Furthermore, the relatively lower discount consumers have for GED compared to GM, regardless of the type of information provided, suggests that GED has a greater market prospect in the region. The reduced consumer aversion to GED as a novel food technology has also been reported in other studies (e.g., Yang and Hobbs, 2019; Ding et al., 2023).

***Research question 1(c): How does ANA affect the effect of the information?***

Without informing consumers about these methods, they were likely to ignore attributes relating to these methods in their choices (Alemu, et al., 2013). Indeed, the results confirm that the majority of the participants did not incorporate these attributes into their decision-making, even for those who were informed about the methods, although we observe a slight improvement in attendance to the method attributes among those who were informed about the method, compared to those who were not informed. These results point to the importance of consumer understanding of novel food attributes, especially those relating to the production methods, in the choices of novel food technologies with unfamiliar attributes.

Further, the fact that information about the methods only had a minimal effect on the tendency to ignore the attributes points to the need to go beyond a one-time provision of information for consumers in this context to understand genetically engineered food attributes and use them in their decision-making.

Concerning our estimation approach in this study, our results point to the importance of accounting for ANA when evaluating consumer choices of novel food with unfamiliar food attributes. Specifically, the results show a large downward correction of the WTP estimates when we compare the ANA models to models that assumed full attendance. Previous studies have shown that models accounting for ANA fit data better and provide more realistic WTP estimates (Hess and Hensher, 2010; Largade, 2013). Our findings here suggest that researchers evaluating consumers' WTP for novel food technologies should pay attention to how novel

attributes, which consumers may not be familiar with, may induce ANA and influence the validity of WTP estimates.

### **7.3. Discussion on the Consumer Perception of Genetically Biofortified Food in Nigeria: A MEC Analysis.**

*Research question 2: What are the cognitive processes that determine consumer acceptance of genetically biofortified food?*

Findings from this study show that consumers view micronutrient attributes as beneficial, with these perceptions aligning with personal values such as happiness, peace of mind, and wealth. Our findings align with previous research in SSA (Okello et al., 2017; Oparinde et al., 2016a), indicating that consumers integrate health benefit information when forming preferences. It also supports broader evidence that consumers will accept GE foods with perceived benefits (Colson and Huffman, 2011; Lusk et al., 2018).

The results also indicate a strong consumer preference for the conventional method, primarily driven by its association with naturalness. This finding is consistent with previous studies showing that consumers view conventional breeding as more natural and therefore more favourable than the GE methods (Rozin et al., 2012; Roman et al., 2017; Nales and Fischer, 2023). It also supports evidence that perceived naturalness serves as a key heuristic in consumers' evaluation of GE methods compared to conventional ones (Siegrist, 2008; Siegrist and Hartmann, 2020).

Our findings indicate that consumers' perception of risk associated with GE methods is largely influenced by concerns about food safety and potential health effects. This is consistent with previous studies (Kedisso et al., 2022; Mustafa et al., 2023), which have identified these concerns as significant barriers to the acceptance of GE technologies in the region. Additionally, the lack of trust in the production process observed in our study aligns with earlier

research (Bredahl et al., 1999; Frewer et al., 2013; Siegrist and Hartmann, 2020), highlighting the critical role of consumer trust in the acceptance of novel food technologies, including GE foods. Moreover, the preference for GED over GM supports findings from recent studies (Ding et al., 2023; Meerza et al., 2024), which suggest that GED is more favourably perceived due to its association with greater perceived benefits and lower perceived risks.

#### **7.4 Discussion on the Role of AO in Consumer Acceptance of Genetically Biofortified Food in Nigeria.**

*Research question 3(a): Do consumers' self-reported measures of AO to GE food overestimate their actual behavioural opposition?*

We find that self-reported measures may overestimate the extent of AO, highlighting the need for further validation of how this attitude is assessed. This resonates with the findings of Baron and Leshner (2000) and Royzman et al. (2019). Both studies provide evidence that PVs in terms of AO to GE are malleable if people are made to go through further probing. In their experiments, Baron and Leshner (2000) find that tradeoffs of PVs are possible when people are made to think more about their initial decision. Their results show that tradeoffs of initial PVs are possible when in conflict with other PVs and that PVs are sensitive and liable to change based on the magnitude and likelihood of harm associated with PVs. Royzman et al. (2019) corroborated these findings and concluded that the degree of AO expressed by people is purely a matter of a lack of understanding, ignorance, or not paying full attention to the question of absolutism. In the present study, we similarly find that the choice patterns of some of the participants are not consistent with their initial claim of AO. This affirms that relying only on the self-reported measure for AO could mean that previous studies that made empirical conclusions based only on this measure may have overstated the proportion of people who are

opposed to GE. Therefore, identifying actual absolute opponents of GE requires subjecting participants to further tests for validation of their responses.

***Research question 3(b): Which factors predict the manifestation of AO toward GE?***

Using the choice-based measure of AO to GE, the results show that perceived risk and distrust in scientists are strong predictors of consumers' likelihood of manifesting AO. Gray and Schein (2016) and Royzman et al. (2019) also establish that the dominant reason for AO is harm or risk perception. Therefore, our finding here is a confirmation that AO to the use of GE is mainly driven by risk perception and trust in Nigeria, as has been found in other regions (e.g., Moon and Balasubramanian, 2004; Prati et al., 2012; Lusk et al., 2018).

In relation to the choice-based measure of AO, the empirical evidence provided in this study is consistent with previous research that there is little opposition to the use of GE in Africa (Frewer et al., 2013). Considering that there is a relatively high proportion of consumers with no objective knowledge, one should expect a high level of opposition, given the argument of previous studies. Findings from this study seem not to support this argument, though. This level of opposition cannot be compared to what is obtainable among consumers in developed countries who have no objective knowledge of GE. Indeed, previous studies did not clearly state the relationship between objective knowledge and AO (e.g., Fernbach et al., 2019; Min et al., 2021). These studies only relate objective knowledge to AO in general.

