SENSORY ACCEPTABILITY AND WILLINGNESS TO BUY FOODS WITH NANOTECHNOLOGY BENEFITS

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ABSTRACT OF THE THESIS

Sensory acceptability and willingness to buy foods with nanotechnology benefits

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Nanotechnology manipulates matter on a very small scale (1-billionth of a meter). It may dramatically improve food production, processing and packaging. However, R&D in food nanotechnology can only yield returns if consumers are willing to buy the resulting products. Yet, no studies have investigated consumer attitudes and reactions to tasting foods with nanotechnology benefits.

Fresh cherry tomatoes and chocolate ice cream were evaluated for liking of key attributes and overall liking using 15-cm line scales. Three samples of each food were evaluated one-at-a time. Panelists were told that the first sample of each food had no nanotechnology (control) and that subsequent samples were produced with nanotechnology. For tomatoes, the scenario was that nanoparticles were in the packaging as an anti-microbial or to extend freshness. For ice cream, the nanoparticles were incorporated into the food matrix to deliver probiotics or to reduce icing. In reality, none of the foods were made with nanoscale ingredients. After the taste test, panelists were required to complete a seven-page survey.

The panel consisted of 62% students, 27% faculty/staff, and 11% adults from the

local community. All three tomato samples were equally liked and all three ice cream samples were equally liked regardless of whether they claimed nanotechnology benefits. Most participants (75-86%) were willing to buy at least one of the nanotech foods. For buyers of nanotech products, they gave high liking ratings for all attributes of the nanotech products that were similar to the ratings for the control samples; their primary reason was split, between "sensory appeal" and "nanotechnology benefit" ($p < 0.01$). For non-buyers of nanotech products, they gave lower liking ratings to all attributes of the nanotech samples relative to the control samples ($p < 0.05$); they chose "sensory appeal" as the predominant reason for not buying any nanotech product ($p < 0.01$).

The panel had limited knowledge about nanotechnology, but was not neophobic to food nanotechnology. The majority had positive or neutral attitudes towards the application of nanotechnology in the food production, but they concerned about long-term exposure to nanofoods.

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1.1 Introduction to Nanotechnology

1.1.1 Definition of Nanotechnology

The national Nanotechnology Initiative (NNI) defines nanotechnology as "the understanding and control of matter at the nanoscale, at dimensions between approximately 1 and 100 nanometers, where unique phenomena enable novel applications". One nanometer is a billionth of a meter. Some everyday examples of items measured in the nanoscale range are, a sheet of newspaper which is about 100,000 nanometers thick and a human hair which is approximately 80,000 nanometers wide. Nanotechnology can be applied across a wide range of scientific fields, such as chemistry, biology, physics, materials science, and engineering that involving imaging, measuring, modeling, and manipulating matter at an extremely small scale (National Nanotechnology Initiative, 2011a).

1.1.2 Market Potential of Nanotechnology

Nanotechnology has been described as the new industrial revolution, and it has been increasingly applied in food production, food processing, and food packaging (Helmut Kaiser Consultancy, 2004; Joseph & Morrison, 2006; Kuzma & VerHage, 2006; Sanguansri & Augustin, 2006).

According to the Project on Emerging Nanotechnologies (PEN), a project of the Woodrow Wilson International Center for Scholars and the Pew Charitable Trusts, over 1,300 nanotechnology products of all types have entered the commercial marketplace all over the world, representing an increase of approximately 600% since 2006 (The Project on Emerging Nanotechnologies, 2011). If the current trend continues, the

number of products is expected to reach 3,400 by 2020. Food nanotechnology products are one of the biggest nanotechnology product categories. The inventory of food nanotechnology products has also increased by approximately 500% from 2006 to 2011 (The Project on Emerging Nanotechnologies, 2011). The nanotechnology food market is expected to surge from 2.6 billion USD in 2004 to 20.4 billion USD in 2010 (Helmut Kaiser Consultancy, 2004). An estimate by the Business Communications Company shows that the total market for nanobiotechnology products was $19.3 billion in 2010 and is expected to reach $29.7 billion by 2015. However, the potential market for nanotechnology food products has not been estimated (Business Communications Company, 2011).

A number of companies around the world have realized the market potential of nanotechnology in the food industry (Sanguansri & Augustin, 2006), more than 200 companies around the world were conducting research in food nanotechnologies in 2004; this number is expected to increase to several thousand by 2010. The U.S. is the leader in nanotechnology research followed by Europe and East Asia (Business Communications Company, 2011; Helmut Kaiser Consultancy, 2004; The Project on Emerging Nanotechnologies, 2011).

1.1.3 Applications of Nanotechnology

Nanotechnology brings dramatic changes to food production, processing and packaging (Helmut Kaiser Consultancy, 2004). The word "nanofood" was recently developed. The concept of a nanofood is that "nanotechnology techniques or tools are used during the cultivation, production, processing, or packaging of the food; but not modified or produced food by nanotechnology machines" (Joseph & Morrison, 2006). The application of nanotechnology also includes smart packaging, on demand

preservatives, and interactive foods.

For example, bioanalytical nanotech sensors incorporated into food packaging can serve as detectors of contamination and also monitor food products through the distribution system (ElAmin, 2005; Tarver, 2006). Another application is packaging with self-cleaning surfaces, in which nanoscale coatings of dirt-repellent can protect the food from the invasion by microorganisms and ensure food safety. Nanolaminate is a type of "smart" packaging that is an extremely thin food-grade film. Nanolaminate can keep foods away from outside moisture, lipids, and gases; or it can serve as a carrier of colors, flavors, antioxidants, nutrients, and anti-microbial and improve the texture of foods (Tarver, 2006; Weiss et al., 2006).

Nanoscale particles and materials can also be used to develop custom-made foods and fresher, tastier, healthier, and safer products. Kraft Foods is experimenting with "interactive" foods that allow consumers to modify foods depend on their individual nutritional needs and tastes. For example, nanotechnology could be used to release accurately controlled amounts of the appropriate molecules to customize the smell and taste of the product for a particular consumer; it could also isolate the molecules that could cause certain allergic reaction (John, 2004; Wolfe, 2005).

Nanodispersions and nanocapsules that are made with nanoscale materials are ideal mechanisms for delivery of functional ingredients. These nanodispersions and nanocapsules can encapsulate functional ingredients such as vitamins, anti-microbials, anti-oxidants, flavorings and preservatives and release them in the body at particular sites and at precise times. Two giant food companies Nestle and Unilever are conducting research in this field to seize one part of the nanofood market (Joseph & Morrison, 2006; Tarver, 2006; Wolfe, 2005).

Nanotechnology may revolutionize technology and industry to benefit society

(The White House, 2000). In 2012, The National Nanotechnology Initiative will spend $2.1 billion to improve the understanding of nanoscale phenomena and the capability to create nanoscale devices and systems. This represents an 11.3% increase over the FY 2010 budget (National Nanotechnology Initiative, 2011b; Roco, 2011).

Some nanopackaging and nanofoods are already available in the commercial food market. Miller Brewing Company created a barrier technology using nanocomposite in the plastic beer bottles. Nanoparticles were embedded in plastic to provide a molecule barrier that helps prevent carbon dioxide from escaping from the beverage and prevent oxygen from seeping in. This barrier extends the shelf life of beer up to six months (ETC Group, 2004). However, the success of these products and future products is affected by consumer knowledge and understanding of nanotechnology. In addition, the media plays a critical role in shaping consumer perceptions of these foods (Chaudhry et al., 2008; Dudo et al., 2010).

1.1.4 Media Coverage of Nanotechnology

In addition to increasing public awareness of scientific issues (Ho et al., 2010; McCombs, 2004), the media also influences the formation of perceptions because frequent coverage in the news can make issues more easily accessible in people's minds (Scheufele & Tewksbury, 2007). There were 1971 stories about nanotechnology published in 21 newspapers between 1980 and 2009. Only about 10% of these articles were about food nanotechnology, and the vast majority of them were published between 1999 and 2009. This suggests that media coverage of food nanotechnology has been slow to start (Dudo et al., 2010). Since then, the volume of media coverage of nanotechnology has been growing over time (Arias & Lewenstein, 2004; Friedman & Egolf, 2005; Laing, 2005; Weaver et al., 2009).

Initially, news reports on nanotechnology, carried a positive tone, focusing on progress and potential economic benefits, with little discussion of the risks (Arias & Lewenstein, 2004; Brossard et al., 2009; Gaskell et al., 2005; Laing, 2005; Lewenstein et al., 2005; Stephens, 2005; Wilkinson et al., 2007). This emphasis on benefits can increase the public's positive perceptions of new technologies (Durant et al., 1998). These themes shifted over time; recent content analyses have documented increased coverage of "regulations" and "health and risks", which was rarely mentioned in the past (Dudo et al., 2010; Friedman & Egolf, 2005; Weaver et al., 2009; Wilkinson et al., 2007). As well, reports concerning government regulation of nanotechnology are becoming more numerous in the news media over time (Friedman & Egolf, 2005).

Media coverage of nanotechnology has also been studied in several European countries, and in Canada. Media coverage of nanotechnology in the United Kingdom contains a mix of themes of both benefits and potential risks (Anderson et al., 2005; Friedman & Egolf, 2005; Laing, 2005; Stephens, 2005; Wilkinson et al., 2007). Media coverage of nanotechnology in the U.S. tends to be more positive than negative in general (Friedman & Egolf, 2005; Gaskell et al., 2005; Stephens, 2005) and the same is true in the Netherlands and Denmark (Kjærgaard, 2008; Kulve, 2006).

1.1.5 FDA Regulatory Guidance of Nanotechnology

Recently FDA has distributed a draft guidance document to help industry and others consider the issues that are involved with the application of nanotechnology in FDA-regulated products, such as regulatory status, safety, or public health impact (FDA guidance, 2011). Whether an FDA-regulated product contains nanomaterials or involves the application of nanotechnology, it should meet one of the following criteria: (1) the size of an engineered material or end product must be in the nanoscale range

(approximated 1 nm to 100 nm); or (2) "an engineered material or end product exhibits properties or phenomena, that are attributable to its dimension(s), even if these dimensions fall outside the nanoscale range, up to one micrometer" (FDA guidance, 2011). This document is only guidance that is distributed for public comment purposes only. Currently, FDA is using existing review processes to regulate products that contain or involve nanotechnology on a case-by-case basis. It is believed that FDA may distribute another guidance document for concerning specific products or classes of products in the future (FDA guidance, 2011). It is expected that FDA regulations for food nanotechnology will be introduced in the near future; that will help increase public trust and therefore increase their acceptance of food nanotechnology.

1.1.6 Public Knowledge and Attitudes towards Nanotechnology

Despite the wide mass media coverage of nanotechnology, studies suggest that the general public currently knows little about it, and even lacks familiarity with the term nanotechnology (Cobb & Macoubrie, 2004; Gaskell et al., 2005; Lee et al., 2005; Scheufele & Lewenstein, 2005; Smith et al., 2008; Waldron et al., 2006; Wolfson, 2003). National surveys from 2004 to 2009 showed that only 17% - 40% of the respondents indicated that they had heard about nanotechnology (Cobb & Macoubrie, 2004; Macoubrie, 2005; Pew Project on Emerging Nanotechnologies, 2007, 2009; Satterfield et al., 2009); Scheufele and colleagues showed that in two U.S. surveys in 2004 (Scheufele & Lewenstein, 2005) and 2007 (Scheufele et al., 2007) nanotechnology knowledge increased for highly educated respondents and decreased for the least educated respondents. These data suggest that public awareness of nanotechnology is very low and has not increased over the years.

There is also low awareness of nanotechnology in other countries. Surveys about

public attitudes toward nanotechnology in Europe showed that the public was less accepting of this technology than people in United States. In many European studies, more than half of the respondents didn't know enough to answer a question about "whether nanotechnology would improve people's life in the next 20 years", "whether it would had no effect", or "whether it would make things worse" (Gaskell et al., 2005; Scheufele et al., 2009). Overall, the knowledge of nanotechnology is low around the world.

