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PERCEPTIONS OF BIOENGINEERED FOOD
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PERCEPTIONS OF BIOENGINEERED FOOD INNOVATIONS: THE GHANAIAN COLLEGE STUDENTS' PERSPECTIVE

By

Doe Adovor

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ABSTRACT

PERCEPTIONS AND DISCOURSES OF BIOENGINEERED FOOD INNOVATIONS: THE GHANAIAN COLLEGE STUDENT'S OUTLOOK

By

Doe Adovor

Potential risks and benefits associated with bioengineered food innovations have generated substantial debate in both developed and developing countries. While some view biotechnology as a symbol of hope in securing safer, more abundant food, others remain ambivalent about the potential benefits and risks. This study used a quantitative survey method to explore Ghana's Kwame Nkrumah University of Science and Technology Agricultural Science students' perceptions of agricultural biotechnology. To determine how different information sources influence respondents' self perceived knowledge, self perceived knowledge of biotechnology treated as the dependent variable was correlated with different information sources used in seeking knowledge about biotechnology. Logit and Probit models were used to determine the probability that a respondent will say his/her knowledge is high when a particular information source is used in isolation. Findings from the study suggest that, disregarding the duration of use, the more information sources respondents use in seeking knowledge about biotechnology, the more likely they are to perceive their knowledge as high. "Friends' Belief about Biotechnology" (interpersonal channel), Internet, Newspaper and Radio (mass communication channels), were found to be statistically significant in influencing respondents' self perceived knowledge of biotechnology.

DEDICATION

To my wife
Clarice Mensah
whose love and encouragement keep
my academic aspirations alive

To my daughter
Volta Elolo Adovor
whose wonderful smiles fuel my
desire to succeed in life

To my parents
Samuel and Grace Adovor
who have always encouraged
me to live my dreams

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CHAPTER ONE

INTRODUCTION

1.1 Agricultural Biotechnology and Food Security

The main focus of this study is to assess how bioengineered food innovations, otherwise known as modern biotechnology, are perceived among agricultural science students from the Kwame Nkrumah University of Science and Technology (KNUST) in Kumasi, Ghana. The thesis also presents theoretical and empirical work on bioengineered food innovations and how different individuals, groups and institutions in both developed and developing countries perceive them. To set the stage for this study, chapter one explores the relationship between agricultural production, population dynamics, and food security within a global context, but with particular reference to Africa. Also, chapter one presents the theoretical and conceptual framework on which the study is based.

1.2 Population Growth, Productive Resources and Food Security

A recurring theme in the world food discussion over the past two decades has been the role of bioengineered food innovations in ensuring food security in developing countries. Famine and hunger are both rooted in food insecurity (Ayalew, 1997) yet, ensuring food security in developing countries requires harmonizing complex activities such as agricultural production, natural resource conservation, and population dynamics, a process that many contend could be made feasible with the help of modern agricultural biotechnology. For example, Curtis, McCluskey and Wahl (2004) claim that increased yields from bioengineered crops may provide the answer to food availability issues in the developing world. During the "Proceedings of the African Regional Conference for International Cooperation on Safety in Biotechnology" held in Harare Zimbabwe, Professor Chell touted the science of plant biotechnology by saying it can significantly help make intensive agriculture less damaging to the environment and also make low input (organic) agriculture more productive. Chell (1993) also claimed that in the face of an increasing world population and limited cultivatable land, plant biotechnology is one of the few and most effective methods available to maintain and improve agricultural productivity without destroying the environment.

According to the United Nations' Food and Agriculture Organization (FAO), the growth potential of most developing countries including those of Sub-Saharan Africa is threatened by population explosion, landlessness, poverty, rural unemployment, low returns on productive labor, and massive degradation of the continent's natural resource base (FAO-AFWC, 2000). Although there are many contributing factors to poverty and hunger in Africa, poor performance of the agricultural sector is believed to contribute the most to Africa's problems (USAID and IFPRI, 2002). It is estimated that 80% of all Africans depend on agriculture for their livelihoods, a sector that accounts for 70% of full time employment, one third of total GDP, and 40% of total export earnings (USAID and IFPRI, 2002).

1.3 Global Population Growth Trends and Food Production

With a current population size of 887,223,898 million (GeoHIVE, 2005), Africa's population is expected to increase by more than two fold to 1.8 billion by 2050 (Associated Press, 2000). During the same period Europe's population is expected to decrease from 728 million to 658 million, while the United State is expected to rise from 275 million to 403 million by mid-century, a moderate growth attributed to overall positive economic forecast and continued immigration (Associated Press, 2000). Africa's projected population growth for the next 50 years calls into question the ability for productive resources (i.e., arable land, water, energy, and biological resources) to provide sustenance for humans and other life forms. It may be deduced from Malthus' principles of population that the inability of productive resources to keep up with the rising human population most likely will result in a country's inability to feed its self (Malthus, 1798). Shapuori and Rosen (2001) argue that a country's domestic food production is less critical to food security if it can import required foods. However, financial constraints limit food imports in most African countries. Shapuori and Rosen (2001) explain that if only imports grew at a slightly greater rate than projected, the food gap in most of North Africa could close entirely. On the other hand, many have argued that for Sub-Saharan Africa to close its average nutrition gap, food imports would have to grow by more than 9% annually for the next decade, a growth rate contended by experts to be extremely unlikely, given the region's historic import growth rate of less that 5% (Shapuori & Rosen, 2001).

1.4 Population Growth, Malnutrition and Productive Resources

On the global scale, approximately 842 million people world wide were malnourished between 1999 and 2001, with nearly 80% women and children (FAO, 2004a). Asia and the Pacific currently account for nearly two-thirds of total global cases of malnutrition; however, the situation is especially severe in Central, East and Southern Africa, where 44% of the total population is undernourished (Hunger Notes, 2004). A technical report in support of USAID's agricultural initiative to cut hunger in Africa released August 23, 2002, revealed that one in three people in Africa are currently undernourished and a third of the entire world's undernourished people reside in Sub-

Saharan Africa (USAID and IFPRI, 2002). It has been predicted by the same report that by 2010 Africa may account for nearly two-thirds of all undernourished cases world wide (USAID and IFPRI, 2002).

In addition to Africa's record high malnutrition and population growth rates, research shows that nearly half of the continent's farmland suffers from erosion and nutrient depletion (Cleaver and Schreiber, 1994; cited in Haggblade et al. 2003). Nutrient balance studies suggest annual losses of 22 kg of nitrogen, 2.5 kg phosphorous, and 15 kg of potassium over the last three decades, a nutrient loss valued at $1 - 3 billion per year (Smaling et al. 1997; and Sanchez et al. 1997; cited in Haggblade et al. 2003). During the 39th annual meeting of the Association for International and Rural Development in Washington DC, Anthony Wayne, the United States' Assistant Secretary for Economic and Business Affairs claimed that nearly 2 billion hectares of global arable land has been rendered irreversibly unproductive by soil erosion, salinization, and depletion of organic matter. It is estimated that, without conservation or the use of appropriate technologies, more than 500 million hectares of rain-fed cropland may become unproductive over the long term in Asia, Africa, and Latin America (Wayne, 2003). Similar to the situation in most of Asia, food security experts assert that by 2050, efforts required to ensure food security in Africa and most of the third world will take place under a situation in which yield levels would have already reached a plateau with existing technologies (APO, 1994).

More than any other factor, population growth is said to affect the acquisition and availability of farmlands. In most of Africa and the developing world, where farmlands pass from one generation to other, the result is a high rate of land fragmentation (division among wives and children) (Osei, 2003). The high rates of population growth in developing countries and associated land fragmentation make it difficult for farmers to produce enough food to feed the hungry (Osei, 2003). Estimates show that between 1970 and 1990, India recorded roughly 49 million to 82 million small arable farmlands with less than 2 ha (5 acres) in farm size. Expects argue that if this trend continues these shrinking farmlands will be unable to support a society expected to add about 515 million people to its current population of 1 billion by 2050 (Osei, 2003). In Pakistan where the population is projected to increase from the current 156 million to 345 million by 2050, the average farm size is predicted to shrink from 0.08 ha to 0.03ha (the size of a tennis court) (Osei, 2003). Nigeria, with a current population figure of 111 million is projected to increase to 244 million by 2050. During the same period, Nigeria's per capita farmland is predicted to shrink from 0.15 ha to 0.07 ha thus rendering Nigeria's precarious food production prospect far more difficult (Osei, 2003). Ghana faces a similar fate if the problem of land division and subdivision continues. Ghana is also expected to add an additional 45 million to its current 20 million by the year 2050 and the average farm size is predicted to fall from 0.25 to 0.09 ha/capita (Osei, 2003). High population growth rates coupled with negative agrarian structures and radical changes in world trade scenarios present a bleak picture of Africa's future economic development (Shapuori & Rosen, 2001). With dwindling arable land, the challenge is to provide sustenance for a rapidly growing world population on increasingly smaller plots of land. Experts predict that population explosion expected to occur in the developing world in the next five decades calls for renewed efforts in ensuring food security for a large population currently dependent on a rapidly degrading resource base (APO, 1994).

1.4 Significance of the Study

Food insecurity and famine in Eastern and Southern Africa in recent years have generated a lot of debate and controversy among different political groups and researchers. A recent study states that this debate, which has been largely confined to small and often isolated groups of African scientists and environmental activists, is largely focused on whether products of modern biotechnology, particularly genetically modified (GM) crops, will contribute to the solution of ensuring food security in the region (Mugabe, 2004). Hosain, Onyango, Adelaja, Shilling and Hallman (2002) argue that considerable skepticism amongst scientists, corporations and governments has a negative influence on public perceptions of bioengineered food innovations. Personal and socio-cultural and economic attributes influence how people perceive modern biotechnology. This study is concerned with perceptions of bioengineered food innovations among agricultural science students from KNUST and how these perceptions are influenced by personal attributes, different institutions including the mass media, research, culture and religion.

1.5 Problem Statement

Currently, most developing countries are under enormous internal and external pressure to insure food security to their populations through environmentally sustainable means. Many researchers, including Clark and Juma (1991), claim modern biotechnology has the potential to improve the Third World environment through ecological rehabilitation and pollution abatement. On the medical front, Walgate (1995) claims biotechnology heralds a new era of Third World preventative and curative medicine. In his speech during the 39th annual meeting of association of international and rural development, the United States Secretary for Economic and Business Affairs Anthony Wayne stressed that biotechnology offers tremendous potential for increasing productivity and income for the poor in developing countries. Many experts believe that introducing high yielding GM plant varieties, agro-chemicals and new irrigation techniques into agricultural systems in developing countries, just like the Green Revolution of the 1960s and 1970s will help lift millions in developing countries out of hunger and poverty (FAO, 2004b). Walgate (1995) stressed the potential of biotechnology to provide enough food to feed the hungry in developing countries by making the claim that the yield from cassava, rice, maize and other staple food crops could be quadrupled by producing disease resistant varieties with the aid of biotechnology.

In 2002, Zambia, faced with hunger and starvation, rejected GM corn from the United States on the premise of perceived safety risks associated with foods derived from biotechnology. Even though most critiques claim fear of jeopardizing trade with the EU lies at the core of Zambia's actions, the fact still remains that a knowledge gap exists on research aimed at assessing how potential beneficiaries of bioengineered food innovations in developing countries perceive modern biotechnology and its associated costs and benefits. More research aimed at assessing indigenous perceptions and risks of bioengineered food innovations in Africa and other developing countries is thus needed to better understand and perhaps close this knowledge gap.

1.6 Purpose

The purpose of this study is to examine KNUST agricultural science students' perceptions of bioengineered food innovations. The rationale for selecting a group of agricultural science students for this study is that they are the future change agents (i.e., agricultural communicators, educators, policy makers, etc.) of agricultural biotechnology in Ghana. The study is used to fulfill the following objectives:

1. To describe the demographic composition of agricultural science students in KNUST.
2. To describe current perceptions of bioengineered food innovations amongst KNUST agricultural science students.
3. To determine KNUST students' perceptions regarding government efforts in instituting appropriate frameworks aimed at facilitating adoption and implementation of bioengineered food innovations in Ghana.
4. To determine sources of information used by KNUST students in establishing their knowledge and perceptions regarding bioengineered food innovations.
5. To describe how different sources of information influence respondents' self perceived knowledge of bioengineered food innovations.

The objectives outlined above were used to construct the following research questions:

1. What information sources do KNUST agricultural science students use to obtain information about bioengineered food innovations?
2. What information sources do KNUST agricultural science students believe are most credible regarding information about bioengineered food innovations?
3. How do different information sources influence KNUST students' perceptions of bioengineered food innovations?

1.7 Theoretical Framework

The theoretical framework for this study is provided by Everett Rogers in his 1962 seminal work, "Diffusion of Innovations. Rogers (2003, p. 38) defines "diffusion" as the process by which an innovation is communicated through certain channels over time among members of a social system." Rogers explains that diffusion is a special type of communication in which the message is concerned with new ideas. In Ghana and most of Africa and the developing world, the concept of modern biotechnology is relatively new; hence, sharing information about biotechnology (the focus of this study) falls under the special type of communication described by Rogers. The newness of modern agricultural biotechnology in most developing countries, according to Rogers (2003), implies that some degree of uncertainty is involved in its diffusion process.

A communication channel is the means by which the message gets from one individual to another (Rogers, 2003). At its elementary form, the communication process according to Rogers (2003), involves: 1) an innovation (e.g., agricultural biotechnology in this case), 2) an individual or other unit of adoption that has knowledge of, or has experience using the innovation (e.g., researchers/scientists, etc.), 3) another individual or other unit that does not yet have knowledge of, or experience using the innovation (e.g., governments, students, producers and some scientists), and 4) a communication channel connecting the two units (e.g., mass media).

1.7.1 Rogers Innovation Decision Process

The innovation-decision process is the process through which an individual (or other decision making unit) passes from the first knowledge stage of an innovation, to the formation of perceptions and attitudes towards the innovation, to a decision to either adopt or reject, to implementation and use of the new idea, and to confirmation of this decision (Rogers, 2003, p. 61). The five steps involved in a typical innovation-decision process, e.g., the decision by social units in developing countries to either adopt or reject modern biotechnology, includes: 1) knowledge, 2) persuasion, 3) decision, 4) implementation, and 5) confirmation. Rogers (2003) explains that *knowledge* is gained when an individual (or other decision making unit) learns of the innovation's existence and gains some understanding of how it functions. "*Persuasion* takes place when an individual forms a favorable or unfavorable perception and/or attitude towards the innovation. *Decision* occurs when an individual engages in activities that lead to a choice to adopt or reject the innovation. *Implementation* takes place when an individual puts an innovation into use. *Re-invention* is especially likely to take place at the implementation stage. *Confirmation* occurs when an individual seeks reinforcement of an innovation-decision that has already been made, but he or she may reverse this previous decision if exposed to conflicting messages about the innovation" (Rogers, 2003, p. 62).

1.7.2 Social System

"A social system is defined as a set of interrelated units that are engaged in joint problem solving to accomplish a common goal" (Rogers, 2003, p. 67). A social system may be composed of individuals, informal groups, organizations, and /or subsystems (Rogers, 2003). "The social system constitutes a boundary within which an innovation diffuses" (Rogers, 2003, p. 67). Structure exists in a social system because of differences in culture, personal behavior and other social characteristics of the individuals or units within the system (Rogers, 2003). As diffusion occurs within a social system the social structure of the system affects the innovation's diffusion in several ways, hence the social system can either facilitate or impede the diffusion of an innovation (Rogers, 2003).

1.7.3 Change Agent

Mentioned earlier, the primary reason for selecting agricultural science students for this is study is their role as principal change agents of agricultural biotechnology in Ghana. A wide range of occupations may fit the definition of a change agent. For example, teachers, consultants, public health workers, agricultural extension agents, development workers, and sales people may be considered change agents in facilitating the adoption of modern biotechnology in a social system. The task of a change agent according to Rogers (2003) is to provide communication links between a resource system and client system. The change agent thus facilitates the flow of innovation from the change agency to an audience of clients (Rogers, 2003). For this type of communication to be effective, Rogers contends that the innovation must be selected to match clients' needs. "Feedback from the client system must flow through the change agent to the change agency so that it appropriately adjusts its intervention program to fit the changing needs of clients" (Rogers, 2003, p. 590). Change agency personnel (agents) may be university graduates with a Ph.D. in agriculture or possess some technical training in a specific field in question (Rogers, 2003, p. 591). Rogers (2003, p. 592) outlines the role of the change agent to include: 1) to develop the need for a change, 2) to establish an information exchange relationship, 3) to diagnose the problem, 4) to create an intent to change in the client, 5) to translate an intent into action, 6) to stabilize adoption and to prevent discontinuance, and 7) to achieve a terminal relationship.

1.8 Conceptual Model of How Information and Communication Channels Impact Perceptions of Agricultural Biotechnology

The conceptual framework used in this study is built on the premise that various factors including gender, socio-economic characteristics, information sources and channels, global perception, self perceived knowledge all affect how an individual perceives agricultural biotechnology. The two variables of interest in the study are students' perceptions of agricultural biotechnology and students' self perceived knowledge of agricultural biotechnology.

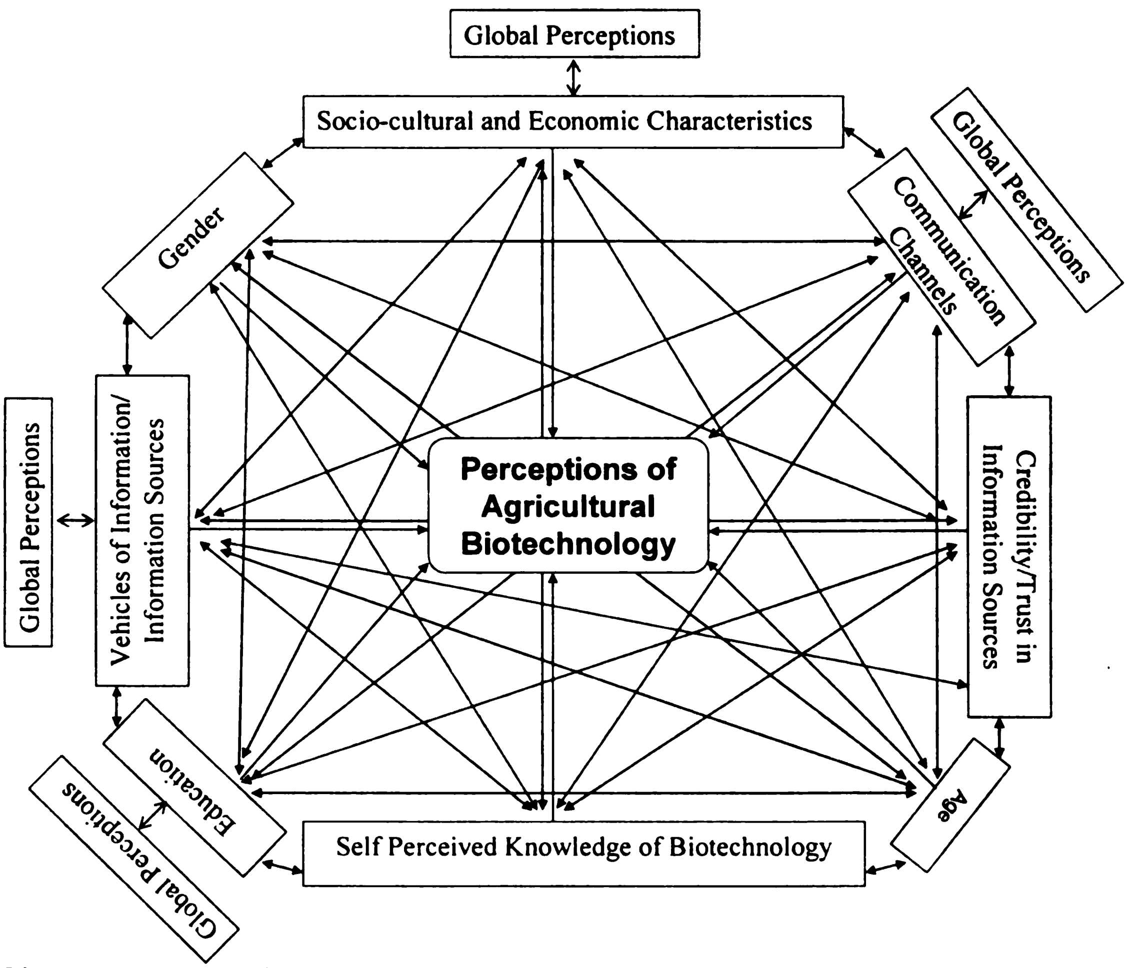

Figure 1: *Conceptual Model of Information/Communication Channels and Perceptions of Biotechnology*

The conceptual framework described above draws heavily on Rogers' theory of "diffusion of innovation." Figure 1 shows how the independent variables interact with each other to influence students' perceptions of modern agricultural biotechnology (treated as the dependent variable). All arrows connecting the independent variables to each other depict a two-way flow of information. Rogers and Kincaid (1981) explain that the communication process involved in informing an audience like KNUST students may be viewed as a two-way process of convergence rather than as a one-way, linear act in which one individual seeks to transfer a message to another in order to achieve certain effects.

In terms of students' perceptions of agricultural biotechnology, self perceived knowledge is treated as an independent variable that influences how one perceives agricultural biotechnology. The independent variables of interest in this study include demographic characteristics, different information and communication channels (e.g., mass media, university course work, government and non-governmental organizations), knowledge of the subject and the potential impact of bioengineered food innovations on the environment and different life forms.

1.9 Limitations of the Study

Even though the data were collected through trusted contacts in Ghana, it is assumed that because the researcher at MSU was not physically present in Ghana, it was not feasible to have full control over data collection.

Given that data collection was done very close to final exams, there is the possibility that the questionnaire was not given full and undivided attention by respondents. Also, the timing of data collection did not allow for double dipping because students went on summer vacation right after the data were collected. Even if double dipping were possible, the final year students would be excluded because they would have completed their programs and would be unlikely to participate in the follow-up process.

Due to negative connotations associated with the word "biotech" and genetic engineering, these two terms were avoided throughout the study. Throughout the study, the term biotechnology and modern biotechnology were used consistently and interchangeably with bioengineered food innovations.

The instrument design did not give respondents an opportunity to include additional comments or personal thoughts on the research topic. No space was provided on the instrument itself nor was additional comments invited. Even though this was done in part to allow for simplicity in analyzing the data using SPSS, it has limitations of excluding comments that could be used to improve on future studies.

1.10 Terms and Definitions

Attitude: Formed as a result of daily social interaction, through direct experience with the subject and verbal transmission of beliefs and evaluation about the subject (Benner, 1985). Unlike perceptions, attitudes are based on long term evaluation of the outcomes associated with a particular activity in this case modern agricultural biotechnology. Like perception, one's attitude is often influenced by socio-cultural and economic background.

Biotechnology: The application of biological research techniques to the development of products that improve human health, animal health, and agriculture (Genencor, 2005).

Famine: Drastic, wide-reaching, long-term shortages or lack of food caused by the regional failure of food production or good distribution systems (ECOHEALTH, 2005). War, poverty, drought, floods, volcanic eruptions, earthquakes and other natural and man made disasters can cause famines (Disaster Relief, 2005).

Food Security: The notion that all people in a community, especially the most vulnerable, have reliable access to good nutritious food into the future (PBS, 2005).

