

*Full Length Research Paper*

# Readiness of the Nigerian public for the introduction of genetically modified crops into the food market

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Received 9 April, 2020; Accepted 17 June, 2020

**Genetically modified crops (GM crops) have gained wide attention over the years some GM crops have been undergoing field trials in Nigeria, but they have not proceeded to commercial cultivation due to the absence of regulatory law. The biosafety act was passed into law in 2015 and the presence of this law, can see to the progression of the GM crops from field trials to commercialization. This study investigated the readiness of potential consumers for the possible introduction of these GM crops into the food market. The survey was designed to investigate among other factors their willingness to consume GM crops and to identify their concerns, if any. The results obtained indicated that most of the respondents have medium level knowledge about GMO\GM crops. The desire to consume GM crops among respondents varied and many respondents indicated that they have concerns about GM crops. Their concern was primarily related to potential health risks. Participants also indicated the need for further information about GMOs and stated the factors that influence their attitude towards GM crops. The internet and the media (newspapers, TV etc.) were stated as the means of previous knowledge about GMOs and the internet was again requested as a means of further information about GMOs. Based on this study, regulatory authorities and relevant stakeholders can understand the position and concerns of the consumers prior to the commercialization of GM crops in Nigeria.**

**Key words:** Genetically modified organisms (GMOs), crops, food, biotechnology, biosafety, risk perception, policy.

## INTRODUCTION

Genetically modified organisms (GMOs) are defined as organisms (e.g., plants, microorganisms, or animals) whose genetic material (DNA) has been altered beyond its natural state either by mating or natural recombination (Information, 2010; Rzymiski and Królczyk, 2016). Crops produced by genetic modification (Genetically modified

crops (GM crops)) are crops whose DNA has been modified using genetic engineering techniques to introduce new traits to the crop, precisely trait(s) which do not naturally occur in the crop (Fraley et al., 1986). The introduced traits can be intended at improving the nutritional value of the crop, prevent pest infestation,

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provide tolerance to pesticides/herbicides or increase adaptability to weather and growth conditions (Ojo and Adebayo, 2012). The introduced traits are mostly obtained from non-related organisms or wild relatives. An example is an insecticidal trait (*Cry* gene) obtained from the bacteria *Bacillus thuringiensis* (*Bt*). Vectors such as bacteria (e.g., *Agrobacterium*) or viruses (e.g., retrovirus, Lentivirus) are used as delivery agents for the introduction of the new gene (Rogers et al., 1987). Chemical or radiation mutagenesis can also be employed to induce random mutations in the crop, and such mutations can also alter the crop's genetic components to produce GM crops (Avery et al., 1944; Matagne, 1969). Emerging gene-editing technologies such as the CRISPR technology can also be employed in the editing of the plant genome. The CRISPR/Cas9 gene-editing system has revolutionized research in plant and animal with its genome editing ability first demonstrated in 2012 in mammalian cells (Aerni, 2005).

The use of genetically modified crops in reducing poverty and solving food security problems has is not without debate. Nevertheless, policymakers from developing countries have considered GM crops as a possible tool for increasing crop productivity (Aerni, 2005). Debates over their benefits and concerns of application have, however, mired its implementation (Aerni and Bernauer, 2006; Kikulwe et al., 2011). Currently, 29 countries of the world are cultivating GM crops, of which 19 are developing countries, and only three of the developing countries are from Africa (Adenle, 2014). Commercial cultivation of GM crops has only been approved in South Africa and Burkina Faso (Adenle, 2001). According to the estimate by the World Bank statistics, ("Population, total - Nigeria Data," n.d. 2018), the population of Nigeria stands at 195,874.74. Traditional agricultural practices can be complemented by plant biotechnologies such as genetic modification to ensure food security for such a populous country (Datta, 2013).

The use of GM crops is influenced by the evaluation of her safety to consumers, farmers, and the environment. This principle is described in biosafety, which is defined in this context as the precautions taken to control the cultivation and distribution of GM crops and products (Prakash et al., 2011). To ensure precautionary safety measures in plant biotechnology, Nigeria signed and ratified the Cartagena Protocol on biosafety in 2002 and 2003, respectively. However, the absence of a national biosafety law was a limiting factor for the commercialization of GM crops in the country. A biosafety bill was passed into law in April 2015. The law is poised to regulate the application of modern biotechnology techniques, management, and the use of obtained products (genetically modified organisms) that may pose potential risks about conservation and sustainable use of biodiversity (Li et al., 2014). The Nigerian food and agricultural landscape can accommodate domestic and international biotechnology, agricultural\seed companies,

and research organizations to engage in commercial activities after due approval by the nations' biosafety regulatory agency. The National Biosafety Agency manages the Nigerian biosafety law, and the agency is responsible for implementing and regulating biosafety activities in Nigeria.

Currently, the following crops are undergoing field trials: Maruca -Resistant Cowpea (Bt Cowpea), Africa Bio-fortified Sorghum Nitrogen Use Efficient, Water Use Efficient and Salt Tolerant (NEWEST) Rice and Bt cotton. A comprehensive database of crops undergoing field trials in Nigeria is provided in Table 1. Other important food crops in the country are also being considered for genetic alteration for desired and improved traits. For example, planned alteration of local tomato varieties (Animasaun et al., 2020) has gotten to an advanced stage, and also, the virus-resistant cassava enhanced with Zinc and Iron (Cassava plus) (Ivase, 2019). After successful approval by the biosafety regulatory agency, these crops may be cultivated for commercial purposes. It is important to note that most of the crops mentioned above are staple crops. Agricultural practices of staple foods are essential for both household self-sufficiency and income generation. The livelihoods and economic wellbeing of the nation can be affected by factors that impact staple food production; therefore, adequate attention must be paid to ensure the sustainability of these crops (Sawicka et al., 2020).

Globally, the cultivation, use, and commercialization of GM crops have been surrounded by many controversies and (negative) attitudes from many sectors, including the consumers (Adeoti and Adekunle, 2007; Aerni and Bernauer, 2006; Kikulwe et al., 2011). Factors responsible for these attitudes include limited knowledge of the scientific principles behind the gene modification technologies, minimal or absence of known potential benefits of GMOs, religious, moral or ethical beliefs and inability to accurately define what constitutes a GMO (Aleksejeva, 2014; Costa-Font and Gil, 2012; Pino et al., 2016). The expression of the views and opinions of the pro and anti-GMO groups in the media has also contributed to misinformation and confusion of potential consumers, users, and growers of GM crops (Rzymiski and Królczyk, 2016). The existence of a biosafety law will enable the regulation of biological entities, including GMOs in Nigeria. It is, however, crucial to study the preparedness of the consumers for the introduction of GM crops as they present the potential end-user. It is also imperative to identify the expectations and perceptions of the subject matter. This study, therefore, evaluates the current knowledge about GMOs among the Nigerian public and the preparedness for the potential commercialization of genetically modified in the Nigerian food chain. Decision and policymakers, potential seed companies and research agencies will be able to benefit from this study as it will provide them insight into the concerns and expectations of the consumers (Table 1).