In this study, we find that the lack of objective knowledge of GE has a different relationship with AO. A lack of objective knowledge does not significantly predict AO. All who had no objective knowledge of GE did not oppose GE. Based on this observation, we may not conclude that promoting objective knowledge in the population of consumers in Africa will mitigate opposition to GE.

## **7.5. Chapter Summary**

This chapter highlights the main research findings based on the three main research objectives of this study. The main results were then discussed in the light of findings from previous research.

## CHAPTER EIGHT

### CONCLUSION, PRACTICAL IMPLICATIONS AND LIMITATIONS

#### 8.1. Chapter Overview

This study focused on three main topics: (i) the role of information on consumers' preferences and WTP for genetically biofortified food; (ii) the perception of consumers towards the genetic engineering methods used in biofortification; and (iii) the role of absolute opposition in consumers' acceptance of genetically biofortified food. Based on the results of the analysis as discussed in the previous chapter, this chapter provides the conclusion, highlights the policy implications, and limitations of this study.

#### 8.2. Conclusion

Novel food technologies to address global food security challenges are emerging. High levels of nutrition insecurity in SSA offer a unique opportunity for scientists to apply GE methods to develop nutritionally enhanced foods. However, results from previous studies focusing on other regions of the world suggest that consumers are likely to discount the use of these technologies. Evidence on how consumers in Nigeria might trade off the benefits of GE methods to enhance their food with a possible aversion to these methods is lacking despite the region's critical role in addressing global food and nutrition insecurity. This dissertation examined how information on the health benefits of biofortified foods and the scientific process of conventional breeding, GM, and GED affects consumer preferences and WTP. Moreover, we investigated how these two types of information influence ANA behaviour and explored the perceptions and underlying values shaping consumer preferences for biofortification methods.

Overall, the findings reveal that consumer awareness and understanding of GE is low, leading to unclear perceptions of the technology. However, providing nutrition information increased WTP for enhanced micronutrient attributes, and the addition of these nutrients

motivated their consumption of biofortified gari. In contrast, scientific information on production methods led to consumer aversion toward GE and a preference for conventional techniques. Most consumers favoured the conventional method due to its perceived naturalness and alignment with the value of long life. The findings also suggest that when consumers lack knowledge about the underlying production methods of novel foods and are faced with DCE, consumers will rather focus on attributes they are familiar with and perceived to be beneficial to them, and may not care about how the food is produced. Conversely, consumers will care about how their food is produced when they learn about the different methods of producing the food.

Although biofortification efforts often target rural households that primarily depend on their food production, many urban and even rural consumers who might be nutritionally insecure are likely to still depend on the market for their common foods.

### **8.3. Policy and Practical Implications**

Drawing from the findings of this study, the policy and practical implications are outlined below.

#### **Consumer Education**

This study shows that effective consumer education is important for consumer perception and WTP for genetically engineered foods in SSA, as most consumers remain unfamiliar with the GE methods. Our findings suggest that a single exposure to information has only a modest effect on consumer understanding. This underlines the need for sustained, transparent, and context-specific educational initiatives to build trust and acceptance.

Furthermore, our results indicate that consumers in SSA place significant value on foods enriched with essential micronutrients. This suggests that communication and marketing strategies should emphasize the tangible health benefits of biofortification, particularly in

addressing widespread micronutrient deficiencies, rather than focusing primarily on the technical aspects of genetic engineering. Positioning genetically biofortified foods as a nutritional solution, rather than a technological innovation, may therefore enhance consumer acceptance and demand.

Notably, consumers are less averse to GED than to GM, suggesting that GED-based biofortification efforts may have better market prospects in SSA. Accordingly, effective promotional strategies should align product messaging with consumers' value orientations. Clear communication that differentiates between GM and GED techniques is therefore essential, as such distinctions may play a critical role in facilitating the acceptance of genetically biofortified foods in Nigeria.

### **Food Labelling and Certification**

A major challenge that could undermine consumer education initiatives in many SSA markets is the absence of standardized food labelling, which restricts consumers' ability to make informed choices. The effectiveness of consumer education is contingent upon access to accurate and transparent labelling information. In the absence of such information, consumers are compelled to rely on subjective cues that may not accurately reflect their true preferences. This lack of labelling, therefore, poses a significant barrier to informed decision-making. To address this gap, policies should prioritize the introduction and enforcement of food labelling regulations that disclose production processes, as is common practice in developed countries. Such measures would not only enhance transparency but also facilitate product differentiation based on production methods.

Moreover, food certification agencies such as the National Agency for Food and Drug Administration and Control (NAFDAC) should be strengthened and closely coordinated with the National Biosafety Management Agency (NBMA) to ensure rigorous safety evaluations of

genetically engineered food products before they reach consumers. The introduction of clear certification marks would serve as visible assurances of safety, helping to reduce consumer uncertainty. In addition, certification policies should be aligned with international biosafety and food regulation frameworks, thereby enhancing transparency and credibility. Together, these measures would play a crucial role in building consumer trust in genetically engineered foods.

### **Commercialization of GE foods**

Although genetically engineered foods are being commercialized in SSA, most consumers are still unfamiliar with the foods, as they are not yet available in the market. Consumer acceptance of these foods may take time, and preferences for genetically engineered foods may change when consumers get familiar with these foods, as studies have shown that familiarity with novel foods predicts acceptance (Bryant et al., 2019). More significantly, as genetically engineered foods are being commercialized and the products made available in the markets, it may be interesting to see if familiarity with the products affects demand over time.

### **Accounting for ANA in Novel Food Choice Experiment**

Our findings reveal a high incidence of ANA when consumers are faced with unfamiliar attributes like the GE attributes. Consequently, studies assessing preferences and WTP for novel foods must account for ANA, as ignoring it can result in biased WTP estimates. These results suggest that researchers evaluating consumer WTP for innovative food technologies should carefully consider how unfamiliar attributes may induce ANA, potentially affecting the accuracy and validity of their estimates.