In general, the public currently has a positive or neutral perception of nanotechnology, with perceived benefits outweighing potential risks (Brossard et al., 2009; Cobb & Macoubrie, 2004; Cook & Fairweather, 2007; Gaskell et al., 2005; Gaskell et al., 2004; Ho et al., 2010; Kahan et al., 2009; Scheufele & Lewenstein, 2005; Smith et al., 2008). On the other hand, a handful of recent studies by Siegrist and colleagues (Siegrist, 2008; Siegrist et al., 2007; Siegrist et al., 2008) have pointed out other factors that may influence public acceptance of food nanotechnologies. These factors are trust in government and the food industry (Gaskell et al., 2005; Ho et al., 2010; Siegrist, 2008; Siegrist et al., 2007; Siegrist et al., 2008; Vandermoere et al., 2010), and perceived naturalness in the food nanotechnology products (Siegrist, 2008; Siegrist et al., 2008; Siegrist et al, 2009). These factors have, also been identified by other researcher (Macoubrie, 2006). Higher levels of trust and higher levels of naturalness in nanotechnology food products may lead to more acceptances of food nanotechnologies.

1.1.7 Public Attitudes towards Other Technologies

The failure of wide-acceptance of other biotechnologies such as genetically modified foods and food irradiation is a good lesson for scientists and government to

understand consumers' acceptance of nanotechnology. Consumers' inability to separate the concept of irradiation and radiation, led them to believe that irradiated foods were contaminated by radiation, which resulted in negative attitudes towards irradiated foods (Resurreccion et al., 1995). Limited knowledge about genetically modified (GM) foods (Bauer & Gaskell, 2002; Knight, 2009; Koivisto et al., 2003; Teisl et al., 2009; Todt et al., 2008) led to low acceptance of GM foods even when consumers clearly perceived the benefits (Cox et al., 2004; Knight, 2009).

As stated earlier, media coverage, knowledge about technologies/science and trust in governments may play an important role in shaping public perceptions and acceptance of new technologies. Consumers in the USA are more accepting of genetically modified foods than consumers in European countries because of the more positive influence of the press, and greater trust in government's regulations (Gaskell et al., 1999; Hallman et al., 2002; Marks et al., 2002; Traill et al., 2004). The intense media coverage of the technological controversies surrounding GM foods in Europe has contributed to European's negative acceptance of GM foods.

Even though Americans are generally more accepting of GM foods than Europeans, American consumers have low knowledge about agricultural biotechnology. Their acceptability of GM foods is split; around 50% of American support plant-based GM foods, 25% support animal-based GM foods (Hallman et al., 2002; Hallman et al., 2003; Hallman et al., 2004). Scientific knowledge has been shown to have a direct positive relationship with public perception of new technology (Brossard et al., 2009; Ho et al., 2008; Sturgis & Allum, 2004). Some studies (Moerbeek & Casimir, 2005; Moon & Balasubramanian, 2001, 2004; Vilella-Vila et al., 2005) have revealed that increasing knowledge of GM technology contributes to an increasing acceptance of GM applications. However, other studies reported that there

was no relationship between scientific knowledge and public acceptance of new technologies (Allum et al., 2008; Priest, 2001). Nevertheless, the current studies still suggest that increased awareness and knowledge of nanotechnology is directly or indirectly related to more positive perceptions of nanotechnology (Brossard et al., 2009; Lee et al., 2005; Satterfield et al., 2009).

Neither Americans nor Europeans were unwilling to purchase a food product with a label indicating that it has a GM ingredient (Hallman et al., 2002; Huffman et al., 2004; Lähteenmäki et al., 2002; O'Fallon et al., 2007). The issue of mandatory labeling of all products that contain GM ingredients is controversial. Opponents of GM foods argued that it was the consumer's right to know which products contain GM ingredients in order to make a purchase decision (Goldman, 2000). However, proponent of GM foods disagreed with that and argued that labeling was irrelevant if the food was safe to be sold to consumers. Moreover, labeling only may cause unnecessary fear among consumers, resulting lower market acceptance and lower profit for industries (Caswell, 1998). Currently, the USA doesn't require labeling of GM products, but countries like Japan, European countries, Australia, New Zealand, and Brazil require labeling of products containing 1-5% of GM components (Huffman, 2003). Some studies have shown that label decreased consumers' intentions to purchase GM foods (Lähteenmäki et al., 2002; O'Fallon et al., 2007). According to this view, mandatory labeling would cause lower acceptance of GM foods in these countries, especially European countries which are known to be critical opponents of GM foods. This is because consumers thought it was necessary to include a label on GM products to make a right purchase decision (O'Fallon et al., 2007). Americans' attitude towards labeling of GM food is unclear (Hallman et al., 2003).

Another important factor contributing to low acceptance of GM food is

naturalness. Less natural GM foods were less accepted (Chun, 2009; Tenbült et al., 2005; Tenbült et al., 2008). Also processed genetically modified products were less accepted than non-processed genetically modified foods (Tenbült et al., 2005), because non-processed GM foods were considered more natural (Tenbült et al., 2008). Consumers consider the production of GM foods which involves modifying genes, tampering with nature. However, it is believed that few consumers will have the same feeling with nanotechnology (Chun, 2009).

Consumers show greater support for the application of biotechnology to plant products than that to meat and animal products (Hallman et al., 2002; Hossain et al., 2002; Macnaghten et al., 2005). For example, consumers are more accepting of genetically modified plants compared to genetically modified animals (Hallman et al., 2002). These findings may help direct the future application of nanotechnologies in food products. A recent study showed that nanotechnology packaging was more acceptable and was perceived as being more beneficial than nanotechnology foods (Siegrist et al., 2007; Siegrist et al., 2008). These findings indicate that acceptance or rejection of food nanotechnology may depend on the specific use of the technology.

1.1.8 Current Research on Public Attitudes of Nanotechnology

Whether nanotechnology foods will be successful in the marketplace depends on the ability to create nanotechnology products, as well as consumes' perceptions and acceptance of them. Thus, understanding consumers' perceptions and acceptance of nanotechnology foods, prior to their introduction, may yield important strategies for educating the public on the benefits of these products.

Public perceptions of nanotechnology should be well studied at an early stage of technology development (Renn & Roco, 2006; Roco, 2003) to avoid public skepticism

and hostility that accompanied the introduction of other modern biotechnologies (Kjølberg & Wickson, 2007). The literature strongly suggests that scientists, government regulators and the food industry should learn the lessons from the launch of other biotechnologies and avoid the same mistakes (Balbus et al., 2006; Macoubrie, 2006; Renn & Roco, 2006; Schummer, 2004; Wolfson, 2003). However, most of the research that examined public perceptions of nanotechnology has done so in the abstract (Brossard et al., 2009; Cobb & Macoubrie, 2004; Gaskell et al., 2004; Lee et al., 2005; Siegrist et al., 2007; Vandermoere et al., 2010). That is, they asked respondents general questions about their attitudes towards nanotechnology foods. Only a few studies have measured attitudes towards specific food products that were assumed to be processed using nanotechnology (Cook & Fairweather, 2007; Siegrist et al., 2007). Cook & Fairweather (Cook & Fairweather, 2007) found that New Zealanders had positive attitudes and intentions to purchase low fat lamb or beef that was processed using nanotechnology; they also showed that nanotechnology foods were more acceptable than genetically modified foods. However, Siegrist and his colleagues (Siegrist et al., 2007) showed that Swiss consumers were hesitant to buy nanotechnology food or food with nanotechnology packaging, but that nanotechnology packaging was more acceptable to them than nanotechnology food. It is important to note that, all available studies have used surveys (telephone, internet, mail, and laboratory questionnaires) to collect consumers' attitudes towards food nanotechnology instead of direct assessment of products in a sensory study. Thus, some scholars suggest that a taste tests measuring consumers' reactions to realistic nanotechnology food and their willingness to purchase these products is necessary (Siegrist et al., 2007). The present study was designed to address this question.

Information provided to consumers is an additional factor that may affect

consumers' attitudes towards different food technologies (Teisl et al., 2009). Information can include knowledge about food technologies, labeling or benefits claims. Nutritional labeling of a food product can influence sensory perceptions and liking of the product in a taste test. A study conducted by Tourila and colleagues (Tuorila et al., 1994) employed a deception to measure consumers' expectations and liking of fat-free and regular-fat foods. They asked participants to taste the same free-fat and regular-fat products three times: without information, with correct information and with incorrect information. Their results showed that both hedonic expectations and information about the products determined actual liking and therefore probably affect consumers' food preference. Another study conducted by Bower and colleagues (Bower et al., 2003) found similar results. When participants were given descriptions (identity, price and nutritional benefit) of the products prior to tasting them, liking ratings and intention to buy the products were higher than when no information was given. They also found that health benefit label increased purchase intention for the same product.

1.1.9 Preliminary Studies

The current study was conducted as part of a project entitled, "Food nanotechnology: understanding the parameters of consumer acceptance" under the direction of Dr. Hallman from the Food Policy Institute of Rutgers University. The results of two previous studies from this project served as preliminary data and helped to inform the design of the current study.

A focus group study (preliminary study 1 of this project) was conducted in 31 consumers who came to the Rutgers University campus to participate in the study. Results showed that 52% of the participants knew little about nanotechnology. Results

also indicated that participants' willingness to taste and buy the foods appeared to be influenced more by the perceived benefits of the products than the approval or disapproval evaluation of nanotechnology, in general. But, many participants were concerned about the long term effects of consuming nanotechnology foods even though they perceived valuable benefits. The top three nanotech foods that participants were willing to buy were chicken and meat, ice cream, and potato chips.

A national survey conducted on the internet (preliminary study 2 of this project) collected information from 1210 consumers. Results showed that participants had a low level of knowledge about nanotechnology, with an average score of 3 out of 10 points on a knowledge questionnaire. They gave low ratings of nanotechnology foods, and had negative attitudes towards nanotechnology foods. Participants indicated their ranking for nanotechnology delivery mechanism from most acceptable to least acceptable as: in the packaging > as coating > grown into > as an ingredient in food. The top 3 out of 12 acceptable food types were: a food you eat to improve your health, a processed food, and a snack food. And the ranking for nanotechnology benefits from most acceptable to least acceptable was: freshness > health > food safety > environmental > taste.

Based on the data collected in the two preliminary studies, the third study sensory evaluation of nanotechnology products was conducted in the sensory lab in Rutgers University. To date, no studies have investigated consumer attitudes and reactions to tasting foods which are described as having nanotechnology benefits. Thus, the objective of this study was to conduct a consumer taste test in which participants tasted and rated several food products, some of which were described as containing edible nanoparticles that provide specific benefits. Based on the results of the two preliminary studies, we tested two food types, a natural product (tomatoes) and a processed one (ice

cream). We also tested different delivery methods: nanotechnology in the packaging or in the food matrix as well as different types of benefits (health, safety and freshness). The study used deception since the participants were told they would be tasting nanotechnology foods, but none of foods were actually produced with nanotechnology.

1.2 Objectives and Hypotheses

The objectives of this study are:

(1) to assess consumer knowledge and attitudes towards food nanotechnology;

(2) to measure their liking of tasted foods with specific nanotechnology benefits;

(3) to determine their willingness to buy these foods.

Based on the objectives of this study, we hypothesize that participants who have positive attitudes towards food nanotechnology will give high liking ratings for nanotechnology products and are willing to buy these products; those who have negative attitudes towards food nanotechnology will give low liking ratings for nanotechnology products and are not willing to buy these products.

We also hypothesize that participants will give lower liking ratings for products with nanotechnology in the food than those with nanotechnology in the packaging, based on Siegrist's study showing that consumers are more accepting of nanotechnology packaging than nanotechnology foods (Focus Group Study, 2010; National Internet Survey, 2010; Siegrist et al., 2007).