**Table 1.** Database of crops approved for field trials.

Name of crop	Trait	Developer	National collaborating institute	Regulatory status	Status as of December 2016
Maize	Stacked genes for insect resistance and glyphosate herbicide tolerance	Monsanto Nigeria LTD	Institute for Agricultural Research Zaria	CTF approved	Yet to commence
Cotton	Insect resistance	Monsanto Agriculture Nigeria LTD	Institute for Agricultural research Zaria	General release	Ongoing
Rice	Stacked with nitrogen use efficiency, water efficiency, and salt tolerance	African Agricultural Technology Foundation	National cereal research institute Baddegi	CTF	Ongoing
Cassava	Bio cassava plus (pro-vitamin A, protein, iron) cassava mosaic, virus resistance, and brown streak virus resistance	Danforth plant	The national root crop research institute, Umudike	CTF	Concluded
Sorghum (ABS)	Bioavailability of protein, zinc and iron	Africa Harvest	Institute for Agricultural research Zaria	CTF	Ongoing
Cowpea	Maruca insect resistance	CSIRO, Australia	Institute for Agricultural research Zaria	Multi-locations Trait	Ongoing

Adapted from Ivase (2019); CTF: Confined Field Trial, CSIRO: Commonwealth Scientific and Industrial Research Organisation, ABS: Africa Biofortified Sorghum.

## MATERIALS AND METHODS

### Participants and survey

The study design contained sections covering respondent's knowledge, attitude and concerns about GMO, willingness to consume GM crops; GM crops food labeling, GM food benefits and possible application of GM technology to food security and national development, and respondent's demographic characteristics. The sections are described below:

**(i) Prior knowledge about GMO/GM crops:** Participants were asked if they had previous knowledge about GMOs and to indicate their level of understanding if applicable. Participants who had knowledge about GMOs were also asked to indicate the GM crop they know.

**(ii) Attitude towards acceptance of genetically modified crops:** Since some genetically modified crops are undergoing field trials in Nigeria, participants were asked if they are willing to accept these crops when/if they are eventually commercialized following approval by the biosafety regulatory agency.

**(iii) Safety concerns about genetically modified crops:** Participants were asked if they have any concern about genetically modified crops and to state these concerns. They were also asked about the factors that influence their attitude towards genetically modified crops/foods.

**(iv) Food labeling:** Participants were asked to indicate if they read labels of food products during purchase and to indicate if they

would want GM crops or food products containing genetically modified elements to be labeled as such.

**(v) Price advantage of genetically modified crops and meeting the nation's food demands:** Considering the economic capability of an average Nigerian, participants were asked if they would consider a price advantage between a GM crop and its unmodified counterpart. The participants were asked if they think the potential benefits of genetic modification should be applied to meet the nation's food demands.

**(vi) Further information about GMO/GM crops:** According to the participants' current level of information and previous source of information, participants were asked if they required more information about GMOs and their preferred medium of further information.

**(vii) Demographic characteristics** of the participants were collected, including their sex, age group, level of education, geographical location, and profession.

The full list of the survey questions is provided in Table 2.

### Mode of dissemination

The Internet was chosen as a platform to reach participants because it cuts across all geographical regions of the nation. The questionnaire was made accessible for 11 months. Participants were invited to complete the questionnaire through platforms such as Facebook, WhatsApp (personal and group chats), blogs, and email.

**Table 2.** : List of questions asked participants.

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What is the highest level of education you have completed?

Do you know what a genetically modified organism is?

What is your level of understanding about Genetically modified organisms/crops?

Which of the following genetically modified crops do you know about?

How did you know about genetically modified organism/crops?

Genetically modified crops are currently considered for field trials in the country. Are you ready to accept and make use of Genetically Modified organisms/crops in Nigeria when eventually commercialized?

Do you have any concern about Genetically Modified organisms/crops?

If yes, what is your major concern about genetically modified organisms/crops?

Have you ever knowingly eaten a genetically modified food?

Would you eat a Genetically modified crop when eventually introduced in Nigeria market?

Do you read labels carefully before buying food or crops ?

Would you like a Genetically Modified crop to be distinguished from its non-Genetically Modified crop counterpart in Nigerian markets (Clear labelling)?

For processed food products, Would you like them to be labelled if they contain Genetically modified elements?

Would you consider a price advantage between a Genetically Modified crop/food and its non-Genetically Modified counterpart?

Do you think Nigeria should harness the potentials of Genetically Modified crops to meet national food security and economic/commercial demands?

In addition to resistances to insects and disease, crops can also be modified to have a better flavor, increased shelf life and nutritional value. What features are important to you when shopping for food?

Which of the following factors influence your attitude towards Genetically modified crop/food

Do you need more information on genetically modified organism/crops?

Where would you prefer to get (further) information on Genetically modified organisms/crops from?

What suggestions do you have for the use of genetically modified organisms in Nigeria

What is your age group

What is your gender

Where is your current geographical location

Occupation

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### Data analysis

A total number of 335 responses were collected, and the data obtained were analyzed using the IBM SPSS statistics for windows, version 22 (SPSS Statistics, 2013), and Microsoft Excel 2016. The Chi-Square test of dependency was conducted to find relationships between variables and the level of significance ( $p$ ).  $p$  values of  $<0.05$  were considered statistically significant.

## RESULTS

### Demographics characteristics

A total of 226 of the respondents were male (67.5%), and 88 were female (26%), 21 respondents did not indicate their sex. The majority of the respondents (43%) live in the Southwest region of the country, and the age range of 25-39 years was predominant among the respondents (58%). The educational background of the respondents showed that 90% was educated beyond high school, 47% had a bachelor's degree, and 40% had a post-graduate qualification. A significant percentage (41%) of the respondents was working-class professionals (that is,

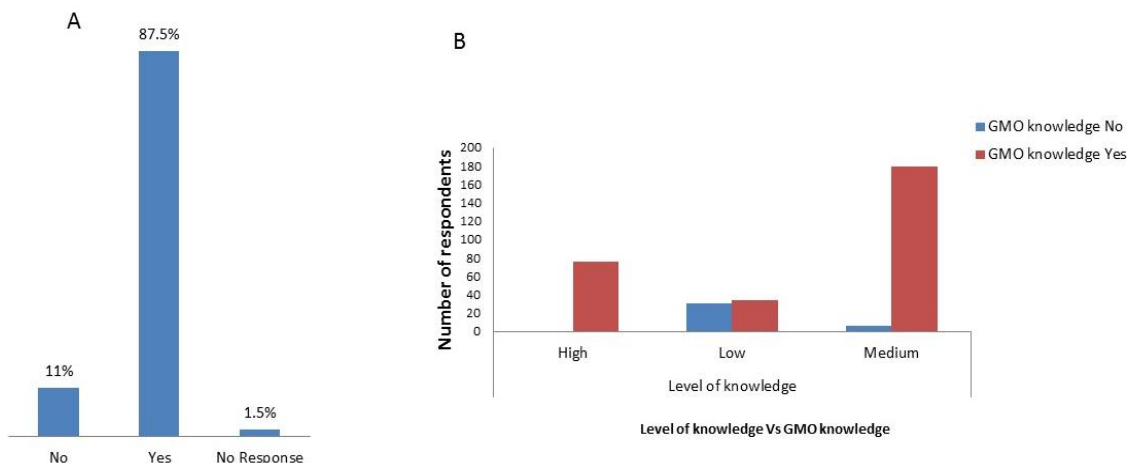
bankers, civil servants, public servants, etc.), 24% are in business, and 26% were students. The overall demographics statistics of survey respondents are presented in Table 3.