Knowledge: The act or state of knowing or having a clear perception of fact, truth, or duty. Knowledge is considered the highest degree of the speculative faculties and is based on the perception of truth based on familiarity, awareness, or understanding gained through experience or study. Knowledge is the result of a cumulative effect of what has been perceived, discovered, or learned through specific information about a subject. It involves a vivid representation of fact, formula, or complex condition backed by strong belief in its truth (Corsini, 1999)

Perception: "The awareness of the senses being stimulated by external objects, qualities ore relations (Corsini, 1999, p. 705)." One's perception about an activity is formed shortly after the period of exposure (based on immediate experiences), as opposed to memory; ability to select, organize, and interpret various sensory experiences into recognizable patterns (Corsini, 1999). Within the context of this thesis, perception refers to respondents' subjective assessment of the probability that modern biotechnology application will yield particular outcomes (either negative or positive for example increased food production or damage to the environment etc.). Students' perception in this thesis is influenced by the level of exposure to modern biotechnology and also by socio-cultural and economic variables.

Sustainable Agriculture: Refers to farming systems that are capable of maintaining their productivity and usefulness to society indefinitely (Gold, 1999).

1.11 Summary

This chapter presents a statement of the problem investigated in the study and the context in which the problem was studied. Special attention is paid to Africa since it is argued that most of Africa is yet to reap the full benefits of bioengineered food innovations. Studies conducted on biotechnology perceptions in both developing and developed countries are presented in chapters two.

CHAPTER TWO

LITERATURE REVIEW

2.1 Chapter Preview

This chapter draws on four areas of literature: 1) historical foundations of bioengineered food innovations, 2) opposing views on bioengineered food innovations (modern biotechnology), 3) perceptions of bioengineered food innovations in developed and developing countries, and 4) information sources used in establishing perceptions of bioengineered food innovations in developed and developing countries. The literature reviewed in this chapter was used to define the study's area of investigation and to set the stage for addressing the study's objectives and research questions outlined in chapter one and five, respectively.

2.2 Historical Foundation of Bioengineered Food Innovations

The term biotechnology as it relates to bioengineered food innovations has been defined in several different ways by different researchers. For instance, Peritore and Galve-Peritore (1995) define modern biotechnology as a set of techniques drawn from microbiology, genetics and biochemistry with the hope of creating products of commercial value through genetic manipulation of living organisms. Also, the European Federation of Biotechnology in 1981 described biotechnology as the integrated use of biochemistry, microbiology and chemical engineering in order to achieve the technological application of the capabilities of microbes and culture of cells (Mahanti, 1998).

Agricultural biotechnology may be categorized into first, second and third generation technologies (Juma and Mugabe, 1996). First generation biotechnology is based on empirical practice with minimum scientific or technological inputs and dates back to the Stone Age (Juma and Mugabe, 1996). First generation biotechnology makes use of biological organisms such as bacteria, yeast, enzymes, and traditional methods of fermentation to produce food and drinks, e.g., bread and wine (Juma and Mugabe, 1996). Second generation biotechnology, however, involves the development of fermentation technology using pure cell culture and sterile manufacturing facilities in an effort to generate new products such as acetones, butanol, glycerol, vitamin B2, citric acid, lactic acid and penicillin (Juma and Mugabe, 1996). Third generation biotechnology, otherwise known as modern biotechnology and the focus of this thesis, first took seed in 1953 with the discovery at Cambridge University (UK) of the structure to DNA (Juma and Mugabe, 1996). It is believed that the practice of traditional plant and animal breeding to yield desirable traits has been in existence for thousands of years in both the industrialized and developing nations; however, it is the recent breaking of genetic codes in the industrialized world that has revolutionized biotechnology (Gold, 1999). According to Mausberg and Press-Merkur (1995), genetic engineering/modern biotechnology differs significantly from traditional biotechnological techniques in that in modern biotechnology, DNA from different species can be combined to create completely new organisms referred to as Genetically Modified Organisms (GMOs).

In "Biotechnology in Latin America: Politics, Impacts and Risks," Patrick Peritore (1995) provides a comprehensive review of how bioengineered food innovations impact political economies and the environment in industrialized and developing countries. Peritore and Galve-Peritore (1995) argue that while most genetic diversity (the invaluable raw material of modern biological technology), is held by less developed nations, the technology that helps to transform these vital raw materials into commodities lies in "genetically poor" developed countries. Peritore (1995) also explains that because of its power over basic life forms, bioengineered food innovation techniques, such as biotechnology have captured the imagination of the public, corporate and government elites by way of their promise to revolutionize all aspects of human activities including medicine, industry and agriculture. Peritore and Galve-Peritore (1995) conclude that the question of who masters the new technology is very relevant since modern biotechnology promises immense profits and world market shares to corporations and nations. Adding to Peritore and Galve-Peritore's claim, Hassebrook and Hegyes (1989) observe that who will be served by bioengineered food innovations and who will set the research agenda of the experts becomes intensely important when only a few people control the tools and language of the trade.

It has been argued that the promises of bioengineered food innovations are so enormous that it is fairly easy for major economic and political actors and scientists to neglect debates regarding the long term effects of releasing engineered organisms into ecosystems whose basic dynamics are yet to be understood (Peritore, 1995; Lappe and Bailey 1998; Juma and Mugabe, 1996). While bioengineered food innovations are advancing rapidly, many biotechnology experts also argue that now is the time to consider its effect on medicine, industry, and agriculture in developed nations and the fragile economies of developing countries (Peritore, 1995; Lappe and Bailey 1998; Juma and Mugabe, 1996).

2.3 Opposing views on Bioengineered Food Innovations

Proponents of bioengineered food innovations believe modern agricultural biotechnology will help increase global food supply while sustaining the natural resource base (Chell, 1993; Hosain et al. 2002; Hoban 2003; and Blanchfield, 2004); however, opponents claim these new technologies have the potential of limiting access to low-income earners in developing countries (Lappe and Bailey, 1998). Hosain et al. (2002) assert that agricultural food innovations have the potential to not only meet basic human needs but to also bring a wide range of economic, environmental and health benefits through the production of food, fiber and pharmaceuticals.

Heusing and English (2004) assert that, since 1994, genetically modified (GM) crops have been planted on more than 67 million hectares (ha) in 18 countries worldwide. Heusing and English (2004) further claim that the total hectares committed to GM crops are increasing by more than 10% annually. Seven such crops currently grown include, cotton, canola, maize, papaya, potato, soybean, and squash, but most of the world's bioengineered hectarage is in cotton (7 million ha), maize (10 million ha), and soybean (33 million ha) (Heusing and English, 2004).

Woodward, Brink and Burger (1999) point out that, in Africa, there are the concomitant problems of food shortages, a burdened economy, political instability and poor environmental sustainability. These problems according to Woodward et al. (1999) have contributed to Africa lagging behind in reaping the benefits of the "Green Revolution," as well as the "Gene Revolution." These authors suggest that Africa implement strategies to increase the efficiency of food production as well as broadening their food base to address problems of nutritional deficiencies. Since pests and diseases account for about 30% yield losses, GM crops would offer an approach which developing countries cannot be excluded from (Vasil, 1998). Heusing and English (2004) claim that at present virtually all GM crops planted in both the developed and the developing world are engineered for resistance to herbicides and resistance to insect pests.

The Union of Concerned Scientists (UCS) and other opponents outline the potential risks of modern biotechnology and its effects on human health to include: new allergens in the food supply, antibiotic resistance, and production of new toxins, concentration of toxic metals, and the enhancement of the environment for toxic fungi. Potential environmental risks cited by opponents of biotechnology include possible gene transfer to wild or weedy relatives and increased weediness, change in herbicide use patterns, squandering of valuable pest susceptibility genes, poisoned wildlife, creation of new or worse viruses, and other, so far unknown harms (UCS, 1999).

2.3.1 Environmental Impact of Bioengineered Food Innovations

Wafula (1999) found that increased agricultural yields through high input chemicals are no longer sustainable in Kenya and other African countries due to high inputs costs and potentially serious environmental hazards posed by agro chemicals. While modern biotechnology might provide an alternative production technology, Wafula (1993) stresses the importance of instituting appropriate biosafety regulations in Africa. According to Wafula (1993), the risks associated with modern biotechnology are potentially high when viewed in an ecological and human health context. However several risk assessment studies conducted in most developed countries have led to the formulation of laws and regulations necessary to protect the environment and human health (Wafula, 1993). It is estimated that scientists worldwide have experimentally modified nearly 100 plant species (Wambugu, 2001). In most developing countries, including Kenya, Wambugu (2001) claims the results of modern biotechnology have been slow to reach farmers due to environmental and food safety concerns. Wambugu (2001) explains that food safety and environmental concerns have led the Kenyan government to introduce stringent biotechnology regulatory procedures.

Blanchfield's (2004) hypothesis is that modern biotechnology has the potential to improve agricultural performance (yields) and confer environmental benefits by reducing labor intensity and input costs of agricultural production. Environmental benefits of modern biotechnology outlined by Blanchfield (2004), Hosain et al. (2002), DeVries and Toenniessen (2001) include those to the soil because of "no-till" farming practices, reduced use of pesticides and herbicides, and the ability to grow crops in previously inhospitable environments (e.g., via increased ability of plants to grow in conditions of drought, high soil salinity and extremes). The ability to produce crops in these environments will improve poor countries' ability feed themselves at a reduced environmental cost. Lappe and Bailey (1998) contend that two-fifths of the world's current food production already comes from 17% of land under irrigation. Therefore, high precision agriculture ought to be enough to reduce land needs dramatically without necessarily turning to modern agricultural biotechnology. Lappe and Bailey (1998) continue to argue that, from an environmental perspective, herbicide resistance conferred to crops may carry a unique downside in the sense that toxic amounts of a given herbicide may be over sprayed on the protected crop resulting in high doses of pesticide residues in edible portions of the crop. While it may be considered an environmentally benevolent action, Lappe and Bailey (1998) contend that less tilling leads to more perennial weeds which may require more herbicides, a cycle the authors believe is the result of a 250 million pounds increase in herbicide usage in the last decade (Lappe and Bailey, 1998). According Lappe and Bailey, "the UN blames poor resource management for much of the world's food woes" (Lappe and Bailey, 1998, p. 88).

2.3.2 Modern Biotechnology and Third World Food Security

Modern biotechnology is important in the overall food production in most developing countries for the simple reason that the masses do not have enough to eat (Wambugu, 2001). The concerns of food availability and nutritional intake are much greater in lesser-developed countries (LDCs) compared to the more developed countries (e.g., United States, Europe, and Japan) (Curtis et al. 2004). According to Wambugu (2001), recent droughts in parts of Africa coupled with large disparities in crop yields between developed and developing countries call for an intervening technology. In maize, for example, the world average yield per hectare is 4 tons compared to 1.6 tons in Kenya (Wambugu, 2001). In other crops such as banana, yields are said to be declining in the face of a rapidly increasing population. It is against this background that Wambugu (2001) argues for the need to adopt modern biotechnology in developing countries in order to increase production of basic staple crops.

During the 1993 African Regional Conference for International Corporation on Safety of Biotechnology, Professor Chetsanga from the Biotechnology Research Institute in Zimbabwe mentioned that "the immediate focus of biotechnology in Africa should be the production of adequate quantities of food crops which can be sold at affordable prices." The application of biotechnology according Chetsanga (1993) should aim at this yardstick otherwise the peasant population will not benefit from the advent of modern biotechnology

Lappe and Bailey (1998) argue that, to date, very few genuine increases in productivity (yield) can be attributed to bioengineered food innovations. The new bioengineered food innovations according to Lappe and Bailey (1998) can only boast of making agricultural products more "consumer friendly." Lappe and Bailey (1998) further explain that, in fact, many of the genetically engineered product features are aesthetic inventions simply geared towards increased corporate profits and dominance but not necessarily increased world food supply, as argued by proponents. For example, changes in ripening or shipping characteristics of crop plants for example increased ripening and enhanced aroma in tomatoes, prolonged shelf life in bell peppers and increased sugar content in peas are all geared towards enhancing consumer acceptance (Lappe and Bailey, 1998). Lappe and Bailey believe that to date, bioengineered food innovations can only boast of aesthetic contributions to crops and not increased production.

In Latin America and other developing countries, the main humanitarian objectives of third world biotechnology claims to be directed towards improvement of the nutritional quality of regional staples to fight malnutrition (Goldstein, 1995). Goldstein (1995) argues that there is no such thing as a Latin American food problem, but rather a problem of hunger. Goldstein (1995) further explains that there is no relationship between food production and food security. Goldstein (1995) believes the latter is a political problem and will not be solved by technological means. In conclusion, Goldstein (1995) argues while technical changes in agriculture can increase food output or improve food quality in a given country, technical changes by themselves do not necessitate the elimination of hunger in any particular country.

Many researchers, including Lappe and Bailey (1998) and Goldstein (1995), believe that precision agriculture and a fairer distribution of food should be more than adequate to secure the world's food system. However, Hoban (2003) and Blanchfield (2004) argue that "world hunger" is a complex phenomenon that involves a combination of both quantity and quality attributes of food. For that reason, the authors argue that production technologies must focus on ensuring the necessary micronutrients required for keeping a vast number of people alive and healthy. For instance, Blanchfield (2004) explains that research underway at the University of Arkansas and Tulane University to remove allergens or toxic components in peanuts and prawns, in order to produce GM non allergenic products, are steps towards ensuring world food security. Similarly, research efforts under way in Japan to produce bioengineered non-allergenic rice and also Ingo Potrykus's EU research project (partly funded by the Rockefeller Foundation) with the aim of increasing "Vitamin A" content in rice are all geared towards increasing not only quantity but also the nutritional components of rice (Blanchfield, 2004). It has been found that rice rich in "Vitamin A" has the potential of preventing blindness among children in Southeast Asia and possibly other developing countries (Blanchfield, 2004).

According to Blanchfield (2004), the announcement in September 2003 by Edgar Cahoon and his team at the Donald Danforth Plant Science Center in Missouri that by inserting a gene extracted from barley into a common type of field corn, they have created a strain that grows with six times the usual amount of vitamin E, a powerful antioxidant, signifies prospects for improved processing characteristics. The potential benefits of Cahoon's research, according to Blanchfield (2004), are improved post harvest characteristics in corn that will result in reduced waste and thus enhanced quantity and quality attributes. In effect, this biotechnology intervention may translate into lower food costs to the consumer (Blanchfield, 2004). In Africa and most of Latin America where banana and plantain constitute a substantial portion of the staple diet, Blanchfield (2004) argues that the development of fungal and disease resistant GM varieties of the Cavendish dessert banana has the potential of increasing productivity and securing the food system in these parts of the world. Current plantain and banana varieties in Africa, South America and Asia are prone to endemic diseases that have adverse consequences for long run species loss and food security (Blanchfield, 2004). For example, farmers in Kenya and most of Africa currently lose an estimated 40% of their maize crops to insect pests (maize stem borer) (Wambugu, 2001). In addition, subsistence growers of banana in Kenya often suffer 100% loss of their harvest to the black sigatoka. Wambugu and others contend that a GM variety resistant to this disease could save the harvests.

Lappe and Bailey (1998) argue that even though insect and drought resistant technologies hold great promises for food production, these particular objectives are simply not aggressively pursued or have currently been side lined by most biotechnology firms. For example, in crops such as cassava and sweet potatoes, only 7% of farmers in Kenya have access to improved planting materials (Wambugu, 2001). It is estimated that a combination of modern biotechnologies such as tissue culture and effective distribution could raise the number to well over 50% (Wambugu, 2001).

Both staunch proponents and opponents of modern biotechnology appear to agree that developing staple crops such as corn, cassava, banana and wheat lines to be insect and drought tolerant holds potential advantages for agriculture, and, if successful, promise much higher yields under a variety of conditions (Lappe and Bailey, 1998; and Blanchfield, 2004).

2.3.3 Modern Biotechnology and the Third World

Osei (2003) asserts that many organizations including the Food and Agricultural Organization of the United Nations believe modern biotechnology will not necessarily contribute to world food security. Also, some biotechnology researchers believe the biotechnology industry has the potential to deepen economic inequalities inherent in the global food trading system by reducing access and affordability to low income consumers (Osei, 2003; Lappe and Bailey, 1998). In its current application, it is argued that bioengineered food innovations target the needs of developed country farmers and consumers and ignore those of developing countries (Mugabe, 2004; Lappe and Bailey, 1998). The reason for this assertion is the devotion of modern biotechnologies to herbicide tolerance in crops such as soybeans, cotton and maize rather than addressing issues such as drought and virus tolerance of tropical plant species (Mugabe, 2004).

Even though many researchers agree that genetically modified crops are mostly associated with high-input industrial economies, Heusing and English (2004) claim farmers in the developing countries, particularly Asia, are rapidly adopting this new technology. Heusing and English (2004) assert that nearly one third of all GM crops are now grown in developing nations. Compared to the industrialized world, Heusing and English (2004) believe that developing nations have more to gain from genetically modified crops because yield constraints such as insects are often far more crippling in poorer countries than in the industrial world. Heusing and English (2004) add that in those places where high percentages of the population are farmers and crop productivity is low, the ramifications of crop pest, weed, and disease control are profound. Whether modern biotechnology contributes significantly to food security in developing countries or is compatible with sustainable agriculture, and if so, in what ways, provokes much controversy among researchers and sustainable agriculture advocates (Gold, 1999).

Comparing the production techniques of modern biotechnology to the those of the Green Revolution, Lappe and Bailey (1998) argue that, unlike the Green Revolution that required judicious conventional breeding techniques to transfer groups of closely linked desirable genes into crops, the key challenges posed to genetically engineered crops/modern biotechnology is whether or not similar advances associated with the Green Revolution could prove attainable through the systematic transfer of single genes as is the case in modern biotechnology (Lappe and Bailey, 1998, p.15). Although many research institutions and international organizations tout bioengineered crops as promising a second Green Revolution, Lappe and Bailey (1998) believe those who control the technology appear less interested in meeting long term world food security. Rather the focus of most biotechnology corporations, according to Lappe and Bailey (1998), is on obtaining short term solutions.

2.3.4 Third World and Bacillus *thuringiensis* (Bt) Technology

It is not certain how socio-cultural and economic characteristics of producers in developing countries will impact acceptability and applications of the Bt technology. Although Bt technology may seem benevolent (in terms of protecting the environment through reduced agricultural intensity and pesticide application), a laboratory study by researchers in Iowa State and Cornell University found possible links between pollen from Bt corn carried by wind onto milkweed, and a potential threat to Monarch butterfly larvae (Sanchez, 2002).

Lappe and Bailey (1998) summarize their concerns about Bt technology by stating that historically, technological inventions are riddled with examples of premature commercialization and often belated testing and evaluation. According to Lappe and Bailey (1998), many potential hidden pitfalls plague the intense race to establish corporate dominance in any new field. For instance, the development of silicon breast implants, the Dalkon shield and the Bjork-Shelley heart valve according to these authors all proceeded with minimal or no long-term safety testing. Lappe and Bailey (1998) caution that researchers pushing for Bt technology may be charting a similar course in their programming of crops to express a bacteria toxin from species of Bacillus thuringiensis. This bacterium believed to occupy a relatively small niche among soil microorganisms has the potential to proliferate its genes in plants and most likely create evolutionary problems for humans (Lappe and Bailey, 1998).

A study by Aerni (2002) to determine public attitudes towards modern agricultural biotechnologies revealed that politicians in South Africa generally expect agricultural biotechnology to address agricultural nutritional problems. Aerni (2002) also found that, "while most respondents do not consider genetically modified food as a health risk for consumers and expect agricultural biotechnology to make contributions to future food security in Africa, they are concerned about sustainability of Bt crops and the proper implementation of biosafety regulations. Moreover, most respondents doubt that such crops would be appropriate for resource-poor-farmers" (Aerni, 2002, p. 4).

Juma and Mugabe (1996) postulates that the anticipated impact of biotechnology is largely based on the experiences of the Green Revolution. Juma and Mugabe (1996) also believes that, unlike the Green Revolution, the emerging techniques associated with agricultural biotechnologies are more suitable for diverse and decentralized production. When issues of equity are considered, however, Juma and Mugabe (1996) contends that what matters is not only technical characteristics, but also forms of social organization. Because it remains partly unclear how bioengineered food innovations such as Bt technologies may affect agricultural productivity in Africa, Juma and Mugabe (1996) suggests that policy research into emerging issues should first and foremost anticipate potential contributions and plan the supply of relevant skills. Secondly, it is important to formulate long-term policies which will not only shape the development and applications of these technologies but also address related forms of social reorganization (Juma and Mugabe, 1996).

2.4 Perceptions of Biotechnology in Developed and Developing Countries

Numerous studies on global perceptions of bioengineered food innovations indicate that indigenous perceptions differ considerably from one country and continent to the other. For instance, a study by Horban (2003), "Public Perceptions and Understanding of Agricultural Biotechnology," revealed that consumers from different parts of the world have very different perceptions and understandings of agricultural biotechnology. In essence, perceptions of bioengineered food innovations are more or less entrenched in the socio-cultural, economic, religious and psychological background of citizens of a particular country.

Hosain et al. (2002) found that public perceptions of biotechnology may have multiple dimensions and are likely to be influenced by multiple forces, preferences, and events. Furthermore, positive benefits resulting from improved nutrition and environmental benefits such as those resulting from minimal fertilizer and pesticide use are likely to encourage public acceptance of biotechnology (Hosain et al. 2002). In spite of positive attributes claimed to be associated with modern biotechnology, research findings by Phillip Aerni, who studied "public attitudes towards agricultural biotechnology in South Africa, Mexico and the Philippines," indicate that most people in developing countries are skeptical about the potential benefits of bioengineered food innovations (Aerni, 2001). Aerni's (2001) study on public perceptions of biotechnology in developing countries reveals that drought is by far the most important agricultural problem among the public in South Africa, Mexico and the Philippines.

Much as it is easy to assume developing countries will perceive bioengineered food innovations positively due to acclaimed potential to increase productivity, relieve pressure on natural resources and stimulate economic growth, recent studies have proven that there is some degree of resentment towards this technology (Aerni, 2001). Aerni's (2002) study on stakeholder perceptions in the Philippines and Mexico confirmed that factual knowledge, world view, stakeholder interest and public perceptions seem to shape political decisions on adoption of agricultural food innovations in developing countries.

While positive attributes of modern agricultural biotechnology are likely to generate positive public perceptions, Hosain et al. (2002) assert that perceived risks to humans and the environment might influence public perceptions and acceptance of bioengineered food innovations. It is a widely accepted view that socio-economic, political, cultural and moral/ethical attributes greatly affect public perceptions and acceptance of bioengineered food innovations. Hosain et al. (2002) stated that, besides perceived risks, factors such as public confidence in government, the scientific community, and biotechnology companies also influence public perceptions and attitudes towards an emerging technology.

2.5 Information Sources and Perceptions of Biotechnology

Chetsanga (1993) asserts that one of the most serious constraints impeding Africa's development is lack of information on virtually all spheres of human activity and development. Chetsanga (1993) further noted that in Africa it is particularly difficult to get data on most issues, including biotechnology. While provision and availability of relevant information are likely to influence attitudes and perceptions, Kamaldeen and Powell (2000) found that the social context in which information is received is just as likely to determine public perceptions as the content of the information itself. The nature of the information exchange relationship between a pair of individuals determines the conditions under which a source will or will not transmit the innovation to the receiver and the effect of such a transfer (Rogers, 2003). When dealing with issues pertaining to bioengineered food innovations, Aerni (2002) believes that it is difficult for most people to count on their own knowledge and experiences. For this reason, Rogers (2003) believes interpersonal channels are more effective in persuading an individual to accept a new idea, especially if the interpersonal channels link two or more individuals with similar socioeconomics status, education, or other important attributes. Interpersonal channels involve face-to-face exchange between two or more individuals. While interpersonal channels may prove most effective in winning the trust of potential adopters of biotechnology, Rogers (2003) explains that mass media channels are usually the most rapid and efficient means of informing a large audience of potential adopters about the existence of an innovation and also to create awareness-knowledge. Examples of mass media channels may include radio, television, newspaper, etc., which enable one or a few individuals to reach an audience of many. Aerni (2002) adds to Rogers' viewpoint by asserting that it is commonplace for people to rely on information distributed either through the mass media, by representatives from industry, government, public interest groups or academia. Information provided by the media, confidence in governmental safeguards, cultural and religious preferences significantly influence public perceptions of bioengineered food innovations (Hoban, 1999).