Finally, we expect that participants will give lower liking ratings for products with health/safety benefits than those with freshness benefit. This hypothesis is based on the data of National Internet Survey showing that the ranking of nanotechnology benefits by consumers from most acceptable to least acceptable is: freshness; health; safety; environmental; and taste.

2. METHODS

2.1 Subjects

Healthy adults who liked fresh tomatoes and ice cream participated in this study. They were recruited via emails and flyers from Rutgers University and local communities around Rutgers University. Participants gave written informed consent for their participation. The Rutgers University Institutional Review Board for the protection human subject in research approved the protocol. Exclusion criteria included severe food allergies, pregnancy, major medical conditions, or age under 18 years. Each subject received compensation at the end of the study.

2.2 Food Tasting

2.2.1 Food Selection

As described in the Background Section, the food products selected for study were based on preliminary data from the focus group study and national internet survey. Two types of food were selected, one was a natural food, and the other was a processed food. Cherry tomatoes represented a natural food while chocolate ice cream represented a processed food. Cherry tomatoes were selected because they have more consistent size, color and taste than regular red round tomatoes, reducing sample variability. Also, both cherry tomatoes and chocolate ice cream are highly preferred by consumers, and both foods could plausibly be produced with nanotechnology in the future. A final consideration was that different kinds of benefits such as health, freshness, and safety benefits could be placed either in the food or the package for these foods.

2.2.2 Food Preparation

Both foods were bought from local grocery stores (Shoprite Supermarket which

was located in New Jersey), and contained no nanotechnology materials. Cherry tomatoes in same brand were bought the day before every taste session to ensure freshness and consistent product. Chocolate ice cream (Breyers®; Green Bay, WI) was bought one time before the study began and kept I n freezer.

Tomatoes were washed and two whole tomatoes were served in a 2 oz. soufflécup. Ice cream was scooped by hand into a 2 oz. soufflécup with a lid, and then stored in a freezer at -18 ^{o}C, and they were taken out of the freezer to room temperature when the participants were going to taste them. All samples were prepared by the author of this paper on the day before each session. The samples of each food were presented one-at-a-time. Each sample was labeled with a same random three-digital-number and the presentation order for each subject was exactly the same.

2.2.3 Experimental Design

The study used a deception. All samples of tomatoes were exactly the same and all ice cream samples were exactly the same, and none of the products contained nanoscale ingredients. However, the subjects were given written information about each sample. Within each food type, a repeated measures design was employed. The subjects were told that the first sample of each food had no nanotechnology, and the subsequent two samples had nanotechnology particles either in the packaging for the tomato or in the food matrix for the ice cream to provide specific benefits. The features and benefits were determined based on the results of the two preliminary studies. For tomato samples, the scenarios were the following: the first sample was produced WITHOUT the use of nanoscale materials; the second sample was wrapped in a package containing anti-microbial nanoparticles that kill harmful microorganisms; and the third sample was wrapped in a package containing nanoparticles that kept tomatoes fresher, longer.

For ice cream samples, the scenarios were the following: the first sample was made WITHOUT the use of nanoscale materials; the second sample contained health promoting nanoparticles that release live cultures (probiotics) into the digestive system; and the third sample contained nanoparticles that preserve freshness and prevent ice crystals from forming. The subjects were also told that the nanoparticles are made from food-grade ingredients that are approved for human consumption (see Table 1). The three tomato samples were served first and then the ice cream samples were served. Thus, the presentation order was kept constant for each subject, which was control tomato, tomato with anti-microbial benefit, tomato with freshness benefit, control ice cream, ice cream with health benefit, and ice cream with freshness benefit.

Table 1: Experimental Design

Type of Food	Control Sample	Health Benefit	Freshness Benefit	Delivery Mechanism
Cherry tomatoes	No nanotechnology	Anti-microbial	Stays fresh longer	In the package
Chocolate ice cream	No nanotechnology	Provides probiotics	Preserves freshness and prevents icing	In the food

2.2.4 Food Ratings

Since all the subjects could not be tested at one time, tastings were conducted on multiple days at the Sensory Evaluation Lab at Rutgers University. Data were collected using FIZZ software (Biosystemes, Couternon, France). Subjects participated in only one session. Subjects came to the sensory lab and sat in an individual booth equipped with a computer. They were given a written description of the purpose of the study including a definition of nanotechnology and instructions for completing the ballot

before they tasted the foods (see Appendix B). Subjects tasted and rated each food for liking of key sensory attributes using 15-cm line scales anchored with "dislike extremely" (scoring 0) at the left end and "like extremely" (scoring 15) at the right end. For tomatoes, the sensory attributes were color, firmness, juiciness, sweetness, tartness, overall flavor and overall liking; for ice cream, the sensory attributes were color, sweetness, creaminess, chocolate flavor, overall flavor and overall liking.

Check boxes were placed after the last scale of each nanotech sample for the subjects to indicate their willingness to buy (yes/no) the nanotech product, reasons for buying and their intention to buy the nanotech product based on price. The response categories for buying or not buying were sensory appeal, nanotech benefit (specific for each sample) and nanotech in the packaging (for tomato samples) or in the food (for ice cream samples). The intention to buy the product based on price was collected using a 5 point category scale ("definitely would not buy", "probably would not buy", "maybe/maybe not", "probably would buy", and "definitely would buy").

2.3 Survey

When the subjects finished the taste test, they completed a seven-page survey (see Appendices C, D, E, F, and G) to indicate their knowledge and attitudes about nanotechnology, general food attitudes, and to provide their personal information. The survey included four questionnaires: knowledge about nanotechnology scale, food choice questionnaire, food technology neophobia scale and food nanotechnology attitudes scale. The questionnaires are described in detail in the following sections. The survey also collected personal information including age range, gender, ethnicity, education, occupation, and internet access, hours spent on internet and household income. Data were collected using FIZZ forms (Biosystemes, Couternon, France).

2.3.1 Knowledge about Nanotechnology Scale

Subjects completed the Knowledge about Nanotechnology Scale developed by Lee et al. (Lee et al., 2005). The scale is composed of 5 knowledge items which we supplemented with 15 other knowledge statements that were developed by the coordinator of this project. Only the 5 statements from the published questionnaire were analyzed to measure the consumers' basic and specific knowledge of nanotechnology. The 5 statement were:

1) Nanotechnology involves materials that are not visible to the naked eye.
2) U.S. corporations are NOT using nanotechnology to make food products sold today.
3) A nanometer is a billionth of a meter.
4) Nanotechnology allows scientists to arrange molecules in ways that do NOT occur in nature.
5) A nanometer is about the same size as an atom.

Subjects provided their responses to these 5 statements by checking only one box for each statement using a 5-point scale ("definitely false", "likely false", "likely true", "definitely true", or "I don't know"). Each statement has a correct answer. For statements 2 and 5, correct answers were "definitely false" or "likely false"; for statements 1, 3 and 4, correct answers were "definitely true" or "likely true". Correct responses to each statement were calculated.

2.3.2 Food Choice Questionnaire

Subjects completed the Food Choice Questionnaire (FCQ) developed by Steptoe et al. (Steptoe et al., 1995). We used the modified FCQ in which 33 items were classified into eight factors by factor analysis (Steptoe et al., 1995). The eight factors

were: health; mood; convenience; sensory appeal; natural content; weight control; familiarity; and ethical concern. The 33 statements were randomly ordered in the questionnaire. Each question in the questionnaire started with the statement, "It is important to me that the food I eat on a typical day…..". Subjects indicated their feeling about each question by checking the corresponding box ("not at all important", "a little important", "moderate important" or "very important"). One point was given for the response of "not at all important", and 4 points were given for the response of "very important". Scores on items contributing to each factor were averaged so that factor scores were between 1 and 4.

2.3.3 Food Technology Neophobia Scale

Subjects completed the Food Technology Neophobia Scale (FTNS) that was developed by Cox and Evan (Cox & Evans, 2008). The FTNS consists of 13 items which were classified into four factors by factor analysis (Cox & Evans, 2008). The four factors were: new food technologies are unnecessary; perception of risks; healthy choice; and information/ media. Subjects used a 7-point scale anchored with "strongly disagree" (score=1) to "strongly agree" (score= 7). The range of possible scores on this questionnaire is 13-91. Some of the questions (Questions 10-13) were scored in the reverse order since agreement with these statements indicated less neophobia.

2.3.4 Food Nanotechnology Attitudes Scale

Subjects completed the Food Nanotechnology Attitudes Scale to indicate their attitudes towards applications, and benefits/risks of food nanotechnology. The scale consists of 8 items, and was developed by Cook and Fairweather (Cook & Fairweather, 2006). Subjects indicated their agreement with each statement using a 5-point scale

which was anchored with “disagree” at one extreme, “neutral” at the middle point and “agree” at the other extreme. Disagreement with the statement was scored 1 or 2 on a 5-point scale, while agreement with the statement was scored 4 or 5 on a 5-point scale. Neutral responses were scored 3.

2.3.5 Demographics

After the subjects completed the questionnaires, personal information was collected, such as age, gender, occupation, education, ethnicity, internet access at home, personal hours spent in the internet, and household income.

3. DATA ANALYSIS

Analysis of variance (ANOVA) was used to assess differences in the attribute ratings among samples of each food type, and between nanotech samples of each food type. Post-hoc comparisons were made using the Duncan's test. Check-box responses for willingness to buy and reasons for buying or not buying nanotech products were analyzed using Chi-square analysis.

Each questionnaire was tabulated separately in excel. Then, a linear regression analysis was used to link the results of each questionnaire to the taste ratings results.

Two-way analysis of variance was used to determine how age, gender, education and ethnicity influence the relationships among samples of each food type. All analyses were conducted using SAS version 9.2 and the statistical cutoff criterion was $p \leq 0.05$ for all tests.

4. RESULTS

4.1 Subjects

One hundred and sixty-one subjects completed the study. In total, 117 females and 44 males participated. Fifty nine percent of the subjects were between 18 to 25 years old; 62% were students, 27% were faculty or staff from Rutgers University and 11% were adults from local communities around Rutgers University. Fifty two percent of the participants were white, 32% East Asian, and 16% described themselves as Hispanic, Black, or other. Fifty two percent of the participants had bachelors or higher degrees, 35% had some college education and 13% had high school education (see Figure 1). Ninety eight percent of the participants had internet access at home, and 26% spent more than 5 hours of personal time every day on the internet. Therefore, the panel in this study was mainly high educated young adults, particularly students.

4.2 Food Tasting

4.2.1 Liking Ratings for All Samples

Table 2 shows the mean scores and standard error of the mean for all attributes of each sample. All three tomato samples were equally liked for all attributes (see 2a in Figure 2). All three ice cream samples were equally liked for all attributes (see 2b in Figure 2) except for the creaminess of the control sample that was less liked than the nanotech samples ($p<0.0001$). This may have been due to variation in the temperature of the samples. The three ice cream samples were taken from the freezer at the same time, but the control sample was always tasted first, followed by the nanotech samples. The nanotech samples might have been perceived as more creamy because they were less cold than the control samples. Since, there were no differences in overall flavor and overall liking ratings among the three samples, the difference in creaminess liking were

considered to be inconsequential for the interpretation of the study. Based on the liking data, we concluded that the panel in this study had positive attitudes towards food nanotechnology products regardless of whether the nanotechnology was applied in the food packaging or in the food matrix; or if nanotechnology was used in the natural food or processed food.

There were no significant differences in liking ratings between the control sample and the nanotech samples or between the nanotech samples by age group, gender, education or ethnicity.