### Prior knowledge of GMO/GM crops

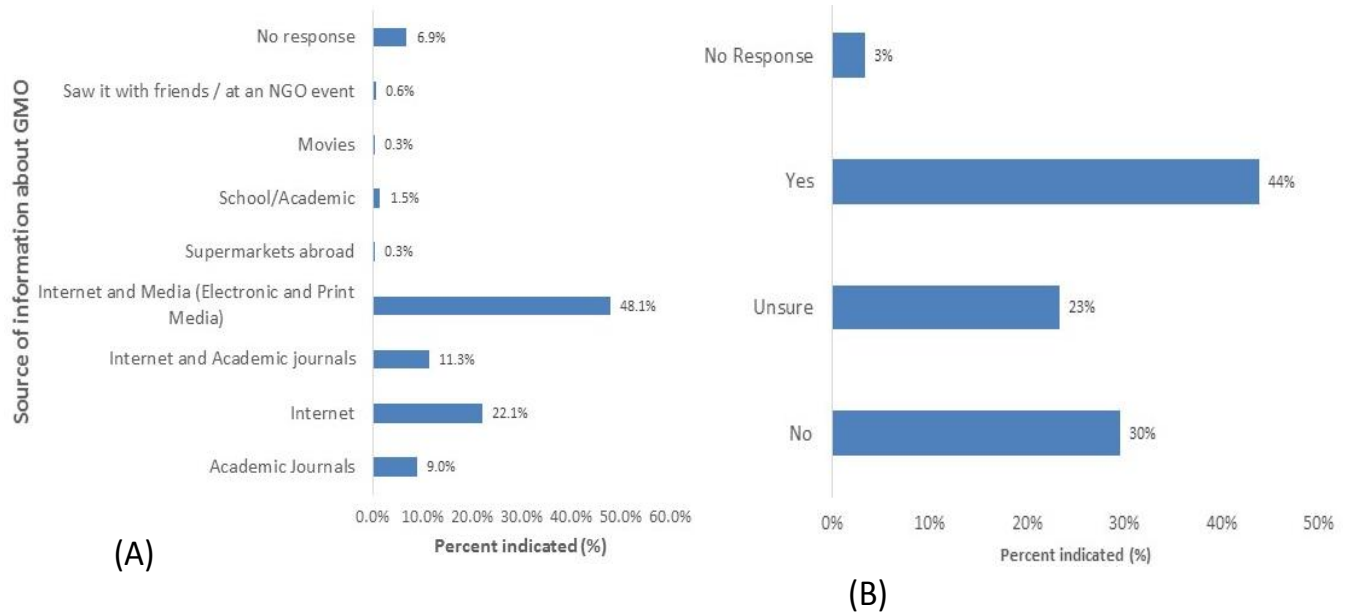
In this study, 88% of respondents had previous knowledge (Figure 1A) of GMOs, and 56% self-rated their knowledge to be medium while 23 and 19% rated their knowledge as high and low, respectively. The low level of knowledge was predominant among respondents who do not have previous knowledge about GMOs, and a medium level of knowledge was predominant among respondents that have previous knowledge (Figure 1B). The genetically modified crops known by the respondent varied, but 28% of the respondents knew only corn. Media sources and the Internet accounted for the primary source of prior knowledge of GMO/GM crops (48%). Based on the results of the Chi-Square test of dependency, the knowledge about GMOs by the respondents is not dependent on the gender ( $p=0.117$ )

**Table 3.** Demographic characteristics of respondents.

Demographic characteristics	Frequency (%) n=335
<b>Age group</b>	
18-24 years old	61(18.2)
25-39 years old	195(58.2)
40-59 years old	61(18.2)
No response	18(5.4)
<b>Gender</b>	
Female	88(26.3)
Male	226(67.5)
No response	21(6.3)
<b>Current geographical location</b>	
North Central	65(19.4)
North East	8(2.4)
North West	35(10.4)
South East	19(5.7)
South-South	39(11.6)
South West	143(42.7)
No response	91(27.2)
<b>Occupation</b>	
Applicant	4(1.2)
Business/trade/self-employed	81(24.2)
Professional	138(41.2)
Student	87(26)
No response	25(7.5)
<b>Highest level of education completed</b>	
Bachelor's degree	157(46.9)
HND/OND	26(7.8)
Postgraduate degree (Masters, Ph.D., Post-doc)	133(39.7)
SSCE)/ (GCE)	14(4.2)
No response	5(1.5)



**Figure 1.** (A) Prior knowledge about GMOs and GM crops as indicated by respondents, (B) Comparison of prior GMO knowledge Vs Level of knowledge.



**Figure 2.** (A) Source of previous information about GMO by the respondents, (B) Willingness to consume GMO after its introduction to Nigerian food market.

nor on their educational qualification ( $p=0.002$ ). According to this study, knowledge of GMOs is regardless of sex or the level of education. The knowledge of GMOs by respondents is, however, dependent on their occupation ( $p=0.002$ ). The media and the Internet jointly accounted for the primary source of previous information about GMOs (48%) and closely followed by the Internet and academic journals, as seen alongside other sources in Figure 2A.

#### Attitude towards acceptance of genetically modified crops

According to this study, a total of 44% of the respondents were willing to consume GM crops when eventually introduced, 30% were not willing to consume, and 23% were uncertain (Figure 2B). The acceptance of GMOs was observed to be age and occupation dependent ( $p=0.001$  respectively) but was independent of location ( $p=0.326$ ) and educational qualification ( $p=0.484$ ). Respondents with medium knowledge about GMO/GM crops were more willing to consume GM crops compared to respondents with high and low knowledge. The highest number of respondents willing to accept GMOs was observed with well-educated respondents. A similar response was observed for respondents that would not accept and those that were not sure. About 44% of the respondents indicated that they had never consumed GM food compared to 24% who had consumed it while 29% were not sure if they had ever consumed GM food (Data not shown).