2.5.1 Trust in Information Sources and Perceptions Biotechnology

Credibility and trust in information sources and government regulators are listed by Kamaldeen and Powell (2000) as likely factors that significantly impact public perceptions of bioengineered food innovations. In explaining perceptions and attitudes leading to public opposition of modern agricultural biotechnology in South Africa, Mexico and the Philippines, Aerni (2002) contends that opposition to modern biotechnology is more complex than is viewed by most natural scientists. At the fundamental level, all risk according to Wolf and Peterson (2000) is perceived no matter the gravity of the risk. Wolf and Peterson (2000) further claim that lack of knowledge, coupled with limited public appreciation of technology, causes risk perception to be skewed by emotive attributes of the risk. According to Aerni (2002), most natural scientists believe information provided through traditional educational systems in the area of science is sufficient to overcome resistance to modern biotechnologies and warrant acceptance of the technology. Based on socially communicated value, social status and professional affiliations, a person regards particular sources of information to be more trustworthy than others" (Aerni, 2002, p.14). Rogers (2003) used results of diffusion investigations to show that most individuals do not evaluate an innovation on the basis of scientific studies of its consequences or risks. While objective evaluations of scientific studies are not entirely irrelevant, especially to the very first individual who adopts, Rogers (2003) asserts that most people depend mainly upon a subjective evaluation of an innovation that is conveyed to them from other individuals like themselves who have already adopted the innovation. The dependence on the experience of near peers suggests that the heart of the diffusion process consists of the modeling and imitation by potential adopters of their network partners who have previously adopted (Roger, 2003).

Dittus and Hillers (1993) found that in the US and UK, perceptions of trust in government regulation and industry, regarding either pesticides or products of agricultural biotechnology, are the strongest predictors of public support. To establish a strong and sustainable information exchange relationship, Rogers (2003) suggests that the change agent (government regulators, researchers, etc.) must be perceived as credible, competent, and trustworthy because the public usually accept the agents before accepting an innovation that is being promoted. Wolf and Peterson (2000) assert that knowledge and trust are major attributes of risk perceptions that will determine acceptance of agricultural biotechnology. Risk researchers are thus increasingly concluding that public opposition to higher technologies is a matter of trust in institutions and world view rather than a lack of understanding of science (Aerni, 2002, p. 9). According to Kamaldeen and Powell (2000), people either trust that bioengineered food innovations, including pesticides, are adequately regulated or they do not. While those with low trust have the highest concerns about the possible risks, Kamaldeen and Powell (2000) believe that those with the highest trust perceive greater benefits from both products. Van Ravenswaay (1995) concluded that trust in government and industry may be a more important influence on risk perception than the inherent safety or danger of a particular agrochemical or biotechnological innovation.

Juma and Mugabe (1996) expresses grave concern about a growing relationship currently existent between corporations involved in bioengineered food innovations and universities and the potential impact of these relationships on global public perceptions. According to Juma and Mugabe(1996), a recent study of public perceptions of biotechnology in the US indicates that 19% of the people will definitely believe university statements about the risks of bioengineered food innovations. However, only 4% believe the actual company making the product. Such perceptions, according to Juma and Mugabe (1996), do not take into account the fact that university scientists have become increasingly linked to industry so that it may be fairly accurate to predict that their views and perceptions on risk converge with those of industry. Aerni (2002) found that science is trusted as long as it is generally perceived to be a disinterested authority that seeks truth for the sake of truth. It thus follows that if science is perceived as detached from the common interest and associated with private interest, it runs the risk of losing public trust, even if excellent research results are produced (Aerni, 2002, p. 9).

2.6 Summary

This chapter draws on four areas of literature: 1) historical foundations of bioengineered food innovations, 2) opposing views on bioengineered food innovations 3) perceptions of bioengineered food innovations in developed and developing countries, and 4) information sources used in establishing perceptions of bioengineered food innovations in developed and developing countries. Chapter three presents the methodology used in conducting the study.

CHAPTER THREE

METHODOLOGY

3.1 Chapter Preview

The previous chapters outlined the scope of this study, the relationship of the investigation to existing research and the conceptual framework (see page 39) used in the study. This chapter explores the survey procedure and the methodology used in collecting the data used in the study. The following specific topics are discussed in this chapter: 1) research design; 2) population and sample; 3) data collection; 4) research questions; 5) instrument validity and reliability; 6) instrumentation; 7) data analysis; and 8) limitations of the study.

3.2 Research Design

This study uses a descriptive methodology, correlation design, and probit and logit models to measure students' perceptions of bioengineered food innovations. The self-selected population for this census study is the 1st through 4th year undergraduate agricultural science students from Ghana's Kwame Nkrumah University of Science and Technology (KNUST).

3.3 Population

The study population was composed of N = 601 agricultural science students from Ghana's Kwame Nkrumah University of Science and Technology (KNUST). The entire population was selected for the study. Three hundred and one (n = 301) questionnaires were completed. Sixty nine (69) respondents were in their 1st year, 60 were in the 2nd year, 96 were 3rd year and 76 were 4th year students. More than three-quarters (77%) of respondents were male, and less than one-quarter (23%) were female.

3.4 Instrument Design

3.4.1 Design

The instrument included ten constructs, with a total of 76 questions measuring students' self perceived knowledge, and general perceptions of bioengineered food innovation issues as reported by government and non-governmental or not-for-profit agencies, mass media, biotechnology industries and academic institutions.

Gaskell et al. (1998) argue in favor of using the term perception in this type of study because they claim most obvious alternatives appear to be unsatisfactory. For example, these authors believe possible alternatives, such as "opinion," have the connotations of being associated with political opinion polling while attitude has connotations of exclusive interest in personal disposition (Gaskell et al. 998). Similarly, it is argued by Gaskell et al. (1998) that the term "acceptance" has connotations associated with the public relations industry. The authors argue that "at best, acceptance is a euphemism for a mixed bag of people's enthusiasm, discontent, worries, imaginations, fears, anticipations and resistance" (Gaskell et al. 1998, p. 10). The term perception is thus endorsed due to its alleged neutrality (Gaskell et al. 1998).

A four-point Likert-scale ranging from one (1), implying an extreme end of the scale ("very positive") through four (4) another extreme end ("very negative") was provided throughout the questionnaire. The four-point scale gave respondents an opportunity to rate the degree to which each variable influences their perceptions regarding bioengineered food innovation issues.

Although the instrument does not include a knowledge section, respondents were asked to rate their level of knowledge regarding bioengineered food innovations based on information sources used in acquiring knowledge of the subject, experiences and previous course work.

For each section of the four-point Likert scale provided, a "don't know" option was intentionally omitted as a response option. According to StatPac (2004), questions that exclude the "don't know" option produce a greater volume of accurate data. Furthermore, StatPac (2004) claims there is generally no difference in response rate depending on the inclusion or exclusion of the "don't know" option. StatPack (2004) further suggests that while many researchers advocate including a "don't know" response category when there is a possibility that the respondents may not know the answer to a question, it is more advantageous to use this option for factual questions and not for attitude/perception questions such as those presented in this study.

3.5.2 Content

The instrument included a brief description on the front cover with directions for completion. Items included in the questionnaire were modified slightly from a similar survey questionnaire used by Texas A & M researchers Wingenbach, Rutherford and Dansford (2004). Wingenbach et al.'s research on "Selected College Students' Perceptions and Attitudes of Biotechnology Issues Reported by the Mass Media" was used to validate and establish reliability of the instrument.

All questions were carefully worded to reflect objectivity in the research process, and also to avoid biasing respondents. A four-point Likert scale was provided throughout the survey to help respondents rate their responses. The ten sections of the instrument used to quantify students' responses embraced items on the following issues: 1) optimism or pessimism about biotechnology in the context of selected activities and issues; 2) degree to which selected sources are used to gain information on bioengineered food innovations; 3) frequency with which selected sources report information on biotechnology; 4) extent to which selected experiences (socio-cultural and economic) are used to establish perceptions about bioengineered food innovations; 5) future expectations about the contributions of bioengineered food innovations to society in terms of ensuring safe food systems and protecting the environment; 6) level of importance placed on investigating claims made about biotechnology by different organizations, individuals, and research institutions; 7) importance to respondent of investigating statements and claims about biotechnology made by different groups and individuals; 8) confidence in statements about bioengineered food innovations made by different institutions, including government; 9) confidence in government legislation to regulate biotechnology; and 10) demographic characteristics.

All questions were closed and ordinal. By definition, an ordinal scale represents "an order that can be imposed on the values of a variable in a subject, where the order ranges from the highest value (such as "very interested") to the lowest value (such as "not at all interested") (OERL, 2004).

The demographic questions consisted of gender, age and education. Self perceived knowledge under demographic item 75 had a scale similar to that of sections 6 and 8. The rating scales used in the instrument corresponding to each of the sections listed above including a modified version of the four point-scale used in data analysis is presented in Table 1.

Table 1: *Regular and Modified Rating Scales Used in Survey Instrument*

Sections of the Instrument	Rating Scale			
	1	2	3	4
	1-1.75	1.75-2.5	2.5-3.25	3.25-4
1	Very Negative	Somewhat Negative	Somewhat Positive	Very Positive
2, 3 & 4	Never	Occasionally	Often	Always
5 & 7	Not At All Important	Fairly Important	Important	Very Important
9	Very Low	Low	High	Very High
6, 8 & 10,75	Strongly Disagree	Disagree	Agree	Strongly Agree

3.5.3 Validity

Five subject matter specialists (two from KNUST, one from Texas A&M and two from MSU) reviewed the instrument for face and content validity. Content validity is the degree to which a test or instrument content is tied to the instructional domain it intends to measure (OERL, 2004). According to StatPac (2004), a question's wording can be extremely important. In fact, many investigators have confirmed that slight changes in the way questions are worded can have a significant impact on how people respond, to the extent that minor changes in question wording can produce more than a 25 percent difference in people's opinions StatPac (2004).

3.5.4 Reliability

Variables derived from test instruments are declared reliable only when they produce replicable and stable responses over repeated administration under which they are likely to be used (Santos, 1999). Wingenbach et al. (2004) used the original version of the survey instrument in a similar study conducted in 11 land-grant universities from ten states in the United States. In the modified survey instrument used in this study, an additional section was added to account for country specific issues such as confidence in the Ghanaian government's role in addressing modern biotechnology issues (i.e. patents, biosafety, overall research support for biotechnology, etc.). When the instrument reliability was recalculated using SPSS, the Cronbach's alpha for 183 cases and 77 items was 0.8880. According to the UCLA Academic Technology Services (2005), reliability coefficients of 0.80 or higher are considered acceptable in most social science applications.

3.6 Data Collection

Prior to data collection, a formal electronic application was submitted to the Michigan State University Committee on Research Involving Human Subjects (UCRIHS) (Appendix A). Upon UCHRIS approval of the research on May 5, 2004, the questionnaire was electronically sent to Ghana and printed. The cost of printing and mailing back to the United States was paid by the researcher through Western Union money transfer. Prior to printing the final instrument, a series of emails and telephone correspondence was initiated to coordinate the final stage of instrument design and data collection protocol. A letter requesting approval of the study (Appendix B) and the sample questionnaire (Appendix C) were sent to the Dean of Agriculture, KNUST via fax, and a hard copy was sent via post mail. Upon the Dean's approval, a letter of encouragement from the dean (Appendix D) seeking students' cooperation with the study was attached to each questionnaire and distributed to all classes. Data collection took approximately two weeks, from May 12-27, 2004.

The instruments were printed in four different colors (white, blue, cream, and yellow), with each color representing a particular year group. Instrument coloring was done for easy tracking and grouping of each year group. Coloring also enhanced visual attractiveness of the instruments.

3.7 Data Analysis Procedure

Statistical Package for Social Scientists (SPSS) version 11.5 and STATA 8.0 were used to analyze the data. All questionnaires received were numbered and grouped into each respective year group. After all the data were entered, the researcher cross checked to be sure all data were properly entered. Descriptive statistics (means, standard deviations, chi-squares and Pearson's p-value) were obtained using SPSS.

For the purpose of performing cross tabulations of self perceived knowledge aligned with all variables in the first nine sections of the instrument, self perceived knowledge treated as the dependent variable was grouped into two categories: (1) respondents who perceived their knowledge of bioengineered food innovations as low (Very Low + Low) and (2) respondents who perceived their knowledge of bioengineered food innovations as high (High + Very High). All self perceived "Low" knowledge responses were assigned a code of (0), and all "High" self perceived knowledge responses were assigned a cod of (1). The knowledge variable was coded to allow for cross tabulations with other variables to determine whether these variables had any significant influence on a respondents' self perceived knowledge of the subject.

A Probit and Logit model was generated using STATA 8.0 to determine which information sources significantly impacted respondents' self perceived knowledge of bioengineered food innovations. Dummy variables similar to those created for the cross tabulations were created for variables in sections two, three and four of the questionnaire (Appendix C). Any information source that was "Never" used to establish knowledge about bioengineered food innovations was coded 0, and all other sources ("Occasionally," "Often" or "Always") used were assigned a code = 1. Both Probit and Logit models were used in this study to: 1) confirm sources of information that were significant (in influencing self perceived knowledge of bioengineered food innovations) from the cross tabulations; 2) to predict respondents' level of knowledge based on information sources used in seeking knowledge of bioengineered food innovations; and 3) to calculate the probability that a respondent will rate his/her self perceived knowledge as high when a particular information source in used in isolation in seeking knowledge about bioengineered food innovations.

After generating the Probit model, the STATA function "mfx compute" was used to generate the probability that each independent variable will contribute to a respondent's high self perceived knowledge, all else being equal. Also, the STATA function "lstat" was used to predict whether a respondent's self perceived knowledge was low or high, with knowledge treated as the dependent variable and others treated as independent variables. This procedure was repeated for the Logit model.

3.8 Summary

Research methods for this study of KNUST agricultural science students' perceptions of bioengineered food innovations have been described. The study population consisted of 601 agricultural science students from the Kwame Nkrumah's University of Science and Technology, Ghana. Three hundred and one (301) surveys were received, a response rate of 50%. Statistics used to analyze the data include: frequencies, percentages, means, standard deviations, cross tabulations, chi-squares, and Probit and Logit models. Chapter four will present the research findings of Ghana KNUST students' perceptions of bioengineered food innovations.

CHAPTER FOUR

FINDINGS

4.1 Chapter Preview

The previous chapters of this thesis outlined the scope of the study (Chapter 1), the relationship of the investigation to existing research and the conceptual framework used in the study (Chapter 2), and a research design and methodology for the study (Chapter 3). This chapter reports the results of the study. The data presented in this chapter fulfill the following research objectives:

1. To describe the demographic composition of agricultural science students in KNUST.
2. To describe current perceptions of bioengineered food innovations amongst KNUST agricultural science students.
3. To determine KNUST students' perceptions regarding government efforts in instituting appropriate frameworks aimed at facilitating adoption and implementation of bioengineered food innovations in Ghana.
4. To determine sources of information used by KNUST students in establishing their knowledge and perceptions regarding bioengineered food innovations.
5. To describe how different sources of information influence respondents' self perceived knowledge of bioengineered food innovations.

Analysis of the survey data was completed using the Statistical Package for the Social Sciences (SPSS) version 11.5 and STATA (Statistical Data Analysis) version 8.0. The findings presented are correlated with all five objectives used to guide the study.

4.2 OBJECTIVE 1: To Describe the Demographic Composition of Agricultural Science Students in KNUST.

Description of Demographic Composition of KNUST Agricultural Science Students

Demographic data collected from respondents were: age, sex and current year in college and specific discipline studied at the time of the study.

Respondents were 22.70% female (n = 64) and 77.30% male (n = 218). Of all respondents, 3.08% (n = 9) were ages 19 years or less, 79.12% (n = 231) were between ages 20 and 24 and 17.81% (n = 52) were 25 and above. With regard to year in college, first year students represented 22.45% (n = 66) of respondents, second year 19.73% (n = 58), third year 32.31% (n = 95) and fourth/final year 25.51% (n = 75). Table 2 provides a summary of the various disciplines and the year groups within the KNUST agricultural science program .

Table 2: *Descriptive Statistics of Demographics*

Variable	*n*	Percentage (%)
Disciplines (N = 301)		
Animal Science	16	5.32
Crop Science	32	10.63
Agric Economics	15	4.98
Horticulture	8	2.66
Mechanization	5	1.66
General Agric	225	74.75
Year Group (N = 294)		
1st Year	66	22.45
2nd Year	58	19.73
3rd Year	95	32.31
4th Year	75	25.51

4.3 OBJECTIVE 2: To Describe Current Perceptions of Bioengineered Food Innovations Amongst KNUST Agricultural Science Students

Description of Current Perceptions of Bioengineered Food Innovations among KNUST Agricultural Science Students

4.3.1 Effect of Biotechnology on Selected Activities

Respondents were asked to rate, based on a four point Likert-scale, the extent to which they believe bioengineered food innovations would affect commercial farming, the environment, fish and wildlife, food production, small scale farming, world hunger and personal health. From Table 1 the rating scale is as follows: 1-1.75 = *very negative*, 1.75-2.5 = *somewhat negative*, 2.5-3.25 = *somewhat positive* and 3.25-4 = *very positive*. Table 3 provides summary statistics of percentage responses, means and standard deviations.

Table 3: *Descriptive Statistics of Impact of Bioengineered Food Innovations*

		Percent					
Variable/Scale N = 301	*n*	Very Negative	Somewhat Negative	Somewhat Positive	Very Positive	*M*	*SD*
Food Production	293	.7	3.8	31.4	64.2	3.59	.60
Commercial Farming	296	1.7	3.7	29.7	64.9	3.58	.65
World Hunger	292	1.4	6.5	29.1	63.0	3.54	.68
The Environment	293	3.8	19.1	42.3	34.8	3.08	.83
Small Scale Farms	283	5.7	18.0	44.2	32.2	3.03	.85
Your Health	286	5.9	20.6	41.3	32.2	3.00	.88
Fish and Wildlife	289	6.2	17.3	52.6	23.9	2.94	.81

Summary statistics outlined in Table 3 indicate that 90% to 95% of all respondents recorded a mean between 3.50 to 3.60 and SD between 0.6 to 0.7 with respect to food production, commercial farming and world hunger. This implies that a greater majority of respondents believe bioengineered food innovations will have a somewhat positive to very positive effect on food production, commercial farming and world hunger. On the other hand, less than 10% of all respondents believe bioengineered food innovations would have a somewhat negative to very negative effect on food production, commercial farming and world hunger.

An average of 74% of respondents said biotechnology would have a somewhat positive impact on the environment, small scale farms, personal health, fish and wildlife. Also, respondents believe biotechnology will have a more positive effect on food production than commercial farming, world hunger, environment, small scale farms, personal health and fish & wildlife, in that order. Relatively small standard deviations associated with food production, commercial farming and world hunger indicate respondents have concurring views on these particular issues.

4.3.2 Importance of Biotechnology Research Regarding Selected Activities

Table 4 represents the level of importance respondents believe should be placed on bioengineered food innovations research regarding seven selected issues. Following the rating scale on Table 1, the scale in Table 4 is modified as follows: 1-1.75 = Not At All Important, 1.75-2.5 = Fairly Important, 2.5-3.25 = Important and 3.25-4 = Very Important. Table 4 thus provides, in decreasing order of rating, summary statistics of percentage responses, means and standard deviations.

Table 4: *Descriptive Statistics of the Importance of Bioengineered Food Innovations Research*

Variable/Scale N = 301	*n*	Percent Not At All Important	Fairly Important	Important	Very Important	*M*	*SD*
Safer Food	295	1.36	5.76	18.98	73.90	3.65	0.65
Benefits To The Environment	294	1.02	10.88	29.59	58.50	3.46	0.73
Control Of Released Genes	292	1.71	10.27	30.48	57.53	3.44	0.75
Added Nutritional Value To Food	296	1.69	10.14	31.08	57.09	3.44	0.74
Reduction Of Pesticides	295	2.03	12.20	30.85	54.92	3.39	0.78
Risk Compared To Pesticides	293	4.78	13.99	32.42	48.81	3.25	0.87
Harming The Environment	292	13.36	11.99	16.78	57.88	3.19	1.10

The findings from Table 4 indicate that approximately 85% to 95% of all respondents recorded means ranging from 3.39 to 3.65 with SD 0.65 to 0.78 on "Safer Food," "Benefit to the Environment" and "Control of Released Genes into the Environment." This implies 85% to 95% of all respondents believe it is either "Important" or "Very Important" that biotechnology research focus on "Safer Food," "Benefit To the Environment," "Control Of Released Genes Into The Environment," "Added Nutritional Value To Food" and "Reduction Of Pesticides." On the other hand, less than 15% of respondents believe bioengineered food innovations research regarding the above issues is "Not At All Important" or just "Fairly Important."

Approximately 75% to 80% of respondents believe it is either 'Important" or "Very Important" that bioengineered food innovations research focus on "Risk Compared To Pesticides" and "Harming The Environment." Roughly 15% to 20% of respondents think it is either not "Important" or just "Fairly Important" that bioengineered food innovations research focus on "Risk Compared to Pesticides" and "Harming the Environment."

In order of decreasing importance, respondents believe bioengineered food innovations research should focus first and foremost on "Safer Food," followed by "Benefit To the Environment," "Control Of Released Genes Into The Environment," "Added Nutritional Value To Food," "Reduction Of Pesticides," and "Risk Compared To Pesticides" and least on "Harming The Environment." The relatively high standard deviations (0.87 and1.10) and varying means associated with "Risk Compared To Pesticides" and "Harming The Environment" indicate that respondents had very divergent views on these two issues.

4.3.3 Confidence in Statements Made about Bioengineered Food Innovations

Respondents in Table 5 were asked how much confidence they placed in statements about bioengineered food innovations made by spokespersons from selected organizations, groups and individuals (Table 5). A four point Likert-Scale of the form: 1-1.75 = Very Low, 1.75-2.5 = Low, 2.5-3.25 = High and 3.25 - 4 = Very High was used to rate respondent confidence levels. Table 5 below presents summary statistics of results in order of decreasing level of confidence in statements about biotechnology made by different individuals, groups and organization spokespersons.

Table 5: *Descriptive Statistics of Level of Confidence in Statements Made by Different Groups about Biotechnology Research*

Variable/Scale N = 301	n	Percent: Very Low	Percent: Low	Percent: High	Percent: Very High	*M*	*SD*
Researchers	295	2.03	7.46	28.47	62.03	3.51	0.72
Health Professionals	293	3.41	11.60	41.98	43.00	3.25	0.79
Biotechnology Companies	292	7.19	19.18	46.58	27.05	2.93	0.87
Food Companies	294	6.46	28.91	46.60	18.03	2.76	0.82
Extension Specialists	292	5.14	30.48	50.68	13.70	2.73	0.76
Non-Governmental Organizations	292	6.16	31.51	47.95	14.38	2.71	0.79
Government Agencies	290	6.55	34.14	43.79	15.52	2.68	0.81
Farm Groups	291	9.62	41.24	41.24	7.90	2.47	0.78
Activist Groups	288	19.10	35.42	36.46	9.03	2.35	0.89
Celebrities/Popular Stars	292	35.27	34.93	25.00	4.79	1.99	0.89

Approximately 90% (mean = 3.51, SD = 0.72) of respondents said they have "High" to "Very High" confidence in statements made by "Researchers" regarding bioengineered food innovations. Less that 10% said their confidence level was "Very Low" to "Low."