Table 2: Liking Ratings for Key Sensory Attributes of Samples by the Whole Panel

Liking Ratings for Tomato Samples (n=161)

Samples	Color	Firmness	Juiciness	Sweetness	Tart-ness	Overall flavor	Overall liking
Control	12.3±0.2	11.2±0.3	11.5±0.2	9.4±0.3	9.1±0.3	10.5±0.3	10.7±0.3
Anti-microbial	12.2±0.2	10.8±0.3	11.0±0.2	9.5±0.3	9.4±0.3	10.0±0.3	10.1±0.3
Keep fresher	12.1±0.2	10.9±0.3	11.1±0.3	9.8±0.3	9.4±0.3	10.2±0.3	10.1±0.3

Liking Ratings for Ice Cream Samples (n=161)

Samples	Color	Sweetness	Creaminess	Chocolate flavor	Overall flavor	Overall liking
Control	11.4±0.2	11.5±0.3	10.0±0.3^{+}	11.3±0.3	11.2±0.2	11.2±0.2
Provide probiotics	11.6±0.2	11.5±0.2	11.4±0.2	11.5±0.2	11.7±0.2	11.8±0.2
Prevent icing	12.0±0.2	11.4±0.2	11.6±0.2	11.6±0.2	11.6±0.2	11.5±0.3

Values are Means ± SEM. $^{+}$ indicate significance difference in creaminess between the control ice cream sample and nanotech ice cream samples ($p<0.0001$).

4.2.2 Willingness to Buy Nanotech Products

4.2.2.1 Buyers and Non-buyers of Nanotech Products

The subjects were then divided into two groups based on their willingness to buy each nanotech product. Subjects who were willing to buy the nanotech products are considered "buyers", and those who were not willing to buy the nanotech products are considered "non-buyers". Table 3 summarizes the percentage of buyers and non-buyers for each nanotech product. The majority of the participants (74.5% - 85.7%) were willing to buy the nanotech products. Only a few participants (14.3% - 25.5%) were not willing to buy the nanotech products. These data also support the conclusion that the majority of the panel in this study had positive attitudes towards food nanotechnology products, and that they were willing to buy them if the products were available in the food market.

Table 3: Percentages of Subjects Who were Willing or Not Willing to Buy Nanotech Tomatoes and Ice Cream with Specific Benefits

	YES	NO
Tomato: Anti-microbial	**82.0%**	**18.0%**
Tomato: Freshness	**74.5%**	**25.5%**
Ice cream: Provide Probiotics	**85.7%**	**14.3%**
Ice cream: Prevent Icing	**79.5%**	**20.5%**

4.2.2.2 Overall Liking of Nanotech Products Based on Willingness to Buy Them

In general, buyers of the nanotech products gave high liking ratings for all attributes of the nanotech products that were similar to the ratings for the control

samples. In contrast, non-buyers of nanotech products gave lower liking ratings to all attributes of the nanotech samples relative to the control samples. These data are shown in their entirety in the Figures (see Figure 3). Since overall liking is the main attribute representing consumers' global acceptance of a food product, the analyses presented here will focus on this measure.

Subjects who were willing to buy the tomato sample with anti-microbial benefit gave high overall liking ratings for both the control tomato and the tomato with anti-microbial benefit, while those who were NOT willing to buy gave significant lower overall liking rating for the tomato with anti-microbial benefit than that for the control tomato, $p < 0.05$ (see 3a in Figure 3). For the tomato with freshness benefit, buyers gave high overall liking ratings for both the control tomato and the tomato with freshness benefit; in contrast, non-buyers gave significant lower overall liking rating for the tomato with freshness benefit than that for the control tomato, $p < 0.05$ (see 3a in Figure 3). Non-buyers gave high overall liking rating for the control tomato, but low overall liking rating for the nanotech tomatoes, which indicated that they had negative attitudes towards nanotechnology and were not willing to buy nanotechnology products.

Subjects who were willing to buy the ice cream with health benefit gave high overall liking ratings for both the control ice cream and the nanotech products, while non-buyers gave significant lower overall liking rating for the nanotech ice cream product than that for the control ice cream, $p < 0.05$ (see 3b in Figure 3). The same pattern of response was observed for the ice cream with freshness benefit.

These data suggested that the majority of participants were willing to buy the nanotech products and liked them equally well as the control products. Those less willing to buy the nanotech products liked the nanotech samples less than the control

samples even though all the tomato samples were identical and all of the ice cream samples were identical. Thus, for these subjects, the knowledge that some of the samples had nanotechnology in them shifted their sensory acceptability of these products.

4.2.2.3 Reasons for Buying/ Not Buying Nanotech Products

Chi-square analysis showed that there were significant differences between buyers and non-buyers in their reasons for buying/not buying the four nanotech products presented in this study (χ^2= 10.04 – 27.33; $p < 0.01$). For those who were willing to buy nanotech products, their primary reason was split, between "sensory appeal" and "nanotechnology benefit". This was true regardless of whether the nanotech benefit was in the package (for tomatoes) or in the food (for ice cream). For those who were not willing to buy the nanotech products, "sensory appeal" was the predominant reason for not buying any nanotech product (see Figure 4). Since the non-buyers gave lower liking ratings to all four nanotech samples relative to control samples, it is assumed that *low* sensory appeal was the basis of their decision to not buy these products.

Finally, it is also clear from these results that placing nanotechnology in the food (ice cream) versus in the packaging (tomatoes) led to the same responses. These data suggest that participants did not routinely reject the idea of consuming and buying foods with nanotechnology in the food product.

4.2.2.4 Intention to Buy Nanotech Products Based on Price

Figure 5 shows that the majority of the participants in this study were willing to buy the nanotech tomatoes or nanotech ice cream if the price was comparable to what they usually paid for these products.

4.2.3 Survey Results

4.2.3.1 Knowledge about Nanotechnology Scale

The percentage of subjects who correctly answered each question was calculated and the data are shown in Figure 6. The results showed that participants had a high level knowledge (>70-90%) for questions related to a basic understanding of nanotechnology. For these two questions, the answers differed significantly from 50%, z value is -10.64 and $p < 0.0001$ for question "Nanomaterials not visible", and z value is -4.4922 and $p < 0.0001$ for question "Nano allows modifications that do not occur in nature". However, only 50% of respondents correctly answered the questions related to the economic implications of nanotechnology and specific knowledge about nanotechnology such as the definition of a nanometer and the size of nanoparticles. For these questions, the answers did not differ significantly from 50%. The participants had positive attitudes towards nanotechnology and were willing to buy food nanotechnology products even though they had a low knowledge level about nanotechnology.

A linear regression analysis was used to determine the relationship between the participants' knowledge about nanotechnology and their acceptance of nanotechnology and willingness to buy foods with this technology. No significant associations were found in the regression model.

4.2.3.2 Food Choice Questionnaire

All of the revised FCQ items were scored from one to seven, and for each factor, a score based on the average of all items that contributed to that factor was calculated. The mean values of the eight factors were calculated (see Table 4). The top three important factors for the participants' food choices were sensory appeal, health and

convenience. As for most consumers, participants in this study considered sensory appeal, health and convenience of food very important for them when they are choosing food to eat (Chen, 2009; Pollard et al., 1998).

A linear regression analysis was used to determine the relationships between the participants' general food choice and their attitudes towards food nanotechnology. The regression model showed no significant associations between the food choice motives and liking ratings of or willingness to buy nanotechnology products.

Table 4: Mean Values, Standard Deviation and Standard Error for Each Factor in the Food Choice Questionnaire

It is important to me that the food I eat on a typical day:	Mean	Standard deviation	Standard error
Factor 1 -- Health	**3.17**	**0.57**	**0.05**
20. Contains a lot of vitamins and minerals			
27. Keeps me healthy			
9. Is nutritious			
25. Is high in protein			
28. Is good for my skin/teeth/hair/nails etc.			
8. Is high in fiber and roughage			
Factor 2 -- Mood	2.41	0.75	0.06
14. Helps me cope with stress			
32. Helps me to cope with life			
24. Helps me relax			
22. Keeps me awake/alert			
11. Cheers me up			
29. Makes me feel good			
Factor 3 -- Convenience	**3.03**	**0.65**	**0.05**
1. Is easy to prepare			
13. Can be cooked very simply			
26. Takes no time to prepare			
33. Can be bought in shops close to where I live or work			
10. Is easily available in shops and supermarkets			

Table 4: Mean values, Standard Deviation and Standard Error for Each Factor in the Food Choice Questionnaire (Continued)

It is important to me that the food I eat on a typical day:	Mean	Standard deviation	Standard error
Factor 4 -- Sensory Appeal	**3.25**	**0.52**	**0.04**
12. Smells nice			
23. Looks nice			
16. Has a pleasant texture			
4. Tastes good			
Factor 5 -- Natural Content	2.81	0.83	0.07
2. Contains no additives			
5. Contains natural ingredients			
21. Contains no artificial ingredients			
Factor 6 -- Weight Control	2.72	0.87	0.07
3. Is low in calories			
15. Helps me control my weight			
6. Is low in fat			
Factor 7 -- Familiarity	2.18	0.73	0.06
31. Is what I usually eat			
7. Is familiar			
19. Is like the food I ate when I was a child			
Factor 8 -- Ethical Concern	2.23	0.84	0.07
18. Comes from countries I approve of politically			
30. Has the country of origin clearly marked			
17. Is packaged in an environmentally friendly way			

4.2.3.3 Food Technology Neophobia Scale

Table 5 shows the mean values and standard errors for each question and each factor in the Food Technology Neophobia Scale. A 7-point scale was used to collect the responses to the food technology neophobia statements, and higher scores indicated greater neophobia (score>4). Since the mean value for all the questions was 3.57 which is lower than 4, the participants in this study were not considered neophobic to food

technology. The 13 questions were then divided into four factors, and the mean values for each factor was calculated (see Table 5). Except for the "perception of risks" factor which was neutral, the other three factors such as "new food technologies are unnecessary", "healthy" and "information/media" scored less than 4, which also indicated a low level of neophobia to new food technologies.

The participants in this study had positive attitudes towards food nanotechnology and were willing to buy food with nanotechnology benefit, and they were not food neophobic. A linear regression analysis model was used to determine the relationships between participants' responses to the food technology neophobia scale and their attitudes towards food nanotechnology. However, this scale was not a significant predictor of "willingness to buy" nanotechnology foods.

Table 5: Results for Food Technology Neophobia Scale

Questions	Mean value	Std dev	Std error
Factor 1: New food technologies are unnecessary	**3.38**	**1.26**	**0.10**
Q1. There are plenty of tasty foods around so we don't need to use new food technologies to produce more.	2.43	1.82	0.14
Q2. The benefits of new food technologies are often grossly overstated.	3.62	1.8	0.14
Q3. New food technologies decrease the natural quality of food.	3.79	1.96	0.15
Q4. There is no sense trying out high-tech food products because the ones I eat are already good enough.	2.55	1.62	0.13
Q5. New foods are not healthier than traditional foods.	3.27	1.75	0.14
Q6. New food technologies are something I am uncertain about.	4.61	1.83	0.14

Table 5: Results for Food Technology Neophobia Scale (Continued)

Questions	Mean value	Std dev	Std error
Factor 2: Perception of risks	**4.27**	**1.18**	**0.09**
Q7. Society should not depend heavily on technologies to solve its food problems.	3.43	2.07	0.16
Q8. New food technologies may have long term negative environmental effects.	4.24	1.64	0.13
Q9. It can be risky to switch to new food technologies too quickly.	4.96	1.59	0.13
Q10. New food technologies are unlikely to have long term negative health effects. (R)	4.43	1.38	0.11
Factor 3: Healthy	**3.13**	**1.38**	**0.11**
Q11. New products produced using new food technologies can help people have a balanced diet. (R)	3.08	1.5	0.12
Q12. New food technologies gives people more control over their food choices. (R)	3.19	1.61	0.13
Factor 4: Information/Media	**2.81**	**1.73**	**0.14**
Q13. The media usually provides a balanced and unbiased view of new food technologies. (R)	2.81	1.73	0.14
Total mean	**3.57**	**1.72**	**0.14**

- Agree to the statement is score 7, neither agree nor disagree to the statement is score 4, and disagree to the statement is score 1
- Higher scores indicate greater neophobia
- (R) means reversed scored item, scores for question 10-13 were already reversed here, so if higher scores for these questions, that means greater neophobia

4.2.3.4 Food Nanotechnology Attitudes Scale

Table 6 provides the results for agreement or disagreement with statements

regarding the use of nanotechnology in food production. Three notable findings were observed. Over half of the respondents felt comfortable eating foods with nanotechnology (Question 1) but they had concerns about the long-term exposure to nanotechnology foods (Question 3). The subjects neither agreed nor disagreed with the statement that food produced using nanotechnology would be unnatural (Question 8). These results differ from the findings of another study showing that most respondents agreed it would be unnatural (Cook & Fairweather, 2006).