#### Safety concerns about genetically modified crops

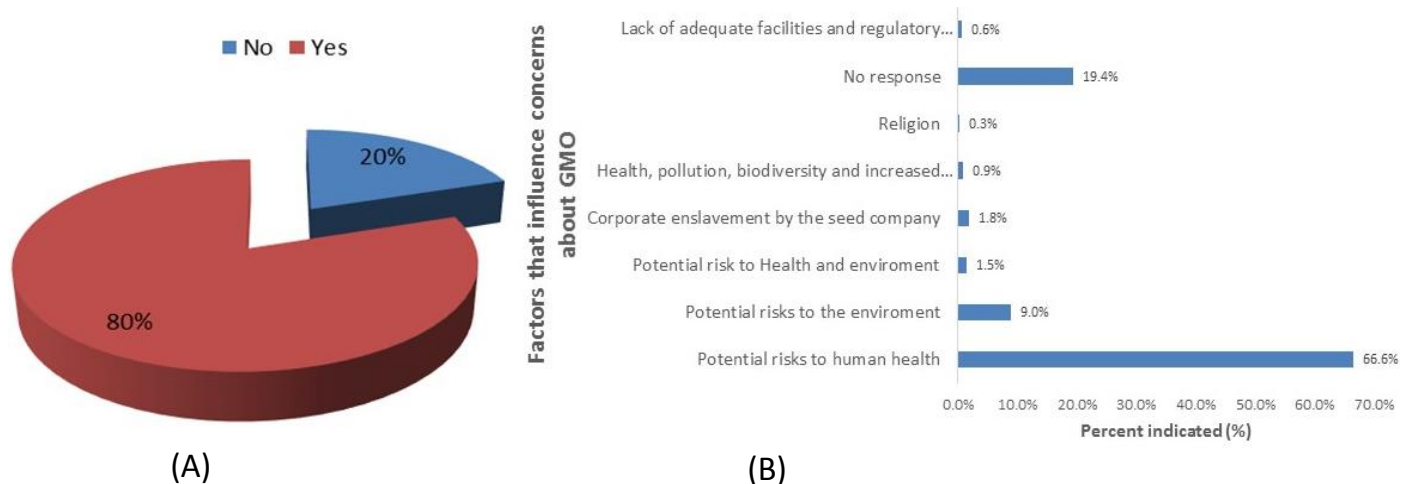
Generally, 80% of the respondents indicated that they have concerns about the potential use of GM crops, and more than 65% of this concern was attributed to perceived potential risks on human health, as shown in Figure 3A and B respectively. Respondents mostly expressed concerns about GMOs/GM crops with more than a bachelor's degree, and the majority of the respondents with such concerns were in the Southwest region of the country (Data not shown). The concern for the environment was indicated by only 10%. Based on the respondents in this study, minimal concerns were attributed to religious or ethical beliefs and biosafety regulation.

#### Food labeling and price advantage of genetically modified crops

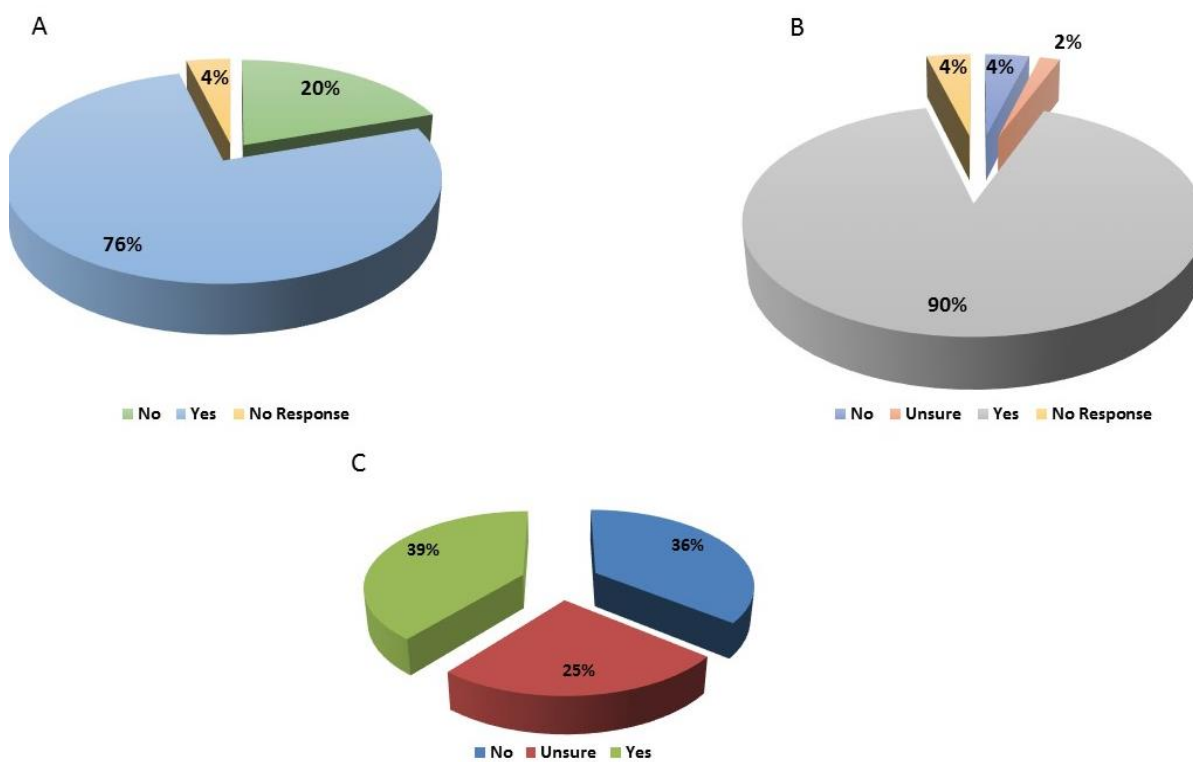
A substantial percentage of the respondents (76%) claim that they read product labels during the purchase (Figure 4A), and 90% would want GM crops and food products containing GMO elements to be labeled accordingly (Figure 4B). Inclination towards buying GM crops based on price advantage between GM food/crops varied among the respondents (Figure 4C); about 39% would consider a price advantage while 36% would not, and 25% were not sure yet if they would consider a price advantage.

#### Desired crop/food feature

Considering many modifications that crops could undergo



**Figure 3.** (A) Factors that influence respondent's attitudes towards GMO when it is eventually introduced, (B) Participants indication of their specific concerns/attitude about GM crops when eventually introduced.