Approximately 65% to 85% (mean = 2.73 to 3.25 with SD = 0.76 to 0.87) of the respondents said they have "High" to "Very High" confidence in statements about bioengineered food innovations made by Health Professionals," spokesmen from

"Biotechnology Companies," "Food Companies" and "Extension Specialists" while, conversely, about 35% to 15% of respondents say their confidence was "Low" to "Very Low."

With respect to "Non-Governmental Organizations," "Government Agencies" and "Farm Groups," approximately 50% to 60% (mean = 2.47 to 2.71 and SD = 0.78 to 0.81) of the respondents said they had "High" to "Very High" confidence in statements regarding bioengineered food innovations made by spokesmen from these groups. Conversely, 40% to 50% said they had "Low" to "Very Low" confidence in statements made by the spokesmen from the same groups.

Nearly 30% (mean = 2.35, SD = 0.89) of all respondents said they had "High" to "Very High" confidence in statements about bioengineered food innovations made by "Celebrities/Popular Stars." On the other hand, almost 70% said their confidence was "Low" to "Very Low" when it comes to statements about bioengineered food innovations made by "Celebrities/Popular Stars."

On the whole, a majority of respondents said they had more confidence in statements about bioengineered food innovations made by researchers than by any other group or organization. Respondents' confidence was lowest when it came to statements about bioengineered food innovations made by celebrities/popular stars. Using the adjusted Likert-scale: 1-1.75 = Very Low, 1.75-2.5 = Low, 2.5-3.25 = High and 3.25-4 = Very High, it may be concluded that respondents had highly concurrent ("Very High") views with respect to statements made by researchers and very different views ranging from "Low" to "Very High" with respect to statements made by spokesmen from any other organization.

4.3.4 Importance of Investigating Claims made about Bioengineered Food Innovations

Respondents were asked to rate how important it is for them as future agricultural industry professionals to investigate claims about bioengineered food innovations made by selected groups, individuals and organizations.

Table 6: *Descriptive Statistics of Level of Importance Placed on Investigating Statements Made by Different Groups Regarding Biotechnology*

		Percent					
Variable/Scale N = 301	n	Not At All Important	Fairly Important	Important	Very Important	*M*	*SD*
Researchers	293	2.73	9.22	23.21	64.85	3.50	0.77
Health Professionals	293	3.07	9.22	32.76	54.95	3.40	0.78
Biotechnology Companies	291	2.41	12.37	33.68	51.55	3.34	0.79
Food Companies	288	1.74	15.28	38.54	44.44	3.26	0.78
Extension Specialists	291	2.06	17.87	43.99	36.08	3.14	0.78
Farm groups	288	4.17	18.06	42.71	35.07	3.09	0.83
Government Agencies	292	3.77	21.92	39.73	34.59	3.05	0.85
Non-Governmental Organizations	293	2.05	23.89	41.64	32.42	3.04	0.80
Activist Groups	291	6.53	24.40	31.27	37.80	3.00	0.94
Celebrities/Popular Stars	292	21.92	30.14	24.32	23.63	2.50	1.08

Table 6 above shows how a four-point Likert scale of the form 1 = Not At All Important, 2 = Fairly Important, 3 = Important, 4 = Very Important, was used to obtain the above results. Nearly 80% to 90% (mean = 3.14 to 3.50, SD = 0.77 to 0.79) of all respondents contend that it is "Important" to "Very Important" that statements about bioengineered food innovations made by "Researchers," "Health Professionals," "Biotechnology Companies," "Food Companies" and "Extension Specialists" be thoroughly investigated.

Approximately 70% to 79% (mean = 3.0 to 3.09, SD = 0.80 to 0.94) of the respondents contend that it is "Important" to "Very Important" that statements about bioengineered food innovations made by "Farm Groups," "Government Agencies," "Non-Governmental Agencies" and "Activist Groups" be thoroughly investigated.

Less than 50% (mean = 2.50, SD = 1.08) of all respondents said that statements about bioengineered food innovations made by "Celebrities/Popular Stars" should be investigated. Put differently, more than 50% of all respondents believe statements about biotechnology made by "Celebrities/Popular Stars" are not worth investigating.

On the whole, even though a majority of respondents attest to having high confidence in statements about bioengineered food innovations made by "Researchers," "Health Professionals," "Biotechnology Companies," "Food Companies" and "Extension Specialists," as presented in Table 6, they still believe statements from these groups need to be thoroughly investigated. Respondents' confidence was lowest with respect to statements about bioengineered food innovations made by Ghanaian celebrities/popular stars; however, they believe statements from this particular group warrant very little investigation.

Using the adjusted Likert-scale (1-1.75 = Not At All Important, 1.75-2.5 = Fairly Important, 2.5-3.25 = Important and 3.25-4 = Very Important), it may be concluded that respondents had highly convergent views ranging from "Important" to "Very Important." This is reflected in the small differences in standard deviations with respect to investigating statements made by "Researchers," "Health Professionals," "Biotechnology Companies," "Food Companies" and "Extension Specialists." On the other hand, respondents' views were highly varied, ranging from "Not At All Important" to "Very Important" when asked the importance of investigating claims about biotech made by "Farm Groups," "Government Agencies," "Non-Governmental Agencies," "Activist Groups" and "Celebrities/popular stars." This is reflected by differences in standard deviations associated with these groups.

Table 6 above summarizes the results (in order of decreasing level of importance) of statements about bioengineered food innovations made by different individuals, groups and organization spokespersons.

4.3.5 Extent to Which Selected Issues Impact Perceptions of Biotechnology

Table 7 provides the findings of selected issues likely to impact respondents' perceptions of bioengineered food innovations. A four-point Likert scale (1 = Very Low, 2 = Low, 3 = High and 4 = Very High) was used to rate the degree to which four selected issues impact respondents' perceptions of bioengineered food innovations. Table 7 below provides a summary of percentages, means and standard deviations of responses pertaining to factors likely to impact respondents' perceptions of bioengineered food innovations.

Table 7: *Descriptive Statistics of Different Factors/Issues That Impact Biotechnology Perceptions*

Variable/Scale N = 301	$\underline{n}$	Percent				*M*	*SD*
		Very Low	Low	High	Very High		
Fear Of Genes Moving Unchecked To Other Plants, Insects Or Microorganisms	293	6.83	18.09	32.76	42.32	3.11	0.93
Fear Of Food Safety Consequences	293	10.58	18.77	28.33	42.32	3.02	1.02
Fear Of Harm To The Environment	294	13.61	22.79	36.05	27.55	2.78	1.00
Religious Concerns About "Altering Nature"	294	29.25	32.65	22.45	15.65	2.24	1.04

From the results obtained, more than 70% of respondents assert that, "Fear of Genes Moving Unchecked to Other Plants, Insects or Microorganisms" (mean = 3.11 and SD = 0.93) and "Fear Of Food Safety Consequences" (mean = 3.02 and SD = 1.02) had a "High" to "Very High" impact on their perceptions of bioengineered food innovations. Less than 30% of respondents' said "Fear Of Genes Moving Unchecked To Other Plants, Insects Or Microorganisms" and "Food Safety Consequences" had a "Very Low" to "Low" impact on their perceptions of bioengineered food innovations. When the adjusted Likert scale (1-1.75 = Very Low, 1.75-2.5 = Low, 2.5-3.25 = High and 3.25-4 = Very High) is used, "Fear Of Genes Moving Unchecked To Other Plants, Insects Or Microorganisms" and "Food Safety Consequences" had a "Low" to "Very High" impact on respondents' perceptions of bioengineered food innovations. This is explained by the relatively large SD = 0.93 and SD = 1.02.

More than 60% (mean = 2.78 and SD = 1.0) of all respondents said "Fear Of Harm To The Environment" had a "High" to "Very High" impact on their perceptions of bioengineered food innovations while less than 40% said "Fear Of Harm To The Environment" had a "Low" to "Very Low" impact on their perceptions of bioengineered food innovations.

When asked how "Religious Concerns About Altering Nature" impacted their perceptions of bioengineered food innovations, more than 60% (mean = 2.24, SD = 1.04) of respondents said this particular issue had a "Low" to "Very Low" impact on their perceptions of bioengineered food innovations. On the other hand, less than 40% of respondents said "Religious Concerns About "Altering Nature" had a "High" to "Very High" impact on their perceptions of bioengineered food innovations.

4.4 OBJECTIVE 3: To Determine KNUST Students' Perceptions Regarding Government Efforts in Instituting Appropriate Frameworks Aimed at Facilitating the Adoption and Implementation of Bioengineered Food Innovations in Ghana

KNUST Students' Perceptions of Government's Role in Promoting Modern Biotechnology in Ghana

Table 8 represents the degree to which respondents agree or disagree with statements regarding Ghana government's efforts to promote bioengineered food innovations research, bio-safety, labeling and patents. A four point Likert-Scale of the form 1 = Strongly Disagree, 2 = Disagree, 3 = Agree, 4 = Strongly Agree was provided to help respondents rate their responses. Table 8 below provides response percentages, means and standard deviations.

Table 8: *Descriptive Statistics of Government's Role in Biotechnology Research, Bio-Safety, Labeling and Patents in Ghana*

Variable/Scale N = 301	*n*	Percent Strongly Disagree	Percent Disagree	Percent Agree	Percent Strongly Agree	*M*	*SD*
The Ghanaian Government Should Require Labeling Of Transgenic Animal Products.	291	1.4	6.9	41.2	50.5	3.41	0.68
The Ghanaian Government Should Require Labeling Of Transgenic Plant Products.	291	1.7	6.5	46.1	45.7	3.36	0.68
The Ghanaian Government Should Reject Patent Protection Of Transgenic Animals.	288	21.5	39.2	28.8	10.4	2.28	0.92
Ghana Has In Place The Essential Bio-Safety Legislation To Receive GM Crops From Abroad.	294	22.8	38.8	27.6	10.9	2.3	0.93
The Ghanaian Government Should Reject Patent Protection Of Transgenic Plants.	290	21.0	40.7	30.7	7.6	2.35	0.87
There Are Enough Qualified Persons To Test Transgenic Crops In Ghana.	296	24.7	38.5	29.0	7.8	2.20	0.90

Over 90% (mean = 3.41 and 3.36, SD = 0.68 and 0.68) of respondents "Agree" to "Strongly Agree" that "The Ghanaian Government Should Require Labeling of

Transgenic Plant and Animal Products." Less than 10% "Disagree" to "Strongly Disagree" on the issue of "Labeling Transgenic Plants and Animals."

Less than 40% (mean = 2.28 and 2.25, SD = 0.92 and 0.87) of respondents "Agree" to "Strongly Agree" that "The Ghanaian Government Should Reject Patent Protection of Transgenic Animals and Plants." Slightly more than 60% of respondents said the government should allow "Patent Protection of Transgenic Animals and Plants."

When asked the extent to which they agree with the statement "Ghana Has In Place The Essential Bio-Safety Legislation To Receive GM Crops From Abroad," less than 40% (mean = 2.27, SD = 0.93) of respondents "Agree to "Strongly Agree" with this statement; a little over 60% of all respondents "Disagree" to "Strongly Disagree" with this statement.

Respondents were also asked the extent to which they agree or disagree with the statement "There Are Enough Qualified Persons to Test Transgenic Crops in Ghana." From the results, less than 40% "Agree" to "Strongly Agree" with this statement. About 60% of all respondents do not believe Ghana has "Enough Qualified Persons to Test Transgenic Crops."

4.5 OBJECTIVE 4: To Determine Sources of Information Used by KNUST Students in Establishing their Knowledge and Perceptions of Biotechnology.

4.5.1 Extent to which selected sources are used to obtain information on biotechnology

Table 9 presents the results obtained when respondents were asked how often they used selected sources to gain information on bioengineered food innovations. A four-point Likert scale (1 = Never, 2 = Occasionally, 3 = Often, 4 = Always) was used to rate the degree to which each source is used. In descending order (using percentages, means, and standard deviations), Table 9 presents the extent to which various sources are used to seek information on bioengineered food innovations.

Table 9: *Descriptive Statistics of Sources of Information on Biotechnology*

Variable/Scale N = 301	n	Percent: Never	Occasionally	Often	Always	*M*	*SD*
University Coursework	294	9.86	31.29	31.63	27.21	2.76	0.96
Scientific Journals	294	11.42	33.22	39.10	16.26	2.60	0.89
Local Television Programs	293	10.69	46.21	30.34	12.76	2.45	0.85
Internet	293	20.48	30.38	35.49	13.65	2.42	0.96
Technical Publications/Reports	291	15.81	48.45	24.40	11.34	2.31	0.87
Newspaper	291	17.93	50.00	25.52	6.55	2.21	0.81
Radio	290	26.53	43.54	21.77	8.16	2.12	0.89
Popular Magazines	290	28.67	47.10	17.75	6.48	2.02	0.85
Non-Governmental Organizations	289	37.72	42.56	15.57	4.15	1.86	0.83
Extension Agents/Government Services	289	40.55	43.64	10.31	5.50	1.81	0.83

Almost 90% (mean = 2.60, SD = 0.90) of respondents "Occasionally" to "Always" utilize "University Coursework," "Scientific Journals" and "Television" to gain information on biotechnology. On the other hand, 10% of respondents "Never" utilize "University Coursework," "Scientific Journals" or "Television" to gain information on bioengineered food innovations.

The "Internet," "Technical Publications/Reports" and "Newspaper" on average are used "Occasionally" to "Always" by 82% (mean = 2.31, SD = 0.88) of all respondents to gain information on bioengineered food innovations. An average of 18% of respondents "Never" use any of these three sources to gain information on bioengineered food innovations.

While about, 72% (mean = 2.07, SD = 0.87) of respondents said they "Occasionally" to "Always" use "Radio" and "Popular Magazines" to again information on bioengineered food innovations, 27% said they "Never" use these sources to gain information on bioengineered food innovations.

About 61% (mean = 1.84, SD = 0.83) of respondents said they "Occasionally" to "Always" use "Non-Governmental Organizations" and "Extension/Government Services" to gain information on bioengineered food innovations, while 39% said they "Never" use these sources to gain information on bioengineered food innovations.

In summary, an average of 67% of all respondents "Occasionally to Often" use all ten information sources listed in Table 9, while only 11% "Always" utilize these sources to gain information on bioengineered food innovations. About 20% of all respondents said they "Never" use any of the sources listed in Table 9 to gain information on bioengineered food innovations. Information obtained in Table 9, indicates that respondents use "University Coursework" the most to gain information on bioengineered food innovations. "Extension/Government Services" was the least used.

4.5.2 Extent to which something about bioengineered food innovations is heard from selected sources

Respondents were asked how often they heard something about bioengineered food innovations from a list of ten selected information sources. Table 10 shows how respondents answered the questions in this category. A four-point Likert scale (1 = Never, 2 = Occasionally, 3 = Often, 4 = Always) was used to rate the degree to which information on bioengineered food innovations was received from each selected source.

Table 10: *Descriptive Statistics of Sources Used to Receive Information on Biotechnology*

Variable/Scale N = 301	*n*	Percent				*M*	*SD*
		Never	Occasionally	Often	Always		
University Coursework	292	8.56	34.93	33.90	22.60	2.71	0.91
Scientific Journals	292	11.30	36.99	35.62	16.10	2.57	0.89
Television	291	10.65	51.20	27.15	11.00	2.38	0.82
Internet	292	18.49	36.64	33.22	11.64	2.38	0.92
Technical Publications/Reports	286	15.73	44.76	29.72	9.79	2.34	0.86
Newspaper	294	17.69	57.48	21.77	3.06	2.10	0.71
Radio	293	24.23	52.56	16.72	6.48	2.05	0.82
Popular Magazines	290	28.97	52.41	16.21	2.41	1.92	0.74
Non-Governmental Organizations	285	33.68	47.02	16.49	3.51	1.89	0.79
Extension/Government Services	294	35.71	46.60	13.27	4.42	1.86	0.81

On average, 90% (mean = 2.56, SD = 0.87) of all respondents said they "Occasionally" to "Always" use "University Coursework," "Scientific Journals" and "Television" to gain information on bioengineered food innovations. About ten percent (10%) of respondents said they "Never" use "University Coursework," "Scientific Journals" or Television to gain information on bioengineered food innovations.

"Internet," "Technical Publications/Reports" and "Newspaper" on average are used "Occasionally" to "Always" by approximately 83% (mean = 2.27, SD = 0.83) of all respondents to gain information on bioengineered food innovations. An average of 17.3% of respondents said they "Never" use any of these three sources to gain information on bioengineered food innovations.

While about 73% (mean = 1.99, SD = 0.78) of respondents said they "Occasionally" to "Always" used "Radio" and "Popular Magazines," 27% said they "Never" use any of these sources to gain information on bioengineered food innovations.

Sixty-five percent (65%) (mean = 1.88, SD = 0.80) of respondents said they "Occasionally" to "Always" use "Non-Governmental Organizations" and "Extension/Government Services" to gain information on bioengineered food innovations, while 35% said they have "Never" used any of these sources to gain information on bioengineered food innovations.

In summary, approximately 70% of all respondents "Occasionally to Often" use at least one of the ten information sources provided in Tables 10 while only 10% said they "Always" use these sources to gain information on bioengineered food innovations. Also, approximately 20% of all respondents said they "Never" used any of the sources provided in Table 10 to gain information on bioengineered food innovations. From Table 10, respondents use “University Coursework” the most in gaining information on bioengineered food innovations. “Extension/Government Services” was, however, the least used. Table 10 presents in descending order (using percentages, means, and standard deviations) the extent to which various sources are use to gain information on bioengineered food innovations.

4.5.3 Extent to which selected social interactions impact students' perceptions of bioengineered food innovations

Respondents' were asked to what extent selected social interactions impact their perceptions of bioengineered food innovations. Table 11 below presents in descending order of percentages, means, and standard deviations, the extent to which selected social interactions impact respondents' perceptions of bioengineered food innovations.

Table 11: *Descriptive Statistics of Different Social Interactions Used in Establishing Perceptions of Biotechnology*

		Percent					
Variable/Scale N = 301	n	Never	Occasionally	Often	Always	*M*	*SD*
Knowledge From Science Classes	293	5.12	28.67	44.03	22.18	2.83	0.83
University Professors Beliefs About Biotechnology	294	12.93	26.19	35.03	25.85	2.74	0.99
Experience in Science Labs	293	20.14	36.52	32.08	11.26	2.34	0.93
Publicly Accepted Attitudes Towards Biotechnology	290	20.00	49.31	24.48	6.21	2.17	0.82
Friends' Beliefs About Biotechnology	291	31.62	44.33	20.27	3.78	1.96	0.82
Family's Beliefs About Biotechnology	292	52.74	32.53	11.30	3.42	1.65	0.81
Religious Beliefs	292	58.22	25.00	11.30	5.48	1.64	0.89

About 95% of respondents in Table 11 said "Knowledge From Science Classes" "Occasionally" to "Always" impact their perceptions of bioengineered food innovations while 5% said "Knowledge From Science Classes" "Never" impact their perceptions of bioengineered food innovations. The results also indicated that, about 73% (Mean = 2.83, SD = 0.83) of respondents said "Knowledge From Science Classes" "Occasionally to Often" impacted their perceptions of bioengineered food innovations while 22% said "Knowledge From Science Classes" "Always" impacted their perceptions of bioengineered food innovations.

The findings show that on average 80% of respondents said "University Professors Beliefs About Biotechnology," "Experience in Science Labs," "Publicly Accepted Attitudes Towards Biotechnology" and "Friends' Beliefs About Biotechnology" "Occasionally" to "Always" impacted their perceptions of bioengineered food innovations. Broken down further, 67% (mean = 2.30, SD = 0.89) said "University Professors Beliefs About Biotechnology," "Experience in Science Labs," "Publicly Accepted Attitudes Towards Biotechnology" and "Friends' Beliefs About Biotechnology" only "Occasionally to Often" impact their perceptions of bioengineered food innovations. An average of 12 % of respondents said these issues "Always" impacted their perceptions of bioengineered food innovations while 21% said they "Never" impacted their perceptions.

An average of 55 % (mean = 1.65 and SD = 0.85) of respondents indicated that "Family and Religious Beliefs about Biotechnology," "Never" impact their perceptions of bioengineered food innovations. Forty-percent (40%) of respondents said "Family and Religious Beliefs about Biotechnology" "Occasionally to Often" impacted their perceptions of bioengineered food innovations, while 5% of said these issues “Always” impacted their perceptions of bioengineered food innovations.

In summary, “Knowledge From Science Classes” impacted respondents’ perceptions of bioengineered food innovations the most. “Family and Religious Beliefs about Biotechnology” had the least impact on respondents’ perceptions of bioengineered food innovations.

4.6 OBJECTIVE 5: How Different Information Sources/Channels Influence Respondents’ Self Perceived Knowledge of Biotechnology.

4.6.1 Respondents’ self perceived knowledge of bioengineered food innovations

On a four-point Likert scale (1 = Very Low, 2 = Low, 3 = High and 4 = Very High), respondents were asked to rate their self-perceived knowledge of bioengineered food innovations.

Table 12: *Descriptive Statistics of Student's Perceived Knowledge Regarding Biotechnology*

		Percent					
Variable/Scale N = 301	n	Very Low	Low	High	Very High	*M*	*SD*
How Would You Rate Your Current Level Of Knowledge Regarding Biotechnology?	289	10.03	43.94	41.52	4.50	2.40	0.73

The findings in Table 12 indicate that about 54% of respondents reported their knowledge of bioengineered food innovations was “Low” to “Very Low” (mean = 2.40, SD = 0.73) while 46% said their knowledge was “High” to “Very High.” A more detailed breakdown of the results indicates that approximately 10% of respondents said their knowledge was "Very Low" while only 5% said their knowledge was "Very High."

4.7 Knowledge Cross Tabulations

In this section cross tabulations are performed based on respondents' self perceived knowledge of bioengineered food innovations to determine if there was a significant difference between the mean of a respondent's self perceived knowledge of bioengineered food innovations and questions pertaining to the first nine sections of the questionnaire (Appendix C). If the asymptotic significance (p) value is less that 0.05, then a significant difference exists between respondents' self perceived knowledge of bioengineered food innovations and the question under consideration (Norusis, 2000).

4.7.1 Self-Perceived Knowledge Aligned With Internet, Technical Publications/Reports and "University Course Work"

Table 13 shows that a statistically significant difference exists between the extent to which the Internet (χ^2 = 11.772, p = 0.008), Technical Publications/Reports (χ^2 = 8.070, p = 0.045) and University Course Work (χ^2 = 8.109, p = 0.044) are use to seek information on bioengineered food innovations and a students' "Self Perceived Knowledge of Biotechnology."

Table 13 below presents summary statistics of cross tabulations of self perceived knowledge of bioengineered food innovations aligned with "Internet," Technical Publications/Reports, and "University Course Work."

Table 13: *Cross Tabulation- Self-Perceived Knowledge of Biotechnology Aligned With Utilization of Sources of Information*

Variable/Scale N = 301	n	Percent Never	Occasionally	Often	Always	P	χ^2
Internet	283					0.008	11.772
Low		39	52	45	15		
High		18	37	53	24		
Technical Publications/Reports	281					0.045	8.070
Low		31	65	39	15		
High		13	72	29	17		
University Course Work	284					0.044	8.109
Low		20	51	45	36		
High		7	36	46	43		

Of the 53.36% (n = 151) of respondents who said their knowledge of bioengineered food innovations was "Low," about 14% (n = 39) said they "Never" use "Internet" as a source of information while 5% (n = 15) said they "Always" use "Internet" as a source of information. About 34% (n = 94) said they "Occasionally" to "Often" use the "Internet" for information on bioengineered food innovations.

The results from Table 13 indicate that out of approximately 47% (n = 132) of respondents who said their knowledge of bioengineered food innovations was "High," about 6% (n = 18) "Never" used the "Internet" as a source of information on bioengineered food innovations. Eight percent (8%, n = 24) said they "Always" use the

"Internet" as a source of information. Sixty-eight percent (68%, n = 90) of all respondents who perceived their knowledge to be "High," also said they "Occasionally" to "Often" use the "Internet" to seek information on bioengineered food innovations.