Table 6: Attitudes towards the Use of Nanotechnology in Food Production

	Questions	N	Mean values	Disagree %	Neither %	Agree %
Q1	**It would feel uncomfortable knowing I was eating nanoparticles.**	**161**	**2.37**	**57.1**	**24.8**	**18.0**
Q2	The use of nanoparticles in food production will benefit the producer more than the consumer.	161	2.94	31.1	46.0	23.0
Q3	**Nobody really knows whether widespread, long term exposure to nanoparticles in food will be harmful.**	**161**	**3.71**	**10.6**	**27.3**	**62.1**
Q4	Nanotechnology will result in savings for food consumers.	161	3.03	20.5	54.7	24.8
Q5	Because of a limited budget many people could not avoid buying cheaper food produced using nanotechnology.	161	3.44	14.9	38.5	46.6
Q6	Nanotechnology will result in convenience foods being more nutritious.	161	3.42	11.8	39.8	48.4

Table 6: Attitudes towards the Use of Nanotechnology in Food Production (Continued)

	Questions	N	Mean values	Disagree %	Neither %	Agree %
Q7	Food produced using nanotechnology will be more acceptable than food produced using genetic modification	161	3.41	11.8	44.1	44.1
Q8	**Food produced using nanotechnology would be unnatural**	**161**	**2.84**	**36.6**	**38.5**	**24.8**

5. DISCUSSION and CONCLUSIONS

5.1 Positive Attitudes towards Food Nanotechnology

In the present research, we examined consumers' attitudes toward nanotechnology foods with different benefits, and their liking responses to taste samples of these foods. The general findings were that all four nanotech foods were highly acceptable to this panel of well-educated consumers, and the majority of subjects were willing to buy these foods. These findings agree with survey research about the public's general perceptions of other nanotechnology applications. Specifically, these surveys show that consumers currently have positive or neutral attitudes towards nanotechnology (Brossard et al., 2009; Cobb & Macoubrie, 2004; Cook & Fairweather, 2007; Gaskell et al., 2005; Gaskell et al., 2004; Ho et al., 2010; Kahan et al., 2009; Scheufele & Lewenstein, 2005; Smith et al., 2008). However, the results from this sensory test were different from the national internet survey (preliminary study 2 of this project), which concluded that the national population's acceptance of nanotechnology in food was extremely low.

Some scholars found that higher educated people were more positive towards new technologies than lower educated people; also, men and younger adults were more positive than women and older adults (Magnusson et al., 2002; Scheufele et al., 2007; Scheufele & Lewenstein, 2005). More than half of the participants in the present study were < 25 years of age, and the majority were well educated Caucasian and female. Due to the narrow demographic of our panel, the present study did not show that participants with a higher level of education were more accepting of food nanotechnology than those with lower level of education. As well, age, gender and ethnicity had no influences on attitudes towards food nanotechnology.

Religious belief is another factor that affects consumers' attitudes towards new

food technologies; highly religious consumers were less accepting of nanotechnology than less religious individuals (Brossard et al., 2009; Ho et al., 2010). However, the present study cannot address this question since it did not measure the effects of religious belief on perceptions of nanotechnology.

5.2 Nanotechnology Packaging and Nanotechnology Foods

Participants in this study gave high liking ratings for all attributes for both nanotechnology tomatoes (where the nanoparticles were added to the packaging) and nanotechnology ice creams, where the nanoparticles were in the food matrix). This result suggested that consumers accepted both nanotechnology packaging and nanotechnology foods. This finding was different from those reported by Siegrist et al. (Siegrist et al., 2007; Siegrist et al., 2008), which found that nanotechnology packaging was perceived to be more beneficial to consumers than nanotechnology foods, although respondents were not willing to buy either type of product (Siegrist et al., 2007). However, in the studies by Siegrist et al. (Siegrist et al., 2007; Siegrist et al., 2008) respondents did not actually taste samples of the foods. Also, in our study, participants read a statement about the benefits of each nanotech product before tasting the sample, whereas Siegrist et al. (Siegrist et al., 2007; Siegrist et al., 2008) provided statements about the benefits as well as the risks of the technology. It is possible that our study showed greater consumer acceptance of nanotech products because information about risks was not provided to our participants.

The national internet survey (preliminary study 2 of this project) came to a similar conclusion as the sensory study showing that information on the benefits of food nanotechnology was related to greater acceptance of this technology. However, our findings conflict with the result of the focus group study (preliminary study 1 of this

project), which suggested that acceptance cannot be driven by benefits alone due to the perceived uncertainty about the long term health effects of consuming nanotechnology foods. We conclude that perceived benefits may have a strong general impact on attitudes towards food nanotechnology, but the acceptance of specific nanotechnology foods depends on both perceived benefits and perceived risks (Siegrist et al., 2007).

5.3 Public Trust and Naturalness

Two other factors have been investigated in connection with consumer perceptions of food nanotechnology. First, public trust in the food industry and public institutions was associated with acceptance of nanotechnology in prior studies (Siegrist et al., 2007; Siegrist et al., 2008). Our study did not measure social trust, but given our findings, a high level of public trust amongst our participants seems highly plausible. Perceived naturalness is a second factor that influences attitudes towards nanotechnology foods (Siegrist et al., 2007). The foods used in the current experiment contained a natural product (tomato) and processed product (ice cream). Results indicated that both the natural product and processed product were equally liked and both were acceptable to the participants. Thus, we did not find that participants had a greater reluctance to accept a fresh tomato with nanotechnology. It should be mentioned, however, that the stated nanotechnology benefits for the tomato samples were in the packaging not in the food matrix, and this might have reduced participants' concerns about this product.

However, some research showed different results, for example the measurement of public acceptance of genetically modified foods, natural products were less acceptable than processed foods when both were genetically modified (Tenbült et al., 2008).

5.4 Purpose of Mild Deception

All the foods that used in this study actually had no nanoparticles at all, they were exactly the same. But participants were told that some of the products contained nanoparticles either in the packaging or in the food to provide specific benefits. The purpose of this deception was to understand consumers' reactions to such products if they were really produced with nanotechnology. If the consumers knew the products were not really produced with nanotechnology prior to tasting, it might influence their reactions to them. The deception was successful because that it shifted the sensory acceptability ratings of these products for at least some of our participants. This is consistent with previous studies showing that information supplied to consumers affects their attitudes about food technologies (Huffman et al., 2004; Lähteenmäki et al., 2002; Teisl et al., 2009; Tuorila et al., 1994).

5.5 Reasons for Willingness to Buy

The majority of the participants in this study were willing to buy nanotechnology products, which indicated that they had positive attitudes towards food nanotechnology and accepted the food nanotechnology products. A subset of participants stated that they were not willing to buy these foods. When the study population was divided into self-described "buyers" and "non-buyers", overall liking ratings for the nanotechnology products were significant lower for non-buyers as compared to buyers. Since overall liking ratings were high for the control products across both groups, this eliminates the possibility that the non-buyers did not like the foods per se. Apparently, the non-buyers thought that the use of nanomaterials changed the taste of the food, so they gave lower liking for the nanotech products than control product even though these products were exact the same. Presumably, those who were not willing to buy the

nanotech products had a negative attitude towards this technology which prompted them to give lower liking rating for these foods. Further information needs to be collected from consumers to understand the relationship between attitudes, purchase intention and liking.

The primary reasons for buying/not buying nanotech products varied according to buyer groups. For buyers of nanotechnology products, the reasons were split, between "sensory appeal" and "nanotechnology benefits". However, the primary reason for non-buyers to reject the nanotechnology products was reduced "sensory appeal". These results suggest that taste is a strong predictor of eating behavior and also influences attitudes toward foods. This finding is in line with most of the past research (Lähteenmäki et al., 2002; Townsend & Campbell, 2004). The present study is a first attempt to examine public reactions toward realistic foods with nanotechnology benefits. The results also suggest that information about the tasted products as well as the sensory taste determine participants' actual liking and therefore their choices of the nanotechnology products.

5.6 GM Foods Studies

Shaping the public's perceptions of new technologies may be important for gaining the public's trust and acceptance of these technologies. However, the results of our study and others (Cook & Fairweather, 2007; Siegrist et al., 2007; Siegrist et al., 2008) suggest that the public's reactions to nanotechnology foods differ in some ways from their reactions to GM foods. In GM foods studies, participants showed low acceptance of GM foods, even though clear benefits to the consumers had been communicated (Cox et al., 2004). This finding differs from our results for nanotechnology foods showing that participants had high acceptance of these foods

while perceiving valuable benefits. Townsend and Campbell (Townsend & Campbell, 2004) found that half of their respondents stated that they would not buy GM food, but 86% of these non-buyers would like to taste the product that was labeled as a GM food. In contrast, our findings showed that participants were willing to taste and buy nanotechnology foods. However, this outcome was not the same as in the internet survey (preliminary study 2) which showed a low level of interest in nanotechnology foods among the general public. In another study, Lähteenmäki and her colleagues (Lähteenmäki et al., 2002) showed that consumers decreased their intentions to buy a highly preferred cheese that was later given a GM label compared to a conventionally labeled cheese. Nevertheless, providing GM cheeses with a label describing a positive taste benefit didn't increase acceptance and willingness to buy this sample. These findings contrast with our results showing that participants were willing to taste and buy nanotechnology foods with a specific benefit. Finally, some GM studies showed that a high level of social trust contributed to high acceptance of GM foods (Gaskell et al., 1999; Marks et al., 2002; Traill et al., 2004). A similar finding was reported, in two nanotechnology foods studies (Siegrist et al., 2007; Siegrist, 2008).

5.7 Knowledge Level about Nanotechnology

Scientists often believe that if the public had more scientific knowledge, they would have more positive attitudes towards new technologies (Brossard & Nisbet, 2007; Nisbet et al., 2002; Sturgis & Allum, 2004). The present study showed that the participants' level of knowledge about nanotechnology was not high, but they still showed high acceptance of nanotechnology foods. Our results disagree with most of the other nanotechnology studies. Those studies suggest that increased awareness and knowledge of nanotechnology is directly or indirectly related to more positive

perceptions of nanotechnology (Brossard et al., 2009; Lee et al., 2005; Satterfield et al., 2009). In our case, the level of scientific literacy did not predict attitudes towards this technology, which is consistent with several other studies on public perceptions of other types of new biotechnologies (Allum et al., 2008; Priest, 2001).

5.8 Questionnaires Responses

We also measured several other attitudes of our participants with questionnaires to better understand their responses in our study. The majority of the participants in the present study were not neophobic to new food technologies and neophobia was not a reliable predictor of liking or willingness to buy the nanotechnology products. A previous study showed that those who were neophobic to new food technologies, rejected new products with these technologies, whereas those who were neophilic to new food technologies, accepted these products (Evans et al., 2010).

We also measure participants' attitudes towards the application of nanotechnology in food production. Most of them had positive or neutral attitudes towards the application of nanotechnology in food production. Despite this favorable attitude, over half of the participants had concerns about long-term exposure to nanofoods. These results are consistent with Cook and Fairweather's findings (Cook & Fairweather, 2006). There were no significant relationships between the tasting results and responses to this questionnaire.

