NANOTECHNOLOGY AND FOOD:

THE PERCEPTION AND LEVEL OF ACCEPTANCE OF NANOTECHNOLOGY USE IN FOODS

BY

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ABSTRACT OF THE THESIS

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The Food Industry is continually growing and looking for new technologies to increase production output as well as profits. Often achieved through technological advancements, one of the newest food technologies is nanotechnology food, which includes any foods that use nanotechnology techniques or tools during its cultivation, processing, production or even packaging of the food. Studies have found that without a positive perception and acceptance by customers, these advances are futile: consumers are more accepting of foods that provide health benefits, and men are consistently more accepting of new food technologies than women. This study surveyed a nationally representative sample of 1,210 individuals to assess their baseline knowledge of nanotechnology and their acceptance of nanotechnology foods in relation to the participant's gender and level of education. The study found that men had a significantly higher knowledge about general nanotechnology itself ($p = 0.00$). As predicted, men showed higher acceptance of nanotechnology foods overall than women [$F(1,1098)=8.15$, $p=0.00$]. Men also showed higher acceptance of nanotechnology foods that offer health benefits with a mean score of 6.40 and women responded with a mean of 5.87

[F(1,1186)=7.152, p=0.01]. In addition, the level of education was not found to have a significant effect on acceptance of nanotechnology foods regardless of the benefit it offered [F(1,1098)=7.07, p=0.91]. These results suggest that men are more likely to accept nanotechnology foods, nanotechnology foods that offer health benefits are accepted over nanotechnology foods that offer non-health benefits, and education level does not indicate acceptance of nanotechnology foods.

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TABLE OF CONTENTS

ABSTRACT OF THE THESIS .... **ii**

ACKNOWLEDGEMENTS .... **iv**

TABLE OF CONTENTS .... **v**

LIST OF TABLES .... **vi**

Chapter 1 .... **1**

Introduction 1

Chapter 2 .... **8**

Review of Literature 8

Introduction to Nanotechnology 8

Uses and potential benefits of nanotechnology 8

General Knowledge about Nanotechnology 11

Risk perception of new technology foods 12

Media coverage of nanotechnology 13

Consumer awareness of nanotechnology use 15

Perception of nanotechnology in food 16

Demographic and Socioeconomic Determinants 18

Knowledge Deficit Model 20

Purpose 22

Hypotheses 23

Chapter 3 .... **25**

Methods 25

Research Design 25

Sample 25

Instrument Development 27

Items 28

Chapter 4 .... **32**

Results 32

Chapter 5 .... **43**

Discussion 43

Conclusion 48

Tables **49**

Appendix A **84**

References **849**

LIST OF TABLES

Table 1: True or False General Knowledge Questions Asked

Table 2: Factor Loadings for 19 Knowledge Based Questions

Table 3: ANOVA for the Total Knowledge by Gender

Table 4: ANOVA for the Total Knowledge by Education Level

Table 5: Tukey HSD Comparison for Total Knowledge by Education

Table 6: Mean of Knowledge by Gender

Table 7: Mean of Knowledge by Education

Table 8: ANOVA for the Acceptance of Nanotechnology in Specific Items by Gender

Table 9: ANOVA for the Acceptance of Nanotechnology in Abstract Items by Education

Table 10: Pearson Correlations Matrix among Acceptance of Specific Items and Knowledge

Table 11: ANOVA for Acceptance of Nanotechnology in Abstract Items by Gender

Table 12: ANOVA for Acceptance of Abstract Items by Education

Table 13: Tukey HSD Comparison for Acceptance of Abstract Items by Education

Table 14: Factor Loadings for 22 Benefit Items

Table 15: ANOVA for Acceptance of Health Benefits by Gender

Table 16: ANOVA for Acceptance of Health Benefits by Education

Table 17: Pearson Correlations Matrix among Health Benefits and Knowledge

Table 18: ANOVA for Acceptance of Paired Benefits Acceptance by Gender

Table 19: ANOVA for Acceptance of Paired Benefits by Education

Table 20: Pearson Correlations Matrix among Paired Benefits and Knowledge

Table 21: ANOVA for Acceptance of Non-Health Benefits by Gender

Table 22: ANOVA for Acceptance of Non-Health Benefits by Education

Table 23: Pearson Correlations Matrix among Non-Health Benefits and Knowledge

Table 24: ANOVA for Total Benefits by Gender

Table 25: ANOVA for Total Benefits by Education

Chapter 1

Introduction

As the world population continues to grow, new means of food production are constantly being sought after. Nanoscience is the study of atoms, molecules, and objects on the nanoscale, while nanotechnology is the application of nanoscience on matter on the atomic and molecular scale and its profound effects (United States National Nanotechnology Initiative, 2008). One of the latest food technologies to emerge is nanotechnology foods, which includes any foods that use nanotechnology techniques or tools during its cultivation, processing, production or even packaging of the food. In 2010, the total expenditure for all of the foods consumed in the United States was approximately $1.24 trillion (Agricultural Marketing Resource Center: USDA Rural Development, 2012). The food industry accounts for more than ten percent of all manufacturing shipments and is one of the largest manufacturing sectors in the United States (U.S. Department of Commerce, 2010). This industry is constantly growing and encompasses all businesses that pertain to the distribution, service, manufacturing, processing, retailing, and wholesaling of food (Agricultural Marketing Resource Center: USDA Rural Development, 2012). In fact, total food expenditures consumed in the United States showed a 3.4 percent increase from $1.998 billion in 2009 (USDA Economic Research Service, 2011; Agricultural Marketing Resource Center: USDA Rural Development 2012; USDA Economic Research Service, 2011). The global population in 2010 was approximately 7 billion people and is projected to reach 9 billion people by the year 2044 (U.S. Census Bureau, Population Division, 2011). The growth of the food industry will parallel this growth in population.

As the world population continues to grow exponentially, increased demand has been placed on food companies. Food companies are constantly looking for innovative ways to meet the needs of consumers, while staying on par with their competitors. One way major food companies are doing so is through the use of technology. Though most people do not necessarily associate the term 'technology' with food, the use of food technology is not a novel concept. In fact, some of the earliest examples of technology in the food industry include canning developed by Nicolas Appert in 1810, and pasteurization modernized by Louis Pasteur in 1862 (N.N. Potter, 1999). More recent examples of food technology include modified atmosphere packaging, food irradiation, animal cloning, and genetically modified food. These techniques are developed to enhance food quality and stability. In addition, they are also a way to lower overall food costs. The Consumer Price Index (CPI) is steadily increasing, and is forecasted to increase from 3.5 to 4.5 percent by 2011 (USDA Economic Research Service, 2011) so any opportunity to reduce costs is greatly welcomed by food companies. One of the most recent technologies to be developed is nanotechnology. One unique aspect of this technology is the impact it will have across industries including medicine, cosmetics, electronics, and food. A statement released by the White House in 2008 deemed nanotechnology as "Leading the next industrial revolution," and its influence on the food industry is projected to be quite significant (The White House, 2000).

In addition to the economic benefits that manufacturers would yield, nanotechnology foods may also offer many health benefits to its consumers. Custom-made foods that are fresher and more healthy are currently being researched by Kraft

Foods. Some properties that are being studied include catering the smells and taste of foods to specific consumers or customizing food by removing food allergens for people with specific food allergies (Food Manufacture Co.UK, 2004; Wolfe, 2005). In addition, nanodispersions which deliver functional ingredients are also being studied by companies such as Unilever and Nestle. By harnessing the ability to fully control the distribution and administration of specific functional ingredients similar to how a medication would work, the food could be used to prevent and treat diseases more efficiently (Food Manufacture Co.UK, 2004; Wolfe, 2005) .

Although many food technologies have been created to improve the cultivation, production, and processing of food, use of these techniques on food are not always well received by consumers. The acceptance of new technology in foods is different than simply just accepting the technology itself. Food carries with it religious, symbolic, and cultural meanings in addition to any other concern other products may cause (Hallman & Hebden, 2005; Tarver, 2006).

One type of food technology that has been recently introduced is genetically modified foods. First introduced into the market in the 1990s, genetically modified foods are a specific form of biotechnology that alters the genetic composition of organisms to produce specific desired characteristics (U.S. Department of Energy Office of Science, 2013). The uses of biotechnology have commonly been divided into the three categories “Healing, Fueling, and Feeding the World” (Biotechnology Industry Organization, 2010). The descriptor to feed the world stems from various benefits that biotechnology has to offer. One positive outcome is increased yields of crops such as cotton, soybeans and corn through identifying the most resilient species. Another benefit is strengthened crops that are more resilient against environmental conditions, disease, and pests. Other properties include using less harsh chemicals and pesticides, which also improves soil quality. In addition to the proposed benefits, determinants of consumers' support for products include environmental, moral, and political factors (Brown & Ping, 2003; Hallman, Adelaja, Schilling, & Lang, 2002; M. Siegrist, 2000). These concerns of safety and morality linger and genetically modified foods are not readily accepted by the public.

In 1999 Secretary of Agriculture Dan Glickman poignantly said, "With all that biotechnology has to offer, it is nothing if it's not accepted" (Glickman, 1999). These words hold true to the success of nanotechnology when introduced to the public. This statement resonates with many manufacturers in the food industry because many Americans have not readily accepted genetically modified foods. In 2001, Hallman reported that while more than half (58%) of respondents approved of the genetic modification of plants, only slightly more than one-quarter (28%) of respondents approved of the genetic modification of animals (Hallman et al., 2002). This finding illustrates that even within the category of food, certain expectations and standards do not apply to all different types of food. While recent studies have shown consumers are slightly less wary of biotechnology than in previous years, consumers do not have full confidence in the U.S. food supply (International Food Information Council Foundation, 2009).

Studies have found the perceived benefits and risks of a technology can be heavily influenced by how the technology itself is viewed (Finucane, Alhakami, Slovic, & Johnson, 2000). Factors such as power, status, alienation, and trust help determine people's acceptance and perceptions of risk (Flynn, Slovic, & Mertz, 1994); however, gender has been found to be the most 'robust variable' regarding the issues of health and food safety (Dosman, Adamowicz, & Hrudey, 2001). Indeed, studies have shown women are more concerned about risks involving technology than men (Brody, 1984; Cardello, 2003; Food Marketing Institute, 2011; Greenberg & Schneider, 1995; Pilisuk & Acredolo, 1988; M. Siegrist, 2008; Stallen & Tomas, 1988).

Previous research on gender differences in environmental risk found women expressed higher levels of concern for potential environmental and technological risks than men (Davidson & Freudenberg, 1996). In a blind pre-test conducted by Cardello in 2003, the mean level of concern for every food technology was greater in females than in males. The finding that females consistently had higher levels of uncertainty with novel technologies was anticipated, but the finding that high levels of uncertainty extended to nonhazardous and commonly used technologies such as "thermal energy" and "heat pasteurization" illustrated a more conservative approach towards all technologies in general (Cardello, 2003). They further concluded that men tend to have greater trust in institutions that involve the study of science and technology, which may account for a lesser concern in environmental risk among men. Additionally, they concluded women tend to be more concerned about issues related to health and safety because females generally assume the roles of nurturer and caregiver in family units.

Risk perception is believed to stem from societal ideals instilled in individuals (Gustafson, 1998). In general, there seems to be a greater level of concern for health and safety among women. In addition, women tended to express more concern toward new technologies.

A study conducted in 1943 first introduced the concept of ‘women as gatekeepers of the flow of household food’ finding women control what food is purchased and brought into the home (Lewin, 1943). Though different studies have reexamined this role, despite a change in societal status in women, it is still agreed that women generally continue to hold the responsibility of controlling the flow of the household’s food (McIntosh & Zey, 1989). This is supported by a study conducted to evaluate consumer behavior, and found women have a greater frequency of completing the household grocery shopping responsibility than men (Food Marketing Institute, 2011; Joh, Arentze, & Timmermands, 2006). In a nationally representative telephone study with a sample of 601 adults conducted in 2008 by Bellows et al., more women (73.5%, n=313) self-reported being the household’s predominant food shopper than men (35.7%, n=284) (Bellows, Alcaraz, & Hallman, 2010). This is important because the primary grocery shopper assumes control of the household’s flow of food (Smith & Carsky, 1996), and the decision to allow what products can cross the threshold often fall under the direct jurisdiction of women. Even in the American society where eating out is very common, a majority of a household’s total food cost (52.1%) is still dedicated to purchasing foods prepared at home (Smith & Carsky, 1996).

Food production, processing and packaging are changing dramatically, and with an emphasis on the research and development of nanotechnology in food, more money is being dedicated to this field. The technology has the potential to make a positive impact on all the different areas of the food industry but first must be accepted by its consumers, which may be difficult as illustrated by the introduction of several food technologies in the past. In an effort to avoid a low level of acceptance of nanotechnology food products, it is important for the opinions and concerns of the consumer to be taken into consideration. This study evaluated the type of benefits that have the most positive impact on the level of acceptance of nanotechnology use in foods, and what products are more likely to meet the needs and desires of its consumers.

Chapter 2

Review of Literature

Introduction to Nanotechnology

Defining Nanotechnology

Nanotechnology is the study of the manipulation of matter on the atomic and molecular scale and its profound effects (United States National Nanotechnology Initiative, 2008). Professor Norio Taniguchi of the Tokyo Science University (Taniguchi, 1974) first coined it as ‘nano-technology’ in 1974. The National Nanotechnology Initiative (NNI) specifically states, nanotechnology is “the understanding and control of matter at dimensions between approximately 1 and 100 nanometers (nm), where unique phenomena enable novel applications (United States National Nanotechnology Initiative, 2008). Materials altered on the nanoscale have an increased relative surface area, which result in different properties than the same material on a conventional scale. To put the size of a nanometer in perspective, 1 strand of hair is about 80,000 nm wide and a single sheet of newspaper is 100,000 nanometers thick (International Food Information Council Foundation, 2009). Nanoscience is the field of science that focuses on the new properties and behaviors exhibited by materials when manipulating biological or nonbiological structures on the nanoscale (Weiss, Takhistov, & McClements, 2006).