In summary, about 20% of respondents (Low plus High self-perceived knowledge respondents) "Never" used the "Internet" to seek information on bioengineered food innovations while about 66% "Occasionally" to "Often" used the "Internet" for information. In all, about 14% of respondents said they "Always" used the "Internet" as a source of information on bioengineered food innovations.

From the cross tabulation results in Table 13, about 11% (n = 31) of the respondents who said their knowledge of bioengineered food innovations was "Low" also said they "Never" use Technical Publications/Reports to gain information on bioengineered food innovations. About 5% (n = 13) of respondents who said their knowledge was "High" said they "Never" used Technical Publications/Reports as a source of information on bioengineered food innovations. A total of 16% (n = 44) of respondents said they "Never" used Technical Publications/Reports to gain information on bioengineered food innovations.

Of respondents who said their knowledge was "Low," about 37% (n = 104) said they "Occasionally" to "Often" used Technical Publications/Reports to gain information on bioengineered food innovations. Similarly, about 36% (n = 101) of those who said their knowledge was "High" also said they "Occasionally" to "Often used Technical Publications/Reports to seek knowledge on biotechnology. About 73% (n = 205) of respondents said they "Occasionally" to "Often used Technical Publications/Reports to gain information on bioengineered food innovations. Among respondents who indicated that their knowledge was "Low," about 5 % (n = 15) said they "Always" used Technical Publications/Reports to gain information on biotechnology. The findings also indicated that of 6% (n = 17) of respondents who said their knowledge was "High," said they "Always" used Technical Publications/Reports to seek information on bioengineered food innovations.

Of respondents who said their knowledge was "Low," about 7% (n = 20) "Never," 39% (n = 96) "Occasionally" to "Often" and 13% (n = 36) "Always" used "University Course Work" to seek information on bioengineered food innovations. With respect to self perceived "High" knowledge respondents, about 2% (n = 7) said they "Never" used "University Course Work" to seek information on bioengineered food innovations, 29% (n = 82) "Occasionally" to "Often" while 15 % (n = 36) "Always" used "University Course Work" to seek information on bioengineered food innovations.

It can be deduced from the findings that respondents who said their knowledge of bioengineered food innovations was "Low" were more likely to "Never" use any of the three information sources provided in Table 13 while those who said their knowledge was high were most likely to use these information sources to gain knowledge about bioengineered food innovations.

4.7.2 Self-Perceived Knowledge Aligned With Scientific Journals

Table 14 shows a statistically significant difference between the extent to which respondents used Scientific Journals (χ^2 = 16.044, p = 0.001) to seek information on bioengineered food innovations and their self perceived knowledge of bioengineered food innovations.

Table 14: *Cross Tabulation- Self-Perceived Knowledge of Biotechnology Aligned With Utilization/Awareness of Information Sources*

		Self Perceived Knowledge of Biotechnology					
Variable/Scale N = 301	*n*	Never	Occasionally	Often	Always	p	χ^2
Scientific Journals	283					0.001	16.044
Low		25	53	57	17		
High		6	53	42	30		

Results from Table 14 show that about 9% (n = 25) of respondents who said their knowledge of biotechnology was "Low" also said they "Never" used Scientific Journals as a source of information on biotechnology. About 39% (n = 110) of respondents with "Low" self perceived knowledge of biotechnology said they "Occasionally" to "Often" used Scientific Journals to seek information on biotechnology. About 6% (n = 17) of respondents with "Low" self perceived knowledge said they "Always" used Scientific Journals to seek information on biotechnology. The results obtained from Table 14 indicate that about 2% (n = 6) of respondents with "High" self perceived knowledge said they "Never" used Scientific Journals to seek information on biotechnology. In all, approximately 34% (n = 95) of the respondents said they "Occasionally" to "Often" used Scientific Journals to seek information on biotechnology while 11% (n = 30) said they "Always" used "Scientific Journals" to seek information on biotechnology.

4.7.3 Self-Perceived Knowledge Aligned with Friends' Beliefs about Biotechnology and Knowledge from Science Classes

Table 15 shows a statistically significant difference between self perceived knowledge of bioengineered food innovations and the different levels to which they used friends' beliefs (χ^2 = 11.221, p = 0.011) and knowledge from science classes (χ^2 = 9.046, p = 0.029) to establish their perceptions of bioengineered food innovations.

Table 15: *Cross Tabulation- Self-Perceived Knowledge of Biotechnology Aligned With Different Experiences*

Variable/Scale N = 301	*n*	Self Perceived Knowledge of Biotechnology: Never	Occasionally	Often	Always	p	χ^2
Friends' Beliefs About Biotechnology	283					0.011	11.221
Low		57	69	23	3		
High		31	58	35	7		
Knowledge From Science Classes	285					0.029	9.046
Low		7	56	61	30		
High		5	27	65	34		

Table 15 shows that about 20% (n = 57) of respondents who said their knowledge of bioengineered food innovations was "Low" also said their Friends' Beliefs about bioengineered food innovations "Never" impacted their own perceptions of bioengineered food innovations. About 33% (n = 92) of respondents who rated their self perceived knowledge as "Low," also said their Friends' Beliefs about biotechnology "Occasionally" to "Often" impacted their own perceptions of bioengineered food innovations. About 1% (n = 3) of those who rated their self perceived knowledge as "Low" also said their Friends' Beliefs about bioengineered food innovations "Always" impacted their own perceptions of biotechnology. About 11% (n = 31) of respondents who said their self perceived knowledge was "High," said their Friends' Beliefs about the subject "Never" impacted their perceptions of bioengineered food innovations. Approximately 2% (n = 7) of "High" self perceived knowledge respondents also said their Friends' Beliefs always impacted their perceptions of biotechnology. On the whole, about 33% (n = 93) of respondents said their Friends' Beliefs about bioengineered food innovations "Occasionally" to "Often" influence their own perceptions of the subject.

From Table 15, 2% (n = 7) respondents who said their self perceived knowledge was "Low" Knowledge also said Knowledge From Science Classes "Never" impacted their perceptions of biotechnology." About 10% (30) of respondents who said their self perceived knowledge was "Low" also said Knowledge from Science Classes "Always" impacted their perceptions of bioengineered food innovations. A total of about 41% (n = 117) of self perceived "Low" knowledge respondents also said Knowledge from Science Classes "Occasionally" to "Often" impacted their perceptions of bioengineered food innovations. With respect to "High" knowledge respondents, about 2% (n = 5) said Knowledge from Science Classes "Never" impacted their perceptions bioengineered food innovations. About 12% (n = 34) said Knowledge From Science Classes always impacted their perceptions of bioengineered food innovations. About 32% (n = 92) of self perceived "High" knowledge respondents also said Knowledge from Science Classes "Occasionally" to "Often" impacted their perceptions of bioengineered food innovations.

In summary, a greater percentage of respondents with "Low" self perceived knowledge of bioengineered food innovations said Knowledge from Science Classes "Never" impacted their perceptions. On the other hand, a greater percentage of respondents with "High" self-perceived knowledge of bioengineered food innovations said Knowledge from Science Classes "Always" impacted their perceptions of bioengineered food innovations.

4.7.4 Self-Perceived Knowledge Aligned With Control of Released Genes into the Environment

Table 16 shows a statistically significant difference between different levels of importance placed on bioengineered food innovations research regarding "control of released genes" (χ^2 = 10.555, p = 0.014) and respondents' self perceived knowledge of bioengineered food innovations.

Table 16: *Cross Tabulation- Self-Perceived Knowledge of Biotechnology Aligned With Different Types of Biotechnology Research*

		Self Perceived Knowledge of Biotechnology					
Variable/Scale N = 301	*n*	Not At All Important	Fairly Important	Important	Very Important	p	χ^2
Control of Released Genes	285					0.0144	10.555
Low		4	16	58	76		
High		1	14	29	87		

With regard to the importance placed on biotechnology research aimed at controlling released genes into the environment, the cross tabulation results show that a little more than 1% (n = 4) of respondents with "Low" self perceived knowledge believe it is "Not at all Important" for biotechnology research to focus on Controlling Released Genes into the environment. On the other hand, about 27% (n = 76) of self perceived "Low" knowledge respondents believe it is "Very Important" that bioengineered food innovations research Controlling Released Genes from entering the environment. About 26% (n = 74) of "Low" self perceived knowledge respondents also said it is "Fairly Important" to "Important" that bioengineered food innovations research involves Controlling Released Genes into the environment.

Less than 1% of "High" self perceived knowledge respondents (n = 1) said it is "Not at all Important" that biotechnology research focus on Controlling Released Genes into the environment. Thirty percent (30%, n = 87) of high knowledge respondents also said bioengineered food innovations research aimed at Controlling Released Genes into the environment was "Very Important." About 15% (n = 43) self perceived "High" knowledge respondents said it is "Fairly Important" to "Important" that bioengineered food innovations research focus on Controlling Released Genes into the environment.

4.7.5 Self-Perceived Knowledge Aligned With Confidence in Statement Made About Biotechnology by Extension Specialists, Health Professionals and Non-Governmental Organizations

Table 17: *Cross Tabulation- Self-Perceived Knowledge of Biotechnology Aligned With Confidence in Statement Made About Biotechnology by Spokespersons from Different Organizations*

Variable/Scale N = 301	*n*	Self Perceived Knowledge of Biotechnology: Very Low	Low	High	Very High	p	χ^2
Extension Specialists	285					0.047	7.949
Low		7	57	74	15		
High		8	30	73	21		
Health Professionals	285					0.028	9.143
Low		8	22	69	56		
High		2	12	49	68		
Non-Governmental Organizations	285					0.042	8.180
Low		12	57	66	18		
High		6	32	72	22		

Table 17 shows a statistically significant difference between different levels of confidence placed in statements about biotechnology made by Extension Specialists ($\chi^2 = 7.949$, p = 0.047), Health Professionals ($\chi^2 = 9.143$, p = 0.028), Non-Governmental Organization ($\chi^2 = 8.18$, p = 0.042) and respondents' self perceived knowledge of bioengineered food innovations.

On average less than 5% (n<14) of both "Low" and "High" self perceived knowledge respondents said they had "Very Low" confidence in statements about bioengineered food innovations made by Extension Specialists, Health Professionals and spokespersons from Non-Governmental Organizations. Less than 10% (n<28) of both "Low" and "High" knowledge respondents, said they had "Very High" confidence in statements about bioengineered food innovations made by Extension Specialists, and spokespersons from Non-Governmental Organizations. More than 20% (n>57) of both "Low" and "High" knowledge respondents, said they had "Very High" confidence in statements about biotechnology made by Health Professionals. Between 17% (n = 45.45) to 26% (n = 74.1) of respondents on average, said they had "High" confidence in statements made about bioengineered food innovations by spokespersons from all three groups listed in Table 17.

4.7.6 Self-Perceived Knowledge Aligned With Claims Made About Biotechnology by Spokespersons from Different Organizations

Table 18 shows a statistically significant difference between levels of importance placed on investigating statements about bioengineered food innovations made by spokespersons from Biotechnology Companies ($\chi^2 = 8.151$, $p = 0.043$) and respondents' self perceived knowledge of bioengineered food innovations.

Table 18: *Cross Tabulation- Self-Perceived Knowledge of Biotechnology Aligned Importance of Investigating Claims Made About Biotechnology by Spokespersons from Different Organizations*

Variable/Scale N = 301	*n*	Percentage				p	χ^2
		Not At All Important	Fairly Important	Important	Very Important		
Biotechnology Companies	284					8.151	0.043
Low		3	26	48	77		
High		4	8	49	69		

Less than 2% (n=6) of both "High" and "Low" self perceived knowledge respondents said it was "Not At All Important" to investigate statements about bioengineered food innovations made by spokespersons from biotechnology companies. More "Low" self perceive knowledge respondents (27%, n = 77) relative to "High" self perceived knowledge respondents (24%, n = 69) said it was very important to investigate statements about bioengineered food innovations made by biotechnology companies. Similarly, a higher percentage of "Low" self perceived knowledge respondents 26% (n = 74) relative to "High" knowledge respondents (20%, n = 57) said it was "Fairly Important" to "Important" to investigate statements about bioengineered food innovations made by biotechnology companies.

4.7.7 Self-Perceived Knowledge Aligned With Confidence in Government Policies Regarding Biotechnology

Table 19 shows a statistically significant difference between the level of confidence placed in Ghanaian government's role in instituting legislation regarding bio-safety (χ^2 = 13.559, p = 0.004), labeling of transgenic plant products (χ^2 = 11.215, p = 0.011) and respondents' self perceived knowledge of bioengineered food innovations.

Table 19: *Cross Tabulation- Self-Perceived Knowledge of Biotechnology Aligned With Confidence in Government Policies Regarding Biotechnology*

		Percentage					
	n	Strongly Disagree	Disagree	Agree	Strongly Agree	p	χ^2
Ghana has in place the essential bio-safety legislation to receive GM crops from abroad	285					0.004	13.559
Low		45	51	47	11		
High		20	60	32	19		
The Ghanaian Government Should Require Labeling Of Transgenic Plant Products	282					0.011	11.215
Low		2	17	70	63		
High		1	2	61	66		

About 16% (n = 45) of "Low" self perceived knowledge respondents, "Strongly Disagree" while 18% (n = 51) simply "Disagree" with the statement that "Ghana has in place the essential bio-safety legislation to receive GM crops from abroad." About 16% (n = 47) "Low" self perceived knowledge respondents simply "Agree" while 4% (n = 11) "Strongly Agree" with the same statement. With respect to "High" self perceived knowledge respondents, 7% (n = 20) said they "Strongly Disagree" while 21% (n = 60) said they "Disagree" with the statement "Ghana has in place the essential bio-safety legislation to receive GM crops from abroad." About 11% (n = 32) of "High" self perceived knowledge respondents said they simply "Agree" with the statement while 7% (n = 19) said they "Strongly Agree" with this statement. Disregarding the degree to which respondents agree or disagree, it can be concluded that a greater percentage of respondents 62 (n = 176) "Disagree" (Strongly Disagree plus Disagree) with the statement "Ghana has in place the essential bio-safety legislation to receive GM crops from abroad" relative to 38% (n = 109) of respondents who "Agree" (Strongly Agree plus Agree).

Less than 1% (n = 3) of "Low" and "High" self perceived knowledge respondents "Strongly Disagree" with the statement "The Ghanaian Government Should Require Labeling Of Transgenic Plant Products." On the contrary, about 22% (n = 63) and 23% (n = 66) "Strongly Agree" that government should require labeling of transgenic plant products. Disregarding the degree to which Low" and "High" knowledge respondents either agree or disagree, about 92% (n = 260) of respondents said the agree with the statement "The Ghanaian Government Should Require Labeling Of Transgenic Plant Products" while only 8% (n = 22) said they disagree with this statement.

4.8 Cross Tabulations with Demographic Variables

4.8.1 Self-Perceived Knowledge of Modern Biotechnology Aligned With Gender

Table 20 shows no statistically significant difference (χ^2 = 6.597, p = 0.159), between how males and females perceive their knowledge of bioengineered food innovations.

Table 20: *Cross Tabulation- Self-Perceived Knowledge of Biotechnology Aligned With Gender*

Variable/Scale N = 301	*n*	Percentage: Very Low	Percentage: Low	Percentage: High	Percentage: Very High	p	χ^2
Sex	278					0.159	6.597
Male	214	7.01	45.79	42.52	4.21		
Female	64	17.19	37.50	40.63	4.69		

About 7% (n = 15) of all males and 17% (n = 11) of all female perceived their knowledge of biotechnology to be "Very Low." Approximately 46% (n = 98) of males and 38% (n = 24) of females perceived their knowledge to be simply "Low." About 43% (n = 91) of all male and 41% (n = 26) of all females perceived their knowledge to be "High." About 4% (n = 9) of males and 5% (n = 3) of females perceived their knowledge to be "Very High." On each end of the spectrum of self perceived knowledge, approximately 55% of all females compared to 53% of males perceive their knowledge as "Low" (Very Low + Low). About 47% of males compared to 45% of females perceive their knowledge to be "High" (High +Very High).

4.8.2 Self-Perceived Knowledge of Modern Biotechnology Aligned With Age

Table 21 shows that there is no significant difference (χ^2 = 4.785, p = 0. 780), between how different age groups of KNUST Agricultural Science Students perceive their knowledge of bioengineered food innovations. For the purpose of data analysis the age variable was grouped into three different categories (19 Years or Less, Between 20 to 24, and 25 Years and above). The entire breakdown of all different age categories is presented in Appendix E.

Table 21: *Cross Tabulation- Self-Perceived Knowledge of Biotechnology Aligned With Age Distribution*

		Percentage					
Variable/Scale N = 301	*n*	Very Low	Low	High	Very High	p	χ^2
	286					0.780	4.785
19 Years or Less	9	22.22	33.33	44.44	0.00		
Between 20 to 24	227	9.25	44.93	42.29	3.52		
25 Years and Above	50	12.00	40.00	40.00	8.00		

Of all nine respondents under the age of 19, about 22% (n = 2) perceive their knowledge of biotechnology to be "Very Low." About 33% (n = 3) perceive their knowledge as simply "Low" while 44% perceive their knowledge to be "High." No respondents under the age of 19 perceive their knowledge of modern biotechnology to be "Very High."

Two hundred and twenty seven (227) students between ages 20 and 24 rated their knowledge of modern agricultural biotechnology. Of all respondents between the ages of

20 and 24, approximately 9% (n = 21) rated their knowledge to be "Very Low." About 45% (n = 102) rated their knowledge to be simply "Low" while 42% (n = 96) said their knowledge was "High." About 4% (n = 8) of respondents in this age category said their level of knowledge of modern agricultural biotechnology was "Very High."

Fifty student (n = 50) above the age of 25 rated their knowledge of modern biotechnology of which 12% (n = 6) said their knowledge was "Very Low" and 40% (n = 20) said their knowledge was simply "Low." Another 40% (n = 20) of respondents said their knowledge was "High" while 8% (n = 4) rated their knowledge as "Very High."

4.9 Probit and Logit Model

Tables 22 and 23 present Probit and Logit model estimates based on different sources of information used by respondents to establish their knowledge about bioengineered food innovations. In Table 24, the Probit and Logit classifications were used to predict respondents' self-perceived knowledge of bioengineered food innovations. The predicted results were then compared with respondents' actual response to the self-perceived knowledge question.

4.9.1 Purpose

The Probit and Logit models were used to further investigate factors that significantly influence KNUST agricultural science students' self perceived knowledge of bioengineered food innovations. Both models were used to predict at a 90% confidence level the probability that a marginal or unit change in a respondent's self-perceived knowledge will occur when she/he uses a particular information source in isolation. In other words, both models were used to predict at a 90% confidence level, the probability that a respondents' self-perceived knowledge will increase from "Low" to "High" when that individual uses only one source of information to gain knowledge about biotechnology. In order to account for the unit change in the models, both "Low" and "Very Low" self-perceived options of the questionnaire were recoded "Low = 0." Similarly, all both "High" and "Very High" self-perceived knowledge responses were recoded "High = 1." For the interpretations of both models to hold, all non-usage of biotechnology information sources (Never) was coded 0 and all usage (Occasionally, Often, and Always) disregarding the degree of use was coded 1. In other words, both models assumed respondents either used an information source (disregarding the degree of use) or did not.

4.9.2 Statistical Significance of Coefficients

For both the Probit and Logit models, obtaining information on bioengineered food innovations using "Internet" and "Newspapers" had a significant positive impact on "High" self perceived knowledge at a 10% level of significance. Similarly, both models suggest that establishing knowledge using "Friend's Beliefs about Biotechnology" had a positive and significant influence on "High" self-perceived knowledge at a 10% level of significance.

The data from both Probit and Logit models suggest that using only "Radio" as a source of information on bioengineered food innovations had a negative but significant influence on a "High" self perceived knowledge at a 10% level of significance.

The R squared of 0.1235 and 0.1229 for both Probit and Logit models respectively, suggests that only 12.35% and 12.29% of the variations in the model are explained, suggesting that these models might be weak.

At 10% level of significance, only "Internet," "Newspapers," "Radio," and "Friends' Beliefs about Biotechnology" were found to be significant.

4.9.3 Interpretation of Probabilities Associated With Significant Variables

Results from both Probit and Logit models suggest that using "Internet," "Newspapers," "Radio," and "Friends Beliefs about Biotechnology" explains why a respondent's self perceived knowledge about bioengineered food innovations was "High."

Assuming no other sources besides "Internet" were used to gain information on bioengineered food innovations, the Probit and Logit models indicated that the expected marginal effect of a unit change in "Internet" usage on the probability that a respondent's self perceived knowledge is "High" is 0.271 and 0.281 respectively. This means that one can say with a 90% confidence level that if a respondent uses only "Internet" to gain information on biotechnology, there is a 0.271 or 0.281 chance that individual's self-perceived knowledge will increase from "Low" (0) to "High" (1). The Logit model presents a slightly higher probability than the Probit model. For this interpretation to hold, it is important that non-Internet usage is coded zero (0) while usage (disregarding the degree or level of usage) is coded one (1). To make provision for a unit change in self-perceived knowledge, "Very Low" and "Low" responses were labeled "Low" and coded (0) while "High and Very High" were labeled "High" and coded (1).

Using both Logit and Probit models, the expected marginal change in a respondent's perceived knowledge level resulting from using only "Newspapers" to gain information about bioengineered food innovations, *ceteris paribus*, on the probability that a his/her self-perceived knowledge is "High" is 0.274 and 0.283 respectively.

Alternatively, one can predict with a 90% level of confidence that if a respondent uses only "Newspaper" sources to gain information about biotechnology, the probability that his/her self-perceived knowledge will increase from "Low" to High" is a 0.274 (for the Probit model) and 0.283 (for the Logit model). "Non -newspaper" usage is coded (0) while usage (disregarding the degree or level of usage) is coded (1). Likewise "Low" and "Very Low" self perceived knowledge disregarding the degree were coded (Low = 0) and "High" and "Very High" self perceived knowledge were coded (High = 1).

Using the Probit and Logit models, the expected marginal effect resulting from a respondent using only "Radio" to gain information on bioengineered food innovations, *all else equal*, on the probability that his/her self perceived knowledge is "High" is -0.311 and -0.319 respectively. The negative probability associated with "Radio" implies that increased "Radio" usage has the effect of increasing respondents self perceived knowledge, with this increment occurring at a decreasing rate. "Non-radio" usage is coded (0) while usage is (disregarding the degree or level of usage) is coded (1).

From both Probit and Logit models, the expected increase in self perceived knowledge resulting from utilizing "Friends' Beliefs about Biotechnology" to gain information about bioengineered food innovations, *ceteris paribus,* on the probability that a respondent's self perceive knowledge is "High" is 0.200 and 0.202 respectively. Alternatively, one can say with a 90% level of confidence that if respondents in this study use only "Friends' Beliefs about Biotechnology" to inform themselves about biotechnology, there is a 0.200 (Probit) and 0.202 (Logit) chance their self-perceived knowledge will increase from "Low" to High." Non- usage of "Friends' Beliefs about

Biotechnology" was coded (0) while usage (disregarding the degree or level of usage) is coded (1).

4.9.4 Differences in Probit and Logit Model Estimates

From Tables 22 and 23, the results from both Probit and Logit estimates indicate that the set of variables that had negative effects were the same and those that had positive effects were also the same for both models. The independent variables that were statistically significant were the same for both Logit and Probit models.

The marginal effects of the independent variables on the probability that a respondent's self perceived knowledge is "High" in terms of signs, disregarding the magnitudes were the same for both Probit and Logit models. In all cases, the probabilities obtained for the Probit model were lower than those obtained for the same variables in the Logit model. However, in terms of magnitude, the marginal effects were nearly the same at a one (1) decimal point.