As for most consumers, participants in this study considered sensory appeal, health and convenience of food very important for them when they are choosing food to eat. These findings are consistent with other research relating general food attitudes (Steptoe et al., 1995) to food selection. Again, we did not find significant relationship between the liking ratings or willingness to buy nanotechnology products and these

three important food choice factors.

5.9 Limitations of Current Study

Some limitations of the present study should be addressed. We tried to recruit from the general population, but our sample was not representative of the general population of the U.S. The results might have been less positive if we had older participants or those who were not so willing to adopt new technologies. Also, if we had a broad demographic, then maybe the questionnaire responses would have been more predictive of the liking responses and willingness to buy. Thus, it is necessary to run a follow-up study that only recruits people from local communities. This would create a heterogeneous panel, with a large age range, that would be balanced in education background, gender, and ethnicity.

5.10 Summary

In summary, the majority of young, well-educated consumers in this study had positive attitudes towards food nanotechnology and was willing to buy nanotechnology food products because of the perceived nanotechnology benefits of these products and their high sensory appeal. Only a small subset of participants (14-26%) was not willing to buy these products and gave neutral or lower overall liking ratings to these products. These findings will help government, and food companies to better understand consumers' acceptance of food nanotechnology and their purchase intention of food nanotechnology products. Our findings also provide knowledge about what kinds of benefits consumers want from nanotechnology, and what kinds of foods consumers want to buy with nanotechnology. This information should provide enough confidence for governments and food companies to develop commercial nanotechnology products,

and also guide them to develop the types of nanotechnology products that meet consumers' requirements.

6. FIGURES

Figure 1: Demographics

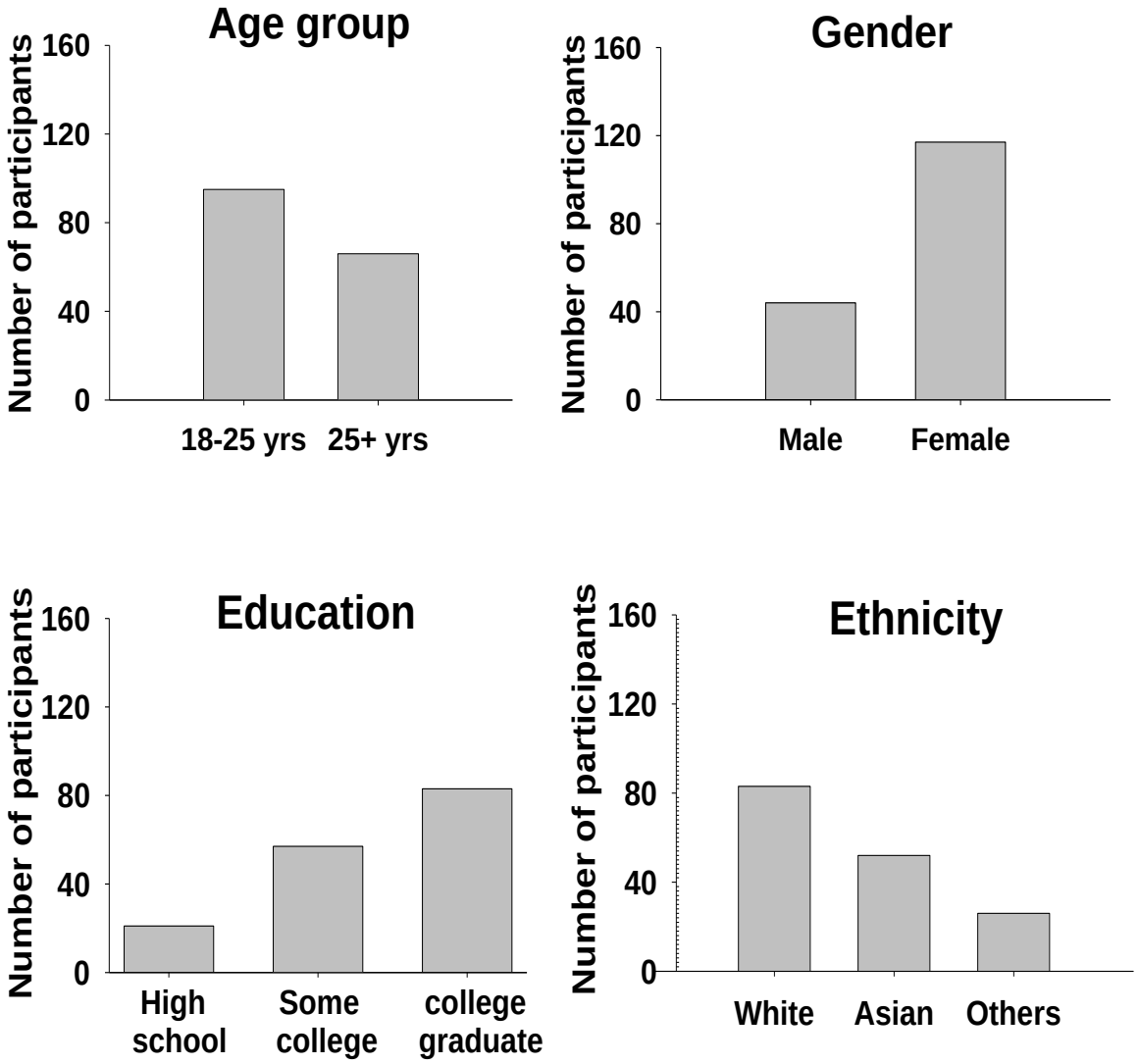
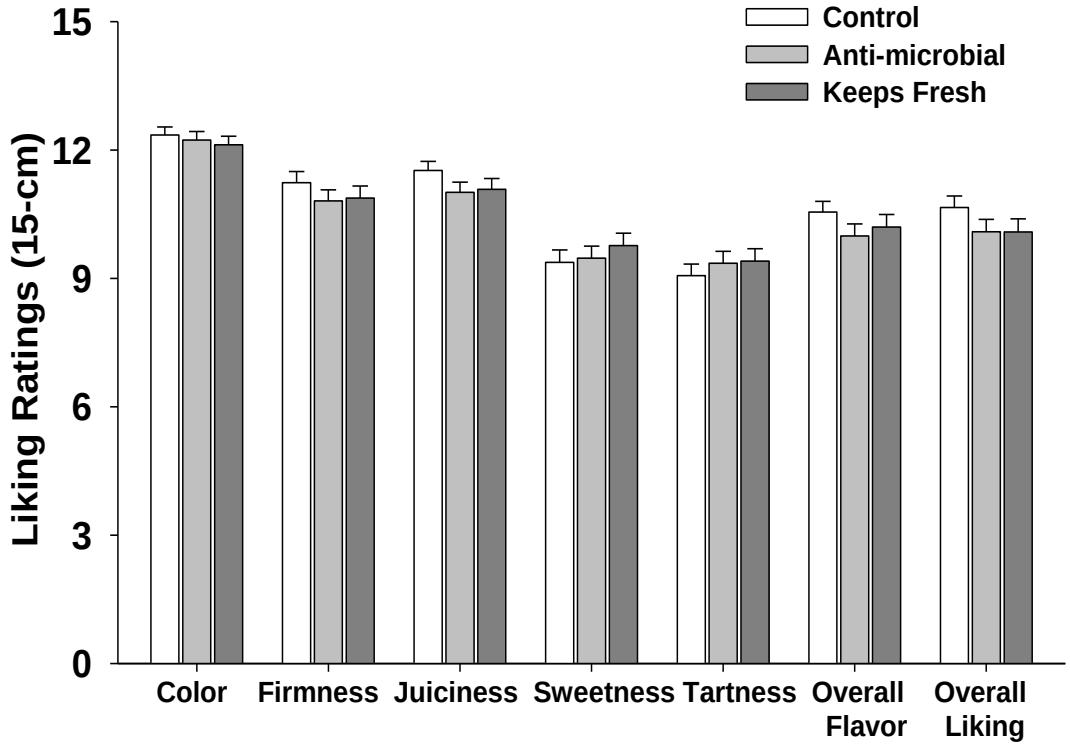


Figure 2: Liking Ratings for All Attributes of Three Samples of Each Food Type – Whole Panel

The scale on the left side of the figure represents 15-cm line scale used to collect the liking ratings. $^{+}$ Significant difference in creaminess between the control sample and the other samples at $p < 0.0001$.

2a) Tomato Samples



2b) Ice Cream Samples

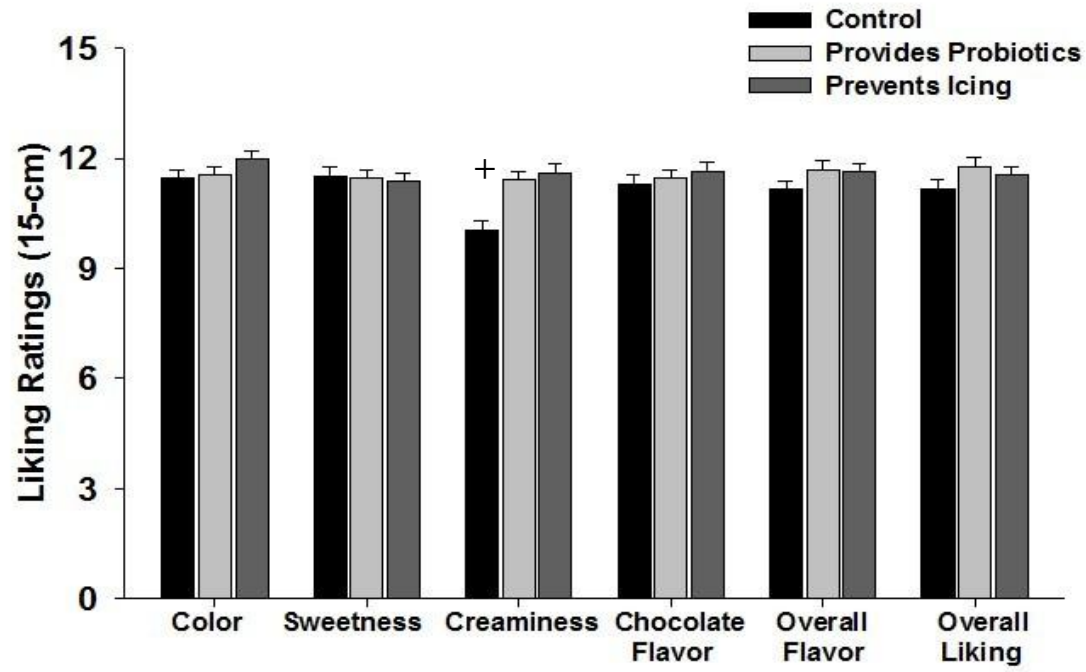
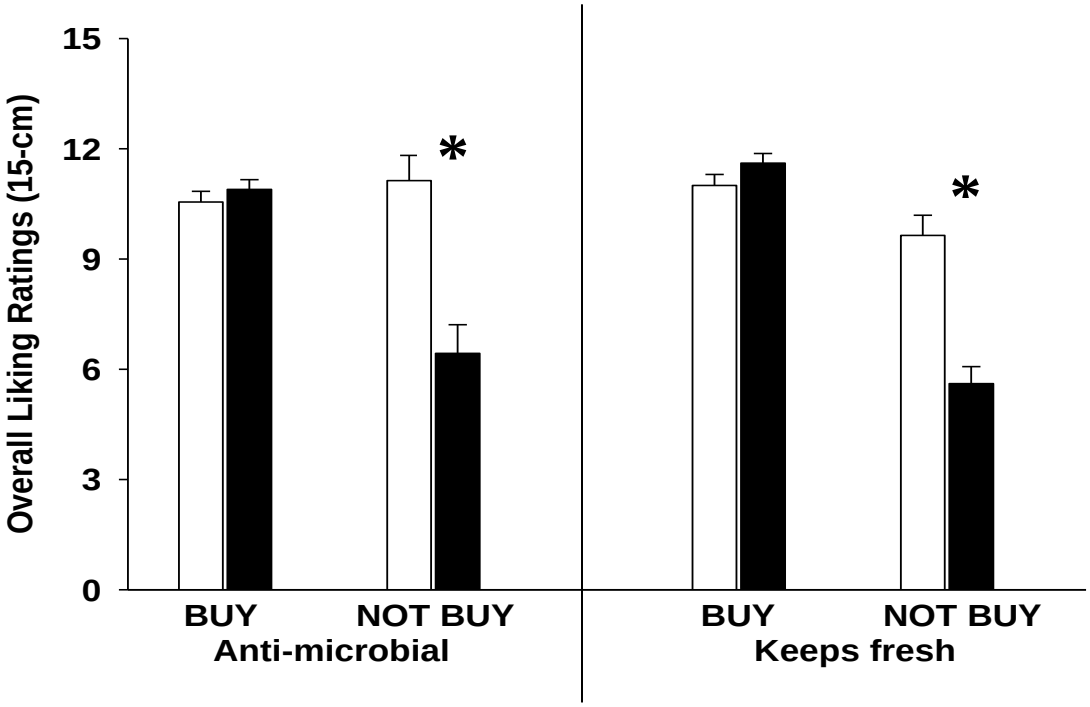


Figure 3: Comparisons of Overall Liking Ratings between Control Samples and Nanotechnology Benefit Samples Based on Willingness to Buy

The scale on the left side of the figure represents overall liking ratings for control and nanotech samples. The white bars represent control samples, and the black bars represent nanotechnology samples. *Significant difference between the control samples and nanotech samples in participants not willing to buy these products at $p < 0.05$.