Uses and Potential Benefits of Nanotechnology

The potential of this new technology has led to billions of dollars invested in researching and developing nanotechnology (Hullmann, 2006). Companies are heavily invested in improving current products, and developing completely new products as well. Nanotechnology is used in several different stages of the food industry from food production to processing and packaging (Helmut Kaiser Consultancy, 2008). While this new technology may seem to be a step forward, it is faced with numerous obstacles. The main one being consumer acceptance. As seen with genetically modified (GM) foods and irradiated foods, the technology overall may not be accepted unless the proposed benefits of the applications seem to be positive such as health benefits, lower pesticide residues, and more environmental friendliness (Gaskell et al., 2003).

Nanotechnology is unique since it affects several industries, and nanoscale discoveries are used in extremely versatile ways. Nanotechnology is being used in a variety of products including electronics, medications, materials, and cosmetics (United States National Nanotechnology Initiative, 2008). The use of nanotechnology helps make these products more durable, more water-repellent, and enhances materials' abilities to conduct heat and energy. The use of this innovative technology has dramatically increased during the years of 2006 to 2009 by 379% from usage in 212 products, to 803 products (Pew Project on Emerging Nanotechnologies, 2011).

Nanotechnology is also integrated into the fields of agriculture and food, (Pew Project on Emerging Nanotechnologies, 2011). As one of the 'newest' technologies to be applied to food, it is anticipated to have a large impact on the food industry, and was initially seen as "Leading the next industrial revolution" (The White House, 2000). Nanotechnology is being integrated into foods by the way of food production, food processing, food packaging, and food service. Additional food applications of nanotechnology, currently in development, include methods to increase food safety and biosecurity, food material enhancement, and improve product shelf life (Weiss et al., 2006).

The processing stage of food has also incorporated various techniques of nanotechnology. It has been incorporated into farming through nano-encapsulation, which improves fertilizers and increases the effectiveness of pesticides and herbicides by only becoming active during desired conditions, such as, excessive moisture or excessive heat (ETC Group, 2004). Nanotechnology can also create more durable materials that are able to better withstand constant use than ordinary materials. Machines made of more durable material would be better thermal conductors, have a longer factory life, require less replacement, and possibly lower overall production costs (Weiss et al., 2006). The delivery and packaging of foods is also being revolutionized by nanotechnology materials with numerous benefits. Whether the packaging is directly on the food itself in the form of edible coatings, or within the packaging materials that surround the food peripherally, both forms could serve to extend the freshness of foods (Weiss et al., 2006).

Nanotechnology can also improve the materials used in food production, resulting in products that better deliver its functional ingredients. According to Barlow 2009, through applications such as nanocapsules and nano-emulsions, some benefits of incorporating nanotechnology into foods include decreasing fat content of a food product without altering its taste, keeping foods fresh longer, and increasing the bioavailability of nutrients. Nanocapsule technology can enhance the effect of a food's functional ingredients. The capsule can serve as a vehicle to shuttle the nutrient to the desired site in the body, protect the nutrient from potential degradation until consumption, and may be able to control when the nutrient is released at precise times and made biologically available (Barlow et al., 2009; Weiss et al., 2006; Wolfe, 2005).

Nanotechnology used in food packaging may enhance its durability, improve thermoregulation qualities, and also have anti-microbial characteristics (Sorrentino, Gorrasi, & Vittoria, 2007). Food safety and biosecurity may be heightened through the incorporation of nanosensors and nanotracers. These sensors have the ability to detect pathogens and contaminants throughout all stages of food production (Weiss et al., 2006). The ability to improve food safety and security is a common goal in the food industry, and the ability to almost instantaneously trace a pathogen back to its point of origin would be revolutionary. The capability to record a thorough history of a product's origin would allow more efficient recalls of the contaminated food products.

Some applications of this food technology include modifying the texture of a food product (Wolfe, 2005). Nanoparticle emulsions are designed to help improve the texture of products such as ice cream, soft spreads, or other products that require a smooth mouth feel. Since the particle emulsions occur on the nanoscale, this allows the mixture to be more homogenous throughout, creating the smoother and more uniform texture (Wolfe, 2005).

General Knowledge about Nanotechnology

Studies have found that the general population presently knows very little about nanotechnology (Lee, Scheufele, & Lewenstein, 2005). In a multi-stage, random probability face-to-face survey of 15,000 Europeans, Gaskell reported about 25% of respondents in the UK felt nanotechnology, "Will improve our way of life," about 5% responded that it "Will make things worse," and 60% responded they "Don't know" how nanotechnology would impact their lives, where most of this uncertainty came from being unfamiliar with the topic of nanotechnology (Gaskell et al., 2003). In the first nationally representative phone survey of 1,536 Americans, Cobb and Macoubrie found that 83.6% of Americans only "Heard a little" or "Heard nothing" about nanotechnology, and 51.8% of the respondents "Heard nothing" about nanotechnology (Cobb & Macoubrie, 2004). Four years later, another nationally representative telephone survey of 1,014 Americans found that 69.8% of respondents stated they knew "Just a little or nothing at all" about nanotechnology (Smith, Hosgood, Michelson, & Stowe, 2008). In a 1,500 participant study collected in four states throughout the U.S., researchers found that over 60% of respondents said they have never heard of nano or nanotechnology (Waldron, Spencer, & Batt, 2006). These statistics reflect an overall lack of knowledge about nanotechnology.

Risk Perception of New Technology Foods

Many types of food technologies have been introduced to the food industry. Some are designed to improve sanitation, shelf life, and quality of the food through techniques such as ultrasound, pasteurization, food irradiation, modified atmosphere packaging, high pressure microwave processing, and genetic modification of food ingredients (De Gennaro, Cavella, Romano, & Masi, 1999; Mason, Paniwnyk, & Lorimer, 1996). Although these techniques were developed for positive reasons, how they are presented to the public is crucial to their acceptance. This includes responding to consumer concerns, offering specific benefits, and simply providing factual information about the technology (Bruhn, 2007).

Nanotechnology foods are an abstract concept to many consumers, and their limited opinions of nanotechnology foods is based on the food's perceived risks, and not their actual application. Instead, the concern of risk was associated with the new technology itself (Castellini et al., 2006; Eiser, Miles, & Frewer, 2002). People often find it difficult to assess the risks associated with new technologies. In a mail-in survey in Switzerland of 337 participants, individuals were very resistant to using novel food technologies. One contributor to this opposition may result from an insufficient knowledge about the novel technology itself (Siegrist, 2008), it is not the only reason for resistance. This lack of knowledge prevents development of trust, which contributes an important role in the acceptance of new food technologies. Siegrist also found that a sense of 'naturalness' plays a role in its acceptance, and a lack of a natural quality can negatively impact approval amongst consumers (Siegrist, 2008), the more 'natural' something is perceived, the more readily accepted.

Media Coverage of Nanotechnology

The overall tone of coverage by the media of nanotechnology, in the United States, has been positive. It primarily focuses on the potential benefits this technology may provide. A content analysis of three newspapers, *The NY Times, Washington Post,* and the *Wall Street Journal* was conducted and found between January 1986 to June 2004, 600 relevant articles about nanotechnology were found and about 75% of nanotechnology articles were positive, highlighting the benefits of nanotechnology more than its possible risks (Lewenstein, Gorss, & Radin, 2005). A content analytic study examined in U.S. and non-U.S. newspaper narratives about nanoscience and technology, and found many articles placed greater emphasis on its benefits than its risks (Stephens, 2005). The ratio of articles that highlighted benefits more than risks was three to one. The media spoke of nanotechnology very positively. From 1992 to 2005, 31% of newspaper articles highlighted the benefits of nanotechnology outweighing the risks, and had little discussion of the potential risks (Stephens, 2005). A content analysis study was conducted comparing fifteen Canadian and twelve U.S. print publications by Laing, and found a total of 381 articles in the year of 2004 pertaining to nanotechnology. The study found in U.S. articles, 75.8% of articles did not report on risks at all, and 68.8% of articles noted the benefits prominently or briefly (Laing, 2005). The position of the media plays an integral role in establishing the perceptions of risk and possible benefits gained from new technologies (Durant, Bauer, & Gaskell, 1998; Nisbet et al., 2002). Since nanotechnology has received early support from the media, this viewpoint may lead to support of research by the public, approval from the government, minimize comments from skeptics (Holliman, 2004; Priest & Eyck, 2002).

Despite the current positive emphasis placed upon nanotechnology by the media, as with every innovation, nanotechnology is viewed with some caution. With the increase in development and usage of nanotechnology in the production of goods, and in various products themselves, several concerns have surfaced regarding this technology. Some causes for reservation include potential toxicity from the inhalation of ultrafine particles, which may affect the respiratory tract (Borm, 2002). Other concerns include environmental damage from nanoparticle toxicity, health risks of possible immune system damage, inflammation, cardiac distress, and lack of knowledge about this powerful and unpredictable technology (Handy & Shaw, 2007; Oberdörster, Oberdörster & Oberdörster, 2005). There has also been a shift in the media on the area of emphasis in nanotechnology pieces. A content analysis of selected U.S. and U.K. papers resulting in 400 articles show an increase of 58% in risk-centered stories on nanotechnology occurred between 2005 and 2006, and these stories on nanotechnology also focused more on how the government will intervene and regulate the newer technology (Friedman & Egolf, 2005).

Consumer Awareness of Nanotechnology Use

Nanotechnology and its uses are carefully scrutinized by the media, but knowledge about nanotechnology among Americans remains quite low, and does not appear to be significantly increasing. In fact, most Americans have minimal knowledge about nanotechnology in general (Lee et al., 2005). A nationally representative phone survey in the U.S. found 83% of respondents heard nothing or only a little about nanotechnology and could not successfully answer factual questions about the technology (Cobb & Macoubrie, 2004). Yet, “Public awareness of nanotechnology has barely moved a nanometer in over four years of our project’s polling, despite billions of dollars of investment in research and the existence of over 1,000 nano-enabled products in the marketplace. Clearly, the message about this new and important technology is not reaching the public” (Pew Project on Emerging Nanotechnologies, 2011). Additionally, a study published in 2011 by Vandermoere, et al. in France found 57.6% of the participants never heard of nanotechnology while 81.5% of respondents had little or no knowledge about the technology (Vandermoere F, Blanchemanche S, Bieberstein A, Marette S, Roosen J., 2011). The knowledge about nanotechnology is not wide-spread, even outside of the United States.

Although the public does not know a great deal about nanotechnology, studies have indicated Americans hold a positive or neutral view of the technology and its potential benefits (Cobb & Macoubrie, 2004; Scheufele & Lewenstein, 2005). In a multi-staged random probability survey in the U.S. with 850 participants, 50% of the sample was optimistic; agreeing that nanotechnology will improve their way of life (Gaskell et al., 2005). When presented with specific product examples, American consumers indicated their willingness to use products that use or contain nanotechnology regardless of potential associated risks (Currall, King, Lane, Madera, & Turner, 2006). The media will continue to play a critical role in consumer perceptions of nanofoods (Dudo, Choi, & Scheufele, 2011).

Perception of Nanotechnology in Food

The public demonstrates a relatively neutral and even positive perception of nanotechnology, with an emphasis on its benefits (Brossard, Scheufle, Kim, & Lewenstein, 2009; Cobb & Macoubrie, 2004; Gaskell, Eyck, Jackson, & Veltri, 2005). An Internet survey with 3,909 U.S. respondents found 57.3% of respondents agreed with the statement, “Human beings will benefit greatly from nanotechnology, which works at the molecular level atom by atom to build new structure, materials, and machines" (Bainbridge, 2002). Although the public's perception of nanotechnology, overall, may initially be thought of as a fair indicator for the acceptance of nanotechnology in food, the acceptance of newer technology when applied to foods can differ greatly than its use in other products (Pew Project on Emerging Nanotechnologies, 2011). Food is perceived differently from most other products, because it is ingested by the consumer. Since a person's relationship with food is much more intimate than, for example, their relationship with an article of clothing, their concern for the preparation of this product and willingness to take risks understandably differs as well (Fife-Shaw & Rowe, 1996; Sparks & Shepherd, 1994). Food not only serves as a source of nourishment but is also important to several aspects of society, include religious, symbolic, and cultural meanings (Hallman, 2008). Other studies have shown a variety of factors serve to influence public acceptance of nanotechnology, such as, trust in the government as well as trust in the food industry (Gaskell, Eyck, Jackson, & Veltri, 2005; Siegrist, 2008; Siegrist, Stampfli, Kastenholz, & Keller, 2008; Vandermoere, Blanchemanche, Bieberstein, Marette, & Roosen, 2010). In 2008, a study conducted by Siegrist et al., perceived risk and benefits were dependent on nanotechnology located on the outside (nano-outside) of the food as a coating or the inside (nano-inside) of the food, injected or grown into the food (Siegrist et al., 2008). In a regression analysis with perceived nanotechnology risks, nano-outside foods were perceived as less of a risk in comparison to nano-inside foods. Perceived benefits of nanotech foods were more readily recognized in nano-outside foods compared to nano-inside foods. In general, food is perceived differently than other products, and the specific uses of nanotechnology can further impact nanotechnology food acceptance.