In both models, "Low" self perceived knowledge was coded zero (0) while "High" self perceived knowledge was assigned a code of one (1). Tables 22 and 23 present summaries of the findings explained above.

Table 1: *Probit Estimate Results of Self Perceived Knowledge of Biotechnology*

Self Perceived Knowledge of Biotechnology (y)	Coeff (β)	Std. Err.	z	P>z	[90% Conf.	Interval]	dy/dx
To What Extent Do You Use the Following Sources To Gain Information About Biotechnology							
Extension/Government Services	0.012	0.238	0.050	0.958	-0.454	0.479	0.005
Internet*	0.731	0.356	2.050	**0.040**	0.032	1.429	**0.271**
News Papers	-0.564	0.355	-1.590	0.112	-1.259	0.131	-0.221
Non-Governmental Organizations	-0.258	0.275	-0.940	0.349	-0.796	0.281	-0.102
Popular Magazines	0.059	0.269	0.220	0.826	-0.468	0.586	0.023
Radio	0.167	0.310	0.540	0.590	-0.440	0.774	0.066
Scientific Journals	0.047	0.484	0.100	0.922	-0.901	0.995	0.019
Technical Publications/Reports	0.432	0.354	1.220	0.223	-0.263	1.126	0.166
Television	0.355	0.400	0.890	0.374	-0.429	1.140	0.137
University Course Work	0.225	0.438	0.510	0.607	-0.633	1.083	0.088
How Often Do You Hear Something About Biotechnology From The Following Sources							
Extension/Government Services	-0.434	0.245	-1.770	0.077	-0.915	0.046	-0.172
Internet	-0.172	0.392	-0.440	0.661	-0.940	0.597	-0.068
Newspapers*	0.747	0.394	1.890	**0.058**	-0.026	1.520	**0.274**
Non-Governmental Organizations	0.107	0.273	0.390	0.696	-0.429	0.642	0.042
Popular Magazines	0.168	0.302	0.560	0.577	-0.424	0.761	0.066
Radio*	-0.804	0.331	-2.430	**0.015**	-1.453	-0.155	**-0.311**
Scientific Journals	0.437	0.478	0.910	0.360	-0.500	1.375	0.167
Technical Publications/Reports	-0.043	0.404	-0.110	0.916	-0.834	0.749	-0.017
Television	0.182	0.204	0.890	0.373	-0.218	0.581	0.072
University Course Work	-0.221	0.470	-0.470	0.639	-1.142	0.701	-0.088
To What Extent Do You Use The Following Experiences To Establish Your Perceptions About Biotechnology							
Publicly Accepted Attitudes Towards Biotechnology	0.239	0.269	0.890	0.374	-0.288	0.766	0.093
Experience In Science Classes	0.209	0.262	0.800	0.425	-0.305	0.723	0.082
Family's Beliefs About Biotechnology	0.132	0.240	0.550	0.583	-0.339	0.603	0.052
Friend's Beliefs About Biotechnology*	0.516	0.253	2.040	**0.042**	0.020	1.013	**0.200**
Knowledge From Science Classes	-0.209	0.534	-0.390	0.695	-1.255	0.837	-0.083
Religious Beliefs	-0.100	0.222	-0.450	0.653	-0.536	0.336	-0.040
University Professors Beliefs About Biotechnology	-0.351	0.319	-1.100	0.273	-0.977	0.276	-0.139
_cons	-1.392	0.608	-2.290	0.022	-2.584	-0.200	

n = 235, LR chi2 (27) = 40.14, Prob > chi2 = 0.0489, Pseudo R2 = 0.1235, Log likelihood = -142.4631, dy/dx is for discrete change of dummy variable from 0 to 1, y = Self Perceived Knowledge of Biotechnology (Low & High), *Significant Variables

Table 2: *Logit Estimate Results of Self Perceived Knowledge of Biotechnology*

Self Perceived Knowledge of Biotechnology (y)	Coeff	Std. Err.	z	P>z	[90% Conf.	Interval]	dy/dx
To What Extent Do You Use the Following Sources To Gain Information About Biotechnology							
Extension/Government Services	0.019	0.391	0.05	0.961	-0.748	0.786	0.005
Internet*	1.237	0.610	2.03	**0.042***	0.042	2.432	**0.281**
News Papers	-0.932	0.581	-1.6	0.109	-2.069	0.206	-0.228
Non-Governmental Organizations	-0.438	0.460	-0.95	0.341	-1.339	0.463	-0.109
Popular Magazines	0.119	0.456	0.26	0.794	-0.774	1.012	0.029
Radio	0.251	0.512	0.49	0.624	-0.753	1.254	0.062
Scientific Journals	0.141	0.815	0.17	0.863	-1.456	1.737	0.035
Technical Publications/Reports	0.740	0.618	1.2	0.231	-0.470	1.951	0.175
Television	0.621	0.677	0.92	0.359	-0.706	1.948	0.148
University Course Work	0.368	0.738	0.5	0.619	-1.080	1.815	0.089
How Often Do You Hear Something About Biotechnology From The Following Sources							
Extension/Government Services	-0.702	0.407	-1.73	0.084	-1.500	0.095	-0.174
Internet	-0.378	0.683	-0.55	0.58	-1.716	0.960	-0.094
Newspapers*	1.268	0.657	1.93	**0.054**	-0.021	2.556	**0.283**
Non-Governmental Organizations	0.181	0.461	0.39	0.695	-0.722	1.083	0.045
Popular Magazines	0.263	0.510	0.52	0.606	-0.737	1.263	0.065
Radio*	-1.330	0.564	-2.36	**0.018**	-2.435	-0.225	**-0.319**
Scientific Journals	0.675	0.800	0.84	0.399	-0.893	2.243	0.160
Technical Publications/Reports	-0.082	0.685	-0.12	0.905	-1.424	1.261	-0.020
Television	0.274	0.334	0.82	0.411	-0.380	0.928	0.068
University Course Work	-0.326	0.814	-0.4	0.689	-1.921	1.269	-0.081
To What Extent Do You Use The Following Experiences To Establish Your Perceptions About Biotechnology							
Publicly Accepted Attitudes Towards Biotechnology	0.389	0.446	0.87	0.383	-0.486	1.264	0.095
Experience In Science Classes	0.321	0.446	0.72	0.471	-0.553	1.195	0.079
Family's Beliefs About Biotechnology	0.245	0.396	0.62	0.536	-0.531	1.021	0.061
Friend's Beliefs About Biotechnology*	0.839	0.413	2.03	**0.042**	0.029	1.649	**0.202**
Knowledge From Science Classes	-0.310	0.897	-0.35	0.73	-2.067	1.448	-0.077
Religious Beliefs	-0.188	0.365	-0.51	0.608	-0.904	0.529	-0.046
University Professors Beliefs About Biotechnology	-0.553	0.525	-1.05	0.292	-1.581	0.475	-0.137
_cons	-2.366	1.070	-2.21	0.027	-4.463	-0.268	

n = 235, LR chi2 (27) = 39.96, Prob > chi2 = 0.0517, Pseudo R2 = 0.1229, Log likelihood = -142.55, dy/dx is for discrete change of dummy variable from 0 to 1, y = Self Perceived Knowledge of Biotechnology (Low & High), *Significant Variableshh

4.10 Probit and Logit Classifications

When the Probit and Logit models were used to predict respondents' self-perceived knowledge of bioengineered food innovations, both models gave the same results. From the classification results obtained, 37.47% (n = 81) of respondents perceived their knowledge of bioengineered food innovations to be high and both models actually predicted this percentage to be true. However, for the 20% (n = 47) of respondents who said their knowledge of bioengineered food innovations was low, both Probit and Logit models predicted these respondents' knowledge to be high. Similarly, 32.77% (n = 77) of respondents said their knowledge was low, and the models predicted this to be true. However, 12.77% (n = 30) said their knowledge was high, and both models predicted their knowledge to be rather high. For both Probit and Logit models, 67.23% (n = 158) of predicted outcomes were actually true whereas 32.77% (n = 77) of predicted outcomes were false. Table 24 shows that in all instances, both Probit and Logit model predictions were exactly the same.

Table 24: *Classification of Predicted and Actual Level of Knowledge*

Probit and Logit Classifications						
N = 301, n = 235	True High		True Low		Total	
	Frequency	%	Frequency	%	Total Frequency	Total %
Predicted High	81	34.47	47	20.00	128	54.47
Predicted Low	30	12.77	77	32.77	107	45.53
Total	**111**	**47.23**	**124**	**52.77**	**235**	**100**

Correctly Classified 67.23% = (81+77)/(235/100)

4.11 Summary

In this chapter, the findings of the research, guided by the five objectives were presented. The data generated by SPSS 11.0 and STATA 8.0 were summarized and presented in table format. Chapter five presents the conclusions and recommendations of the study.

CHAPTER FIVE

CONCLUSIONS, DISCUSSIONS AND RECOMMENDATIONS

5.1 Chapter Preview

The preceding chapters provided the introduction, literature review, methodology, and findings relative to KNUST students' perceptions of agricultural and food innovations. In this chapter, conclusions, discussions and recommendations are presented for each of the research objectives. Also, this chapter will provide insights into the following research questions:

1. What information sources do KNUST agricultural science students use to obtain information about bioengineered food innovations?
2. What information sources do KNUST agricultural science students believe are more credible regarding information about bioengineered food innovations?
3. How do different information sources influence KNUST students' perceptions of bioengineered food innovations?

5.2 OBJECTIVE 1: To Describe the Demographic Composition of Agricultural Science Students in KNUST.

5.2.1 Summary of Findings

KNUST agricultural science students are 23% female and 77% male. In terms of how males and females perceive their knowledge of modern biotechnology, the results obtained from Table 20 shows no statistically significant different (χ^2 = 6.597, p = 0.159) between how males and females perceive their knowledge of biotechnology.

5.2.2 Discussion

In Ghana, males dominate agricultural science just like most other sciences. According to Agyeman-Mensah (1988), any attempt at human development that ignores more than half a nation's target population is bound to fail. For this reason, there is need for a serious recruitment campaign to be preceded by a general awareness regarding opportunities in science and agriculture for female students. It is important that female recruitment programs be preceded by awareness campaigns in the form of speaker series highlighting the role of women in science and agriculture. Without awareness there will be no interest in science and, without interest, initiatives like female recruitment efforts will continue to be difficult to implement successfully.

Training more females in agriculture will ensure that the necessary human resources are available to carry out gender sensitive activities/roles required especially in rural development. A report by the National Science Foundation (NFS, 2000) has shown that there is a considerable gender gap in attitudes towards biotechnology, even in most developed countries, including the United States. Due to lack of exposure to agricultural science, it was found that women were considerably more likely than men to believe that the risks of modern biotechnology outweigh its benefits (42% of women compared to 33% of men in the US) (Kamaldeen and Powell, 2000).

Low representation of females in the KNUST agricultural science program raises concern about the future of Ghana's agricultural sector, rural and national development. Agriculture is the backbone of Ghana's economy, and women play a central role in all aspects of agricultural production activities. During a 2002 United Nations sponsored conference on "Learning Teaching and Research" in Addis Ababa, Ethiopia, Professor K.

Singh from KNUST stressed the necessity of expanding infrastructure to accommodate possible increases in KNUST future enrollments. Professor Singh's account of gender distribution in KNUST indicates that, out of 11,714 total enrollments in 2002, 79% were males and 21% were female. While it is necessary to expand infrastructure required to meet increased student enrollments, it is equally necessary to institute programs that would help bridge the gender gap at the secondary and tertiary level, particularly in the sciences. According to the World Bank, 70% of the population in developing countries; resides in rural areas where women play a key role in ensuring household food security. Women produce 60% to 80% of the food in most developing countries yet they are the very ones by-passed by most development efforts including education (Udoh, 1995). 1999). Udoh (1995) also asserts that, in most of Africa, women perform most of farm work therefore, it is absolutely necessary to develop programs to recognize and utilize women's expertise.

5.2.3 Recommendations

To substantially increase female enrollments, it will be necessary for KNUST to launch an aggressive recruitment program starting at the primary school level. KNUST must also engage other Ghanaian universities and governmental bodies in this effort. The recruitment program should be aimed at instituting national policies that stimulate interest in science and agriculture among schoolgirls. It is not uncommon to find many Ghanaians who have very negative perceptions of agriculture. It is unfortunate that most Ghanaians view agriculture as a hoe and cutlass (sickle) venture involving solely peasants. Lack of awareness about the vast opportunities in the field of agriculture may be a contributing factor to these negative perceptions. A common trend among Ghanaian female students, especially at the primary and secondary stages, is the tendency to shy away from the science of agriculture. A national campaign is needed to correct these myopic views about agriculture.

5.3 OBJECTIVE 2: To Describe Current Perceptions of Bioengineered Food Innovations Amongst KNUST Agricultural Science Students

5.3.1 Summary of Findings: One

More than 90% of all respondents believe bioengineered food innovations will have a somewhat positive to very positive impact on food production, commercial farming and world hunger. An average 75% of all respondents believe bioengineered food innovations will have a somewhat positive to very positive impact on the environment, small scale farms, human health, fish and wildlife.

5.3.2 Discussion: One

Ten Eyck, Gaskell and Jackson (2004) found that 77% of respondents in the United States think GM foods will be useful in the fight against world hunger, while only 44% in Europe think so. In a similar study in 11 land grant universities in the United States, Wingenbach et al. (2004) found that 92% of future agricultural communicators claim to be aware or somewhat aware of how biotechnology affects their food, health, and environment. Like the findings in the KNUST study, Wingenbach et al. (2004) also found that a greater majority of college students (average M = 2.98) surveyed in the United States believe bioengineered food innovations will have a somewhat positive to very positive effect on world hunger, healthful foods, family farms (small farms) and fish and wildlife. KNUST agricultural science students recorded a mean of M = 3.07 with respect to impact of biotechnology on world hunger, healthful foods, family farms (small farms) and fish and wildlife. While the findings from these two studies appear similar, it may be concluded from the means obtained that KNUST agricultural science students are somewhat more optimistic about the impact of bioengineered food innovations on commercial farming, world hunger, environment, small scale farms, human health, fish and wildlife. For this reason, it is likely that high optimism amongst KNUST agricultural science students may be reflected in future policy decisions regarding agricultural biotechnology implementation in Ghana.

5.3.3 Recommendations: One

A national campaign is needed to stimulate interest in agricultural science at both the high school and college levels. The major agricultural colleges/departments in the country need to lead the charge in formulating a national agricultural organization that promotes agriculture among the youth. The proposed organization should first and foremost encourage the youth to explore science, technology, and citizenship. National student organizations such as the Ghana United Nations Students Association (GUNSA), Ghana Rotary and the Lions Clubs have a long history of promoting educational programs that empower the youth. In the same light, the proposed agricultural organization could employ a similar platform but within a broader context of agriculture. For example, youth programs/symposia may be designed to explore the relationship between agriculture and nutritional aspects of health problems and how this could be used as a weapon against diseases such as HIV/AIDS. Similarly, the role of agriculture in addressing the urban/rural unemployment problem and, environmental problems may be explored. At both the high school and college levels, the national agricultural organization should be run by students with faculty providing some oversight. All effort must be made to include school administrators as an intricate part of program design and implementation because this will ensure the developments of a relationship that is based on trust and hence the likelihood of program success.

5.3.4 Summary of Findings: Two

Approximately 90% of all respondents believe it is either "Important" or "Very Important" that biotechnology research focus on "Safer Food," "Benefit to the Environment," "Control of Released Genes into The Environment," "Added Nutritional Value To Food" and "Reduction of Pesticides." A little more than 75% of all respondents believe it is either 'Important" or "Very Important" that bioengineered food innovations research focus on "Risk Associated with Pesticide Use" and "Harm Caused to the Environment."

5.3.5 Discussion: Two

Hoban (2003) found that in 30 countries in the continents of America, Europe, Asia and the Pacific Rim, over 85% of the public support the use of biotechnology to develop new human medicines. However, this support dropped drastically to about 55% at the mention of using biotechnology to improve the animal and food systems even if it meant healthier food. A 1994 perception study by Jonathan Kelley, a senior fellow of Australia's Institute of Advanced Study, revealed that most Australians gave a highly desirable rating of 92% to bioengineered food innovations that reduced the use of chemicals and pesticides in farming and protected the environment (Kelley, 1994). Desirability for healthier and more nutritious food was rated 90%. Higher yielding crops with the potential for increasing farm incomes through exports were rated 85%. Tastier fresher food was rated 80% for desirability.

Similar to both Hoban's and Kelley's findings, the KNUST study found that more than 80% of agricultural science students interviewed regard as very important, biotechnology research that focus on "Safer Food," "Benefit to the Environment," "Control of Released Genes into The Environment," "Added Nutritional Value to Food" and "Reduction of Pesticides." Yet these same respondents say it is not important for biotechnology research to focus on "Risk associated with Pesticide usage" and "Harm caused to the Environment." It is important to note that research that focus on "Risk associated with Pesticide usage" and "Harm caused to the Environment" is necessary to ensure a safe food system and environment.

Gaskell et al. (1996) point out that as far as modern biotechnology is concerned, there is a structural difference between environmental organizations and medical institutions. According to Gaskell and others, environmental organizations are not responsible for delivering new food crops to the public, but rather they act as watchdogs. By the same token, the medical profession has direct responsibility for the provision of new medical technologies to the public. Gaskell et al. (1996) conclude that because providers of agricultural biotechnologies are far less widely trusted than providers of medical biotechnologies, there is a likelihood that this trend in trust will significantly shape public perceptions and attitudes in the two areas.

Many scientists have hypothesized that modern biotechnologies have the potential to increase Africa's agricultural productivity, while, at the same time, play a significant role in health care. But the potential impacts, positive or negative, remain debatable. The risks posed by bioengineered food innovations have become a major topic of concern in recent years. While it is easy for some, especially industry representatives, to believe that too much attention has been given to remote and negligible risks, Juma and Mugabe (1996) claims that environmental and public interest groups have become more concerned with the long term effects of bioengineered food innovations. The problem of risk assessment, according to Juma and Mugabe (1996), is complicated by the fact that most methods used to determine the level of risk are static and deterministic and at times dangerously rational. While corporations may determine the level of risks largely on the basis of potential effects on their profit earnings, public interest groups and community organizations may base their criteria on non-quantifiable criteria, such as the quality of life, environmental soundness and sustainable development objectives (Juma & Mugabe, 1996, p.122).

It has been argued by Juma and Mugabe (1996) that risk perception changes with the degree of uncertainty and the amount of information available to the public. This implies that the more credible the information that is made available and use by KNUST, the more their perceptions are likely to reflect the true risks and benefits of modern agricultural biotechnologies.

5.3.6 Recommendations: Two

The KNUST main library and the Department of Agriculture need to subscribe to a wide range of scientific journals and books that address issues related to modern agricultural biotechnology. In addition, the three major Ghanaian Universities (i.e. University of Ghana, University of Cape Coast and KNUST) should together institute an "Interlibrary Loan" program that allows students and faculty to access/share electronic research material from a unified database. An "Interlibrary Library Loan Program" may reduce the cost burden on each of the three institutions of having to maintain a regular and current stock of biotechnology research information. A typical interlibrary program may carry hard copies or electronic journals and articles on current issues related to biotechnology. Examples of such journals may include, "The Journal of AgroBiotechnology Management and Economics (AgBioForum)," "African Journal of Biotechnology," "Current Opinions in Biotechnology," "Food Biotechnology," "Journal of Biotechnology," "Nature Biotechnology," "Trends in Biotechnology," and "Trends in Food Science & Technology." Faculty need to encourage students to publish portions of their thesis in some of these journals. The department of agriculture needs to encourage students to publish portions of their thesis in journals by providing supplementary funding for publications.

A course in bioethics or general agricultural ethics that highlights the pros and cons and the ethics of agricultural biotechnology applications needs to be designed and taught within the faculty of Agriculture. This course may also be opened to students from other departments interested in the science of agricultural biotechnology. The course content may include for example biotechnology applications in industrialized and developing countries with special focus on Ghana and West African countries, intellectual property rights, biosafety and also overall preparedness of Ghana for the gene revolution.

One of the ways of ensuring that scientific knowledge and practices reflect the needs of people is to establish close links between the scientific community (KNUST agricultural science students and faculty) and local groups (farmers, local extension units). Juma and Mugabe (1996) contend that currently such links are very minimal in most of Africa, and the two groups tend to view each other with suspicion. Series of symposia and workshop may be organized where researchers (local, regional and international) are invited to speak to specific issues on biotechnology and the implications of those issues on Ghana's economy. The Department of Agriculture and Natural Resources should seek sponsorship of such educational activities from the private sector, businesses and governmental and non-governmental agencies. Revitalizing the channels of communication through continuous dialogue described above may neutralize some of the suspicions and encourage trust in science and agricultural biotechnology.

5.3.7 Summary of Findings: Three

Almost 90% of respondents said their confidence was either "High" or "Very High" in statements made by "Researchers" regarding bioengineered food innovations. On average 75% of respondents said they had "High" to "Very High" confidence in statements about bioengineered food innovations made by Health Professionals," spokesmen from "Biotechnology Companies," "Food Companies" and "Extension Specialists." With respect to "Non-Governmental Organizations," "Government Agencies" and "Farm Groups," approximately 55% of respondents said they had "High" to "Very High" confidence in statements made by spokesmen from these groups. Nearly 70% of all respondents said they had "Low" to "Very Low" confidence in statements about bioengineered food innovations made by "Celebrities/Popular Stars."

More that 75% of respondents contend that it is either "Important" or "Very Important" to investigate statements about bioengineered food innovations made by "Researchers," "Health Professionals," "Biotechnology Companies," "Food Companies" and "Extension Specialists" be thoroughly investigated. Approximately 70% of respondents also said it is "Important" to "Very Important" that statements about bioengineered food innovations made by "Farm Groups," "Government Agencies," "Non-Governmental Agencies" and "Activist Groups" be thoroughly investigated. A little more than 50% of all respondents believe statements about biotechnology made by "Celebrities/Popular Stars" are not worth investigating.

5.3.8 Discussion: Three

A wide range of 5% (n = 14.25) to 20% (n = 57) of both "High and "Low" knowledge respondents said they had "Low" confidence in statements about bioengineered food innovations made Extension Specialists, Health Professionals and spokespersons from Non-Governmental Organization. This wide variation in the number of "Low" confidence response among both "High" and "Low" self perceived knowledge respondents may signal a high degree of uncertainty with respect to confidence in statements made by Extension Specialists, Health Professionals and spokespersons from Non-Governmental Organization

Similar to the KNUST study, when the question of "Who can be trusted to tell the truth about genetically modified foods?" was asked in the Eurobarometer 1996, European responses were as follows: Environmental organizations (23%), consumer organizations (19.2%) farmer organizations (17%), medical profession (14%), universities (11%), television and news papers (4.84%), national public bodies (4%), industry (2%), religious organizations (1%), political parties (.5%) (Gaskell et al. 1996, p. 206). Gaskell et al. (1996) also found that more Europeans trusted international organizations such as the World Health Organization (WHO) and United Nations (UN) (35%) more than their own national institutions in terms of regulating biotechnology (National public bodies (17%) or EU (6%)). Like the KNUST study however, scientific organizations in Europe appear to enjoy a relatively high vote of confidence by being the second highest choice (22%). In terms of new genetically modified crops, Gaskell et al. (1996) found that environmental organizations were trusted the most (22%), with consumer and farming organizations second (17%). Gaskell et al. (1996) also found that, with respect to modern biotechnologies, environmental organizations and the medical profession are generally the most widely trusted institutions within their own spheres of competence. A similar biotechnology perception study by Wagner, Torgesen, Seifert, Grabner, and Lehner (1998) revealed that Austrians who are minimally acquainted with the topic tend to trust consumer organizations more than unacquainted respondents who either select the "Do not know" or "Neutral" option (who have more trust for public authorities the most).