#### **8.4. Limitations and Future Research Directions**

The use of hypothetical DCE to elicit consumer preferences and WTP may have an influence on the outcome of this study. However, the fact that the use of GE methods for the food product investigated in this study has not been commercialized does not permit us to use real food products. With the hope of commercializing these products, further studies can use real food products to provide robust WTP measures of consumers for genetically engineered foods in the region.

We find that the majority of the consumers in our study area have a low level of awareness and knowledge of GE concepts, resulting in high rates of ANA for the GE attributes, even after being provided with both nutrition and scientific process information. Therefore, we suggest future research on novel food technologies using DCE should take into account ANA behaviour in their preference and WTP estimation, even after information provision, especially when participants are unfamiliar with the technologies. Moreover, future studies should also investigate the role of GE labelling on consumers' WTP, as has been done in studies focusing on other regions. We also suggest that future studies carry out multi-country studies that can compare findings for different countries across SSA to test the robustness of our findings in this study.

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## General Appendix: Questionnaire



### **Informed Consent Form for Consumers Who Were Invited to Participate in the Research**

**Title: Consumers' Acceptance of Genetically Biofortified Food: Empirical Evidence from Nigeria.**

#### **Part I: Participant Information Sheet**

This is an invitation to participate in a research project, which is part of a Ph.D. study that is undertaken in Nigeria. You are free to decide whether you will participate or not. You can go through the information provided below and ask questions about anything you do not understand before you make your decision.

#### **Purpose of the research**

The main goal of this study is to investigate whether consumers will choose to buy the newly introduced foods rich in micronutrients. Some of these foods have been introduced, while others are yet to be introduced. The data received through this study will help us know if consumers will buy these foods and how much they will be willing to pay for them.

#### **Why was I chosen to participate in this research?**

You were chosen to participate in this research because you consume gari, you are above 18 years old and you live in this community.

#### **What am I to do to participate in this research?**

Your participation in this research is voluntary. You are to provide answers to the questions from the questionnaire given to you and to participate in a discussion about what you think about these new foods. You may choose to participate or not. Also, choosing to participate will not have any negative effect on you. You can stop participation if you are not comfortable with the questions being asked.

**How long will it take if I participate?**

Participation in the interviews will take about thirty minutes of your time. You will receive a gift for taking your time to participate in the research.

**What will the data provided be used for?**

The data you provide is only for academic purposes. It will not be shared with anyone outside the research team. It will be kept private and shared in a way in which no one will know it is you.

**Who to contact?**

This research has been reviewed and approved by the Ethical Committee, University of Ibadan, Nigeria. You can contact my academic supervisor, Prof. Dr. Ramona Teuber ([ramona.teuber@agrar.uni-giessen.de](mailto:ramona.teuber@agrar.uni-giessen.de)) if you have any questions or concerns.

Thank you very much for your time

**Part II: Certificate of Consent**

I have read the information provided above or it has been read to me. I have asked questions about the exercise and I am well pleased with the answers given. I, therefore, agree to voluntarily participate in this research.

Name of Participant: \_\_\_\_\_

Date (dd/mm/yy) \_\_\_\_\_

Signature: \_\_\_\_\_

**If illiterate**

I have witnessed the reading of the consent form to the potential participant and the individual has decided to participate voluntarily.

Name of Witness: \_\_\_\_\_

Date (dd/mm/yy): \_\_\_\_\_

Signature of Witness: \_\_\_\_\_

Thumbprint of Participant



**Statement by Researcher or Person Taking Consent**

I have provided all the details of the information sheets to the potential participants and to the best of my knowledge made sure that the participant understands that the following should be done:

1. Provide information by filling out the questionnaire given
2. Share honest opinions based on the issue discussed

I confirm that the participant has been given the opportunity to ask all possible questions and the participant is satisfied with the answers provided. I confirm that the participant is not being forced to participate.

A copy of this document has been presented to the participant.

Researcher's Name: \_\_\_\_\_

Date (dd/mm/yy) \_\_\_\_\_

Signature: \_\_\_\_\_

**CONSUMERS' ACCEPTANCE OF GENETICALLY BIOFORTIFIED FOOD:  
EMPIRICAL EVIDENCE FROM NIGERIA**

**SECTION A: Food Purchasing and Consumption Practices**

- A1. Are you responsible most of the time for buying gari for your household? 1. Yes [ ] 2. No [ ]
- A2. Where do you purchase gari most of the time? 1. Open Market [ ] 2. Supermarket [ ] 3. From the Processor [ ] 4. Others, specify ..... (Please check only one).
- A3. Please indicate how much on average your household spends on gari in a month .....
- A4. Do you process your own gari? 1. Yes [ ] 2. No
- A5. If Yes in (A4), How often do you process your own gari? 1. All the times [ ] 2. Sometimes [ ]
- A6. When you process your gari where do you get your cassava from? 1. From my farm [ ] 2. Purchase from other farmers or traders [ ]
- A7. What type of gari did you just buy? 1. White Gari [ ] 2. Yellow Gari [ ] 3. Both [ ]

**SECTION B: Awareness and Knowledge**

- B1. Have you heard of the term “biofortified gari” or “Vitamin A gari” before? 1. Yes [ ] 2. No [ ] 3. Don't Know [ ]
- B2. If Yes in B1, From 1 (Very low knowledge) to 5 (Very high knowledge), how much do you know about “biofortified gari” or “Vitamin A gari”?
- B3. Biofortified gari or Vitamin A gari is not different from conventional gari 1. Yes [ ] 2. No [ ] 3. Don't Know [ ]
- B4. Have you heard of the term “genetically modified food” before? 1. Yes [ ] 2. No [ ] 3. Don't Know [ ]
- B5. From 1 (Very low knowledge) to 5 (Very high knowledge), how much do you know about “genetically modified food”?
- B6. Have you heard of the term “genetically edited food” before? Yes [ ] No [ ]
- B7. From 1 (Very low knowledge) to 5 (Very high knowledge), how much do you know about “genetically edited food”?