In contrast, studies conducted in Europe illustrate a more negative view of nanotechnology and its uses. While Europeans appear to know little about nanotechnology, in a web survey of 752 people in France, Vandermoere, found that with regard to nanotechnology in food packaging, 73.5% believed the risks were either equal to the benefits, or the risks outweighed its benefits. In addition, when nanotechnology was used in the food itself, 75.7% of the respondents believed the risks were either equal or greater than the benefits the foods may offer (Vandermoere, Blanchemanche, Bieberstein, Marette, & Roosen, 2011). This contrast in opinions makes it difficult to predict how American consumers accept the use of nanotechnology in foods and its packaging.

Demographic and Socioeconomic Determinants

Gender is a key demographic variable that was found to have a profound impact on perceptions of food especially when pertaining to health and safety issues (Dosman et al., 2001). A study conducted in 1943 coined women as food's 'gatekeepers' for household food (Lewin, 1943), with the ability to control what is accepted and consumed by the family. Society has dramatically changed, with women as a part of the professional work-force. However, women continue to be the primary grocery shoppers. A more recent study among the Private Labeling Manufacturing Association in 2013 found in a study with 1,000 participant that while the men are shopping more, approximately two-thirds of the primary grocery shopping in the sample of Americans done by women (PLMA, 2013). A 2002 study of 3,909 U.S. and European participants, conducted by Bainbridge helped establish a baseline in the knowledge of general nanotechnology use. It also illustrated hesitation by women to accept the technology (Bainbridge, 2002). In the study, 69.2% of the men agreed with the pro-nanotechnology statement, and in contrast, only 47.6% of the women participants agreed with the pro-nanotechnology statement. Consistent with this finding that men are more accepting than women, the study also found that 7.7% of men were anti-nanotechnology, whereas 10.0% of the women respondents were anti-nanotechnology. Women also expressed a greater concern for health and safety, which could greatly impact the acceptance of nanotechnology foods. If women are not inclined to accept these foods, nanotechnology may face many challenges when it is readily advertised in the food industry. A U.K. study, conducted by Nerlich in 2007, used brief vignettes describing nanotechnology and then gathered information through questionnaires about their perceptions and beliefs about nanotechnology. Nerlich found that men had a more positive perception of the benefits of a nanomedicine than women, and showed a greater acceptance of the medication itself. In addition, a nationally representative phone study conducted in the U.S. with a sample of 1,014 participants, found 64.5% of male participants, as opposed to 35.6% of female participants, reported knowing a lot or some about nanotechnology (Smith et al., 2008).

Another key demographic variable taken into account when researching new technologies is the age of the participants. In a study conducted by Bäckström et al., participants' disposition toward new foods was measured using two different scales, the

Food Neophobia Scale (FNS) and the Change Seeker Index (CSI) (Bäckström, Pirttilä-Backman, & Tuorilaa, 2003). In a 2001 study conducted in Helsinki, 44 participants participated in focus groups and reported young men, both less and more educated, and middle-aged highly educated men were the least neophobic groups with FNS Means of 23, 22, and 23, respectively, while young less-educated women and middle-aged less educated men were the most neophobic groups. In addition, Bäckström et al. reported younger higher educated men were more likely to seek change while younger less educated women were the least change seeking, even less than elderly women (Bäckström, Pirttilä-Backman, & Tuorilaa, 2003). This study shows an uncertain relationship between age and acceptance of novel technology used in food.

Knowledge Deficit Model

Introduced by Tichenor et al. in 1970, the Knowledge Deficit Model, originally known as the Knowledge Gap Model, proposes two major concepts (Tichenor, Donohue, & Olien, 1970). The first states, "*Over time*, acquisition of knowledge of a heavily publicized topic will proceed at a faster rate among better educated persons than among those with less education." The second is "*At any given point in time*, there should be a higher correlation between acquisition of knowledge and education for topics highly publicized in the media than for topics less highly publicized" (Tichenor, Donohue, & Olien, 1970). This model argues that the better educated individuals are, the more likely they are to know about a specific topic. This belief is quite controversial and is not often reflected through data.

Contributory reasons for the formation of this model include *communication skills*, because “persons with more formal education would be expected to have the higher reading and comprehension abilities necessary to acquire public affairs or science knowledge.” A second factor is the amount of *stored information*, as a result of “prior exposure to the topic through the mass media or from formal education itself.” The third is *relevant social contacts,* which reasoned that more education “generally indicates a broader sphere of everyday activity, a greater number of reference groups, and more interpersonal contacts, which increase the likelihood of discussing public affairs topics with others.” The fourth factor includes *selective exposure*, *acceptance, and retention* of information, and reasons that “voluntary exposure is more closely related to education than to any other set of variables” (Tichenor, Donohue, & Olien, 1970).

In the 1970s, much of the explanations for the disparity in knowledge of heavily publicized topics in the media is focused on a disproportionate exposure of information to the better-educated group in comparison to the less educated group. The unbalanced media exposure in the 1970s may be a reasonable explanation for that time period, but it does not resonate well with today’s changed society. Regardless of education status, exposure to the media has increased with the increase in media accessibility, and the exponential rise in personal electronic communication devices, computers, and the internet.

This expert model commonly known as the ‘knowledge deficit’ model concludes, if individuals have the information, they would ‘make the right decisions’ with the information (Einsiedel, 2000; Hansen, Holm, Frewer, Robinson, & Sandøe, 2003). This takes Tichenor's proposal a step further, ultimately concluding that the more knowledge individuals have on a topic, the more willing they are to take a risk. In a 1988 study conducted by Weinstein, the need to recognize the gap between intention and action was also considered (Weinstein, 1988). While some individuals may respond positively to a proposed situation, he or she may not respond the same way to a more specific scenario. This difference illustrates more knowledge does not necessarily result in more acceptance. In a study, further investigating the deficit model which looked at raw data from the 1996 British Social Attitudes Survey, was conducted by Sturgis and Allum in 2004. The data demonstrated scientific knowledge does not have a direct impact on an individual's attitude (Sturgis & Allum, 2004). The public is not only reliant on the scientific knowledge of a topic, but also by personal experience to synthesize a final opinion (Jasanoff, 2000). It is not simply facts that are included in a person's decision, but many other factors that do not include science (Peters, 2000). People include more than factual knowledge into their daily decisions. Their beliefs regarding novel technologies are multifaceted as well.

The American public is not well informed of the application of nanotechnology to food, and this study served to obtain a baseline understanding of what specific benefits increase acceptance and what demographic variables place a salient role in perception and acceptance of nanotechnology foods as well.

Purpose

The purposes of this study were to:

- establish a baseline of the knowledge of nanotechnology in a nationally representative sample in the U.S.
- identify how accepting women are of nanotechnology foods with health benefits.
- identify how accepting women are of nanotechnology foods with non-health benefits.
- identify how accepting men are of nanotechnology foods with health benefits.
- identify how accepting men are of nanotechnology foods without health benefits.
- identify what types of potential benefits are most appealing to female customers.
- identify what types of potential benefits are most appealing to male customers.

Hypotheses

This proposal seeks to investigate 4 main effects:

H_1: The more knowledge an individual has about nanotechnology, the more accepting he or she will be of nanotechnology foods.

H_2: Men will indicate greater acceptance of the use of food nanotechnology overall.

H_3: Overall, nanotechnology foods with health benefits will be seen as more acceptable than non-health benefits, which include the alterations of taste, texture, and color of food.

H_4:

a. women will have a greater acceptance of nanotechnology foods that provide health benefits than men and

b. women will be less accepting of nanotechnology foods that provide non-health benefits than men.

Chapter 3

Methods

Research Design

This study used select items from a large survey conducted with a nationally representative sample of 1,210 Americans, 18 years of age or older. The complete survey questionnaire was administered online through Knowledge Networks, now GfK Custom Research (GfK). The company maintains a database with demographic information of its panelists. Since key demographic information is already known about the participants, this lowers the response burden for each participant. Each study participant completed the computerized survey, and Knowledge Networks compiled all of the participant's responses. Specific items from the complete questionnaire were analyzed in this study to test for this study's hypotheses.

Sample

The sample drawn was from the Knowledge Networks web-enabled Panel that consists of approximately 30,000 people. The panel is used as a representation of the entire population of the United States. Members are recruited randomly through probability-based sampling using random digit dial (RDD) and address-based sampling (ABS) methods (Dennis, 2009). As compensation for completing a short weekly survey, member's households are provided with free-monthly internet access and a laptop computer if needed. If selected members already have internet access, they will earn incentive points per survey that are redeemable for cash and other prizes. In addition, both groups are eligible to receive special incentive points for longer surveys to compensate for the higher response burden.

To recruit panel participants, Knowledge Networks uses a list-assisted RDD technique, which is based on a sampling frame of U.S. residential landline telephones (American Association for Public Opinion Research, 2010). The sampling recruitment is done without replacement and numbers that have been used are not used again. In addition, ABS methodology was also used by Knowledge Networks to account for the growing population of non-landline households. This allows for a sampling of almost all U.S. households.

After the respondents initially join the panel, they then answer several demographic questions about themselves. The composition of the KnowledgePanel® sample is an equal opportunity sample that is later weighted. The sample was weighted using data from the recent Current Population Survey (CPS) and also the 2006 Pew Hispanic Center Survey for the Hispanic language usage (Pew Project on Emerging Nanotechnologies, 2011). These weights were used to appropriately project the proportion of responses to opinion questions observed within the sample selected to those that would have been obtained within the overall population. However, because these sample weights may create errors in variance estimates, they were not used in conducting the inferential statistics reported below.

Instrument Development

The complete questionnaire was developed by the Food Policy Institute (FPI) at Rutgers University to explore important themes and concerns the public may have. This survey was conducted to explore specific issues related to the use of nanotechnology and nanoscale materials in food and to clearly establish baseline parameters of how receptive the public is towards the use of nanotechnology in food.

Each questionnaire had two Build Factors: one that described nanotechnology in a specific condition (Appendix A) and one that addressed the exact location of the use nanotechnology in the product itself (Appendix B). Each Build Factor was randomly assigned to the respondents and had an equal number of participants. Participants were randomly split into nine different groups with different applications of the nanotechnology in food and different descriptions (Appendix F-3).

Participants were asked to complete questions on “foods you like and your thoughts on some new techniques in making packaged foods.” The survey examined the consumer’s perceptions of acceptability of existing and proposed food products that use nanotechnology on several dimensions (Appendix C, Appendix D). These factors were suspected to play significant roles in defining which products consumers would accept and were randomized in presentation to alleviate a possible order of effects.

Several items and scales that measure factors that have been shown to affect technology and food perceptions in earlier studies were included. These studies included: knowledge about nanotechnology (Lee et al., 2005), perceived risks and benefits (Currall et al., 2006), food neophobia (Pline, 1992), nutritional knowledge (Alexander & Tepper, 1995; Tepper et al., 1997) respect for scientific authority (Scheufele & Lewenstein, 2005) and trust in the government (Lang & Hallman, 2005).

Items

This study focused on fifty-nine of the 113 questions that were presented in the questionnaire. Nineteen questions specifically addressed the general knowledge about nanotechnology, eighteen questions addressed the specific acceptance of nanotechnology foods, and twenty-two questions addressed different benefits nanotechnology would provide. (Appendix E).

The sample characteristics that were collected included gender, age, race/ethnicity, education, housing type, marital status, employment status, household size, and region. The general knowledge about nanotechnology was measured through a number of questions which included “Nanotechnology in food is morally acceptable,” “Nanotechnology in food is useful for society,” “Nanotechnology in food is risky for society,” “Nanotechnology in food should be encouraged,” “Creating nanotechnology food products is playing God,” “Nanotechnology in food is unnatural,” and “Growing crops using nanotechnology could affect the balance of nature.” The participants used an 11-point Likert –type scale (0=Disagree Strongly to 10=Agree Strongly).

The behavioral intentions of the participants regarding nanotechnology used in food was assessed through a series of questions, including: “I would purchase foods labeled as containing ‘nanotechnology’ in the grocery store,” “I would eat nanotech foods," "I would serve nanotech foods to my family and friends," and "I would recommend nanotech food to a friend." An 11-point Likert-type scale (0=Disagree Strongly to 11=Agree Strongly) was used to assess the level of intention the participants had towards nanotechnology foods.

The belief that nanotechnology provides health benefits was assessed through a series of questions which included "Nanotechnology that would increase the amount of vitamins you could get from a food," "Nanotechnology that would make the food better for your heart health," "Nanotechnology that would keep food fresher longer," "Nanotechnology that would reduce the likelihood of the food causing an illness," "Nanotechnology that would reduce fat in a product without changing the taste," and "Nanotechnology that would indicate the presence of an allergen in food." The response option was an 11-point Likert-type scale (0=Do Not Approve At All to 10=Totally Approve) to assess their level of approval of these questions, which addressed health benefits.

The intention to purchase nanotechnology foods that provide paired benefits was assessed through a series of questions, which included "Hot dogs with Omega-3 fatty acids to improve heart health," "Ice cream with fiber to improve digestion," "Carbonated soft drinks with calcium to improve bone health," "Peanut butter with Omega-3 fatty acids to improve heart health," "Yogurt with fiber to improve digestion," and "Bottle water with calcium to improve bone health." Participants used an 11-point Likert-type scale (0=Definitely would not buy to 10=Definitely would buy) to assess their level of approval of these questions which address paired benefits. These benefits paired a food with an unlikely health benefit.

The belief that nanotechnology provides non-health benefits was assessed through the series of questions which included “Nanotechnology that would improve the taste of food,” “Nanotechnology that would create new flavors for foods,” “Nanotechnology that would improve the texture of a food,” “Nanotechnology that would change the color of food,” “Nanotechnology that would make the color of the food extra bright,” “Nanotechnology that would make the food change colors when stirred,” “Nanotechnology that would make vegetables taste like chocolate,” “Nanotechnology that would make fruits taste sweeter,” “Nanotechnology that would make foods glow in the dark,” and “Nanotechnology that would reduce the odor from cooking fish.” Participants used an 11-point Likert-type scale (0=Do Not Approve At All to 10=Totally Approve) to assess their level of approval of these questions which address non-health benefits.