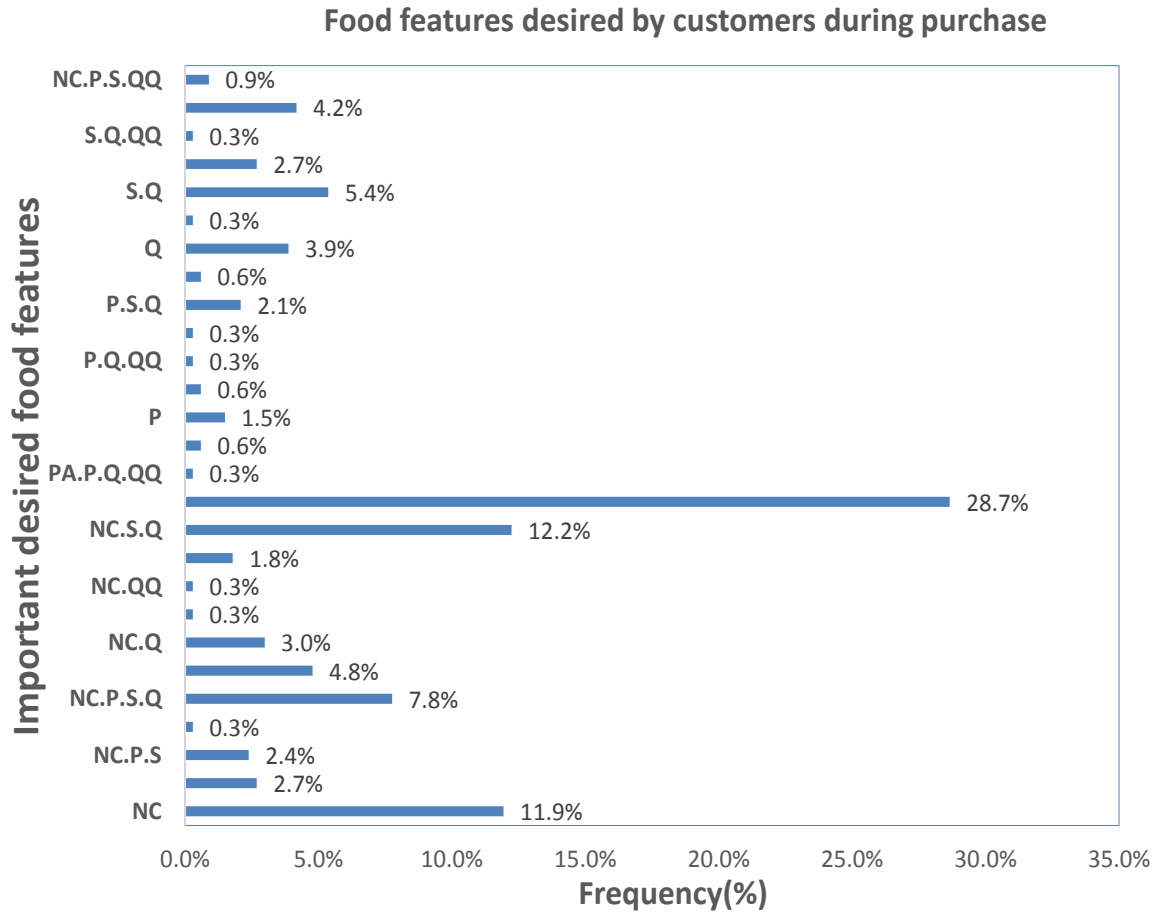


**Figure 4.** (A) Indication of reading of food label by respondents, (B) Participants desire for GMO crops or Food items containing GMO be labelled, (C) Participants consideration for price advantage of GMO crops.

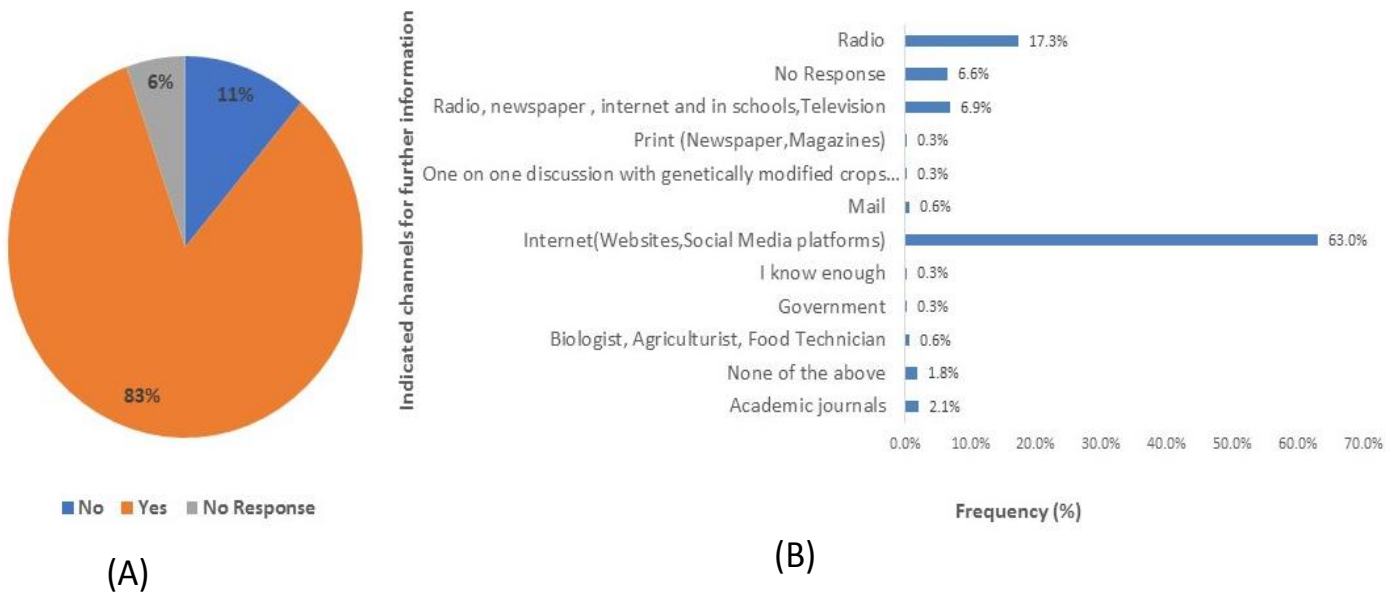
genetically, respondents indicated the features of food products that they consider essential during purchase. Physical appearance, nutritional content, safety, price, and quality were observed to be dominant, as shown in Figure 5.

**Further information about GMO/GMC**

Respondents indicated their desire for further knowledge (83%), awareness, and information about GMO/GM crops (Figure 6A), and they indicated their preferred



**Figure 5.** Important food features desired by respondents. NC=Nutritional content, P=Price, Q=Quality, QQ=Quantity, PA=Physical appearance, S=Safety.



**Figure 6. A.** Indication of desire for more information by respondents **B.** Indication of source of further information about GMO by respondents.



source of further information (Figure 6B). The preferred source of information is through social media and the Internet.

## DISCUSSION

The use of genetically modified organisms (GMOs) is mostly associated with controversies that have divided public opinion. This study accentuated a high degree of concern towards GMOs among the respondents. The study was carried out using the internet and social media tools such as blogs, email, Facebook, WhatsApp, and Instagram as a means of dissemination of the questionnaire. The use of the Internet as a survey tool is mostly characterized by lower data collection costs and qualitative questionnaire designs and administration, and this tool was applied in this study for these reasons mentioned above (Internet Statistics, 2020). Overall, the sample respondents represent an educated segment of the public and only cuts across people that make use of the social media/internet due to the method of dissemination of the survey. It was observed that more than half of the respondents had educational qualifications above the secondary school certificate. Thus, this study is not representative of the general population. The results also indicated a high interest in the survey by the majority of male respondents. Culturally, Nigerian females are more involved in the family's domestic affairs, such as cooking and purchasing food items. Therefore one would expect more females to be more interested in the debate about GMO crops in the country. This observation could have been influenced by many factors, such as lack of interest or limited knowledge of the subject matter or possibility of limited access to the Internet.