- B8. Genetically modified foods contain genes while non-genetically modified foods do not contain genes? 1. Yes [ ] 2. No [ ] 3. Don't Know [ ]
- B9. Human genes can change through consuming genetically modified foods? 1. Yes [ ] 2. No [ ] 3. Don't Know [ ]
- B10. As far as you know, is there any genetically modified crop released for cultivation and commercialization in Nigeria? 1. Yes [ ] 2. No [ ] 3. Don't Know [ ]
- B11. It is impossible to transfer genes from plants to animals. 1. Yes [ ] 2. No [ ] 3. Don't Know [ ]

**SECTION C: Attitude to GM and Editing (Scott et al., 2016)**

*Please tell us your stand about genetically modifying and editing food plants (e.g cassava)*

	<i>Items</i>	<i>Yes</i>	<i>No</i>	<i>I don't know</i>
C1.	I oppose the GM of plants			
C2.	GM of plants should never be allowed no matter how great the benefits and minor the risks associated with it			
C3.	It does not matter whether little or much GM of plants is allowed. It is equally wrong.			
C4.	GM of plants is wrong even if every other person in this country thinks it is right.			
C5.	I oppose GED of plants			
C6.	GED of plants should never be allowed no matter how great the benefits and minor the risks associated with it			
C7.	It does not matter whether little or much GED of plants is allowed. It is equally wrong.			
C8.	GED of plants is wrong even if every other person in this country thinks it is right.			

#### **SECTION D: Benefit and Risk Perception (Lagerkvist et al., 2013)**

- D1. How severe do you think having inadequate micronutrients is to your health?
1. I will not notice any effect on my health [ ]      2. I will feel ill for some days [ ]  
3. I will be unable to work for some days [ ]      4. I will need to see a doctor [ ]  
5. I will be hospitalized [ ]      6. I don't know [ ]
- D2. What do you think is the likelihood that eating food with inadequate micronutrients will affect you? 1. None [ ]      2. Very low [ ]      3. Low [ ]      4. Medium [ ]  
5. High [ ]      6. Very high [ ]      7. I don't know [ ]
- D3. When in the future do you think you will notice any harmful impact of inadequate micronutrients on your health? 1. Immediately I eat it [ ]      2. Within a day or two [ ]  
3. Within a few weeks [ ]      4. After a long time (years) [ ]      5. Not at all [ ]  
6. I don't know [ ]
- D4. In your own view about the impact of genetically modified food on health, which of the following represents your view? 1. Equal health risks and benefits [ ]      2. Health risks are higher than the health benefits [ ]      3. Health benefits are higher than health risks [ ]  
4. I don't know. [ ]
- D5. In your own view about the impact of genetically edited food on health, which of the following represents your view? 1. Equal health risks and benefits [ ]      2. Health risks are higher than the health benefits [ ]      3. Health benefits are higher than health risks [ ]  
4. I don't know [ ]

#### **SECTION E: Risk Preference (Petrolia, 2016)**

On a scale of 1 (I don't take risks at all) to 10 (I take a lot of risks), how much do you tend to take risks in everyday life?

#### **SECTION F: Trust in Government, Institutions, and Science (Tran et al., 2021)**

- F1. From 1 (no trust at all) to 10 (complete trust), Please, to what extent do you trust scientists breeding genetically biofortified foods?
- F2. From 1 (no trust at all) to 10 (complete trust), Please, to what extent do you trust government certification agency in Nigeria?

## SECTION G: Food Choice Behaviour

The next sets of questions are about the sorts of things that influence your decisions about food. We would like you to give each item a score out of five (5) depending on how important it is to you when you make decisions about what you are going to eat.

	Items	Not at all important (1)	Slightly Important (2)	Moderately Important (3)	Very Important (4)	Extremely Important (5)
G1.	Nutritious					
G2.	Colour					
G3.	Tested and certified as safe					
G4.	Is what you usually eat					
G5.	Not forbidden by religion					
G6.	It is recommended by Experts					
G7.	Is not expensive					
G8.	Is not genetically modified					

## SECTION H: INFORMATION TREATMENTS

You will receive information through a video. In this video, you will be provided with two types of information. Please, pay attention as you will be asked some questions about the content later.

### **Treatment 1 – Information on the health risk of micronutrient deficiency and benefits of biofortified food (Nutrition information treatment)**

Vitamin A and Iron are among the micronutrients that our body needs to be healthy. Anyone who does not eat a lot of vegetables and fruits but mainly eats our common foods like gari, rice, maize, yam, etc. is likely to have very low Vitamin A and Iron in his or her body. People who have very low Vitamin A in their bodies may not see well at night and if they do not take care of themselves in time, can lead to permanent blindness. Also, their brain may not function very well and they may be falling sick regularly. Children who have low iron in their bodies may not grow and learn well. Adults who have low iron in their bodies get tired at all times. It

may also cause pregnant women to give birth before they are due. The weight of their babies can be low and the babies may not grow well.

Scientists have found out that in Nigeria, 2 out of 100 children and 8 out of 100 pregnant women cannot see well at night because of low Vitamin A in their bodies. They also found out that some children between 1 and 4 years are dying because of low Vitamin A in their bodies. About 60 out of 100 women of reproductive age are not having sufficient iron in their bodies. For pregnant women, it is about 50 out of 100, and for children, it is about 70 out of 100 who lack sufficient iron in their bodies

To address these problems, scientists have successfully added Vitamin A to cassava because a lot of us eat foods like gari regularly. These cassava varieties have been in the market and used to make gari but still contain a low amount of Vitamin A. Now, there are new types of cassava they have developed which will have sufficient Vitamin A and Iron that our body needs. Gari made from the new cassava varieties may soon be available in the market if approved by the Government of Nigeria.