3a) Tomato Samples



3b) Ice Cream Samples

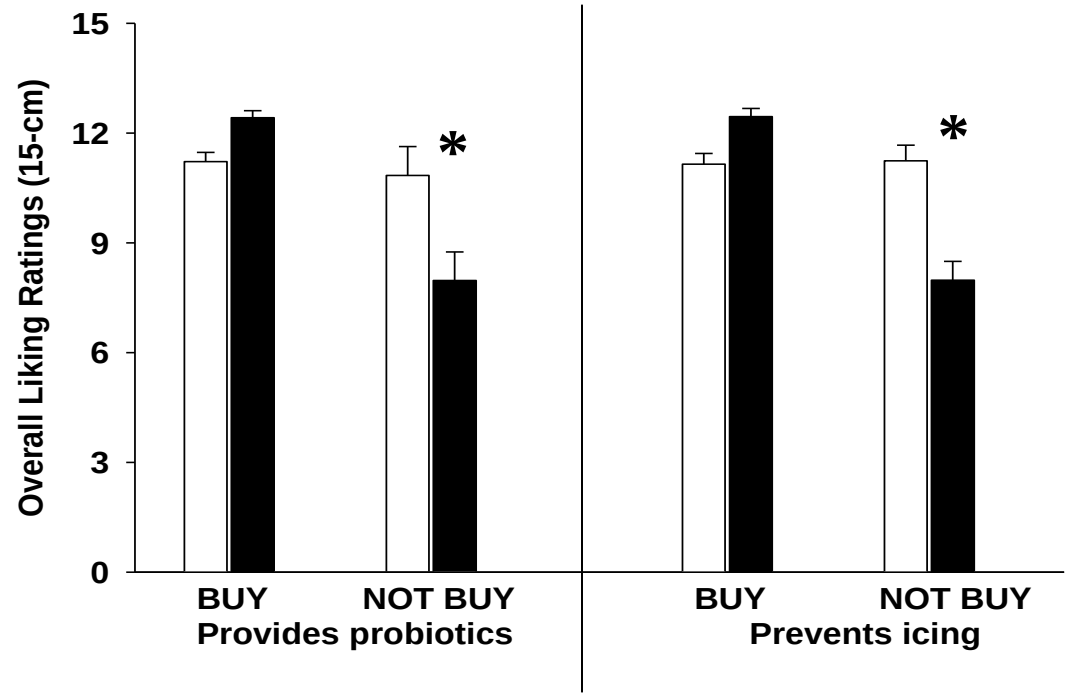


Figure 4: Reasons for Buying/Not Buying Nanotechnology Products

The light gray column in each figure represents the percentage of participants who are willing to buy nanotech products, while the dark gray bar in each figure represents the percentage of participants who are NOT willing to buy nanotech products. Chi-square analysis showed a different pattern of responses for buyers and non-buyers for each of the four samples ($p<0.01$).

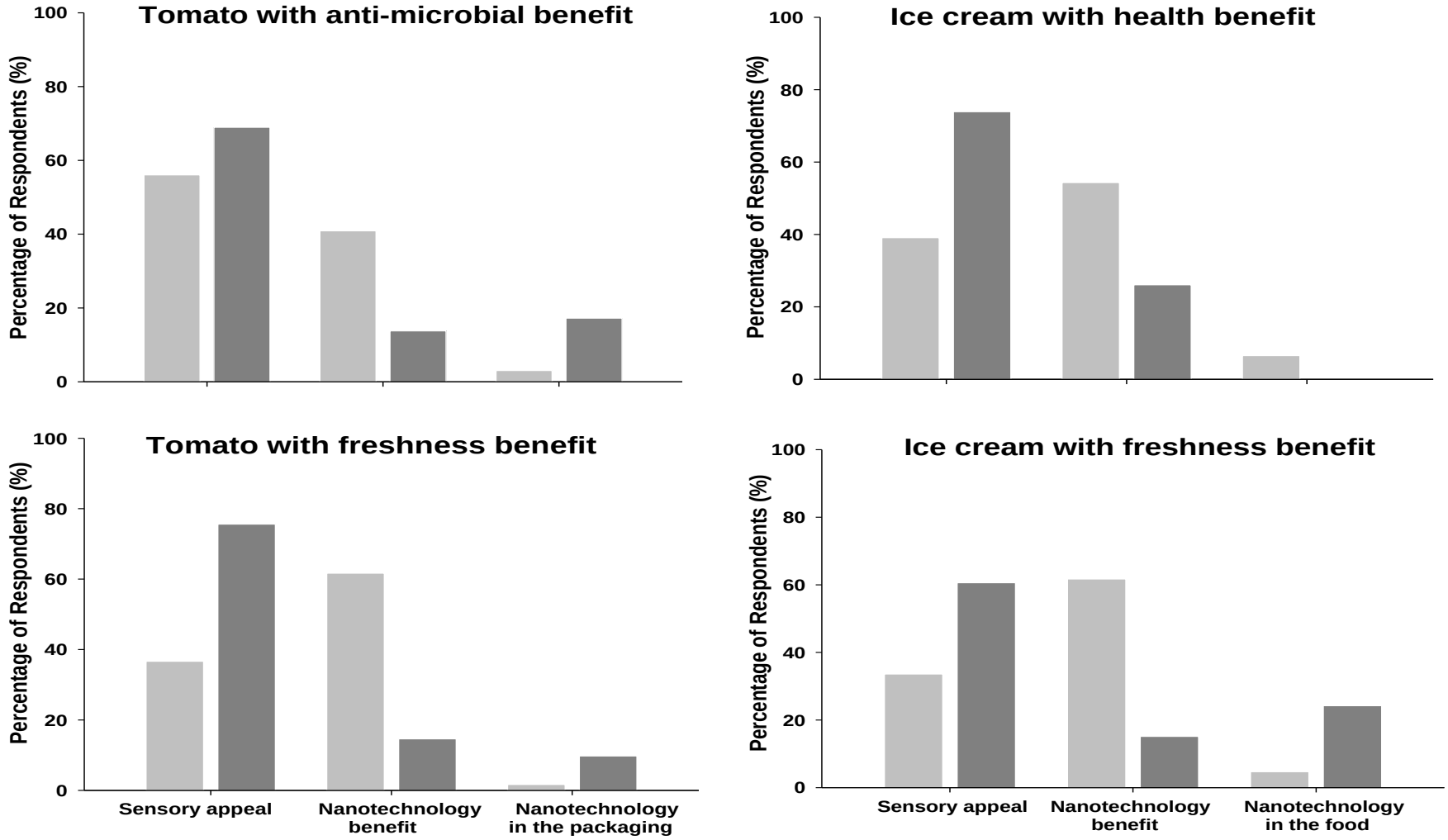
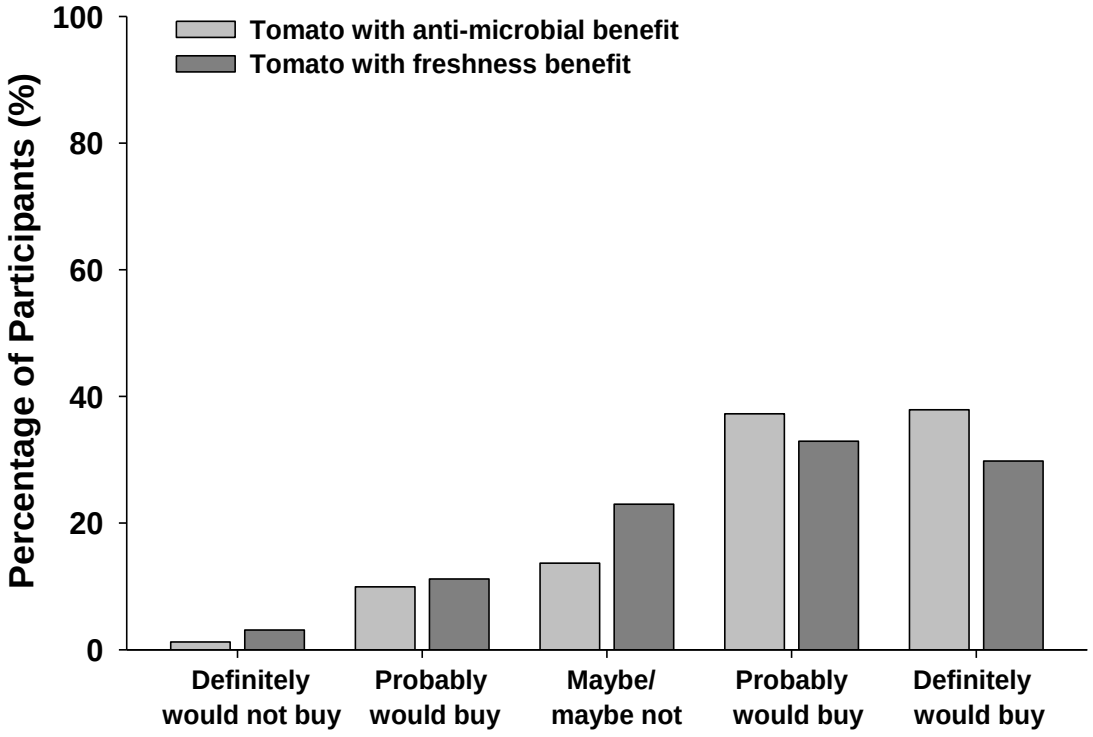


Figure 5: Intention to Buy Nanotechnology Products Based on Price
The scale on the left side of the figure represents percentage of participants' intendance to buy nanotechnology products based on price.