On the whole, even though a majority of KNUST agricultural science students indicated they had high confidence in statements made by "Researchers," "Health Professionals," "Biotechnology Companies," "Food Companies" and "Extension Specialists," they still believe statements from these groups need to be thoroughly investigated. Respondents' confidence was lowest with respect to statements about bioengineered food innovations made by Celebrities/Popular stars; however, they also believe statements from this particular group warrant very little investigation. When viewed in terms of the credibility of information provided, and the value placed on investigation time, it is logical that respondents would rather investigate information provided by "Researchers," "Health Professionals," "Biotechnology Companies," "Food

Companies" and "Extension Specialists" because the value of time spent on these investigations is higher than on groups (i.e. celebrities etc.) deemed less credible.

Ten Eyck et al. (2004) hypothesize that trust or confidence is a significant determinant of perceptions and attitudes towards GM food, and that differential levels of trust may help explain differences in respondents' perceptions of modern biotechnology. The aouthors further argue that "if one has confidence in the regulators of a technology then the issue of trust does not arise in the sense that one places his or her fate in the hands of trusted others" (Ten Eyck et al. 2004, p. 262).

Gaskell et al. (1996) argue that knowledge is an important determinant of trust and support for science and technology; therefore, the more informed the public, the more likely they are to be supportive of science. For a new science like biotechnology, the knowledge-support hypothesis by Gaskell et al. (1996), might, in part, explain some of the ambivalence observed amongst KNUST students. Wagner et al. (1998) suggest that findings such as those reported in the KNUST study must be qualified by the degree of contact with the issue under discussion. It thus follows that the less contact with issues related to biotechnology, the lower the level of knowledge displayed and hence the higher the discourse displayed by respondents.

5.3.9 Recommendations: Three

From the above discussion, it is apparent that the degree of contact with issues on biotechnology through various communication channels (e.g., mass media, journals, coursework, etc.) will determine students' understanding and, consequently, level of ambivalence about the subject. In addition to university course work, the department of agriculture may occasionally organize debates for students on issues/topics surrounding biotechnology and its impact on food security and the environment. Panel discussions and symposia may also be organized to discuss the issues and concerns about modern biotechnology.

5.3.10 Summary of Findings Four

More than 60% of respondents said "Religious Concerns about Altering Nature" had a "Low" to "Very Low" impact on their perceptions of bioengineered food innovations.

5.3.9 Discussion: Four

The CIA World Fact Book (2005) indicates that Christians (63%) and Moslems (16%) together constitute nearly 80% of Ghana's population However, the results of this study show that religious concerns about biotechnology's ability to alter nature had very little impact on KNUST agricultural science students. When it comes to religion and biotechnology, Chapman (2001) explains that religious perspectives on genetics can offer broad frameworks for understanding the moral issues necessary to deal with the complexities of modern biotechnology. Religious organizations are known to influence people's perceptions of modern biotechnology in other places, but this influence appears to be very minimal amongst respondents in this study.

Chapman (2001) claims that when dealing with issues related to modern biotechnology, theologians and ethicists can draw on centuries, or even millennia of reflections about the nature of the person, human relationships, and social responsibilities. It has often been said that religious communities constitute historical traditions of moral wisdom, and thus provide the ethical background for understanding and interpreting embedded social morality (Campbell, 2001). But Chapman (2001) contends that, in contrast to the radical individualism so prevalent in today's society, most religious traditions have a concept that considers human beings as merely social and interdependent beings with a commitment to the common good. The genetic revolution offers both a challenge and an opportunity to religious communities: a challenge to apply values and frameworks to new and unprecedented issues and an opportunity to help interpret and illuminate significant ethical choices before members and the wider society (Chapman, 2001). The challenge in Ghana and most of Africa is how to get religious leaders involved in an educated debate on biotechnology issues. To be actively involved in the biotechnology debate requires a deeper understanding of the subject. While it is commonplace for some commentators to assume that religious communities or thinkers have positions based on their heritage that they can readily apply to biotechnology, Chapman (2001) contends that is clearly not the case. One theologian argued that in discussing the subject of modern biotechnology (e.g., cloning), it is practically impossible to directly apply religious tradition that has been worked out over centuries of cultural shift as though it were a cook book to a new discovery (Chapman, 2001, p. 113). Written within the context of pre-scientific societies, the foundational text of most religious communities does not speak directly to the ethical dilemmas raised by biotechnology (Chapman, 2001). Philosophical, ethical and theological concepts that were relevant to the intellectual milieu of past centuries do not easily illuminate the interpretation and analysis of contemporary science (Chapman, 2001, p. 113).

It would be erroneous to say or believe that religion does not play a part in shaping the biotechnology debate in Ghana. One possible reason why religious concerns about altering nature had a "Low" to "Very Low" impact on respondents' perceptions of bioengineered food innovations may be lack of knowledge about the subject among Ghanaian religious leaders themselves.

5.3.11 Recommendations Four

To shape a meaningful and effective moral response to the genetics revolution, religious thinkers must dig deeper into scientific literature on the subject of modern biotechnology. The seminaries could do more by organizing debates, lecture series and seminars on the subject of modern biotechnology (e.g., the ethics of modern biotechnology and implications for Africa or Ghana). Also, religious leaders need to educate themselves more on current and future trends in biotechnology by using the mass media, books and scientific journals as a source of information. A collaborative linkage founded on open discussions and exchange of ideas regarding modern biotechnology needs to be forged between religions thinkers and the scientific community both in Ghana and abroad.

5.3.12 Summary of Findings Five

The study results indicate that a greater majority (more than 60%) said, "Fear of Genes Moving Unchecked to other Plants, Insects or Microorganisms," "Fear of "Food Safety Consequences" and "Fear of Harm to the Environment" had either "High" or "Very High" impact on their perceptions of bioengineered food innovations.

5.3.13 Discussion Five

The study results obtained regarding the influence of gene movements between plants, insects and microorganisms and also potential harm to the environment show that respondents have serious concerns about bioengineered food innovations. These concerns expressed by respondents may perhaps be due to the perception that there are not enough researchers in the various institutions charged with biotechnology oversight in Ghana. When dealing with the introduction and implementation of modern agricultural biotechnologies in a country, lack of adequately trained researchers to draft and implement appropriate biosafety regulations can generate fear and concern among the public. The findings from this study suggest such fears among at least 60% of respondents surveyed. In most of Sub-Saharan Africa for instance, very few people are trained to carryout modern biotechnology research. Most tertiary institutions in Africa have the fundamentals of modern biotechnology (i.e. cell biology and tissue culture training) either completely missing in their curricula or at an infant stage. The few institutions that offer cell biology and tissue culture techniques are also constrained by lack of adequate laboratory facilities/equipments, well trained faculty to deliver the program or lack the necessary finances to sustain their programs. Even though the literature in this thesis points to numerous potential applications of modern biotechnology in Africa, the focus of biotechnology research in Ghana and most of Africa appears to be on traditional biotechnology with little or no work done in the area of modern biotechnology. Given the sophistication and financial costs associated with modern biotechnology, the decision by most African nations to keep their biotechnology programs at the traditional level makes sense, but this is not without costs. With the exception of South Africa and Egypt and a few other African countries that have the capacity to undertake modern biotechnology research, the majority of African countries simply focus their research efforts on traditional biotechnology research. Countries that focus entirely on traditional biotechnology may suffer the consequences of continued dependency on countries with well developed modern biotechnology programs.

The growing numbers of local, regional and international conferences held in Africa on modern biotechnology since 1990 indicate that a majority of African countries have an interest in modern biotechnology research. Clearly, the will to become a part of the gene revolution is there, but the means are yet to be firmly established in Africa.

In contrast to the situation in Africa, the "African Regional Conference for International Cooperation on Safety in Biotechnology" held in Zimbabwe in 1993 concluded that unlike their African counterparts, most Asian countries have a national policy and well defined research programs in modern biotechnology, as well as collaborative links with overseas experts.

5.3.14 Recommendations Five

Training of biotechnology researchers must be a well rounded process in that trained biotechnologists must be conversant with issues on biosafety, intellectual property rights and the ethics of biotechnology applications. Designing a well rounded modern biotechnology training program in African universities and research centers will equip future change agents with the necessary tools needed to improve the overall food system in Africa. Future change agents will then be better positioned to design national biotechnology policies and also provide the leadership needed to implement them. While it is important that the public in a country maintain some level of confidence in scientists and researchers, confidence must be earned. For example, the real threat faced by most African countries is the lack of well trained scientists to design and implement regulations which would allow for field-testing of organisms. Who would argue that poorly trained biotechnologist should not be trusted? Modified organisms can pose a real threat to humans and the environment. Oduwo (1993) argues that, that in most cases, populations in developing countries (like their scientists) are not as well informed as those in developed countries; hence, their inability to apply pressure or challenge planned biotechnology applications that have the potential to harm the environment and humans. Adequate access to current information on biotechnology advances in other countries is necessary to inform the masses of current and future trends of the technology. Breaking down the barriers posed by information asymmetry between developed and developing countries will facilitate the inclusion of Africa countries in the gene revolution. Participation in international conferences and seminars on modern biotechnology is one excellent way of obtaining current information and gaining knowledge on the subject; however, African countries must be willing to invest in these avenues.

A collaborative regional program needs to be forged between nation states (e.g., Benin, Burkina Faso, Ivory Coast, Ghana, Nigeria, and Togo). Once this program is in place, together the member states could seek supplementary funding from international donor agencies (e.g., USAID, UNESCO, The World Bank, etc.) for training and other needs. Establishing a collaborative linkage with regional and international experts and also involving the private sector in biotechnology research is key to the success of biotechnology research in Africa.

In terms of specific areas of training, experts suggest that developing nations interested in enhancing their modern biotechnology programs should focus on: microbiology, plant biology, cell biology, virology, genetics, biochemistry, molecular biology and the ethics of biotechnology. From an operational stand point, however, experts suggest that a new national biotechnology program must first and foremost focus on microbiological, cell and tissue culture as well as biochemical/molecular techniques.

5.4 OBJECTIVE 3: To Determine KNUST Students' Perceptions Regarding Government Efforts in Instituting Appropriate Frameworks Aimed at Facilitating the Adoption and Implementation of Bioengineered Food Innovations in Ghana.

5.4.1 Summary of Findings One

Nearly all (90%) respondents said they either "Agree" or "Strongly Agree" that the "Ghanaian Government Should Require Labeling of Transgenic Plant and Animal Products."

5.4.2 Discussion One

The above findings indicate how respondents perceive agricultural biotechnology and government's role in ensuring human and environmental safety. It is interesting that nearly all respondents surveyed would like to see the Ghanaian government enforce labeling of biotechnology products. This result is consistent with findings in most developed countries. A recent study in the United States found that an astonishing 92% of respondents favored labeling of GM products (Wimberley, Reynolds, Vander Mey, Wells, Ejimakor, Burmeister, Harris, et al. (2003). Michigan State University distinguished professor Lawrence Busch claims that "rarely is such level of consensus found on any issue" (Busch, 2004, p. 33). Even though some industry spokespersons have argued that labeling may be viewed by the public as a warning about potentially dangerous substances, Busch (2004) contends that regulations would enhance public confidence in new products. Busch (2004) further explains that any campaign to avoid regulations such as labeling will make it appear as though the biotechnology industry has something to hide.

The concerns raised by nearly 90% of KNUST respondents regarding labeling appear to be the heart of the European Union (EU) and the United States' GM labeling legislations. As far as labeling of GM products are concerned, both the EU and the US face essentially the same challenges in terms of the food supply and safety however they both have very different approaches/policies with respect to the introduction of bioengineered food innovations. It has been argued that substantial regulatory differences between the US and the EU in the area of biotechnology have been apparent for nearly two decades. While the US has moved from a strict regulatory stance since the early 1980s to one that is considered more permissive, the EU has changed over during the same period from a less to a more conservative and cautious regulatory approach (Patterson and Josling, 2001). In short, the US adopts what is known as the substantial equivalent approach while the EU adopts a more precautionary regulatory approach to products of bioengineered food innovations.

Table 25 presents the fundamental differences in U.S and EU labeling legislation.

Table25: *Alternative Models of Biotechnology Regulation in the US and EU*

	Precautionary	**Preventive**
Philosophy of Regulation	❖ Proactive regulatory approach ❖ Anticipates environmental hazards not currently documented but which could conceivably occur.	❖ Reactive regulatory approach ❖ Attempts to minimize environmental harm whenever the existence of harm has been scientifically demonstrated.
Basis of Regulation	❖ Based on process by which product is produced	❖ Based on safety, quality, and efficacy of product regardless of method of production

	Precautionary	Preventive
	Horizontal Regulation	**Vertical Regulation**
Type of Regulation	❖ Cross-cutting regulations need to be adopted to insure a basic level of human and environmental safety	❖ Existing sectoral regulations modified to insure human and environmental safety of new biotech products.

Source: Patterson and Josling, (2001)

Many researchers believe that the two models presented in Table 25 are at the heart of the major differences in biotechnology regulation in the US and the EU. While the first model represents a regulatory paradigm that is process-based, horizontal, and precautionary, the second represents a more traditional product-based, vertical, preventive approach. In most cases, aspects of both models have played a role in the development of biotechnology regulations in both the US and the EU (Patterson and Josling, 2001). According to Kershen (2003), the EU for example defends its "process-based" labeling on the grounds that it honors the consumer's right to know, and for reasons that consumers' will gain confidence in agricultural biotechnology. Another reason cited for mandatory labeling is that it facilitates efficient monitoring of agricultural biotechnology foods, including product recalls if and when necessary. Lastly, it is argued that mandatory labels respect the ethical concerns of consumers by providing them the information upon which they can choose foods that accord with their ethical frameworks Kershen (2003). Kershen (2003) explains that a major difference between the EU and US with respect to GM labeling is that, while the US is willing to place the burden of responsibility on a free and fair market to decide consumer acceptability of biotechnology foods, the EU on the other hand does not seem to trust that a free market will work in the case of GM foods. While the US can use the same reasons outlined above to justify its product labeling, it still remains debatable which strategy (product or process) affords consumers the most protection.

5.4.3 Recommendations One

It is not certain how the two regulatory principles presented in Table 25 will affect labeling of GM products in developing countries; however African countries specifically Ghana have a lot to learn from both the EU and US approach. Developing countries may either design their own distinct labeling legislation or adapt a pre-existing legislation (either precautionary-EU or substantial equivalent-US). It has been argued that social and philosophical differences resulting from different historical, political and cultural experiences define GM labeling legislation in developed countries. Thus simply adopting GM legislation from a more advanced country might not necessarily present a perfect fit for African countries. While it may appear logical to simply copy pre-existing GM legislation from a more advanced country, African nations needs to seriously consider both short and long term implications of coping versus designing their own. Regardless of which type of legislation that is adopted/adapted, developing countries need to study how GM regulations have evolved overtime in other countries. What led to the evolution? What are the implications both local and international? What has been accomplished etc.? African countries will need to develop labeling regulations that will first and foremost meet local conditions/needs while at the same time keep them active within the global economy.

The implications of the findings in this study may reflect in future policy decisions regarding GM labeling in Ghana because how well future GM labeling policies address local, regional and global needs will depends on how much the future change agents (i.e. KNUST and other college students) are exposed to the subject.

5.4.4 Summary of Findings Two

A greater majority of respondents (60%) either "Disagree" or "Strongly Disagree" with the statement that "Ghana Has in Place the Essential Bio-Safety Legislation to Receive GM Crops from Abroad." Similarly, majority of respondents 60% either "Disagree" or "Strongly Disagree" with the statement that Ghana has "Enough Qualified Persons to Test Transgenic Crops."

5.4.5 Discussion Two

Like most African countries, Ghana has had a relatively long history of traditional biotechnology research, especially in agriculture yet their human and natural resource base still remains weak compared to the tasks that need to be performed in modern biotechnology. From the literature reviewed in this thesis, it is apparent that most African countries suffer the same plight because their biotechnology industry appears to be defined by a lack of adequately trained biotechnologists, and also lack of equipment and adequate facilities to conduct modern biotechnology research. Clearly, African countries have an interest in modern biotechnology; however, their interest is yet to be transformed into a vibrant biotechnology sector. Tedla and Berhe (1995) explain that scientific research and technological innovations are essential for sustaining and accelerating rapid development of developing nations. For agricultural biotechnology to fulfill its promise of providing food security in Africa and elsewhere, it will require private-public collaboration and government support of universities and research institutions in order to produce high quality and technically competent scientist.

"More perhaps than any other technology except for nuclear fusion, biotechnology derives from university science" (Avramovic, 1996, p. 34). It is therefore appropriate to say that modern agricultural biotechnology is mostly research intensive, and dependent for its success on high quality research personnel. For example, Avramovic (1996) points out that since 1985, all the seminal discoveries in modern biotechnology have come from universities or research institutions, not large firms. The success of the biotechnology industry in developed countries may thus be attributed to government support for major universities and research institutions through funding and other logistical aid. A major hindrance to biotechnology development in Africa is the disconnect between university scientists/researchers and national policy makers. For example Juma and Mugabe (1996) noted that formulation of public policy is undertaken by very few people, mainly within government, with very little or no university or private sector participation in these processes. Juma and Mugabe (1996) add that drafts of policy documents are rarely made available for comments outside the relevant government agencies because the political systems generally do not allow public participation in matters of national concern. According to Chetsanga (1993), East Asian countries, unlike their African counterparts have established linkages between private and public sector bodies in their biotechnology programs. It is worth noting that Asian countries have national policies and well-defined research programs in biotechnology to complement a well developed collaborative linkage with technologically advanced nations.

5.4.6 Recommendations Two

One of the major challenges for most African nations interested in developing a national modern biotechnology program is training of citizens in the relevant areas. Currently, training of African biotechnologists is done by the International Institute of Tropical Agriculture (IITA) and the Life Science Program of UNESCO (Woodward et al. 1999). It is believed that between 1990 and 1995, IITA trained about 50 African scientists six of whom obtained a doctor of philosophy degree. Within the same period, UNESCO also trained 180 scientists from 23 African countries in basic and advanced tissue culture techniques, and application of molecular markers (Woodward et al. 1999). Without well-trained researchers in Ghana there is bound to be increased ambivalence among the public regarding the safety of biotechnology. Recruiting and training biotechnology researchers and personnel requires the necessary financial and institutional investments/commitments. For this reason, for Ghana and other African countries to be part of the gene revolution, they must take the necessary steps including making available funds for training, identifying the persons to be trained, where the training is to be take place and finally make available incentives for the trainees to apply their knowledge at home.

Lack of the opportunity to apply skills obtained in developed countries upon returning home prevents most African students from returning home where their skills are most needed. A probable solution to this problem will be to adopt "sandwich" training programs where potential African biotechnologists/researchers receive parts of their training regionally and part in more advance/developed countries. Adopting a "sandwich" strategy will ensure that skills acquired have meaning and can be applied in a continental and regional context. According to Woodward et al. (1999), some countries in Africa now send their students for training in South African universities in the hope that graduates will be more willing to return to their home-countries at the end of their programs. While the applicability of skills acquired from more advanced countries may not be readily observed, such skills in the long-run will help inform developing country biotechnologists of the present and future trends within the field of biotechnology. A well informed scientist will be better positioned to advice government about which areas of biotechnology are relevant both for present and future investment purposes.

In all biotechnology applications, the appropriate biosafety protocol needs to be in place before the final product of the technology is passed onto consumers. Putting in place appropriate safety protocols will boost public confidence in the technology. Currently, only 5 out of 53 countries in Africa have official regulations governing the commercial release and distribution of transgenic seeds (Kent, 2004). The lack of appropriate regulations in 48 countries: either their complete absence or their impractical nature according to Kent (2004) is the biggest single barrier to the development of commercial biotechnology products (seeds) in developing countries. At present, the benefits of modern biotechnology advances are minimal in developing countries partly due to beauraucratic procedures involved in evaluation and approval procedures. To change this situation, Kent (2004) suggests that the US and other developed country governments need to encourage the development of a more appropriate regulation in developing countries, through projects such as USAID's new Program for Biosafety Systems (PBS). Also, developing nations need to actively seek and forge collaborative linkages that will allow them to benefit directly from programs such as USAID's PBS.

Specifically, developing countries can benefit directly by adapting preexisting models of regulations to their specific needs. Additionally, African countries need to embark on their own awareness and educational campaigns and if need be appeal to international and donor agencies to complement their efforts in training and raising awareness in specific areas of modern biotecnology.

Developing country governments need to provide the staff within their Ministry of Agriculture and Environmental Protection Services with training on risk assessments and management within the framework of biotechnology. This could be done through organized regional workshops where collaborators and modern biotechnology experts from both developed and developing countries converge to discuss region specific issues and craft long and short term action plans. These training programs and workshops can also serve as a platform for raising awareness and addressing relevant biosafety concerns. Previous studies on the safety of specific biotechnologies, e.g., Bt technology, may be analyzed as part of a regional workshop/training package. Thorough analysis of previous bio safety research studies (on specific biotechnology products) will allow developing countries to question the safety of specific biotechnology applications and their implications in a local and regional context. In the US, for example, the Food and Drug Administration (FDA), USDA, and Environmental Protection Agency (EPA) carryout extensive studies before products are released onto the market. Some of these reports/studies are made available to the public and may be obtained and studied.

Unlike most developed countries, in most of Africa, the public is rarely involved in decision making on issues such as modern biotechnology applications. Very little thought is given to the fact that decisions made on biotechnology applications may pose risks to the public and their environment. Juma and Mugabe (1996) contend that these methods of policy design and implementation need serious reconsideration/revision in order for African countries to benefit from modern agricultural biotechnology. Due to uncertainties associated with biotechnology, it is recommended that African countries institute appropriate biosafety standards that would allow screening of transgenic crops and animals received from abroad. Such mechanisms, according to Wafula (1999), should encompass developing adequate risk assessments strategies for biotechnological products, and mechanisms and instruments for monitoring use and compliance in order to minimize harmful effects to the environment and humans. A more inclusive or participatory approach to policy design and implementation is needed to close the institutional gap in Africa and boost public confidence in modern biotechnology. Borrowing from Wafula (1999), one way to ensure full involvement in the biotechnology debates is to require or ensure, through training programs, increased technical expertise among mid and high-level positions in ministries and research institutes. While these individuals may play strategic roles in cultivating extensive international contacts needed to augment local and regional expertise, Wafula (1999) adds that they may also provide the capacity for technical analysis, critical review of information, consultation, and peer review.

5.5 OBJECTIVE 4: To Determine Sources of Information used by KNUST Students in Establishing their Knowledge and Perceptions Regarding Bioengineered Food Innovations.

The fourth objective was to describe sources of information used in obtaining information on bioengineered food innovations and how these sources impact respondents' knowledge and perceptions of modern agricultural biotechnology.

5.5.1 Summary of Findings One (a)

About 90% or more respondents on average said they either "Occasionally" or "Always" utilize "University Coursework," "Scientific Journals" and "Television" to gain information on biotechnology. More than 80% of respondents said they either "Occasionally" or "Always" used "Internet," "Technical Publications/Reports" and "Newspaper" to obtain information on bioengineered food innovations. More than 70% said they either "Occasionally" or "Always" used "Radio" and "Popular Magazines" to gain information on bioengineered food innovations. An average of 61% of respondents said they "Occasionally" to "Always" used "Non-Governmental Organizations" and "Extension/Government Services" to gain information on bioengineered food innovations.

5.5.2 Summary of Findings One (b)

When respondents were asked to rate the extent to which they hear something about bioengineered food innovations from selected sources, the results obtained were nearly the same as those obtained in section 5.5.1. Only "Non-Governmental Organizations" and "Extension/Government Services" produced different results. On average, 65% of respondents said they "Occasionally" to "Always" hear something about biotechnology from "Non-Governmental Organizations" and "Extension/Government compared to 61% who said used these sources to seek information on the subject.