## **Treatment 2 – Information on the different production methods used for biofortification of Cassava. (Production method treatment)**

Up till now, scientists have used two different methods to add micronutrients to Cassava in Nigeria. These methods are referred to as conventional and GM approaches. Now, they are considering an additional method referred to as GED. In this video, we will give you brief information about these three methods while we highlight the main differences between them.

### **Conventional Method for Adding Vitamin A to Cassava**

Scientists used this method to develop vitamin A Cassava in Nigeria. To start with, they identified two types of cassava. The first cassava type, which most farmers like to grow, contains little amount of vitamin A. The second cassava type is rich in vitamin A but not usually grown by farmers. Scientists then combined these two types of cassava in a way that is very similar to how humans and animals meet sexually to produce their children. Thereafter, they selected the cassava varieties with the highest amount of vitamin A among different varieties produced during this process. The cassava type produced from this method is has been approved by the Government and now available in the market. One limitation with this method is that only Vitamin A can be added to cassava using this method. Also, the amount of vitamin A that can be added is not sufficient for what our bodies need.

### **GM (Transgenesis)**

This is a genetic engineering method used to introduce a new desired trait into the DNA of an organism by transferring the desired trait from another organism. Scientists have used this method to develop new Vitamin A and Iron cassava in Nigeria. They took genes that were rich in substances that can produce a lot of vitamin A and iron from bacteria and inserted them into the DNA of cassava which was not having sufficient vitamin A and iron. The cassava type produced has been tested and grown on the field to see if it adapts to the environment and is not harmful to the body. However, scientists in Nigeria are still waiting for the approval of the government to allow farmers to be growing genetically modified cassava. Therefore, it may be released into the market if approved by the government. With this method, scientists can add more than one type of micronutrient which is not possible with the conventional method.

### **GED**

This will allow scientists to make certain changes to genes of the same organism without the need to transfer genes from another organism. In the case of Cassava, scientists will change the sequence of the DNA of the cassava in a way that will make that cassava have more vitamin A. Cassava made from this method has not been developed but is only being considered by scientists. Scientists may also develop them if the government gives them approval. Like the GM method, scientists can add more than one type of micronutrient to crops which is not possible with the conventional method.

To summarize, the conventional method involves combing traits between one cassava and another cassava type through a natural process. The GM involved transferring genes from bacteria to cassava artificially. GED will involve changing the gene of cassava that is not having sufficient Vitamin A and iron into a form that can make it produce sufficient vitamin A and Iron.

Please, answer the following questions from the information treatment.

#### **Treatment 1:**

The new type of gari has vitamin A and iron that is sufficient for the body? 1. Yes [ ]  
2. No [ ]

### **Treatment 2:**

GM of cassava involves the transfer of genes from bacteria to cassava?

1. Yes [ ] 2. No [ ]

Gene-editing of cassava involves changing the genes of cassava without the need to transfer genes? 1. Yes [ ] 2. No [ ]

### **SECTION I: Benefit and Risk Perception after Information Treatment**

H1. In your own view about the impact of genetically modified food on health, which of the following represents your view? 1. Equal health risks and benefits [ ] 2. Health risks are higher than the health benefits [ ] 3. Health benefits are higher than the health risks [ ]

H2. In your own view about the impact of genetically edited food on health, which of the following represents your view? 1. Equal health risks and benefits [ ] 2. Health risks are higher than the health benefits [ ] 3. Health benefits are higher than the health risks [ ]

### **SECTION K: CHOICE EXPERIMENT**

**NOW, PLEASE TAKE TIME TO CAREFULLY READ THE FOLLOWING INSTRUCTIONS BEFORE PROCEEDING.** In the following, you will see eight choice questions. Each choice question includes a description of two different gari products – biofortified gari and non-biofortified gari. The gari products in each choice question are identical except that they vary in terms of the type of production method used, amount of micronutrients, certification of production method, color, and price per kilogram (kg). In each choice question, please indicate the gari product that you would choose to purchase. Alternatively, you may choose NOT TO PURCHASE either product. Please carefully examine each option before you decide and select the decision that you would make based on your own preferences. Previous similar studies show that people often respond in one way on a survey but act differently in real life. In studies where people do not actually have to pay money for a product when indicating a preference, people state a higher willingness to pay than what one actually is willing to pay for the good. A possible reason for this is that people do not really consider how large the impact of this extra cost is on the available family budget. It is easy to be generous when you do not really have to pay for it. In the market, people might think in a different way: the amount of money spent on this good cannot be spent on other things. **We ask you to respond to each of the following choice questions just exactly as you would if**

**you were in a real market and had to pay for your choice.** Please keep this in mind when answering the following choice questions.




### **IMPORTANT**

Choose one of the gari products in each choice task. Or you may choose "I would not buy gari": You might see a few options that may seem counter-intuitive (e.g. a lower price, but a higher micronutrient in your opinion). Be assured that this is not an error but part of the design of the survey. Simply choose the option in each choice question that you prefer the most, based on its characteristics.

## CHOICE TASKS

### BLOCK 1




#### Choice Situation 1

	Gari 1	Gari 2	Gari 3 (Status quo)
			
Vitamin A	Contains 60% of the average Vitamin A required by the body.	Contains 60% of the average Vitamin A required by the body.	Does not contain Vitamin A required by the body.
Iron	Does not contain Iron required by the body	Contains 25% of the average Iron required by the body.	Does not contain Iron required by the body
Starch Content	Contains High Starch	Contains High Starch	Contains High Starch
Plant Breeding Method	Conventional Method	Gene-Editing Method	None
Price per Kg	₦ 300	₦ 500	₦ 300
I will buy	( )	( )	( )

Which of the following attributes did you ignore (i.e. **NOT CONSIDER**)? Please, check all that apply.