Data Collection Procedure

This online survey underwent two stages of testing, a pretest followed by the main test. Before the pretest, a pilot study was conducted in several undergraduate classes to determine its readability, provide feedback in regard to the appropriateness of questions, and to identify any other errors. In the pretest, 100 Knowledge Network panelists 18 years of age or older were invited to complete the survey between March 31, 2010 and April 5, 2010. The pretest was administered to assess several aspects of the survey: its functionality, estimated time for completion, and clarity of newly developed survey items. Only 61 panelists completed the pretest, resulting in a 61% completion rate.

The second stage was the main administration of the test. A total of 1,836 Knowledge Network panelists 18 years of age or older were invited to participate in the study between April 9, 2010 and April 27, 2010. Of the 1,836 invited, 1,210 surveys were completed, resulting in a 65.9% completion rate.

Data Analysis

All data analyses were performed using SPSS. The two independent variables were gender and the type of benefit offered by the nanotechnology food. The dependent variable was the level of acceptance the individual had for foods with nanotechnology. Means, Standard Deviations (SD), and ranges were calculated comparing the results between the two groups. A factor analysis using a standard Principal Component Analysis was used with a Promax Rotation using Kaiser Normalization was conducted to understand the relationship among the attitudes and opinions held by the public regarding food nanotechnology. The data was further analyzed using tests of significance (t-test and Analysis of Variance [ANOVA]) to determine whether the results varied among the different groups. A p-value threshold of ≤ 0.01 was used to indicate a significant difference. The p-value of ≤ 0.01 was used because of the large sample size to help control for experiment-wise errors.

Chapter 4

Results

Specific Knowledge

The first objective was to determine the basic level of knowledge regarding nanotechnology foods. Nineteen True or False questions, specifically addressing the participant's knowledge of general nanotechnology, were asked. As seen through the literature review, the public is not very familiar with essential facts about nanotechnology (Table 1). An incorrect answer was coded as "0" and a correct answer was coded as "1." The question with the highest mean score was "Nanotechnology involves materials that are not visible to the naked eye."

Factor Analysis of Knowledge Based Questions

A factor analysis was conducted using Principal Component Analysis (PCA) extraction with a Promax rotation of all 19 knowledge-based questions. Promax rotation was used to allow for the factors to be correlated with one another, while allowing for the items to load cleanly onto only one factor. Five components were identified in this analysis. These five factors accounted for 50.69% of the total variance (Table 2).

Five Knowledge Factors

Five items loaded onto the first component, which pertains to questions that address the basic definition of nanotechnology. Together, these questions serve to assess whether the participant has the most basic understanding of nanotechnology and accounted for 20.88% of variance. Questions ranged from size descriptions of nanotechnology to how nanotechnology can actually be used. This factor was labeled, "General knowledge of nanotechnology."

The second factor was composed of five items as well. This factor was composed of items that all relate to food policy and availability and accounted for 9.89% of variance. Items contained information regarding use, labeling, and distribution were all included in this factor, which was labeled, "Knowledge of nanotechnology food policy and availability."

Five items also loaded onto the third factor. All of the items in this factor pertain specifically to the size of nanotechnology. Several items in this factor used measurement units, making their descriptions more accessible. This factor was labeled "The size of nanotechnology" and accounted for 8.12% of variance.

The two items that loaded cleanly onto Factor 4 discussed the difference between nanomaterials and normal-sized materials. This factor specifically addressed how the properties of these two materials behave differently and accounted for 6.39% of variance. This factor was labeled "Different properties in nanomaterials and regular materials".

The last two items in the knowledge based questions loaded onto Factor 5, which addressed the uncertainty felt about nanotechnology and accounted for 5.40% of variance. The uncertainty was about the expert's understanding of the technology, and how it would affect people's health. This factor was labeled, "Uncertainty about nanotechnology."

After conducting an ANOVA using the 5 knowledge factors in comparison to gender, 4 of the 5 factors yielded statistically significant results. Factor 1 [F(1,1208)=14.442, p=0.000], Factor 2[F(1,1208)=5.446, p=0.020], Factor 3 [F(1,1208)=36.535, p=0.000], and Factor 4 [F(1,1208)=4.185, p=0.041]. The fifth factor that was extracted from this survey addressed the 'Uncertainty about nanotechnology' and did not yield a significant difference between the two genders (Table 3).

When comparing education levels to knowledge of nanotechnology, there were statistically significant difference between education groups and their total knowledge of nanotechnology. When compared to level of education, Factor 1 [F(4, 1205)=12.623, p=0.00], Factor 3[F(4, 1205)=27.314, p=0.00], and Factor 4 [F(4, 1205)=12.049, p=0.0] all yielded statistically significant differences. These three factors are all related to a basic overall definition and understanding of the technology itself (Table 4).

Tukey HSD comparisons were conducted to further evaluate the relationships between the different education levels and total knowledge of nanotechnology. The differences found in Factors 1, 3, and 4 seemed to separate the respondents into two groups, less education, and more education. Respondents with 'less education' is defined as individuals who completed less than high school, high school, or some college. Participants with 'more education' obtained a Bachelor's degree, Masters, or Ph.D. degrees. Tukey HSD tests showed that the groups with more education had a higher total knowledge compared to the groups with less education, but there was not a statistically significant difference between the Bachelor's degree group and the Masters or Ph.D. degree group.

Gender

The first portion of this analysis examined the difference in knowledge between males and females. Males have a higher number of correct responses with a mean of 3.21, whereas women responded with a mean of 2.45 correct answers [$F(1, 1210)=23.14$, $p=0.000$]. Males were less likely to respond “I don’t know” (9.72) than females (11.27) [$F(1, 1210) = 21.51$, $p \leq 0.000$] (Table 6).

Education

The impact of education on knowledge-based questions was also assessed. There was not a linear progression of education level and general knowledge about nanotechnology, and the Bachelor’s degree participants had a higher mean correct score of 3.90 in comparison to the Master’s or Ph.D. respondents’ mean score of 3.80.

When assessing the mean number of missing answers, a negative trend occurs, indicating that with higher levels of education, the less likely people are to not answer a question. The group with the lowest level of education had the highest mean of missing answers (11.99) while the lowest mean of missing answers was found in the Master's or Ph.D. group (8.60). This finding is statistically significant with [$F(4,1205)=15.11$, $p=0.000$] (Table 7).

Post HOC comparisons, using the Tukey HSD test, indicated the mean score for less than high school level participants was significantly different from Bachelor’s, Master’s, and Ph.D. level participants, and significant differences were also found between Bachelor’s and Master’s or Ph.D. participants. When looking at the results from the ANOVA and Post HOC tests, the results suggest there is not a linear relationship between general knowledge of nanotechnology and education level.

Acceptance

Specific Items

After assessing the survey tool, a Cronbach's alpha on the 12 acceptance related questions regarding specific food items, the results displayed that a reliable scale can be created from these 12 items (Cronbach's alpha = 0.986). When looking at ways to improve the reliability of this scale, the omission of only two items "Nanotechnology in baby food" and "Nanotechnology in a food to improve your health" would have affected the Cronbach's alpha very minimally so these items were not eliminated. Overall, these items were all highly correlated and create a very reliable scale.

Gender

Assessing acceptance of nanotechnology, when nanotechnology items of a specific nature were presented to respondents, men had significantly higher acceptance rates in all of the items than women. The statement that received the lowest response mean in both groups was "Nanotechnology in baby food" men responding with a mean of 4.15 and women with a mean of 3.40 (Table 8). While this statement had the lowest mean score, men still had a greater acceptance of the product than women.

Education

There were no significant differences between education levels for the level of acceptance of the specific items (Table 9). Post HOC analyses were not conducted, because no significant results were found during the ANOVA.

Knowledge

Acceptance of nanotechnology in a processed food was strongly correlated with knowledge about nanotechnology and was significant at $p<0.01$. While a correlation between the acceptance of other specific items and knowledge about nanotechnology was found, statistically significant results were only found with a p value of <0.05, and due to the large sample size, was more likely due to an experiment-wise error (Table 10).

Abstract Items

After assessing the survey tool, a Cronbach's alpha on the six items of abstract acceptance related items the results displayed that this was a reliable scale (Cronbach's alpha = 0.956). No items were omitted from the analysis.

Gender

An ANOVA for the acceptance of nanotechnology in abstract items by gender was conducted and significant differences between genders were found in all items. Men continued to have greater acceptance than women. The item that had the highest mean was “Nanotechnology in food is morally acceptable” (Table 11).

Education

An ANOVA for the acceptance of nanotechnology in abstract items by education was conducted and found statistically significant differences in two of the statements, “Nanotechnology in food is morally acceptable” and “Nanotechnology in food is useful for society” (Table 12). Tukey HSD tests were completed to see specifically where these differences occurred. Differences were found between individuals with a Bachelor's, Master's, or Ph.D. degrees versus individuals who have less than high school, high school and some college education (Table 13).

Knowledge

When examining the relationship between knowledge of nanotechnology and the acceptance of abstract items, the number of correct answers held a significant correlation with all of the abstract items except, "Nanotechnology should be encouraged" (Table 14).

Benefits

A factor analysis was conducted using Principal Component Analysis (PCA) extraction with a Promax rotation of all twenty-two health benefits. Three components were identified in this analysis. These three factors accounted for 79.91% of the total variance.

After conducting a factor analysis on the statements pertaining to all benefits, three factors were extracted. Ten items loaded onto the first factor. The first factor described different health and wellness benefits of nanotechnology use in foods. The factor is labeled "Health or Wellness Benefits" accounting for 63.862% of the total variance.

A total of six items loaded onto the second factor, which paired a health benefit with a food that does not typically provide that benefit. This factor was labeled "Paired Benefit Statements" and accounted for 10.374% of total variance.

The third and final factor in this section of the research that specifically examined benefits also had a total of six factors load. This factor examined the acceptance of non-health benefits, such as, foods changing color or foods adopting unlikely tastes. This factor was labeled "Non-Health Benefits" and accounted for 5.679% of the total variance (Table 14).

Crohnbach's alpha was used to assess the reliability of the acceptance of benefits scale. Accounting for all twenty-two benefit items, the resulting score of 0.973 verifies that this is a reliable scale.

Health and Wellness

Gender

Overall even when presented with the possible health and wellness benefits that nanotechnology foods can provide, there still is not great acceptance. Of the six items within the Health and Wellness factor, only 1 displayed a statistically significant difference between men and women. The statement is, "Nanotechnology would keep food fresher longer." Men showed higher acceptance with a mean score of 6.40 and women responded with a mean of 5.87 [$F(1,1186)=7.15$, $p=0.01$] (Table 15) .

Education

In an ANOVA analyzing the acceptance of health benefits by education, no significant results were found between the different education groups (Table 16).

Knowledge

Similar to the poor relationships between the acceptance of nanotechnology foods with health benefits and education, there were no strong correlations found between knowledge of nanotechnology and acceptance of these foods that provide health benefits (Table 17).

Paired

Gender

As expected, when the paired statements were compared between groups, men had an overall higher acceptance of nanotechnology foods. Within this factor, certain pairs deal specifically with foods commonly thought of as poor choices and another group that is not typically deemed a poor choice. For all of the pairings where a commonly perceived bad food was paired with an unlikely benefit, men responded with a higher mean. In the two pairings "Yogurt with fiber to improve digestion" and "Bottled water with calcium to improve bone health," these specific food products are typically categorized as healthy and did not yield a significant difference between groups. So while a food was paired with a non-naturally occurring benefit, the food itself was perceived as good. Significant differences occurred between genders when asked about "Hot dogs with Omega-3 fatty acids to improve heart health" [F(1, 1184)=9.93, p=0.00], "Ice cream with fiber to improve digestion" [F(1, 1180)=6.97, p=0.01], Carbonated Soft Drinks with calcium to improve bone health" [F(1,1180)=14.40, p=0.00], and "Peanut Butter with Omega-3 fatty acids to improve heart health" [F(1, 1180)=6.47, p=0.01] (Table 18).

Education

When an ANOVA was conducted comparing paired benefits with different education levels, no significant results were found (Table 29).

Knowledge

No correlation was found between knowledge of nanotechnology and the acceptance of nanotechnology foods with paired benefits (Table 20).

Non-Health Benefits

Gender

In the section that pertains specifically to non-health benefits, men once again responded with higher means overall than women. This section did exhibit the lowest mean score response, which was expected. All 6 of the statements yielded a statistically significant difference between men and women (Table 21).

Education

After conducting an ANOVA on Non-Health Benefits in comparison to education level obtained, there were no differences between the 5 groups. The overall mean acceptance of the non-health benefits still remained low with a score ranging from a mean score of 2.46 to 4.60 (Table 22).

Knowledge

Only very weak correlations were observed between knowledge of nanotechnology and the acceptance of nanotechnology foods that provide non-health benefits. None were significant at the $p<.01$ level (Table 23).

All Benefits

Gender

When comparing the means of the three different benefit factors, there was no statistically significant difference between the acceptance of health benefits or paired benefits by gender. The mean acceptance of peripheral benefits was statistically significant between genders, and men were more accepting of these benefits. Overall, men were more accepting of nanotechnology foods when looking at benefits they would provide (Table 24).

Education

When comparing the means of the different benefit factors, no statistically significant differences between the groups with varying levels of education were found (Table 25).