The participants self-reporting knowledge about GMOs is high based on the results observed in this study. Although the level of knowledge is mostly medium (63%) amongst the respondents, there is no clear indication of how the level of knowledge can be measured within the scope of this study. The indication of the desire for further information on GMOs by more than 83% of the respondents can attest to the fact that the medium level of knowledge is not deemed significant by the respondents. There is, therefore, the need to increase awareness and level of knowledge about GMOs. Increasing awareness and providing relevant information about genetic modification techniques and its associated biosafety components will provide valuable, well-balanced information on biotechnological processes and final products. Previous studies have shown that attitude towards GMOs is a crucial factor in understanding the public's perception of associated risks and benefits (Verdurme and Viaene, 2003). The process of modifying these perceptions requires accurate communication of science to mass-media and relevant stakeholders to

prevent media hype (Rodríguez-Entrena and Salazar-Ordóñez 2013). Choosing an efficient means of communication for this purpose is also very important, and the respondents in this study attributed their primary source of previous knowledge to the print and electronic media (TV, radio, newspaper), Internet, and academic journals. Stating their preferred source of further information, about 68% of the respondents would prefer the use of social media platforms and the Internet.

In principle, all available mass media can be applied in communicating scientific information to the public. However, the limitation of this general approach is that some media channels may be dominated by sensationalism (Ransohoff and Ransohoff, 2001). The Internet has gained popularity as a source of information on safety assessment and approval procedures to the public. However, while considering the different media of information, the value should be placed on credible sources of information as information from credible sources is more likely to influence the perception of the public rather than information from sources that lack credibility. Factors that determine the credibility of such sources include trustworthiness, fairness, recognized competence or expertise, and lack of bias. Terms such as factual, knowledgeable, expert, public, welfare, responsible, truthful, and excellent track record are mostly associated with high credibility by the consumers (Aung and Chang, 2014). Trust and credibility should be cherished; otherwise, they can be lost through ineffective or inappropriate communication (Aung and Chang, 2014).

The respondents in this study also indicated academic journals as their source of information, and about 21% still desired further information via this channel. This quest can be fulfilled by increasing the rate of peer-review papers published in this field of study and any related discipline. The availability of such articles should be considered by ensuring that these publications are in open access (OA) mode. The use of academic publications, in this case, would only be useful for educated persons and, most likely, students, researchers, and scientists. It should also be noted that valuable free, full-text, online resources increase the chance of instant and accurate science communication to the public while contributing to the avoidance of media hypes and miscommunication (Rzymiski and Królczyk, 2016). The role of academicians and school teachers in the public understanding of GMO risks and benefits should not be underestimated. Educational programs can be modified for increased biotechnology content. The teachers can also be given specialized training for this purpose, and this can be achieved by using specialized training materials such as the intersectional training developed by UNESCO in 2004. This kit is known as the "GMO Teaching Kit," is aimed at empowering secondary school teachers to educate and communicate developments and potential uses and risks of new technological advances (UNESCO, 2004).

Based on Internet usage in Nigeria, the Internet offers an excellent platform for the dissemination of information about GMOs. An efficient internet information dissemination strategy can be applied to achieve maximum impact. The Internet can host a massive repository of dynamic information that can be made available to everyone anywhere at any time (Vermesan et al., 2011). The social media platforms are also useful in reaching a target audience and stakeholders for scientific communication. Social media should, however, be engaged credibly to enhance the acceptability of the information being passed across. Other communication channels, such as public debates and information meetings organized by the government, churches, and other stakeholders, should also be considered. Although GMOs possibly remain controversial to some people, there is a need that the public has a balanced and evidence-based opinion rather than hysteric or reliant on populist views and debates (Rzymiski and Królczyk, 2016). The relevant stakeholders in Nigeria, such as the ministry of health and the biosafety regulator, can fortify their efforts in communication strategies concerning health and safety assessment of food/feed derived using the inclination of the respondents in this study.

Almost half (45.3%) of the respondents were willing to accept the introduction of GM crops in Nigeria, and 24.4% were uncertain, and 30.3% were not willing to accept. Respondents with medium knowledge about GMO/GM crops were more willing to accept GM crops compared to respondents with high and low knowledge. Numerous factors could have influenced the decision of participants about the acceptance of GMOs. Significant determinants of human behavior include emotional needs, experience, and knowledge, and knowledge, in this case, includes regulations and principles that dominate individual and social life. Internalizing these markers and molding of attitudes contribute to decision making and undertaking of actions according to personality and temperamental traits (Lachowski et al., 2017). The acceptance of GMOs is observed to be occupation dependent in this survey as the Business/Trade/Self-employed, Professionals, and students were more willing to accept GM crops. Educational qualifications did not influence the attitude towards GMOs. The percentage of respondents that have concerns about GM crops was observed to be high in this study, and the results indicate the perceived risks associated with GMO products within this sample population. Comparable results were observed in (Rzymiski and Królczyk, 2016), in which the study group generally perceived GM foods as unsafe for humans and the environment.

Based on the Eurobarometer survey, the level of worry about GMOs was indicated to have increased over the years since 2005 (European Commission, 2010). Generally, perceived health risks of GMOs have been observed as one of the major deterrents to public

acceptance of GMO products. Fears have been expressed about the possibility of carcinogenesis, allergenicity, and the threat to biota (Rzymiski and Królczyk, 2016). However, it should be noted that these health concerns about GMOs expressed by respondents are perceived and most probably not based on any scientific knowledge. There is there for a need to recognize further exact public apprehension behind their concerns about GM crops in Nigeria (Hilbeck et al., 2015; Krimsky, 2015). The use of GMO products as food or feed products is, in many cases are met by public resistance based on health concerns.

In contrast, the use of GMOs for medical and pharmaceutical purposes, for instance, in vaccine production or lifesaving medical procedures, is met with little resistance from the public (Amin et al., 2013). GM crops can also be considered for other fields of application in Nigeria. Activists and anti-GMO campaigners have built a significant percentage of their campaign on the potential (negative) environmental impact of GMOs, but the respondents in this survey attached little emphasis on the potential impact of GMOs on the environment. There was also less emphasis on religious or ethical/moral concerns about GMOs. Some participants indicated concerns about seed monopoly by the biotechnology companies. Because companies developing GMOs own the intellectual property right on their modifications, farmers must purchase the products annually from them. This requires continuous re-investment in seed purchase, increased financial commitment, and risks in case of a low yield farming season.

For the different levels of knowledge declared by the respondents, their attitude towards acceptance of GM crops could have also been influenced by their level of knowledge. Expectedly a low level of knowledge would account for limited knowledge of the technology behind these GM crops and the inherent inability to decide if they want the crops or not (Rodríguez-Entrena and Salazar-Ordóñez, 2013). The respondent with medium knowledge levels might also be skeptical because of the level of their knowledge. The respondents with high knowledge were willing to accept GM crops, and this could be rated as an informed choice. Because if they have excellent knowledge, then they possibly have good knowledge about gene modification technology and associated risks and benefits. Respondents within the age group 25-39 were the most willing to accept GM crops, followed by the 18-24years age group. The varying willingness of the age groups can be taken into consideration when planning GMO communication campaigns in the country. This strategy could determine the type and mode of communication methods to be used based on the different age groups in a particular audience. The age group that showed limited willingness can first be introduced to the basics during initial campaigns. The geographical location did not affect this attitude and therefore suggests

that based on this study, the general attitude towards GMC in Nigeria cannot be rated based on geographical locations.