5.5.3 Summary of Findings One (c)

It is not surprising that almost 95% of respondents said "Knowledge from Science Classes" "Occasionally" to "Always" impact their perceptions of bioengineered food innovations. The results obtained above indicate that university course work is use the most in obtaining knowledge about modern agricultural biotechnology. The findings also show that, on average for 80% of respondents, "University Professors Beliefs about Biotechnology," "Experience in Science Laboratories," "Publicly Accepted Attitudes towards Biotechnology" and "Friends' Beliefs about Biotechnology" "Occasionally" or "Always" impacted their perceptions of bioengineered food innovations. With respect to "Family and Religious Beliefs about Biotechnology," the results depict that approximately 66% of respondents said these issues either "Occasionally" or "Always" impact their perceptions of bioengineered food innovations.

5.5.4 Discussion One

The findings indicate that KNUST agricultural science students mostly use, "University Coursework" and "Knowledge from Science Classes" to gain information about bioengineered food innovations. This result is not surprising because the structure of KNUST agricultural science program mandates that students take certain core science classes and attend laboratory sections, some of which touch on the subject of modern agricultural biotechnology. In contrast to the findings in this study, Hoban (2003), found that most people in developed countries including the United States get their information on biotechnology from media coverage. In a similar study done by Fritz et al. (2003), "Newspapers" emerged as the most popular media source use by both adults (73.8%) and undergraduates (76.7%) for information on biotechnology in the United States. The authors also found that the Internet was cited as another important source by 58.9% of adults and 58.2% of the undergraduates (Fritz et al. 2003). Hagedorn and Allender-Hagedorn (1995) also found that 25% of respondents in the United States felt they understood introductory science concepts and indicated that most of their information on biotechnology comes from television (90%) and newspaper (80%) sources. It is however encouraging to find that Scientific Journals," "Television" and the "Internet" are often used by most respondents in this study. While most scientific/electronic journals may contain very specific and credible information on bioengineered food innovations, the internet in a broad sense may contain much information most of which might not be credible and thus will need further verification. Even though "Extension/Government Services" may be very useful in informing students about agricultural biotechnologies, this particular medium is least used. A reason for this may be the structure of Ghana's agricultural extension program, which lacks adequate agricultural extension personnel thus making it impossible for extension staff to share field knowledge with students even if they possess the knowledge.

Bauer, Durant and Gaskell (1998) hypothesize that the degree of public engagement is dependent upon the degree of professional engagement with modern biotechnology issues in any particular country. It is believed that perceptions and degree of understandings of agricultural biotechnology in most developed countries is strongly influenced by the type of information provided by the media, confidence in governmental safeguards, and cultural preferences (Hoban, 2003). According to Bauer et al. (1998) countries that are earlier entrants into the policy and media debate are those with relatively more "mature" public debates about modern biotechnology. The authors define maturity in this context to mean either that there is a "natural" trajectory of public debate about biotechnology or that earlier entrants are somehow more informed and, for that reason, maintain a higher standard of public debate. Earlier entrants may be classified as countries in which the public domain has had a greater opportunity to experience, learn about, deliberate on, display extensive and wide ranging public discourses and possibly come to hold clear views about modern biotechnology (Bauer et al. 1998).

Hoban (1999) explains that due to incomprehensible responses from scientist working on biotechnology, the mass media has become the major public source of information on the subject. Findings from this study indicate otherwise. Relatively few respondents use media sources to obtain information on modern agricultural biotechnology in Ghana. Generally, the media in both technologically advanced and developing nations have the tendency to present sensational and new stories (Hoban, 2002) resulting in biased coverage of issues that only appeal to or arouse the public's concerns (Wingenbach et al. 2004). While it is a fairly accurate assertion that the Ghanaian media currently play a limited role in shaping public perceptions of biotechnology in Ghana, this role will increase with increased adoption of modern biotechnology in Ghana. Ensuring that students use a wide range of information sources to gain knowledge about the modern biotechnology issues will allow KNUST students and the public at large to critically evaluate media publications and not be swayed by sensational coverage.

5.5.5 Recommendations One

The results obtained in this study indicate that information on agricultural biotechnology is provided mostly through university coursework. In most cases university course work may be deemed more credible in terms of providing accurate and unbiased information on the subject. If perceptions are developed from knowledge gained in science classes, laboratories, and interactions with biotechnology scientists, students may have a clear and better understanding of the issue at stake (Wingenbach et al. 2004). Compared to most developed countries, the free media in Ghana is relative new. However, with a rapidly growing mass media, it is possible that the media will become much more influential in shaping biotechnology perceptions among the public in the next five to ten years.

Gaskell et al. (1996), assert that knowledge is an important determinant of support for science and technology. Therefore, the more informed the public the more likely they are to be supportive of bioengineered food innovations. Low knowledge of basic agricultural and biological sciences in Ghana and most of Africa adds to the misinformation already existent on the subject of modern biotechnology. This lack of understanding according to Hoban (2003) generates concern, especially when coupled with negative media coverage. Wingenbach et al. (2004) contend that understanding the science of biotechnology will increase students' confidence in communicating these issues in future careers. Therefore, it is recommended that educators in KNUST and other secondary and tertiary institutions evaluate the depth and clarity of their science curriculum in order to ensure true understanding and knowledge transfer to students. To be able to critically analyze media stories on biotechnology will require substantial knowledge about the subject. Deep knowledge of modern biotechnology can only come through using a range of information sources namely, internet, scientific journals, course work, participation in workshops, etc. Students and faculty need to be active participants in local, regional and international conferences on modern agricultural biotechnology.

5.6 OBJECTIVE 5: To Describe How Different Sources of Information Influence Respondents' Self Perceived Knowledge of Bioengineered Food Innovations.

5.6.1 Summary of Findings

The final objective of this study determined how different information sources and experiences influence KNUST agricultural science students' self perceived knowledge of bioengineered food innovations. When self-perceived knowledge was correlated (through cross tabulations) with all other variables in the questionnaire, of thirteen variables, as depicted in Tables 13 through 21, were found to be significant ($p < 0.05$) in influencing respondents' self-perceived knowledge of bioengineered food innovations. Upon further statistical analysis using Probit and Logit models, only four variables were found to significantly increase respondents' self perceived knowledge from "Low" to "High" when used in isolation. Using Probit and Logit models, the extent to which "Internet," "Radio," and "Newspapers" were used in seeking information on biotechnology was found to significantly increase respondents self perceived knowledge from "Low" to "High." Similarly, Friends' Beliefs about biotechnology were also found to significantly ($p < 0.05$) increase self-perceived knowledge from "Low" to "High."

A comparison of "Low" and "High" self perceived knowledge respondents show that respondents who said their knowledge was "Low" also said their friends' beliefs "Never" impacted their perceptions of bioengineered food innovations ("Low" = 20.14% compared to "High" = 10.95%). A greater percentage of respondents who said their self perceived knowledge was "High" also said their friends' beliefs about bioengineered food innovations "Always" influenced their perceptions ("High" = 2.47% compared to "Low" = 1.06%).

Comparatively, a greater percentage of "High" self perceived knowledge respondents relative to "Low" knowledge respondents said it was "Very Important" for bioengineered food innovations research to focus on control of released genes into the environment. On the other hand, a greater percentage of "Low" knowledge respondents, relative to "High" knowledge respondents believe it is "Not at all Important" for bioengineered food innovations research to focus on control of released genes into the environment.

5.6.2 Discussion

Even though tables 13 through 21 indicate that "Internet," "Technical Publications/Reports," "University Course Work," "Scientific Journals," Knowledge From Science Classes" and "Friends' Beliefs about Biotechnology" were all significant in shaping respondents self-perceived knowledge of bioengineered food innovations, it is surprising that only four out of thirteen variables were significant in the Probit and Logit models. To broaden students' knowledge of bioengineered food innovations, it is important that all the other variables included in Tables 13 through 21 be seriously considered as potentially useful sources of information on modern biotechnology.

5.6.3 Recommendations

In a 2004 study involving 11 land grant universities in 10 states in the US, Wingenbach et al. (2004) found that 84% of future agricultural science students (communicators) involved in the study believed their level of scientific knowledge was average to high, and 24% believed they had "above-average" scientific knowledge. The authors also found a positive correlation between experience in agriculture and respondents' knowledge of biotechnology. Even though Wingenbach et al. (2004) claim that the difference between perception and reality may be debatable, the authors contend in their study, students' perceived and actual knowledge of biotechnology was not debatable. It is thus recommended that KNUST agricultural science students (future agricultural communicators and change agents) interact with others involved in science and biotechnology research. Options that might be considered may include student internships, field experience (also known as vacation trainings) that focus on agricultural biotechnology training and workshops, visits to biotechnology research stations/firms and agencies, experimental farms and other organizations undertaking biotechnology research.

5.7 Conclusion

Determining knowledge and perception levels of biotechnology among KNUST students and then providing relevant information on the subject through the appropriate channels will help reduce the degree of uncertainty regarding acceptance or rejection of bioengineered food innovations among students. The theoretical framework presented in chapter one explains that through communication, participants involved in diffusion of innovations (change agent and client) create and share information with one another in order to reach a mutual understanding. This thesis provides KNUST students with information on modern agricultural biotechnology so that they may make informed choices in the future regarding issues related to modern agricultural food innovations.

Ghanaian college students, including those from KNUST, are the future change agents (policy makers and opinion leaders). It follows that if opinion leaders/change agents are to be recognized by their peers as competent and trustworthy experts regarding an innovation, they should have ample knowledge about the innovation. According to Rogers (2003), opinion leaders often have greater exposure to mass media, are more cosmopolitan and have higher socio-economic status than their followers. Also, change agents have the responsibility of reviewing the practical applications of an innovation, adopting or rejecting the innovation before their followers are exposed to them. KNUST students fit perfectly the description of future change agents described above. In order for KNUST students to effectively play the role of change agents of modern agricultural biotechnology, they will need to employ a wide range of information sources and communication channels in seeking the relevant knowledge. The Probit and Logit models presented in chapter four indicate that respondents who used "Internet," "Newspaper," "Radio," and "Friends' Beliefs about Biotechnology" were more likely to proclaim high self perceived knowledge of modern agricultural biotechnology. It may be inferred from the theoretical framework that most developing countries, including Ghana, are currently at the "Knowledge," "Persuasion" and "Decision" stage of modern agricultural biotechnology innovations where mass media and interpersonal channels appear to be the most important channels of information. Mass media channels are relatively more important at the knowledge stage, while interpersonal channels are more important at the persuasion stages in the innovation-decision process (Rogers, 2003). The Probit-Logit results regarding the significance of "Internet," "Newspaper," "Radio," as communication channels are in line with Rogers' recommended information channels for the knowledge stage. "Friends' Beliefs about Biotechnology," constitutes an interpersonal communication channel which is most important at the persuasion stage in the innovation-decision process.

It may be concluded from the Probit-Logit models that "Internet," "Newspaper," and "Radio" sources are the communication channels used the most by KNUST students to obtain information on agricultural biotechnology. The theoretical framework presented in chapter one suggests that these communication channels are most appropriate for facilitating information flow at the "Knowledge," "Persuasion" and "Decision" stages of an innovation in this case modern biotechnology. Even though "Journal Articles" were not significant in the models, they are most likely the most objective/unbiased and reliable source of information on modern agricultural biotechnology and are highly recommended for use by KNUST agricultural science students.

KNUST students, by virtue of their educational backgrounds, fit perfectly the description of innovators and early adopters described in Rogers' adopter categories in Table 26. Like other college students in Ghanaian universities, there is some degree of interaction between KNUST agricultural science students and university faculty and researchers. Generally, Ghanaian college students have the capacity to access various sources of information. Therefore, they can play a key role in shaping the biotechnology debate in Ghana. Table 26 presents the Roger's adoption categories and their characteristics.

Table 26: *Rogers Adopter Categories and Characteristics*

Adopter Category	Characteristics
1) Innovators - First 2.5% of individuals in a social system to adopt an innovation	❖ Venturesome and eager to try new ideas ❖ Have more years of formal education ❖ Have higher social status ❖ Have substantial financial resources ❖ Able to cope with high degree of uncertainty ❖ Contacts outside peer group ❖ May or may not be respected by peers
2) Early Adopters - Next 13.5% of individuals in a social system to adopt an innovation	❖ Respected by peers ❖ More integrated part of the local system ❖ Opinion leaders - potential adopters look to them for advice and information ❖ Change agents ❖ Role models for other members of social system
3) Early Majority - Next 34% of individuals in a social system to adopt an innovation	❖ Deliberate before adopting new idea ❖ Adopt new ideas just before the average member of a system ❖ Interact frequently with peers ❖ Rarely hold positions of opinion leadership ❖ Provide interconnectedness in the system's interpersonal networks
4) Late Majority - Next 34% of individuals in a social system to adopt an innovation	❖ Approach innovations with caution and skepticism ❖ Adopt new ideas just after the average member of a system ❖ Adoption may be due to economic necessity or peer pressure ❖ Unwillingness to risk scarce resources ❖ Uncertainty about innovation must be removed before adoption
5) Laggards - Last 16% of individuals in a social system to adopt an innovation	❖ Hold on to traditional values ❖ Resistance to innovations ❖ Last to adopt an innovation ❖ Near isolates in the social networks of local system ❖ Suspicious of innovations and change agents

Source: Winnie Tsang-Kosma: http://www2.gsu.edu/~mstswh/courses/it7000/papers/rogers'.htm

5.8 Recommendations for Further Research

1.) It is recommended that future research monitor trends in student perceptions by replicating this study over regular intervals in major universities in Ghana and across other developing countries in Africa. When dealing with biotechnology, it is extremely important that researchers and national leaders understand what people truly think and want to know about this science. Future research of this nature should include a “simple straightforward” knowledge test sections. Knowledge tests will enable researchers to explore relationships between respondents’ self perceived knowledge and actual knowledge using correlations, cross-tabulations or appropriate statistical tools. It is important to establishing the exact nature of the relationship between students’ actual and perceived knowledge because this may be incorporated in the science curricula design aimed at expanding students’ knowledge of science and modern biotechnology.

2.) Future research studies should explore how socio-cultural and economic characteristics influence respondents’ perceptions of risk associated with modern agricultural biotechnology. Due to different socio-cultural and economic experiences, perceptions and acceptance of health and environmental risks associated with modern biotechnology may vary across countries. Harsh socio-economic conditions in most developing countries are likely to overshadow the perceived risks of agricultural biotechnology. At best, the risks of agricultural biotechnology may be considered abstract. Further research in this area may involve the use of Logistic Regression models or the Logit/Probit models to predict respondents’ perceptions of risks. Like the Probit-Logit models used in predicting KNUST students’ self-perceived knowledge about biotechnology, a Logistic Regression model may be used to predict risk perception based on whether respondents agree or disagree with various statements related to risks associated with modern biotechnology. This analysis has the advantage of broadening the scope of future research by incorporating perceptions of risk into general perceptions of modern biotechnology.

3) It is recommended that future research include non-agricultural science students. Due to the different levels of exposure to modern biotechnology and also the different information channels used in obtaining knowledge about biotechnology, it is possible that non-agricultural science students will perceive modern biotechnology differently from agricultural students. Further research is needed to validate this claim and to uncover the information gaps.

4) Future studies must also target current policy makers and government officials (current change agents) in Ghana. It is important to know how they perceive biotechnology, if possible their actual knowledge levels and also the sources of information most frequently used to obtain information on the subject.

5) It is recommended that a comparative study be undertaken to determine differences in biotechnology perception between the current study group (KNUST or other similar populations) and non-agricultural science students and policy makers. Such a study may also investigate the differences in the information channels/sources used and the degree to which they are used by each of the study groups.

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APPENDIX A

Letter to the Dean of KNUST

12 April 2004

Professor D. B. Okai, Dean
Faculty of Agriculture
Kwame Nkrumah University of Science & Technology
Kumasi - Ghana

Dear Professor Okai:

By way of introduction, my name is Michael Woods, an Assistant Professor in the Department of Community, Agriculture, Recreation and Resource Studies (CARRS) at Michigan State University. Currently, I am working with Mr. Doe Adovor, a master's student in the CARRS department. Mr. Adovor is a Ghanaian and former student from the Faculty of Agriculture at Kwame Nkrumah University of Science & Technology.

Currently, we are conducting a research study that seeks to investigate Ghanaian college student's perceptions of biotechnology. This research study will be used to fulfill part of Mr. Adovor's master's theses requirement in the CARRS department. In anticipation of including agricultural students from KNUST in our study, we write to seek your permission to conduct this study among students from academic programs offered by the Faculty of Agriculture.

For your review, we have attached a sample of our questionnaire. Presently, Mr. Adovor is seeking a collaborating faculty research partner from the Faculty of Agriculture for this study. Please note that your faculty and institution will not incur any financial burdens associated with this project. We will provide all survey to distribute to the respondents and cover all postage costs.

We appreciate your full consideration of this request. Should you need further information regarding this request, please call upon me at mwoods@msu.edu or 517.355.6580 x 202. We look forward to working with your institution and faculty in launching this baseline study regarding Ghanaian college student's perceptions of biotechnology.

Sincerely,

Michael D. Woods, Ph.D.

Assistant Professor

APPENDIX B

The Survey Questionnaire

When completed, please return your survey booklet to the survey administrator.

Thank you for your cooperation with this study.

Ghanaian College Students' Perception of Biotechnology

Directions

Purpose: The purpose of this status survey is to assess Ghanaian college student's perceptions of biotechnology.

The Questions: Please read each statement and immediately respond with your initial reaction. We are only interested in your honest opinions. There are no correct or incorrect answers.
This questionnaire takes about 10 minutes to complete.

Confidentiality: We respect your confidentiality by removing your name and other identifying information from your survey. Your participation in this study is voluntary and you may withdraw at any time. Your privacy will be protected to the maximum extent allowable by law.

When Finished: Upon completion of the questionnaire, please return your survey booklet to the survey administrator.

Questions: Please feel free to contact Dr. Richard Akromah at rakromah@yahoo.com or Dr. Michael Woods at mwoods@msu.edu if you have questions regarding this study.

By completing the survey, you acknowledge that this questionnaire is voluntary and recognize that you will not be penalized if you choose not to participate. By completing this questionnaire you give your consent to be included in the study.

Begin survey.

To what extent do you believe that biotechnology will affect the following?	Very Negative	Somewhat Negative	Somewhat Positive	Very Positive
1. Commercial farming	1	2	3	4
2. The environment	1	2	3	4
3. Fish and wild life	1	2	3	4
4. Food production	1	2	3	4
5. Small scale farms	1	2	3	4
6. World hunger	1	2	3	4
7. Your health	1	2	3	4

To what extent do you utilize the following source(s) to gain information about biotechnology?	Never	Occasionally	Often	Always
8. Extension/Government Services	1	2	3	4
9. Internet	1	2	3	4
10. Newspapers	1	2	3	4
11. Non-Governmental Organizations	1	2	3	4
12. Popular magazines	1	2	3	4
13. Radio	1	2	3	4
14. Scientific journals	1	2	3	4
15. Technical publications/reports	1	2	3	4
16. Television	1	2	3	4
17. University course work	1	2	3	4

How often do you hear something about biotechnology from the following sources?	Never	Occasionally	Often	Always
18. Extension/Government Services	1	2	3	4
19. Internet	1	2	3	4
20. Newspapers	1	2	3	4
21. Non-Governmental Organizations	1	2	3	4
22. Popular magazines	1	2	3	4
23. Radio	1	2	3	4
24. Scientific journals	1	2	3	4
25. Technical publications/reports	1	2	3	4
26. Television	1	2	3	4
27. University course work	1	2	3	4

To what extent do you use the following experiences to establish your perceptions about biotechnology at the present time?	Never	Occasionally	Often	Always
28. Publicly accepted attitudes toward biotechnology	1	2	3	4
29. Experience in science labs	1	2	3	4
30. Family's beliefs about biotechnology	1	2	3	4

31. Family's beliefs about biotechnology	1	2	3	4
32. Friends' beliefs about biotechnology	1	2	3	4
33. Knowledge from science classes	1	2	3	4
34. Religious beliefs	1	2	3	4
35. University professors' beliefs about biotechnology	1	2	3	4

What level of importance should be placed on biotechnology research regarding the following issues?	**Not at all Important**	**Fairly Important**	**Imprtant**	**Very Important**
35. Added nutritional value to food	1	2	3	4
36. Benefits to the environment	1	2	3	4
37. Control of released genes	1	2	3	4
38. Harming the environment	1	2	3	4
39. Reduction of pesticides	1	2	3	4
40. Risk compared to pesticides	1	2	3	4
41. Safer food	1	2	3	4

How much confidence do you place in statements about biotechnology made by spokespersons from the following organizations?	**Very Low**	**Low**	**High**	**Very High**
42. Activist groups	1	2	3	4
43. Biotechnology companies	1	2	3	4
44. Celebrities/popular stars	1	2	3	4
45. Extension specialists	1	2	3	4
46. Farm groups	1	2	3	4
47. Food companies	1	2	3	4
48. Government agencies	1	2	3	4
49. Health professionals	1	2	3	4
50. Non-governmental organizations	1	2	3	4
51. Researchers	1	2	3	4

How important is it for you as a future agricultural industry professional to investigate claims made about biotechnology by the following groups?	**Not at all Important**	**Fairly Important**	**Imprtant**	**Very Important**
52. Activist groups	1	2	3	4
53. Biotechnology companies	1	2	3	4
54. Celebrities/popular stars	1	2	3	4
55. Extension specialists	1	2	3	4
56. Farm groups	1	2	3	4
57. Food companies	1	2	3	4
58. Government agencies	1	2	3	4
59. Health professionals	1	2	3	4
60. Non-governmental organizations	1	2	3	4
61. Researchers	1	2	3	4

To what extent do the following issues impact your perception of biotechnology?	**Very Low**	**Low**	**High**	**Very High**
62. Fear of harm to the environment	1	2	3	4
63. Fear of food safety consequences	1	2	3	4
64. Fear of genes moving unchecked to other plants, insects or microorganisms	1	2	3	4
65. Religious concerns about "altering nature"	1	2	3	4

To what extent do you agree with the following statements?	**Strongly Disagree**	**Disagree**	**Agree**	**Strongly Agree**
66. There are enough qualified persons to test transgenic crops in Ghana.	1	2	3	4
67. Ghana has in place the essential bio-safety legislation to receive GM crops from abroad.	1	2	3	4
68. The Ghanaian government should reject patent protection of transgenic plants.	1	2	3	4
69. The Ghanaian government should reject patent protection of transgenic animals.	1	2	3	4
70. The Ghanaian government should require labeling of transgenic plant products.	1	2	3	4
71. The Ghanaian government should require labeling of transgenic animal products.	1	2	3	4

Demographic Questions	
72. Age	**a. 19 or less** **b. 20** **c. 21** **d. 22** **e. 23** **f. 24** **g. 25+**
73. Sex	**a. Female** **b. Male**
74. What is your current year in college?	**a. 1st year** **b. 2nd year** **c. 3rd year** **d. 4th year**
75. How would you rate your current level of knowledge regarding biotechnology?	**a. Very low** **b. Low** **c. High** **d. Very high**
76. What discipline are you studying?	**a. Animal science** **b. Crop science** **c. Agric Econ** **d. Horticulture** **e. Mechanization** **f. General Agric**

APPENDIX C

Age Distribution of Respondents

Age Categories	Frequency	Percent
19 or less	9	3.0
20	32	10.6
21	38	12.6
22	60	19.9
23	52	17.3
24	49	16.3
25+	52	17.3
Non-Respondents	9	3.0
Total	**301**	**100.0**