Chapter 5

Discussion

Nanotechnology is currently used in various industries such as electronics, pharmaceuticals, materials and cosmetics, and its uses are continuing to grow. The use of nanotechnology in the food manufacturing industry will become more prevalent as (United States National Nanotechnology Initiative, 2008) scientists continue to invest resources and time into the field. The benefits of nanotechnology are far reaching and hold an influence in all stages of food production, processing, and packaging (Helmut Kaiser Consultancy, 2008). Its wide ranging ability to improve food packaging by enhancing durability, thermoregulation qualities, and anti-microbial characteristics (Sorrentino et al., 2007) along with its ability to improve food safety and biosecurity with nanotracers (Weiss et al., 2006), and improve the mouth feel and texture of different products (Wolfe, 2005) can make a significant contribution to the food industry. As we were able to see with genetically modified foods, regardless of the potential benefits a food technology may offer, its level of integration is contingent upon the acceptance of the product by the consumer (Gaskell et al., 2003). This study drew its data from the time series data set from the 2002 Eurobarometer (EB) study to assess the evolution of the public perception of biotechnology over time. Regardless of the benefits and enhancements it may provide, if the consumer does not purchase it, its benefits are not actualized.

The lack of knowledge about nanotechnology itself is consistent with previous quantitative study performed by Bainbridge, which surveyed 3,909 American Respondents. Bainbridge found that while a majority of Americans were not highly knowledgeable about nanotechnology, those who were science-attentive members of the population were enthusiastic about its possible contributions (Bainbridge, 2002). In addition to the quantitative responses, 598 participants provided written comments, which will lend to future qualitative studies. This lack of knowledge was also consistent with the 2005 study, conducted by Lee, found Americans do not have a comprehensive knowledge of nanotechnology. However, consumer acceptance and perception is based on their attitudes towards science and basic knowledge of other technologies (Lee et al., 2005). This nationally representative telephone survey reached 705 individuals using Likert-responses questions, the favored method used when assessing acceptance of new technologies. A web-survey conducted in France by Vandermoere, et al., also found people never heard of nanotechnology or only heard little about nanotechnology in Europe (Vandermoere F, Blanchemanche S, Bieberstein A, Marette S, Roosen J., 2011). The previous literature on the knowledge of nanotechnology has not advanced much throughout the years, and the majority of Americans are still unaware of what the technology is. Our findings were consistent with this data and of the nineteen knowledge questions asked. Only one question, 'Nanotechnology involves materials that are not visible to the naked eye," yielded a correct response from a majority of the participants (Table 1). This further illustrates that most Americans do not know what nanotechnology is, thus making it more difficult to predict their acceptance of this new technology in food.

While there is a universal lack of knowledge in regards to nanotechnology itself, there was a significant gap in the knowledge level of nanotechnology in men and women. The significant results between men and women in their knowledge in regards to Factor 1, Factor 2, Factor 3, and Factor 4, readily illustrates that the independent variable 'gender' is very robust in the four different factors (Table 3). When the top two responses were counted as the correct choice, men had a significantly higher mean for correct responses than females (Table 5). When the choices were limited to one correct response, while the mean scores of both males and females decreased, males still had a significantly higher average of correct responses than women (Table 6).

Still examining the knowledge of nanotechnology in individuals, education level was not found to have profound results, as with gender and general knowledge of nanotechnology. The finding that general scientific knowledge of nanotechnology is higher amongst the respondents with higher levels of education is not surprising. The interesting finding is the two factors that did not yield statistically significant results, 'Policy and availability' and 'Uncertainty about nanotechnology' (Table 4). These two factors pertain more to a social understanding of the technology, which is something that is not common within the US population today. These insignificant results help illustrate that the country as a whole simply does not know about the current and potential use of nanotechnology in foods. When the correct response included the top two choices, the group with the highest number of correct responses were the respondents with Masters or Ph.D. level education, with the lowest number of correct responses from the group of respondents with lower than a high school education (Table 7). When further analyzing the data limiting the correct response to the top choice, the group with the highest mean score was no longer the most educated group, instead it was the respondents with a Bachelor's degree, and the lowest scoring group again was the respondents with less than a high school education (Table 8). This further demonstrates that level of education is not the only indicator for acceptance of a new technology. This result also counters the Knowledge Deficit Theory, which believes that with higher education comes greater understanding and greater acceptance.

When assessing the acceptance of nanotechnology in specific food items, men consistently illustrated a greater acceptance of its use in foods. In all twelve specific food items proposed, there was a statistically significant difference between males and females, illustrating a greater acceptance of nanotechnology use in foods in men regardless of the food item (Table 9). Assessing the acceptance in the same items in regard to education level, no statistically significant results were found. This further demonstrates that education level is not a robust variable (Table 10).

The results of Table 11 further demonstrate the gender disparity in acceptance of nanotechnology in foods, even in regards to abstract statements. All 11 statements yielded statistically significant results and males had a higher acceptance of nanotechnology's integration into food. When abstract statements about food and nanotechnology was analyzed in regards to education level, only three statements yielded statistically significant results. The first statement, "I would serve nanotech foods to my family and friends" had the greatest acceptance in Masters and Ph.D. level respondents, and the lowest acceptance in high school educated respondents, which does not support the Knowledge Deficit Theory that a greater level of education will produce greater acceptance. The two other abstract statements that resulted in statistically significant responses were “Nanotechnology in food is morally acceptable” and “Nanotechnology in food is useful for society.” With both of these statements, the greatest acceptance was found in the Masters and Ph.D. educated respondents, and the lowest acceptance in individuals with less than a high school education. The lack in consistency of education being an indicator of acceptance is once again apparent, even in abstract items.

Previous studies illustrate the perceived benefits and ways the technology is used in food affects the acceptance of the food (Siegrist et al., 2008). This study conducted by Siegrist in Switzerland, had 337 participants over the age of 18 with varying education levels. This mail-in survey looked at specific benefits nanotechnology foods might offer and their acceptance by the people of Switzerland. The influence a benefit has on the acceptance of the novel food led to their conclusion that the food industry must identify the benefits the consumer finds acceptable rather than developing technologies that will benefit the manufacturers. One of the benefits that cause consumers to be more favorable to acceptance is a health benefit. In general, the participants in this study were found to be more accepting of a health benefit nanotechnology food, than a non-health benefit. In regards to non-health benefits, males had significantly higher mean levels of acceptance than females (Table 14). Consistent with the previous results in this study, level of education was not a reliable predictor of the acceptance of nanotechnology use in foods, and yielded no statistically significant results when evaluating non-health benefits in regards to educational level (Table 15).

When respondents were shown the health benefits of nanotechnology, gender did not produce statistically significant results for health benefits, but when a benefit was paired with a food, males had a higher level of acceptance than females (Table 16). Again, when total benefits were analyzed in regards to education level, no statistically significant results were found even when reviewing health benefits.

Conclusion

Upon examining the literature and reviewing the results of this study, education did not yield strong results, indicating that amount of knowledge cannot predict the acceptance of nanotechnology in food. In contrast, as predicted, gender is the most robust variable when pertaining to the acceptance of a new technology used in foods. The variable of gender was consistently the most salient indicator of acceptance in nanotechnology foods. Since women have been shown to be the primary grocery shoppers, the hesitation amongst this population could be the deciding factor in the acceptance of nanotechnology foods in the food industry (PLMA, 2013). Future studies can further explore the specific applications of nanotechnology that would be most accepted by this population.

Tables

Table 1

True or False General Knowledge Questions Asked

Question Asked	Mean	Std. Deviation
Nanotechnology involves materials that are not visible to the naked eye. *T*	.62	.48
A nanometer is a billionth of a meter. *T*	.14	.35
Nanotechnology allows scientists to arrange molecules in ways that do NOT occur in nature. *T*	.21	.41
Nano-sized materials behave differently from the same materials when they are on a larger scale. *T*	.20	.40
Scientists do not understand many of the ways nanotechnology might affect the environment. *T*	.15	.36
It is difficult to predict the effects of nanotechnology on human health. *T*	.21	.41
Foods containing nanotechnology are currently available for sale in the United States. *T*	.01	.11
Nanotechnology can be grown into a food. *T*	.03	.18
Nanotechnology involves extremely short amounts of time. *F*	.11	.32
US corporations are NOT using nanotechnology to make food products sold today. *F*	.03	.16
Nanotechnology means using very small quantities of materials. *F*	.07	.25
A nanometer is about the same size as an atom. *F*	.07	.25
Materials on the nano scale have the same properties as those materials on a bigger scale. *F*	.17	.37
By law, nanotechnology can only be used in food packaging. *F*	.04	.19
Humans cannot digest nanotechnology. *F*	.07	.266
Foods containing nanotechnology are required to have special labels. *F*	.01	.12
Nanotech foods cannot be cooked in microwave ovens. *F*	.18	.39
Through the use of nanotechnology, food products are made smaller. *F*	.10	.30
A millimeter is smaller than a nanometer. *F*	.39	.49

Note: F = False, T = True   N = 1210

Table 2
Factor Loading for 19 Knowledge Based Questions[a]

	Factor Loadings				
	1	2	3	4	5
Nanotechnology means using very small quantities of materials.	**.63**	-.03	.14	-.05	.09
Through the use of nanotechnology, food products are made smaller.	**.59**	-.09	.08	.31	-.02
Nanotech foods cannot be cooked in microwave ovens.	**.49**	.38	-.03	.04	-.09
Nanotechnology can be grown into a food.	**-.47**	.35	.37	.13	-.09
Nanotechnology involves extremely short amounts of time.	**.46**	.06	.19	.25	-.10
Foods containing nanotechnology are currently available for sale in the United States.	-.05	**.72**	-.05	-.14	.19
US corporations are NOT using nanotechnology to make food products sold today.	-.06	**.71**	-.06	-.03	.06
Foods containing nanotechnology are required to have special labels.	.35	**.52**	-.12	-.15	.05
Humans cannot digest nanotechnology.	.12	**.48**	.04	.29	-.29
By law, nanotechnology can only be used in food packaging.	.29	**.39**	-.14	.07	.09
A nanometer is a billionth of a meter.	.10	-.04	**.83**	-.27	-.03
A millimeter is smaller than a nanometer.	.27	-.15	**.69**	.06	.02
Nanotechnology involves materials that are not visible to the naked eye.	.06	-.18	**.55**	.14	.13
A nanometer is about the same size as an atom.	.40	.14	**.41**	-.28	.01
Nanotechnology allows scientists to arrange molecules in ways that do NOT occur in nature.	-.13	.13	**.38**	.34	.16
Nano-sized materials behave differently from the same materials when they are on a larger scale.	-.02	-.08	-.07	**.88**	.04
Materials on the nano scale have the same properties as those materials on a bigger scale.	.18	-.04	-.15	**.80**	.09
Scientists do not understand many of the ways nanotechnology might affect the environment.	.02	.12	.02	.08	**.81**
It is difficult to predict the effects of nanotechnology on human health.	.03	.08	.07	.08	**.78**

Note: Extraction Method: Principal Component Analysis.
Rotation Method: Promax with Kaiser Normalization.
a. Rotation converged in 7 iterations.

Table 3
ANOVA for the Total Knowledge by Gender

		Sum of Squares	df	Mean Square	F
Factor 1 Mean - General Knowledge	Between Groups	.33	1	.33	14.44*
	Within Groups	27.74	1208	.02	
	Total	28.07	1209		
Factor 2 Mean - Policy and Availability	Between Groups	.06	1	.06	5.45**
	Within Groups	13.07	1208	.01	
	Total	13.13	1209		
Factor 3 Mean - Small in size	Between Groups	2.63	1	2.63	36.54*
	Within Groups	87.09	1208	.07	
	Total	89.65	1209		
Factor 4 Mean - Behave Different than normal material	Between Groups	.39	1	.39	4.19**
	Within Groups	112.17	1208	.09	
	Total	112.56	1209		
Factor 5 Mean - Uncertainty about nanotechnology	Between Groups	.01	1	.01	.05
	Within Groups	134.36	1208	.11	
	Total	134.36	1209		

**p<0.05, *p<0.01

Table 4
ANOVA for the Total Knowledge by Education Level

		Sum of Squares	df	Mean Square	F
Factor 1 Mean - General Knowledge	Between Groups	1.13	4	.28	12.62*
	Within Groups	26.94	1205	.02	
	Total	28.07	1209		
Factor 2 Mean - Policy and Availability	Between Groups	.07	4	.02	1.49
	Within Groups	13.07	1205	.01	
	Total	13.13	1209		
Factor 3 Mean - Small in size	Between Groups	7.45	4	1.86	27.31*
	Within Groups	82.19	1205	.07	
	Total	89.65	1209		
Factor 4 Mean - Behave Different than normal material	Between Groups	4.33	4	1.08	12.05*
	Within Groups	108.23	1205	.09	
	Total	112.56	1209		
Factor 5 Mean - Uncertainty about nanotechnology	Between Groups	.49	4	.12	1.10
	Within Groups	133.87	1205	.11	
	Total	134.36	1209		