- Vitamin A
- Iron
- Starch Content
- Plant Breeding Method
- Price




## Choice Situation 2

	Gari 1	Gari 2	Gari 3 (Status quo)
			
Vitamin A	Contains 100% of the average Vitamin A required by the body.	Contains 100% of the average Vitamin A required by the body.	Does not contain Vitamin A required by the body.
Iron	Contains 25% of the average Iron required by the body	Contains 50% of the average Iron required by the body	Does not contain Iron required by the body
Starch Content	Contains High Starch	Contains Low Starch	Contains High Starch
Plant Breeding Method	GED Method	GED Method	None
Price per Kg	₦300	₦700	₦300
I will buy	( )	( )	( )

Which of the following attributes did you ignore (i.e. **NOT CONSIDER**)? Please, check all that apply.

- Vitamin A
- Iron
- Starch Content
- Plant Breeding Method
- Price




### Choice Situation 3

	Gari 1	Gari 2	Gari 3 (Status quo)
			
Vitamin A	Contains 60% of the average Vitamin A required by the body.	Contains 100% of the average Vitamin A required by the body.	Does not contain Vitamin A required by the body.
Iron	Does not contain Iron required by the body	Does not contain Iron required by the body	Does not contain Iron required by the body
Starch Content	Contains High Starch	Contains Low Starch	Contains High Starch
Plant Breeding Method	GM Method	GM Method	None
Price per Kg	₦ 500	₦ 300	₦ 300
I will buy	( )	( )	( )

Which of the following attributes did you ignore (i.e. **NOT CONSIDER**)? Please, check all that apply.

- Vitamin A
- Iron
- Starch Content
- Plant Breeding Method
- Price




#### Choice Situation 4

	Gari 1	Gari 2	Gari 3 (Status quo)
			
Vitamin A	Contains 60% of the average Vitamin A required by the body.	Contains 60% of the average Vitamin A required by the body.	Does not contain Vitamin A required by the body.
Iron	Does not contain Iron required by the body	Does not contain Iron required by the body	Does not contain Iron required by the body
Starch Content	Contains Low Starch	Contains Low Starch	Contains High Starch
Plant Breeding Method	Conventional Method	Conventional Method	None
Price per Kg	₦ 300	₦ 500	₦ 300
I will buy	( )	( )	( )

Which of the following attributes did you ignore (i.e. **NOT CONSIDER**)? Please, check all that apply.

- Vitamin A
- Iron
- Starch Content
- Plant Breeding Method
- Price




### Choice Situation 5

	Gari 1	Gari 2	Gari 3 (Status quo)
			
Vitamin A	Contains 100% of the average Vitamin A required by the body.	Contains 60% of the average Vitamin A required by the body.	Does not contain Vitamin A required by the body.
Iron	Does not contain Iron required by the body	Contains 25% of the average Iron required by the body.	Does not contain Iron required by the body
Starch Content	Contains High Starch	Contains Low Starch	Contains High Starch
Plant Breeding Method	GM Method	GM Method	None
Price per Kg	₦ 700	₦ 700	₦ 300
I will buy	( )	( )	( )

Which of the following attributes did you ignore (i.e. **NOT CONSIDER**)? Please, check all that apply.

- Vitamin A
- Iron
- Starch Content
- Plant Breeding Method
- Price




### Choice Situation 6

	Gari 1	Gari 2	Gari 3 (Status quo)
			
Vitamin A	Contains 100% of the average Vitamin A required by the body.	Contains 60% of the average Vitamin A required by the body.	Does not contain Vitamin A required by the body.
Iron	Contains 50% of the average Iron required by the body.	Does not contain Iron required by the body	Does not contain Iron required by the body
Starch Content	Contains High Starch	Contains High Starch	Contains High Starch
Plant Breeding Method	GM Method	Gene-Editing Method	None
Price per Kg	₦ 700	₦ 500	₦ 300
I will buy	( )	( )	( )

Which of the following attributes did you ignore (i.e. **NOT CONSIDER**)? Please, check all that apply.

- Vitamin A
- Iron
- Starch Content
- Plant Breeding Method
- Price




**Choice Situation 7**

	<b>Gari 1</b>	<b>Gari 2</b>	<b>Gari 3</b> <b>(Status quo)</b>
			
Vitamin A	Contains 60% of the average Vitamin A required by the body.	Contains 100% of the average Vitamin A required by the body.	Does not contain Vitamin A required by the body.
Iron	Contains 50% of the average Iron required by the body	Does not contain Iron required by the body	Does not contain Iron required by the body
Starch Content	Contains High Starch	Contains Low Starch	Contains High Starch
Plant Breeding Method	GM Method	GED Method	None
Price per Kg	₦ 300	₦ 300	₦ 300
<b>I will buy</b>	( )	( )	( )

Which of the following attributes did you ignore (i.e. **NOT CONSIDER**)? Please, check all that apply.

- Vitamin A
- Iron
- Starch Content
- Plant Breeding Method
- Price

**Choice Situation 8**




	<b>Gari 1</b>	<b>Gari 2</b>	<b>Gari 3</b> <b>(Status quo)</b>
			
Vitamin A	Contains 100% of the average Vitamin A required by the body.	Contains 100% of the average Vitamin A required by the body.	Does not contain Vitamin A required by the body.
Iron	Contains 25% of the average Iron required by the body	Does not contain Iron required by the body	Does not contain Iron required by the body
Starch Content	Contains High Starch	Contains High Starch	Contains High Starch
Plant Breeding Method	GED Method	Conventional Method	None
Price per Kg	₦ 300	₦ 700	₦ 300
<b>I will buy</b>	( )	( )	( )

Which of the following attributes did you ignore (i.e. **NOT CONSIDER**)? Please, check all that apply.