Food labels are designed to provide and communicate information about production techniques, ingredients used for the production, and quality of food/feed products. These product attributes reflect consumer's interests intentionally in making purchase decisions (Gautam, 2017). Labels can, however, be confusing, misleading, and improperly placed on the product (e.g., place in such a manner that they can be easily ignored or written in a clumsy or tiny text font) and thereby, consumers can ignore them. To find out the label reading habits of respondents, participants in this study were asked if they read food labels before making a purchase. A sizable percentage of the respondents (76%), read food labels of GMO foods, and 88% of respondents believed GMO foods and food products containing GMO entities should be clearly labeled. Many countries have adopted labeling policies for genetically modified foods in recent years, and it is currently mandatory in 64 countries. The European Union was the first to introduce these policies in 1997. However, many countries have followed, including all developed countries that have adopted some types of labeling policy for GM food. In the EU, products containing at least 0.9% of GM ingredients should be labeled as containing GM ingredients (Information, 2010). The appropriate authorities in Nigeria will also be required to identify and set the benchmark for GM content for labeling. In the United States of America (USA), labeling policy is mostly unimplemented and often criticized due to additional cost and potential call for caution by anti-GMOs. It is mostly suggested that most people who are interested in GMO labelling would avoid buying GM foods (Kling, 2014), but this study cannot establish this. Although labeling policies may differ in their nature, scope coverage, exceptions, and level of enforcement (Gruère and Rao, 2007), there is a need for the relevant stakeholders in Nigeria to consider the desire for GMO labeling as indicated by respondents in this study. Key features that respondents look for while purchasing food items are quality, safety, and nutritional content of GMOs and derived food/feed products. These features can be considered for future crop improvement, and modification plans strategies should take note not to impart on the state features negatively.

The influence of price and physical appearance on the purchasing power was indicated by 45% and 30% of the respondents, respectively. Genetically modified crops are cheaper in terms of production, and this would eventually affect the retail price of food products (Gaisford, 2001). Only 37% of the respondents are ready to consider a price advantage, 34% would not, and the rest were not sure they would. The exact effect of a cheaper GMO food can only be established when the food gets to the market because this will be influenced by many factors such as earning power, knowledge, and perception about GMOs.

A section of the public with limited financial resources may be persuaded by quantity (cheaper prices) rather (Gaisford, 2001) than quality and might not be bothered if the crop is a GM crop or not. Many factors can affect food security in a developing country like Nigeria; genetic modification can offer profitable solutions regarding disease protection, drought resistance, postharvest sustainability, etc. This is in resonance with the respondents as 63% (data not shown) support the idea that GMOs can be applied to meet food demand in the country.

## Conclusion

This study represents research on the attitude and readiness towards GMOs in Nigeria by a sampled segment of the population. It provides an empirical analysis using descriptive statistics to determine the willingness of the public to accept GM crops when they are eventually introduced in Nigeria. This study is also able to provide a broader understanding to readers, policy makers, regulatory agencies, and the government about the public opinion and attitudes about GMOs. Based on the results obtained, there is a reasonable level of awareness of GMOs in Nigeria. However, participants still indicated the need for the provision of further substantive information on GMOs. The outcome of this study shows that Nigerians have divided opinions about the willingness to accept GM crops when eventually introduced. A high level of concern about the potential health implications of these crops was expressed. Although a small sample size limits the study, there is a need to implement evidence-based educational programs to increase the public understanding of potential applications and limitations of GMOs. The outcome of this study can also be employed by relevant stakeholders to address issues of inadequate information, non-evidence-based perceived risks, and general apathy towards GMOs.

## Limitations of the study

This study was limited through its inability to capture members of the public that do not have access to the Internet. People living in remote locations may have limited possibilities to use the Internet. We, therefore, look forward to future research on public perception during which we will capture persons located in rural areas with limited possibilities for education in the field of modern plant breeding and the use of modern information technologies.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

## ACKNOWLEDGEMENTS

The authors appreciate the support of Prof Bruno Mezzeti of the Università Politecnica delle Marche, Department of Agricultural, Food and Environmental Sciences, for his contribution towards the study design and also express their appreciation to all respondents of this survey.