**p<0.05, *p<0.01

Table 5

Tukey HSD Comparison for Total Knowledge by Education

Dependent Variable	(I) ED[a]	(J) ED[a]	Mean Difference (I-J)	Std. Error	99% Confidence Interval Lower Bound	99% Confidence Interval Upper Bound
Factor 1 Mean - General Knowledge	1.00	2.00	.00	.014	-.03	.04
		3.00	-.02	.015	-.06	.02
		4.00	-.07*	.016	-.11	-.03
		5.00	-.07*	.019	-.12	-.03
	2.00	1.00	-.00	.014	-.04	.03
		3.00	-.02	.011	-.05	.01
		4.00	-.07*	.012	-.10	-.04
		5.00	-.08*	.016	-.12	-.04
	3.00	1.00	.02	.015	-.02	.06
		2.00	.02	.011	-.01	.05
		4.00	-.05*	.013	-.08	-.02
		5.00	-.06*	.016	-.09	-.01
	4.00	1.00	.07*	.016	.03	.11
		2.00	.07*	.012	.04	.10
		3.00	.05*	.013	.02	.08
		5.00	-.00	.017	-.05	.04
	5.00	1.00	.07*	.019	.03	.12
		2.00	.08*	.016	.04	.12
		3.00	.06*	.016	.01	.09
		4.00	.00	.017	-.04	.05
Factor 2 Mean - Policy and Availability	1.00	2.00	.02	.010	-.01	.04
		3.00	.01	.010	-.01	.04
		4.00	.02	.011	-.01	.05
		5.00	-.00	.013	-.03	.03
	2.00	1.00	-.02	.010	-.04	.01
		3.00	-.00	.0078	-.02	.02
		4.00	.00	.009	-.02	.03
		5.00	-.02	.011	-.05	.01
	3.00	1.00	-.01	.010	-.04	.01
		2.00	.00	.008	-.02	.02
		4.00	.01	.009	-.02	.03
		5.00	-.02	.011	-.04	.01

Table 5 – (Continued)

	4.00	1.00	-.02	.011	-.05	.01
		2.00	-.00	.009	-.03	.02
		3.00	-.01	.009	-.03	.02
		5.00	-.02	.012	-.05	.01
	5.00	1.00	.00	.013	-.03	.03
		2.00	.02	.011	-.01	.05
		3.00	.02	.011	-.01	.04
		4.00	.02	.012	-.01	.05
Factor 3 Mean - Small in size	1.00	2.00	-.04	.025	-.10	.03
		3.00	-.11*	.026	-.18	-.05
		4.00	-.21*	.028	-.28	-.14
		5.00	-.22*	.032	-.31	-.14
	2.00	1.00	.04	.025	-.03	.10
		3.00	-.08*	.020	-.13	-.02
		4.00	-.17*	.022	-.23	-.11
		5.00	-.19*	.027	-.26	-.11
	3.00	1.00	.11*	.026	.05	.18
		2.00	.08*	.020	.02	.13
		4.00	-.10*	.023	-.15	-.04
		5.00	-.11*	.028	-.18	-.04
	4.00	1.00	.21*	.028	.14	.28
		2.00	.17*	.022	.11	.23
		3.00	.10*	.023	.04	.15
		5.00	-.02	.030	-.09	.06
	5.00	1.00	.22*	.032	.14	.31
		2.00	.19*	.027	.11	.26
		3.00	.110	.028	.04	.18
		4.00	.02	.030	-.06	.09
Factor 4 Mean - Behave Different than normal material	1.00	2.00	-.042	.029	-.12	.03
		3.00	-.092	.030	-.17	-.02
		4.00	-.19*	.032	-.27	-.10
		5.00	-.13*	.037	-.23	-.03
	2.00	1.00	.04	.029	-.03	.12
		3.00	-.05	.022	-.11	.01
		4.00	-.14*	.025	-.21	-.08
		5.00	-.09*	.031	-.17	-.01

Table 5 – (Continued)

	3.00	1.00	.09*	.030	.02	.17
		2.00	.05	.022	-.01	.11
		4.00	-.09*	.026	-.16	-.03
		5.00	-.04	.032	-.12	.05
		1.00	.19*	.032	.10	.27
	4.00	2.00	.14*	.025	.08	.21
		3.00	.09*	.026	.03	.16
		5.00	.06	.034	-.03	.15
	5.00	1.00	.13*	.037	.03	.23
		2.00	.09*	.031	.01	.17
		3.00	.04	.032	-.05	.12
		4.00	-.06	.034	-.15	.03
	1.00	2.00	.01	.032	-.08	.09
		3.00	-.02	.033	-.11	.07
		4.00	-.04	.035	-.14	.05
		5.00	.01	.041	-.09	.12
	2.00	1.00	-.01	.032	-.09	.07
		3.00	-.03	.025	-.09	.04
		4.00	-.05	.028	-.12	.02
		5.00	.01	.035	-.08	.09
	3.00	1.00	.02	.033	-.07	.11
Factor 5 Mean - Uncertainty about nanotechnology		2.00	.03	.025	-.04	.09
		4.00	-.03	.029	-.09	.05
		5.00	.03	.036	-.06	.13
	4.00	1.00	.04	.035	-.05	.14
		2.00	.05	.028	-.02	.12
		3.00	.03	.029	-.05	.10
		5.00	.06	.038	-.04	.16
	5.00	1.00	-.01	.041	-.12	.09
		2.00	-.01	.035	-.09	.08
		3.00	-.03	.036	-.13	.06
		4.00	-.06	.038	-.16	.04

**. The mean difference is significant at the 0.01 level.*

Ed[a] = Education Level

1.00 = Less than High School, 2.00 = High School, 3.00 = Some College, 4.00 = Bachelor's Degree, 5.00 = Masters or Ph.D.

Table 6
Mean of Knowledge by Gender

		N	Mean	Std. Deviation	F	Sig
Number of Correct Answers	Male	592	3.21	2.92	23.14*	.00
	Female	618	2.45	2.57		
		1210	2.82	2.77		
Total Number of "I don't know" responses	Male	592	9.72	5.92	21.51*	.00
	Female	618	11.27	5.75		
		1210	10.51	5.88		

*p<0.01

Table 7
Mean of Knowledge by Education

		N	Mean	Std. Deviation	F	Sig
Number of Correct Answers	1.00	146	1.99	2.23	21.96*	.00
	2.00	405	2.20	2.45		
	3.00	317	2.86	2.79		
	4.00	225	3.90	3.11		
	5.00	117	3.80	2.73		
	Total	1210	2.95	2.6		
Total Number of "I don't know" responses	1.00	146	11.99	6.03	15.11*	.00
	2.00	405	11.60	5.80		
	3.00	317	10.45	5.85		
	4.00	225	8.67	5.53		
	5.00	117	8.60	5.35		
	Total	1210	10.51	5.88		

Note: *p<0.01

1.00 = Less than High School, 2.00 = High School, 3.00 = Some College, 4.00 = Bachelor's Degree, 5.00 = Masters or Ph.D.

Table 8

ANOVA for the Acceptance of Nanotechnology in Specific Items by Gender

		N	Mean	Std. Deviation	F
Nanotechnology in a fresh fruit	Male	574	4.94	3.30	18.83*
	Female	603	4.13	3.08	
	Total	1177	4.52	3.22	
Nanotechnology in a fresh vegetable	Male	578	4.89	3.34	15.37*
	Female	600	4.15	3.09	
	Total	1178	4.51	3.23	
Nanotechnology in milk	Male	579	4.72	3.29	21.37*
	Female	605	3.88	2.94	
	Total	1184	4.29	3.14	
Nanotechnology in beef	Male	578	4.85	3.24	12.81*
	Female	603	4.20	3.02	
	Total	1181	4.52	3.15	
Nanotechnology in pork	Male	580	4.79	3.20	9.47*
	Female	603	4.23	3.03	
	Total	1183	4.51	3.13	
Nanotechnology in cereal	Male	578	4.88	3.25	18.58*
	Female	602	4.10	2.98	
	Total	1180	4.48	3.14	
Nanotechnology in a processed food	Male	580	5.10	3.32	13.31*
	Female	604	4.43	2.98	
	Total	1184	4.76	3.17	
Nanotechnology in a food that is normally eaten without being cooked	Male	580	4.89	3.23	15.48*
	Female	605	4.18	2.99	
	Total	1185	4.53	3.13	
Nanotechnology in baby food	Male	575	4.15	3.16	18.96*
	Female	603	3.40	2.79	
	Total	1178	3.77	2.99	
Nanotechnology in a food you eat to improve your health	Male	580	5.61	3.45	14.01*
	Female	605	4.88	3.33	
	Total	1185	5.24	3.41	
Nanotechnology in a dessert food	Male	580	4.86	3.22	13.90*
	Female	605	4.20	2.96	
	Total	1185	4.52	3.10	
Nanotechnology in a snack food	Male	579	4.91	3.23	14.23*
	Female	598	4.23	2.95	
	Total	1177	4.57	3.11	

*p<0.01

Table 9

ANOVA for Acceptance of Nanotechnology in Abstract Items by Education

		Sum of Squares	df	Mean Square	F
Nanotechnology in a fresh fruit	Between Groups	18.36	4.00	4.59	.44
	Within Groups	12149.34	1172.00	10.37	
	Total	12167.70	1176.00		
Nanotechnology in a fresh vegetable	Between Groups	9.08	4.00	2.27	.22
	Within Groups	12289.26	1173.00	10.48	
	Total	12298.33	1177.00		
Nanotechnology in milk	Between Groups	20.80	4.00	5.20	.53
	Within Groups	11663.25	1179.00	9.89	
	Total	11684.05	1183.00		
Nanotechnology in beef	Between Groups	15.84	4.00	3.96	.40
	Within Groups	11657.09	1176.00	9.91	
	Total	11672.93	1180.00		
Nanotechnology in pork	Between Groups	22.75	4.00	5.69	.58
	Within Groups	11524.94	1178.00	9.78	
	Total	11547.69	1182.00		
Nanotechnology in cereal	Between Groups	10.36	4.00	2.59	.26
	Within Groups	11624.36	1175.00	9.89	
	Total	11634.73	1179.00		
Nanotechnology in a processed food	Between Groups	51.60	4.00	12.90	1.29
	Within Groups	11804.80	1179.00	10.01	
	Total	11856.40	1183.00		
Nanotechnology in a food that is normally eaten without being cooked	Between Groups	41.28	4.00	10.32	1.05
	Within Groups	11550.02	1180.00	9.79	
	Total	11591.30	1184.00		
Nanotechnology in baby food	Between Groups	14.98	4.00	3.74	.42
	Within Groups	10559.83	1173.00	9.00	
	Total	10574.80	1177.00		
Nanotechnology in a food you eat to improve your health	Between Groups	6.11	4.00	1.53	.13
	Within Groups	13762.25	1180.00	11.66	
	Total	13768.37	1184.00		
Nanotechnology in a dessert food	Between Groups	24.43	4.00	6.11	.63
	Within Groups	11379.22	1180.00	9.64	
	Total	11403.66	1184.00		
Nanotechnology in a snack food	Between Groups	18.22	4.00	4.56	.47
	Within Groups	11330.79	1172.00	9.67	

Table 9 – (Continued)

	Total	11349.014	1176

*p<0.01

Table 10

Pearson Correlations Matrix among Acceptance of Specific Items and Knowledge

	Nanotechnology in a fresh fruit	Nanotechnology in a fresh vegetable	Nanotechnology in milk	Nanotechnology in beef	Nanotechnology in pork	Nanotechnology in cereal
Number of Correct answers	.038	.046	.053	.047	.057*	.054
Nanotechnology in a fresh fruit		.941**	.887**	.889**	.859**	.906**
Nanotechnology in a fresh vegetable			.886**	.894**	.878**	.898**
Nanotechnology in milk				.892**	.862**	.895**
Nanotechnology in beef					.932**	.901**
Nanotechnology in pork						.873**

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table 10 (Continued)

	Nanotechnology in a processed food	Nanotechnology in a food that is normally eaten without being cooked	Nanotechnology in baby food	Nanotechnology in a food you eat to improve your health	Nanotechnology in a dessert food	Nanotechnology in a snack food
Number of Correct answers	.077**	.067*	.019	.058*	.064*	.068*
Nanotechnology in a processed food		.842**	.787**	.844**	.882**	.887**
Nanotechnology in a food that is normally eaten without being cooked			.762**	.823**	.854**	.867**
Nanotechnology in baby food				.715**	.813**	.796**
Nanotechnology in a food you eat to improve your health					.835**	.831**
Nanotechnology in a dessert food						.915**

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table 11
ANOVA for Acceptance of Nanotechnology in Abstract Items by Gender

		N	Mean	Std. Deviation	F
I would purchase foods labeled as containing 'nanotechnology' in the grocery store.	Male	584	3.61	2.63	13.21*
	Female	606	3.08	2.45	
	Total	1190	3.34	2.55	
I would eat nanotech foods	Male	583	3.74	2.69	14.24*
	Female	605	3.18	2.51	
	Total	1188	3.45	2.61	
I would serve nanotech foods to my family and friends	Male	581	3.50	2.56	11.18*
	Female	608	3.02	2.38	
	Total	1189	3.25	2.48	
I would recommend nanotech food to a friend	Male	579	3.32	2.45	13.3*
	Female	608	2.82	2.28	
	Total	1187	3.06	2.38	
Nanotechnology in food is morally acceptable	Male	580	5.31	2.90	8.99*
	Female	604	4.82	2.71	
	Total	1184	5.06	2.82	
Nanotechnology in food is useful for society	Male	581	5.30	2.75	9.88*
	Female	605	4.80	2.65	
	Total	1186	5.04	2.71	
Nanotechnology in food should be encouraged	Male	577	4.90	2.71	17.70*
	Female	604	4.25	2.57	
	Total	1181	4.57	2.66	

*p<0.01

Table 12

ANOVA for Acceptance of Abstract Items by Education

		Sum of Squares	df	Mean Square	F	Mean
I would purchase foods labeled as containing 'nanotechnology' in the grocery store	Between Groups	54.66	4	13.66	2.10	3.34
	Within Groups	7703.14	1185	6.50		
	Total	7757.79	1189			
I would eat nanotech foods	Between Groups	51.09	4	12.77	1.88	3.45
	Within Groups	8055.45	1183	6.81		
	Total	8106.55	1187			
I would recommend nanotech food to a friend	Between Groups	32.75	4	8.19	1.40	3.06
	Within Groups	6674.38	1182	5.65		
	Total	6707.13	1186			
Nanotechnology in food is morally acceptable	Between Groups	355.69	4	88.92	11.62*	5.06
	Within Groups	9023.94	1179	7.65		
	Total	9379.62	1183			
Nanotechnology in food is useful for society	Between Groups	119.59	4	29.89	4.12*	5.04
	Within Groups	8573.05	1181	7.26		
	Total	8692.63	1185			
Nanotechnology in food should be encouraged	Between Groups	42.33	4	10.58	1.50	4.57
	Within Groups	8287.29	1176	7.05		
	Total	8329.63	1180			