- Vitamin A
- Iron
- Starch Content
- Plant Breeding Method
- Price

## BLOCK 2




### Choice Situation 1

	Gari 1	Gari 2	Gari 3 (Status quo)
			
Vitamin A	Contains 100% of the average Vitamin A required by the body.	Contains 100% of the average Vitamin A required by the body.	Does not contain Vitamin A required by the body.
Iron	Does not contain Iron required by the body	Does not contain Iron required by the body	Does not contain Iron required by the body
Starch Content	Contains High Starch	Contains Low Starch	Contains High Starch
Plant Breeding Method	Conventional Method	GM Method	None
Price per Kg	₦ 500	₦ 300	₦ 300
I will buy	( )	( )	( )

Which of the following attributes did you ignore (i.e. **NOT CONSIDER**)? Please, check all that apply.

- Vitamin A
- Iron
- Starch Content
- Plant Breeding Method
- Price




## Choice Situation 2

	Gari 1	Gari 2	Gari 3 (Status quo)
			
Vitamin A	Contains 60% of the average Vitamin A required by the body.	Contains 60% of the average Vitamin A required by the body.	Does not contain Vitamin A required by the body.
Iron	Does not contain Iron required by the body	Contains 25% of the average Iron required by the body.	Does not contain Iron required by the body
Starch Content	Contains Low Starch	Contains High Starch	Contains High Starch
Plant Breeding Method	GM Method	GM Method	None
Price per Kg	₦ 700	₦ 300	₦ 300
I will buy	( )	( )	( )

Which of the following attributes did you ignore (i.e. **NOT CONSIDER**)? Please, check all that apply.

- Vitamin A
- Iron
- Starch Content
- Plant Breeding Method
- Price




### Choice Situation 3

	Gari 1	Gari 2	Gari 3 (Status quo)
			
Vitamin A	Contains 100% of the average Vitamin A required by the body.	Contains 60% of the average Vitamin A required by the body.	Does not contain Vitamin A required by the body.
Iron	Does not contain Iron required by the body	Does not contain Iron required by the body	Does not contain Iron required by the body
Starch Content	Contains Low Starch	Contains High Starch	Contains High Starch
Plant Breeding Method	GM Method	Conventional Method	None
Price per Kg	₦ 300	₦ 700	₦ 300
I will buy	( )	( )	( )

Which of the following attributes did you ignore (i.e. **NOT CONSIDER**)? Please, check all that apply.

- Vitamin A
- Iron
- Starch Content
- Plant Breeding Method




### Choice Situation 4

	Gari 1	Gari 2	Gari 3 (Status quo)
			
Vitamin A	Contains 100% of the average Vitamin A required by the body.	Contains 60% of the average Vitamin A required by the body.	Does not contain Vitamin A required by the body.
Iron	Does not contain Iron required by the body	Does not contain Iron required by the body	Does not contain Iron required by the body
Starch Content	Contains High Starch	Contains High Starch	Contains High Starch
Plant Breeding Method	GED Method	Conventional Method	None
Price per Kg	₦ 500	₦ 700	₦ 300
I will buy	( )	( )	( )

Which of the following attributes did you ignore (i.e. **NOT CONSIDER**)? Please, check all that apply.

- Vitamin A
- Iron
- Starch Content
- Plant Breeding Method
- Price



### Choice Situation 5

	Gari 1	Gari 2	Gari 3 (Status quo)
			
Vitamin A	Contains 60% of the average Vitamin A required by the body.	Contains 100% of the average Vitamin A required by the body.	Does not contain Vitamin A required by the body.
Iron	Does not contain Iron required by the body	Contains 50% of the average Iron required by the body.	Does not contain Iron required by the body
Starch Content	Contains Low Starch	Contains High Starch	Contains High Starch
Plant Breeding Method	Conventional Method	GED Method	None
Price per Kg	₦ 300	₦ 300	₦ 300
I will buy	( )	( )	( )

Which of the following attributes did you ignore (i.e. **NOT CONSIDER**)? Please, check all that apply.

- Vitamin A
- Iron
- Starch Content
- Plant Breeding Method
- Price




### Choice Situation 6

	Gari 1	Gari 2	Gari 3 (Status quo)
			
Vitamin A	Contains 60% of the average Vitamin A required by the body.	Contains 100% of the average Vitamin A required by the body.	Does not contain Vitamin A required by the body.
Iron	Does not contain Iron required by the body	Contains 25% of the average Iron required by the body.	Does not contain Iron required by the body
Starch Content	Contains Low Starch	Contains High Starch	Contains High Starch
Plant Breeding Method	GED Method	GM Method	None
Price per Kg	₦ 300	₦ 500	₦ 300
I will buy	( )	( )	( )

Which of the following attributes did you ignore (i.e. **NOT CONSIDER**)? Please, check all that apply.

- Vitamin A
- Iron
- Starch Content
- Plant Breeding Method
- Price




**Choice Situation 7**

	<b>Gari 1</b>	<b>Gari 2</b>	<b>Gari 3 (Status quo)</b>
			
Vitamin A	Contains 100% of the average Vitamin A required by the body.	Contains 60% of the average Vitamin A required by the body.	Does not contain Vitamin A required by the body.
Iron	Contains 25% of the average Iron required by the body.	Contains 50% of the average Iron required by the body.	Does not contain Iron required by the body
Starch Content	Contains Low Starch	Contains High Starch	Contains High Starch
Plant Breeding Method	GM Method	GM Method	None
Price per Kg	₦ 700	₦ 700	₦ 300
I will buy	( )	( )	( )

Which of the following attributes did you ignore (i.e. **NOT CONSIDER**)? Please, check all that apply.