## REFERENCES

- Adenle A (2001). Are transgenic crops safe GM agriculture in Africa - United Nations University. Retrieved from <https://unu.edu/publications/articles/are-transgenic-crops-safe-gm-agriculture-in-africa.html>
- Adenle AA (2014). Stakeholders' Perceptions of GM Technology in West Africa: Assessing the Responses of Policymakers and Scientists in Ghana and Nigeria. *Journal of Agricultural and Environmental Ethics* 27(2):241–263.
- Adeoti JO, Adekunle AA (2007). Awareness of and attitudes towards biotechnology and GMOs in Southwest Nigeria: A survey of people with access to information. *International Journal of Biotechnology* 9(2):209-230.
- Aerni P (2005). Stakeholder attitudes towards the risks and benefits of genetically modified crops in South Africa. *Environmental Science and Policy* 8(5):464-476.
- Aerni P, Bernauer T (2006). Stakeholder attitudes toward GMOs in the Philippines, Mexico, and South Africa: The issue of public trust. *World Development* 34(3):557-575.
- Aleksejeva I (2014). ScienceDirect EU experts' attitude towards use of GMO in food and feed and other industries. *Inese Aleksejeva / Procedia-Social and Behavioral Sciences* 110:494-501.
- Amin L, Jahi J, Abd R (2013). Stakeholders' attitude to genetically modified foods and medicine. *The Scientific World Journal* 2013. <https://doi.org/10.1155/2013/516742>
- Animasaun DA, Azeez MA, Adubi AO, Durodola FA, Morakinyo JA (2020). Trends in genetically modified crops development in Nigeria. In *Genetically Modified and Irradiated Food* (pp. 131–150). Elsevier. <https://doi.org/10.1016/b978-0-12-817240-7.00008-5>
- Aung MM, Chang YS (2014). Traceability in a food supply chain: Safety and quality perspectives. *Food Control*. Elsevier BV. <https://doi.org/10.1016/j.foodcont.2013.11.007>
- Avery OT, Macleod CM, McCarty M (1944). Studies on the chemical nature of the substance inducing transformation of pneumococcal types: Induction of transformation by a desoxyribonucleic acid fraction isolated from pneumococcus type iii. *Journal of Experimental Medicine* 79(2):137-158.
- European Commission (2010). Special Eurobarometer - Κίνδυνοι που σχετίζονται με τα τρόφιμα (στοιχεία για Ελλάδα).
- Costa-Font M, Gil JM (2012). Meta-attitudes and the local formation of consumer judgments towards genetically modified food. *British Food Journal* 114(10):1463–1485.
- Datta A (2013). Genetic engineering for improving quality and productivity of crops. *Agriculture & Food Security* 2(1):15.
- Fraley RT, Rogers SG, Horsch RB (1986). Genetic Transformation in Higher Plants. *Critical Reviews in Plant Sciences* 4(1):1-46.
- Gaisford J (2001). The economics of biotechnology. Retrieved from [https://books.google.com/books?hl=en&lr=&id=dCy\\_MtJwmlC&oi=fnd&pg=PR7&dq=Gaisford,+James,+et+al.+The+Economics+of+Biotecnology.+Cheltenham:+Edward+Elgar,+2001&ots=cdeVboC2h2&sig=7aqEh\\_1\\_qiNL9DrwbyOUG7SJPE](https://books.google.com/books?hl=en&lr=&id=dCy_MtJwmlC&oi=fnd&pg=PR7&dq=Gaisford,+James,+et+al.+The+Economics+of+Biotecnology.+Cheltenham:+Edward+Elgar,+2001&ots=cdeVboC2h2&sig=7aqEh_1_qiNL9DrwbyOUG7SJPE)
- Gautam R (2017). Label Position and Its Impact on Willingness To Pay for Products Containing Genetically Modified Organisms. *Dissertations and Theses in Agricultural Economics*. Retrieved from <http://digitalcommons.unl.edu/agecondisshttp://digitalcommons.unl.edu/agecondiss/40>
- Gruère GP, Rao SR (2007). A review of international labeling policies of genetically modified food to evaluate India's proposed rule. *AgBioForum*. AgBioForum.
- Hilbeck A, Binimelis R, Defarge N, Steinbrecher R, Székács A, Wickson F, Antoniou M, Bereano PL, Clark EA, Hansen M, Novotny E (2015). No scientific consensus on GMO safety. *Environmental Sciences Europe* 27(1):4.
- Information P (2010). A decade of GMO research. Retrieved from <http://ec.europa.eu/research/research-eu>
- Internet Statistics (2020). World Internet Users Statistics and 2020 World Population Stats. Retrieved June 3, 2020, from <https://www.internetworldstats.com/stats.htm>
- Ivase TJ (2019). Current Status and Challenges of Agricultural Biotechnology in Nigeria: A Concise Review. *Journal of Multidisciplinary Engineering Science and Technology* 6(9):10656–10662. Retrieved from [https://www.researchgate.net/publication/336891097\\_Current\\_Status\\_and\\_Challenges\\_of\\_Agricultural\\_Biotechnology\\_in\\_Nigeria\\_A\\_Concise\\_Review](https://www.researchgate.net/publication/336891097_Current_Status_and_Challenges_of_Agricultural_Biotechnology_in_Nigeria_A_Concise_Review)
- Kikulwe EM, Wesseler J, Falck-Zepeda J (2011). Attitudes, perceptions, and trust: Insights from a consumer survey regarding genetically modified banana in Uganda. *Appetite* 57(2):401-413.
- Kling J (2014). Labeling for better or worse. Retrieved from <https://www.nature.com/nbt/journal/v32/n12/abs/nbt.3087.html>
- Krimsky S (2015). An Illusory Consensus behind GMO Health Assessment. *Science, Technology and Human Values* 40(6):883-914.
- Lachowski S, Jurkiewicz A, Choina P, Florek-Łuszczki M, Buczał A, Goździewska M (2017). Readiness of adolescents to use genetically modified organisms according to their knowledge and emotional attitude towards GMOs. *Annals of Agricultural and Environmental Medicine* 24(2):194-200.
- Li Y, Peng Y, Hallerman EM, Wu K (2014). Biosafety management and commercial use of genetically modified crops in China. *Plant Cell Reports* 33(4):565-573.
- Matagne R (1969). Induction of chromosomal aberrations and mutations with isomeric forms of L-threitol-1,4-bismethanesulfonate in plant materials. *Mutation Research - Fundamental and Molecular Mechanisms of Mutagenesis* 7(2):241-247.
- Ojo EO, Adebayo PF (2012). food security in Nigeria: An overview. *European Journal of Sustainable Development* 1(2):199-222.
- Pino G, Amatulli C, De Angelis M, Peluso AM (2016). The influence of corporate social responsibility on consumers' attitudes and intentions toward genetically modified foods: Evidence from Italy. *Journal of Cleaner Production* 112:2861-2869.
- Population, total - Nigeria | Data. (n.d.). Retrieved June 11, 2020, from <https://data.worldbank.org/indicator/SP.POP.TOTL?locations=NG>
- Prakash D, Verma S, Bhatia R, Tiwary BN (2011). Risks and Precautions of Genetically Modified Organisms. *ISRN Ecology* 2011, 1-13.
- Ransohoff DF, Ransohoff RM (2001). Sensationalism in the media: when scientists and journalists may be complicit collaborators. *Effective Clinical Practice: ECP* 4(4):185-188.
- Rodríguez-Entrena M, Salazar-Ordóñez M (2013). Influence of scientific-technical literacy on consumers' behavioural intentions regarding new food. *Appetite* 60(1):193-202.
- Rogers SG, Klee HJ, Horsch RB, Fraley RT (1987). Improved Vectors for Plant Transformation: Expression Cassette Vectors and New Selectable Markers. *Methods in Enzymology* 153(C):253-277.
- Rzymiski P, Królczyk A (2016). Attitudes toward genetically modified organisms in Poland: to GMO or not to GMO? *Food Security* 8(3):689-697.
- Sawicka B, Umachandran K, Skiba D, Ziarati P (2020). Plant Biotechnology in Food Security. In *Natural Remedies for Pest, Disease and Weed Control* (pp. 163–177). Elsevier. <https://doi.org/10.1016/b978-0-12-819304-4.00014-2>
- Statistics IS (2013). IBM Corp. Released 2013. IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp. - Google Search. Retrieved from [https://www.google.com/search?q=IBM+Corp.+Released+2013.+IBM+SPSS+Statistics+for+Windows%2C+Version+22.0.+Armonk%2C+NY%3A+IBM+Corp.&rlz=1C1CHBF\\_enDE727DE728&oq=IBM+Corp.+Released+2013.+IBM+SPSS+Statistics+for+Windows%2C+Version+22.0.+Armonk%2C+NY%3A+IBM+Corp](https://www.google.com/search?q=IBM+Corp.+Released+2013.+IBM+SPSS+Statistics+for+Windows%2C+Version+22.0.+Armonk%2C+NY%3A+IBM+Corp.&rlz=1C1CHBF_enDE727DE728&oq=IBM+Corp.+Released+2013.+IBM+SPSS+Statistics+for+Windows%2C+Version+22.0.+Armonk%2C+NY%3A+IBM+Corp)
- UNESCO (2004) GMO Teaching Kit. [http://portal.unesco.org/education/en/file\\_download.php/3d503b8b5b70152f9d29d2ab066a4936GMO+](http://portal.unesco.org/education/en/file_download.php/3d503b8b5b70152f9d29d2ab066a4936GMO+)

Flyer+1.pdf. Accessed 18 December 2015.  
Verdurme A, Viaene J (2003). Consumer beliefs and attitude towards genetically modified food: Basis for segmentation and implications for communication. *Agribusiness* 19(1):91-113.

Vermesan O, Peter F, Patrick G, Sergio G, Harald S, Alessandro B, Ignacio Soler J, Mazura M, Harrison M, Eisenhauer M, Doody P (2011). Internet of Things: Strategic Research Roadmap. In *Internet of Things-Global Technological and Societal Trends*, pp. 9-52.