*p<0.01

Table13
Tukey HSD Comparison for Acceptance of Abstract Items by Education

Dependent Variable	(I) ED	(J) ED	Mean Difference (I-J)	Std. Error	99% Confidence Interval Lower Bound	Upper Bound
I would purchase foods labeled as containing 'nanotechnology' in the grocery store	1.00	2.00	.11	.25	-.53	.74
		3.00	-.27	.26	-.93	.39
		4.00	-.37	.27	-1.07	.34
		5.00	-.45	.32	-1.27	.37
	2.00	1.00	-.11	.25	-.74	.53
		3.00	-.38	.19	-.88	.12
		4.00	-.47	.21	-1.02	.08
		5.00	-.56	.27	-1.25	.14
	3.00	1.00	.27	.26	-.39	.93
		2.00	.38	.19	-.12	.88
		4.00	-.09	.22	-.67	.49
		5.00	-.18	.28	-.90	.54
	4.00	1.00	.37	.27	-.34	1.07
		2.00	.47	.21	-.08	1.02
		3.00	.09	.22	-.49	.67
		5.00	-.09	.29	-.84	.67
	5.00	1.00	.45	.32	-.37	1.27
		2.00	.56	.27	-.14	1.25
		3.00	.18	.28	-.54	.90
		4.00	.09	.29	-.67	.84

Table 13 – (Continued)

Dependent Variable	(I) ED	(J) ED	Mean Difference (I-J)	Std. Error	Lower Bound	Upper Bound
I would eat nanotech foods	1.00	2.00	.07	.25	-.58	.73
		3.00	-.13	.26	-.81	.55
		4.00	-.41	.28	-1.13	.31
		5.00	-.49	.33	-1.34	.34
	2.00	1.00	-.07	.25	-.73	.58
		3.00	-.20	.19	-.71	.31
		4.00	-.48	.22	-1.04	.09
		5.00	-.57	.28	-1.28	.14
	3.00	1.00	.13	.26	-.55	.81
		2.00	.20	.19	-.31	.71
		4.00	-.28	.23	-.87	.31
		5.00	-.37	.29	-1.10	.37

Table 13 – (Continued)

	4.00	1.00	.47	.28	-.31	1.13
		2.00	.48	.22	-.09	1.04
		3.00	.28	.23	-.31	.87
		5.00	-.09	.30	-.86	.68
	5.00	1.00	.49	.33	-.34	1.34
		2.00	.57	.28	-.14	1.28
		3.00	.37	.29	-.37	1.10
		4.00	.09	.30	-.68	.86
I would recommend nanotech food to a friend	1.00	2.00	.25	.23	-.35	.84
		3.00	-.08	.24	-.70	.54
		4.00	-.11	.26	-.77	.54
		5.00	-.19	.29	-.96	.57
	2.00	1.00	-.25	.23	-.84	.35
		3.00	-.33	.18	-.79	.14
		4.00	-.36	.19	-.88	.15
		5.00	-.44	.25	-1.09	.21
	3.00	1.00	.08	.24	-.54	.70
		2.00	.33	.18	-.14	.79
		4.00	-.03	.21	-.57	.51
		5.00	-.11	.26	-.78	.56
	4.00	1.00	.11	.26	-.54	.77
		2.00	.36	.19	-.15	.88
		3.00	.03	.21	-.51	.57
		5.00	-.08	.27	-.78	.62
	5.00	1.00	.19	.29	-.57	.96
		2.00	.44	.25	-.21	1.09
		3.00	.11	.26	-.56	.78
		4.00	.08	.27	-.62	.78
Nanotechnology in food is morally acceptable	1.00	2.00	-.29	.27	-.99	.40
		3.00	-.54	.28	-1.26	.18
		4.00	-1.35*	.29	-2.11	-.58
		5.00	-1.72*	.34	-2.61	-.83
	2.00	1.00	.29	.27	-.40	.99
		3.00	-.25	.21	-.79	.30
		4.00	-1.05*	.23	-1.65	-.45
		5.00	-1.43*	.29	-2.18	-.67
	3.00	1.00	.54	.28	-.18	1.26
		2.00	.25	.21	-.30	.79

Table 13 – (Continued)

		4.00	-.81*	.243	-1.44	-.18
		5.00	-1.18*	.30	-1.96	-.41
	4.00	1.00	1.35*	.29	.58	2.11
		2.00	1.05*	.23	.45	1.65
		3.00	.81*	.24	.18	1.44
		5.00	-.37	.32	-1.19	.44
	5.00	1.00	1.72*	.34	.83	2.61
		2.00	1.43*	.29	.67	2.18
		3.00	1.18*	.30	.41	1.96
		4.00	.37	.32	-.44	1.19
Nanotechnology in food is useful for society	1.00	2.00	-.11	.26	-.78	.57
		3.00	-.325	.27	-1.03	.38
		4.00	-.80*	.29	-1.55	-.06
		5.00	-.89*	.34	-1.75	-.02
	2.00	1.00	.11	.26	-.57	.78
		3.00	-.22	.20	-.75	.31
		4.00	-.69*	.23	-1.28	-.11
		5.00	-.78*	.28	-1.51	-.05
	3.00	1.00	.33	.27	-.38	1.03
		2.00	.22	.20	-.31	.75
		4.00	-.48	.24	-1.09	.14
		5.00	-.56	.29	-1.31	.19
	4.00	1.00	.80*	.29	.06	1.55
		2.00	.69*	.23	.11	1.28
		3.00	.48	.24	-.14	1.09
		5.00	-.08	.31	-.88	.71
	5.00	1.00	.89*	.34	.02	1.75
		2.00	.78*	.28	.05	1.51
		3.00	.56	.29	-.19	1.31
		4.00	.08	.31	-.71	.88
Nanotechnology in food should be encouraged	1.00	2.00	-.44	.26	-1.11	.23
		3.00	-.50	.27	-1.20	.19
		4.00	-.59	.29	-1.32	.15
		5.00	-.72	.33	-1.57	.14
	2.00	1.00	.44	.26	-.23	1.11
		3.00	-.07	.20	-.59	.45
		4.00	-.15	.22	-.73	.43
		5.00	-.28	.28	-1.00	.44

Table 13 – (Continued)

	3.00	1.00	.50	.27	-.19	1.20
		2.00	.07	.20	-.45	.59
		4.00	-.08	.23	-.69	.52
		5.00	-.21	.29	-.96	.53
	4.00	1.00	.59	.29	-.15	1.32
		2.00	.15	.22	-.43	.73
		3.00	.08	.23	-.52	.69
		5.00	-.13	.30	-.91	.65
	5.00	1.00	.72	.33	-.14	1.57
		2.00	.28	.28	-.44	1.00
		3.00	.21	.29	-.53	.96
		4.00	.13	.30	-.65	.91

**. The mean difference is significant at the 0.01 level.*

Ed[a] = Education Level

1.00 = Less than High School, 2.00 = High School, 3.00 = Some College, 4.00 = Bachelor's Degree, 5.00 = Masters or Ph.D.

Table 14

Factor Loadings for 22 Benefits Items

	Factors		
	1	2	3
Nanotechnology that would reduce the likelihood of the food causing an illness	**.97**	.00	-.17
Nanotechnology that would make the food better for your heart health.	**.97**	.07	-.16
Nanotechnology that would indicate the presence of an allergen in a food.	**.97**	-.01	-.14
Nanotechnology that would increase the amount of vitamins you could get from a food.	**.92**	.05	-.06
Nanotechnology that would reduce fat in a product without changing the taste.	**.88**	.09	-.05
Nanotechnology that would keep food fresher longer.	**.86**	.08	-.01
Nanotechnology that would improve the taste of food.	**.77**	.00	.21
Nanotechnology that would reduce the odor from cooking fish.	**.68**	.03	.20
Nanotechnology that would improve the texture of a food.	**.66**	.03	.27
Nanotechnology that would make fruits taste sweeter.	**.54**	.11	.32
Yogurt with fiber to improve digestion.	.03	**.90**	-.09
Bottled water with calcium to improve bone health.	.03	**.90**	-.01
Ice cream with fiber to improve digestion.	.03	**.90**	.04
Hot dogs with Omega-3 fatty acids to improve heart health.	.06	**.88**	.01
Carbonated Soft Drinks with calcium to improve bone health.	-.01	**.88**	.08
Peanut Butter with Omega-3 fatty acids to improve heart health.	.19	**.81**	-.07
Nanotechnology that would make foods glow in the dark.	-.27	.03	**.97**
Nanotechnology that would change the color of food.	-.04	.02	**.88**
Nanotechnology that would make the food change colors when stirred.	-.03	.03	**.87**
Nanotechnology that would make vegetables taste like chocolate.	-.05	-.06	**.84**
Nanotechnology that would make the color of the food extra bright.	.22	-.02	**.729**
Nanotechnology that would create new flavors for foods.	.41	-.01	**.559**

Extraction Method: Principal Component Analysis.

Rotation Method: Promax with Kaiser Normalization.

a. Rotation converged in 6 iterations.

Table 15
ANOVA for Acceptance of Health Benefits by Gender

		Sum of Squares	df	Mean Square	F
Nanotechnology that would increase the amount of vitamins you could get from a food	Between Groups	34.31	1	34.31	2.96
	Within Groups	13717.48	1184	11.59	
	Total	13751.78	1185		
Nanotechnology that would make the food better for your heart health	Between Groups	36.47	1	36.47	3.11
	Within Groups	13829.88	1179	11.73	
	Total	13866.35	1180		
Nanotechnology that would keep food fresher longer	Between Groups	84.16	1	84.16	7.15*
	Within Groups	13956.62	1186	11.77	
	Total	14040.78	1187		
Nanotechnology that would reduce the likelihood of the food causing an illness	Between Groups	9.86	1	9.86	.85
	Within Groups	13723.71	1183	11.60	
	Total	13733.57	1184		
Nanotechnology that would reduce fat in a product without changing the taste	Between Groups	23.91	1	23.91	1.97
	Within Groups	14364.31	1181	12.16	
	Total	14388.21	1182		
Nanotechnology that would indicate the presence of an allergen in a foo	Between Groups	5.58	1	5.58	.48
	Within Groups	13725.82	1182	11.61	
	Total	13731.39	1183		

*p<0.01

Table 16

ANOVA for Acceptance of Health Benefits by Education

		Sum of Squares	df	Mean Square	F
Nanotechnology that would increase the amount of vitamins you could get from a food	Between Groups	33.21	4	8.30	.72
	Within Groups	13718.58	1181	11.62	
	Total	13751.78	1185		
Nanotechnology that would make the food better for your heart health	Between Groups	76.09	4	19.02	1.62
	Within Groups	13790.26	1176	11.73	
	Total	13866.35	1180		
Nanotechnology that would keep food fresher longer	Between Groups	6.43	4	1.61	.14
	Within Groups	14034.35	1183	11.86	
	Total	14040.78	1187		
Nanotechnology that would reduce the likelihood of the food causing an illness	Between Groups	124.13	4	31.03	2.69
	Within Groups	13609.44	1180	11.53	
	Total	13733.57	1184		
Nanotechnology that would reduce fat in a product without changing the taste	Between Groups	37.29	4	9.33	.77
	Within Groups	14350.91	1178	12.18	
	Total	14388.21	1182		
Nanotechnology that would indicate the presence of an allergen in a food	Between Groups	69.26	4	17.31	1.49
	Within Groups	13662.14	1179	11.59	
	Total	13731.39	1183		

*p<0.01

Table 17
Pearson Correlations Matrix among Health Benefits and Knowledge

	Nanotechnology that would increase the amount of vitamins you could get from a food	Nanotechnology that would make the food better for your heart health	Nanotechnology that would keep food fresher longer	Nanotechnology that would reduce the likelihood of the food causing an illness	Nanotechnology that would reduce fat in a product without changing the taste	Nanotechnology that would indicate the presence of an allergen in a food
Number of Correct answers	.037	.036	.059*	.057*	.015	.043
Nanotechnology that would increase the amount of vitamins you could get from a food		.864**	.853**	.817**	.846**	.791**
Nanotechnology that would make the food better for your heart health			.838**	.858**	.847**	.826**
Nanotechnology that would keep food fresher longer				.820**	.836**	.762**
Nanotechnology that would reduce the likelihood of the food causing an illness					.813**	.809**

Table 17 – (Continued)

Nanotechnology that would reduce fat in a product without changing the taste	.775**

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table 18
ANOVA for Acceptance of Paired Benefits Acceptance by Gender

		Sum of Squares	df	Mean Square	F
Hot dogs with Omega-3 fatty acids to improve heart health	Between Groups	117.97	1	117.97	9.93*
	Within Groups	14061.31	1184	11.88	
	Total	14179.35	1185		
Ice cream with fiber to improve digestion	Between Groups	82.39	1	82.39	6.97*
	Within Groups	13942.99	1180	11.82	
	Total	14025.39	1181		
Carbonated Soft Drinks with calcium to improve bone health	Between Groups	173.91	1	173.91	14.40*
	Within Groups	14250.39	1180	12.08	
	Total	14424.31	1181		
Peanut Butter with Omega-3 fatty acids to improve heart health	Between Groups	77.97	1	77.97	6.47
	Within Groups	14217.55	1180	12.05	
	Total	14295.51	1181		
Yogurt with fiber to improve digestion	Between Groups	21.62	1	21.62	1.86
	Within Groups	13689.31	1180	11.60	
	Total	13710.92	1181		
Bottled water with calcium to improve bone health	Between Groups	19.23	1	19.23	1.57
	Within Groups	14495.64	1184	12.24	
	Total	14514.87	1185		