- Vitamin A
- Iron
- Starch Content
- Plant Breeding Method
- Price

### Choice Situation 8

	Gari 1	Gari 2	Gari 3 (Status quo)
			
Vitamin A	Contains 60% of the average Vitamin A required by the body.	Contains 60% of the average Vitamin A required by the body.	Does not contain Vitamin A required by the body.
Iron	Contains 50% of the average Iron required by the body.	Does not contain Iron required by the body	Does not contain Iron required by the body
Starch Content	Contains Low Starch	Contains High Starch	Contains High Starch
Plant Breeding Method	GED Method	GED Method	None
Price per Kg	₦ 500	₦ 500	₦ 300
I will buy	( )	( )	( )

Which of the following attributes did you ignore (i.e. **NOT CONSIDER**)? Please, check all that apply.

- Vitamin A
- Iron
- Starch Content
- Plant Breeding Method
- Price

**SECTION L: Socio-Economic Characteristics**

- I1. Gender 1. Male [ ] 2. Female [ ]
- I2. Age ..... (Years)
- I3. State of origin .....
- I4. Marital status 1. Single [ ] 2. Married [ ] 3. Widowed [ ] 4. Separated [ ] 5. Others [ ]
- I5. Level of education 1. None [ ] 2. Primary [ ] 3. Secondary [ ] 4. OND/NCE [ ] 5. HND/BSC [ ] 6. Msc/PhD [ ]
- I6. Respondent’s religion 1. None [ ] 2. Christianity [ ] 3. Islam [ ] 4. Traditional [ ]
- I7. How important is religion in your life? 1. Not at all important [ ] 2. Slightly important [ ] 3. Moderately important [ ] 4. Very important [ ] 5. Extremely important [ ]
- I8. What is your main occupation? 1. Civil Servant [ ] 2. Self-employed [ ] 3. Farming [ ] 4. Trading [ ] 5. Others (specify) .....
- I9. What is your average monthly household income from all sources? .....(Naira)

I10. How many people, including yourself, are in the following age categories in your household?

Male Members				Female Members			
Below 5 years	Between 5 and 14 years (5 –14)	Between 15 and 49 years (15 – 49)	Above 50 years (> 50)	Below 5 years	Between 5 and 14 years (5 –14)	Between 15 and 49 years (15 – 49)	Above 50 years (> 50)

- I11. How often do you seek information about nutrition? 1. Frequently (once or more times per week over the last year) [ ] 2. Occasionally (not more than once a month in the last year) [ ] 3. Only once or twice over the last year [ ] 4. Never [ ]
- I12. If you were to receive more information on nutrition, which medium do you prefer most? 1. Radio [ ] 2. TV [ ] 3. Friends [ ] 4. Relative [ ] 5. Religious center [ ] 6. Medical experts [ ] 7. Social media 8. Others (specify) .....

I13. How often do you decide on your own to get a health checkup? 1. Once in 3 months [  
] 2. Once in 6 months [ ] 3. Once a year [ ] 4. Only when needed [ ] 5. Never get it done  
[ ]

**QUALITATIVE STUDY ON CONSUMERS’ ACCEPTANCE OF GENETICALLY BIOFORTIFIED FOOD: EMPIRICAL EVIDENCE FROM NIGERIA.**

**Section 1: Socio-Economic Profile**

Gender 1. Male [ ] 2. Female [ ]

Age ..... (Years)

State of origin .....

Marital status 1. Single [ ] 2. Married [ ] 3. Widowed [ ] 4. Separated [ ] 5. Others [ ]

Level of education 1. None [ ] 2. Primary [ ] 3. Secondary [ ] 4. OND/NCE [ ] 5.

HND/BSC [ ] 6. Msc/PhD [ ]

Respondent’s religion 1. None [ ] 2. Christianity [ ] 3. Islam [ ] 4. Traditional [ ]

How important is religion in your life? 1. Not at all important [ ] 2. Slightly important [ ] 3. Moderately important [ ] 4. Very important [ ] 5. Extremely important [ ]

What is your main occupation? 1. Civil Servant [ ] 2. Self-employed [ ] 3. Farming [ ] 4. Trading [ ] 5. Others (specify) .....

What is your average monthly household income from all sources? .....(Naira)

How many people, including yourself, are in the following age categories in your household?

Male Members				Female Members			
Below 5 years	Between 5 and 14 years (5 –14)	Between 15 and 49 years (15 – 49)	Above 50 years (> 50)	Below 5 years	Between 5 and 14 years (5 –14)	Between 15 and 49 years (15 – 49)	Above 50 years (> 50)

**Note:** Placed before you are two samples of gari. The first one is yellow and the other is white. You will be provided some information through a video to have more understanding of the gari samples.

**Section 2: Awareness and Knowledge of Biofortified Cassava and Gari**

Have you heard of vitamin A cassava or gari before?

If Yes,

- When did you hear about it?

- How did you get to know about it?

What do you know about Vitamin A cassava and gari?

Have you seen vitamin A cassava or gari before?

Have you eaten Vitamin A cassava or gari before?

If Yes:

- How did you get it?

Have you bought Vitamin A gari before?

Can you identify Vitamin A gari from other types of gari in the market?

If Yes: How?

**Note:** Play the video providing information on the health risks of micronutrient deficiencies and the benefits of biofortification

### **Laddering technique for Vitamin A and Iron attributes**

Why would you be interested in eating gari with Vitamin A?

Why is this important to you?

Why would you be interested in eating gari with Iron?

Why is this important to you?

### **Section 3: Awareness and Knowledge of GM and GED**

Have you heard about GM before?

How much have you read or heard about GM?

Have you heard about GED before?

How much have you read or heard about GED?

**Note:** Play the video providing information on the scientific processes of the conventional, GM and GED methods and its application for the biofortification of cassava.

### **Laddering technique for conventional, GM and GED attributes**

How did you perceive the use of conventional method for producing gari with vitamin A and iron?

Why is this important to you?

How did you perceive the use of GM method for producing gari with vitamin A and iron?

Why is this important to you?

How did you perceive the use of GED method for producing gari with vitamin A and iron?

Why is this important to you?