*p<0.01

Table 19
ANOVA for Acceptance of Paired Benefits by Education

		Sum of Squares	df	Mean Square	F
Hot dogs with Omega-3 fatty acids to improve heart health	Between Groups	51.55	4	12.89	1.08
	Within Groups	14127.79	1181	11.96	
	Total	14179.35	1185		
Ice cream with fiber to improve digestion	Between Groups	53.439	4	13.36	1.13
	Within Groups	13971.96	1177	11.87	
	Total	14025.39	1181		
Carbonated Soft Drinks with calcium to improve bone health	Between Groups	107.63	4	26.91	2.21
	Within Groups	14316.67	1177	12.16	
	Total	14424.31	1181		
Peanut Butter with Omega-3 fatty acids to improve heart health	Between Groups	27.30	4	6.83	.56
	Within Groups	14268.21	1177	12.12	
	Total	14295.51	1181		
Yogurt with fiber to improve digestion	Between Groups	39.72	4	9.93	.86
	Within Groups	13671.21	1177	11.62	
	Total	13710.92	1181		
Bottled water with calcium to improve bone health	Between Groups	80.58	4	20.14	1.65
	Within Groups	14434.29	1181	12.22	
	Total	14514.87	1185		

*p<0.01

Table 20
Pearson Correlations Matrix among Paired Benefits and Knowledge

	Hot dogs with Omega-3 fatty acids to improve heart health	Ice cream with fiber to improve digestion	Carbonated Soft Drinks with calcium to improve bone health	Peanut Butter with Omega-3 fatty acids to improve heart health	Yogurt with fiber to improve digestion	Bottled water with calcium to improve bone health
Number of Correct answers	-.024	-.027	-.039	.001	-.014	-.036
Hot dogs with Omega-3 fatty acids to improve heart health		.855**	.834**	.851**	.807**	.824**
Ice cream with fiber to improve digestion			.839**	.845**	.859**	.821**
Carbonated Soft Drinks with calcium to improve bone health				.788**	.758**	.814**
Peanut Butter with Omega-3 fatty acids to improve heart health					.833**	.825**
Yogurt with fiber to improve digestion						.788**

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table 21
ANOVA for Acceptance of Non-Health Benefits by Gender

		Sum of Squares	df	Mean Square	F
Nanotechnology that would improve the taste of food	Between Groups	75.45	1	75.45	6.876*
	Within Groups	12970.17	1182	10.97	
	Total	13045.62	1183		
Nanotechnology that would create new flavors for foods	Between Groups	181.18	1	181.18	19.229*
	Within Groups	11127.49	1181	9.42	
	Total	11308.67	1182		
Nanotechnology that would improve the texture of a food	Between Groups	105.46	1	105.46	10.410*
	Within Groups	11985.15	1183	10.13	
	Total	12090.61	1184		
Nanotechnology that would change the color of food	Between Groups	124.78	1	124.78	17.868*
	Within Groups	8233.22	1179	6.98	
	Total	8357.99	1180		
Nanotechnology that would make the color of the food extra bright	Between Groups	126.66	1	126.66	16.354*
	Within Groups	9154.17	1182	7.75	
	Total	9280.83	1183		
Nanotechnology that would make the food change colors when stirred	Between Groups	154.05	1	154.05	22.026*
	Within Groups	8238.86	1178	6.99	
	Total	8392.92	1179		
Nanotechnology that would make vegetables taste like chocolate	Between Groups	88.16	1	88.16	11.711*
	Within Groups	8935.33	1187	7.53	
	Total	9023.49	1188		
Nanotechnology that would make fruits taste	Between Groups	102.17	1	102.17	10.003*
	Within Groups	12082.99	1183	10.21	
	Total	12185.16	1184		
Nanotechnology that would make foods glow in the dark	Between Groups	143.98	1	143.98	24.000*
	Within Groups	7084.93	1181	5.99	
	Total	7228.90	1182		
Nanotechnology that would reduce the odor from cooking fish	Between Groups	28.02	1	28.02	2.537
	Within Groups	13067.00	1183	11.05	
	Total	13095.02	1184		

*p<0.01

Table 22
ANOVA for Acceptance of Non-Health Benefits by Education

		Sum of Squares	df	Mean Square	F
Nanotechnology that would improve the taste of food	Between Groups	4.72	4	1.18	.107
	Within Groups	13040.91	1179	11.06	
	Total	13045.62	1183		
Nanotechnology that would create new flavors for foods	Between Groups	22.31	4	5.58	.582
	Within Groups	11286.36	1178	9.58	
	Total	11308.67	1182		
Nanotechnology that would improve the texture of a food	Between Groups	6.51	4	1.63	.159
	Within Groups	12084.10	1180	10.24	
	Total	12090.61	1184		
Nanotechnology that would change the color of food	Between Groups	10.47	4	2.62	.369
	Within Groups	8347.52	1176	7.09	
	Total	8357.99	1180		
Nanotechnology that would make the color of the food extra bright	Between Groups	55.74	4	13.94	1.781
	Within Groups	9225.09	1179	7.83	
	Total	9280.83	1183		
Nanotechnology that would make the food change colors when stirred	Between Groups	25.71	4	6.43	.902
	Within Groups	8367.21	1175	7.12	
	Total	8392.92	1179		
Nanotechnology that would make vegetables taste like chocolate	Between Groups	38.69	4	9.68	1.275
	Within Groups	8984.79	1184	7.59	
	Total	9023.49	1188		
Nanotechnology that would make fruits taste sweeter	Between Groups	19.85	4	4.96	.481
	Within Groups	12165.31	1180	10.31	
	Total	12185.16	1184		
Nanotechnology that would make foods glow in the dark	Between Groups	43.43	4	10.86	1.780
	Within Groups	7185.48	1178	6.10	
	Total	7228.90	1182		
Nanotechnology that would reduce the odor from cooking fish	Between Groups	50.99	4	12.75	1.153
	Within Groups	13044.03	1180	11.05	
	Total	13095.02	1184		

*p<0.01

Table 23
Pearson Correlations Matrix among Non-Health Benefits and Knowledge

	Nanotechnology that would make the food change colors when stirred	Nanotechnology that would make vegetables taste like chocolate	Nanotechnology that would make fruits taste sweeter	Nanotechnology that would make foods glow in the dark	Nanotechnology that would reduce the odor from cooking fish
Number of Correct answers	-.017	-.066*	-.042	-.061*	-.054
Nanotechnology that would make the food change colors when stirred		.589**	.583**	.666**	.529**
Nanotechnology that would make vegetables taste like chocolate			.505**	.572**	.447**
Nanotechnology that would make fruits taste sweeter				.438**	.704**
Nanotechnology that would make foods glow in the dark					.386**

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Table 24
ANOVA for Total Benefits by Gender

		Sum of Squares	df	Mean Square	F
Mean of Health Benefits 6 questions	Between Groups	25.39	1	25.39	2.54
	Within Groups	11570.93	1158	9.99	
	Total	11596.32	1159		
Mean of Paired Benefits 6 questions	Between Groups	64.93	1	64.93	6.43
	Within Groups	11617.56	1151	10.09	
	Total	11682.48	1152		
Mean of Peripheral Benefits 10 questions	Between Groups	111.62	1	111.62	19.67*
	Within Groups	6524.05	1150	5.67	
	Total	6635.67	1151		
All benefit means	Between Groups	57.06	1	57.06	8.15*
	Within Groups	7680.25	1097	7.00	
	Total	7737.31	1098		

*p<0.01

Table 25
ANOVA for Total Benefits by Education

		Sum of Squares	df	Mean Square	F
Mean of Health Benefits 6 questions	Between Groups	38.73	4	9.68	.97
	Within Groups	11557.59	1155	10.01	
	Total	11596.32	1159		
Mean of Paired Benefits 6 questions	Between Groups	43.88	4	10.97	1.08
	Within Groups	11638.59	1148	10.14	
	Total	11682.48	1152		
Mean of Peripheral Benefits 10 questions	Between Groups	19.36	4	4.84	.84
	Within Groups	6616.32	1147	5.77	
	Total	6635.67	1151		
All benefit means	Between Groups	7.21	4	1.80	.26
	Within Groups	7730.10	1094	7.07	
	Total	7737.31	1098		

*p<0.01

Appendices

Appendix A

Description of Nanotechnology Described

Groups Presented to	Description Given
Groups A, B, & C	Nanotechnology materials are extremely small. Nanotechnology allows scientists to make and use extremely small materials. These particles are measured in nanometers. One nanometer is one-billionth of a meter. It may be difficult to fully understand just how small a nanometer is. For example, a single human hair is around 80,000 nanometers in width, a single sheet of paper is 100,000 nanometers thick, and the head of a pin is about 1 million nanometers across. Because the materials are so small, it is possible to create mixtures of oil and water that never separate, to add particles that never sink to liquids, and to add ingredients that won't change the taste of foods. The fact that these materials are so small makes it possible to create many new kinds of food products. Researchers working with food companies are developing ways of using nanotechnology in commonly eaten foods, what we refer to here as "nanotech food" or "food nanotechnology." The following questions concern your feelings about food nanotechnology.
Groups D, E, & F	Nanotechnology materials behave differently than their larger counterparts. Nanotechnology allows scientists to make and use extremely small materials. What is important about these small materials is that they act very differently on the nano scale than they do on a larger scale. As a result, even common materials used in foods can have very different physical or biological characteristics when they are used at the nanoscale. Materials made with nanotechnology can also have different chemical reactions and biological properties compared with the same materials when they are not so small. For example, through the use of nanotechnology, it is possible to create mixtures of oil and water that never separate, to add particles that never sink to liquids, and to add ingredients that won't change the taste of foods. The different properties of these nano scale materials make it possible to create many new kinds of food products. Researchers working with food companies are developing ways of using nanotechnology in commonly eaten foods, what we refer to here as "nanotech food" or "food nanotechnology." The following questions concern your feelings about food nanotechnology.
Groups G, H, & I	Effects of nanotechnology materials are unpredictable. Nanotechnology allows scientists to make and use extremely small materials. What is important about these small materials is that they act very differently on the nano scale than they do on a larger scale. Even common materials used in foods can have very different physical, chemical, and biological properties when they are used at the nano scale. For example, through the use of nanotechnology, it is possible to create mixtures of oil and water that never separate, to add particles that never sink to liquids, and to add ingredients that won't change the taste of foods. The different properties of these nano scale materials make it possible to create many new kinds of food products. However, these different properties and their very small size also make it much more difficult for scientists to accurately predict how nano materials might affect people and the environment. Researchers working with food companies are developing ways of using nanotechnology in commonly eaten foods, what we refer to here as "nanotech food" or "food nanotechnology." The following questions concern your feelings about food nanotechnology.

Appendix B

Location of Nanotech Product Described

Groups Presented	Description Given
Presented to Groups A, D, & G	A recently developed type of nanotechnology helps to preserve the freshness of apples. Nanotech particles are added to the soil. The nanotech particles are taken up by the roots of the tree and become part of the apple.
Presented to Groups B, E, & H	A recently developed type of nanotechnology helps to preserve the freshness of apples. Nanotech particles are applied to the outside of the apple after it is picked from the tree. The nanotech particles can be washed off or taken off if the skin of the apple is removed.
Presented to Groups C, F,& I	A recently developed type of nanotechnology helps to preserve the freshness of apples. Nanotech particles are added to the plastic bags manufactured to hold apples. The nanotech particles remain in the plastic bag and do not transfer to the apples.

Appendix C

Examples of Properties of Food Products Presented

Property	Level 1	Level 2	Level 3	Level 4
Type of food	Produce	Dairy	Meat	Cereal or Grain
Processing	Raw	Processed		
Healthfulness of Food	Healthy/Functional	Neutral	Unhealthy "Snack"	

Appendix D

Examples of Properties of Nanotechnology Materials in Food to be Varied

Property	Level 1	Level 2	Level 3	Level 4
Delivery Mechanism	In Food	Packaging	As coating	
Benefit Type	Nutritional	Medical	Shelf-life	Food Safety
Nanomaterial Type	Food/organic	Non-food /organic	Non-food /Non-organic	
Nanotechnology	Nanoparticle	Edible Film	Nanosensor	Encapsulation
Nanoparticle or Film Improves	Taste	Texture	Color	
Nanosensor Detects	Freshness or Spoilage	Allergen	Contaminant	Pathogen

Appendix E

Number of Items in each Measure Category

Measure	Number of Items	Score
General Knowledge about Nanotechnology	19	0 – 10 *
Acceptance of Nanotechnology Foods (Abstract)	6	0 – 10 *
Acceptance of Nanotechnology Foods (Specific)	12	0 – 10 **
Statements about Nanotechnology Foods and Health Benefits	6	0 – 10 **
Statements about Nanotechnology Foods and Health Benefits (Paired)	6	0 – 10 ***
Statements about Nanotechnology and Non-Health Benefits	10	0 – 10 **

Note:
** Participants used an 11-point Likert –type scale (0=Disagree Strongly to 10=Agree Strongly)*
*** Participants used an 11-point Likert –type scale (0=Do Not Approve At All to 10=Totally Approve)*
*** Participants used an 11-point Likert –type scale (0=Definitely would not buy to 10=Definitely would buy)*

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