5a) Tomato Nanotechnology Samples



5b) Ice Cream Nanotechnology Samples

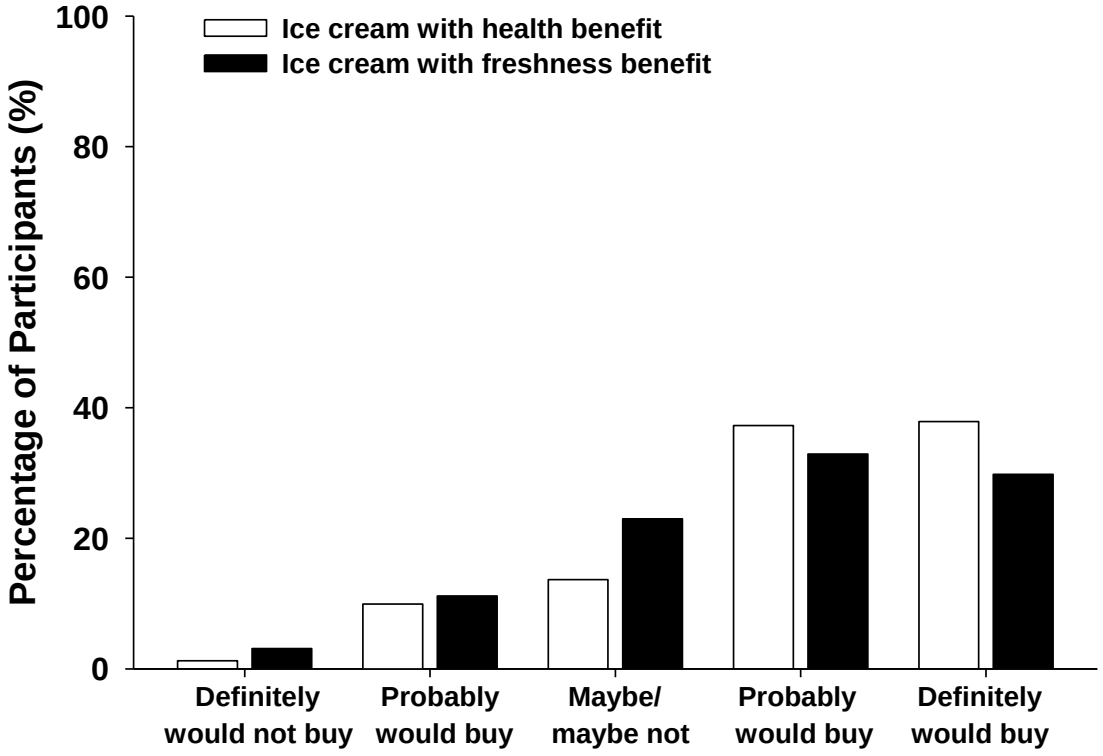
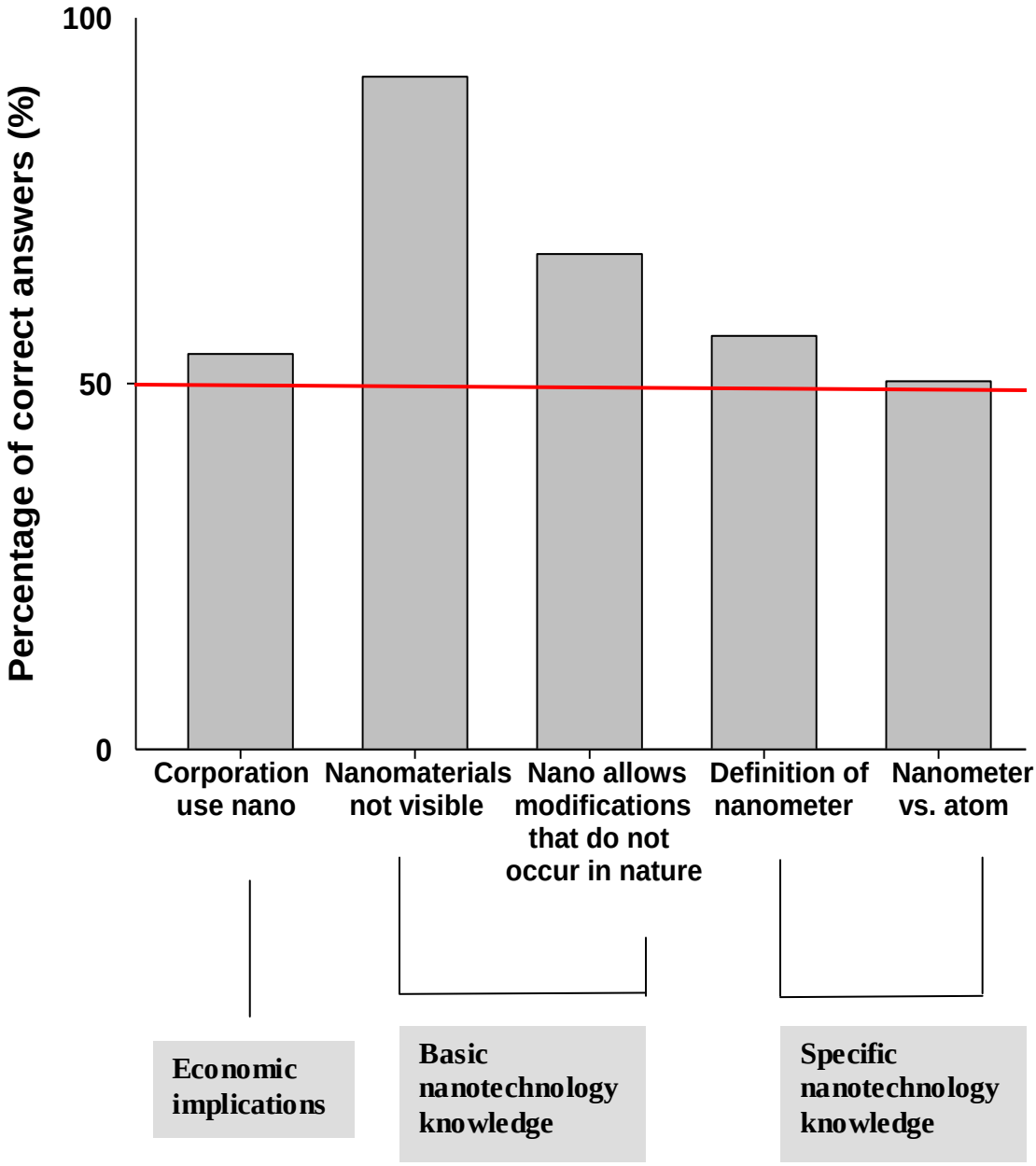


Figure 6: Knowledge Level about Nanotech-related Issues
The scale on the left side of the figure represents the percentage of respondents who answered each question correctly.



REFERENCES

Allum, N., Sturgis, P., Tabourazi, D., & Brunton-Smith, I. (2008). Science knowledge and attitudes across cultures: a meta-analysis. *Public Understanding of Science, 17*(1), 35-54.

Anderson, A., Allan, S., Petersen, A., & Wilkinson, C. (2005). The Framing of Nanotechnologies in the British Newspaper Press. *Science Communication, 27*(2), 200-220.

Arias, A. I., & Lewenstein, B. (2004). The media coverage of nanotechnology, *2004 NNIN REU Research Accomplishiments* (pp. 18-19): National Nanotechnology Initiative.

Balbus, J. M., Florini, K., Denison, R. A., & Walsh, S. A. (2006). Getting it right the first time: developing nanotechnology while protecting workers, public health, and the environment. *Ann N YAcad Sci, 1076*, 331-342.

Bauer, M. W., & Gaskell, G. (2002). *Biotechnology - the making of a global controversy*: Cambridge: Cambridge University Press.

Bower, J. A., Saadat, M. A., & Whitten, C. (2003). Effect of liking, information and consumer characteristics on purchase intention and willingness to pay more for a fat spread with a proven health benefit. *Food Quality and Preference, 14*(1), 65-74.

Brossard, D., & Nisbet, M. C. (2007). Deference to Scientific Authority Among a Low Information Public: Understanding U.S. Opinion on Agricultural Biotechnology. *International Journal of Public Opinion Research, 19*(1), 24-52.

Brossard, D., Scheufele, D. A., Kim, E., & Lewenstein, B. V. (2009). Religiosity as a perceptual filter: examining processes of opinion formation about nanotechnology. *Public Understanding of Science, 18*(5), 546-558.

Business Communications Company, I. (2011). *Nanobiotechnology: applications and global markets*. Retrieved May 19, 2011, from <http://www.bccresearch.com/report/nanobiotechnology-market-nan050a.html>

Caswell, J. A. (1998). Should use of genetically modified organisms be labeled? *AgBioForum, 1*(1), 22-24.

Chaudhry, Q., Scotter, M., Blackburn, J., Ross, B., Boxall, A., Castle, L., et al. (2008). Applications and implications of nanotechnologies for the food sector. *Food Additives & Contaminants: Part A, 25*(3), 241-258.

Chen, M. F. (2009). *What the food choice motivates determine consumers' attitudes toward GM foods in Taiwan?* Retrieved May 25, 2011, from <http://bai2009.org/file/Papers/1623.pdf>

Chun, A. L. (2009). Will the public swallow nanofood? *Nat Nano, 4*(12), 790-791.

Cobb, M. D., & Macoubrie, J. (2004). Public perceptions about nanotechnology: Risks, benefits and trust. *Journal of Nanoparticle Research, 6*(4), 395-405.

Cook, A. J., & Fairweather, J. R. (2006). *Nanotechnology: ethical and social issues: results from a New Zealand survey*.

Cook, A. J., & Fairweather, J. R. (2007). Intentions of New Zealanders to purchase lamb or beef made using nanotechnology. *British Food Journal, 109*(9), 675-688.

Cox, D. N., & Evans, G. (2008). Construction and validation of a psychometric scale to measure consumers' fears of novel food technologies: The food technology neophobia scale. *Food Quality and Preference, 19*(8), 704-710.

Cox, D. N., Koster, A., & Russell, C. G. (2004). Predicting intentions to consume functional foods and supplements to offset memory loss using an adaptation of protection motivation theory. *Appetite, 43*(1), 55-64.

Dudo, A., Choi, D. H., & Scheufele, D. A. (2010). Food nanotechnology in the news. Coverage patterns and thematic emphases during the last decade. *Appetite, 56*(1), 78-89.

Durant, J., Bauer, M. W., & Gaskell, G. (1998). *Biotechnology in the public sphere: A European Sourcebook*: London: Science Museum.

ElAmin, A. (2005). *Nanotechnology targets new food packaging products.* Retrieved May 18, 2011, from <http://www.foodproductiondaily.com/Packaging/Nanotechnology-targets-new-food-packaging-products>

ETC Group. (2004). *Down on the farm. The impacts of nano-scale technologies on food and agriculture.* Retrieved July 27, 2011, from <http://www.etcgroup.org/upload/publication/80/02/etc_dotfarm2004.pdf>.

Evans, G., Kermarrec, C., Sable, T., & Cox, D. N. (2010). Reliability and predictive validity of the Food Technology Neophobia Scale. *Appetite, 54*(2), 390-393.

FDA guidance. (2011). Considering whether an FDA-regulated product involves the application of nanotechnology.

Friedman, S. M., & Egolf, B. P. (2005). Nanotechnology: risks and the media. *Technology and Society Magazine, IEEE, 24*(4), 5-11.

Gaskell, G., Bauer, M. W., Durant, J., & Allum, N. C. (1999). Worlds apart? The reception of genetically modified foods in Europe and the U.S. *Science, 285*(5426), 384-387.

Gaskell, G., Eyck, T. T., Jackson, J., & Veltri, G. (2005). Imagining nanotechnology: cultural support for technological innovation in Europe and the United States. *Public Understanding of Science, 14*(1), 81-90.

Gaskell, G., Ten Eyck, T., Jackson, J., & Veltri, G. (2004). Public attitudes to nanotechnology in Europe and the United States. *Nat Mater, 3*(8), 496.

Goldman, K. A. (2000). Genetic technologies. Bioengineered food--safety and labeling. *Science, 290*(5491), 457-459.

Hallman, W. K., Adelaja, A. O., Schilling, B. J., & Lang, J. T. (2002). *Public perceptions of genetically modified foods: Americans know not what they eat*. Rutgers University, Food Policy Institute Report: RR-0302-001.

Hallman, W. K., Hebden, W. C., Aquino, H. L., Cuite, C. L., & Lang, J. T. (2003). *Public perceptions of genetically modified foods: a national study of American knowledge and opinion*. Rutgers University, Food Policy Institute: RR-1003-004.

Hallman, W. K., Hebden, W. C., Cuite, C. L., Aquino, H. L., & Lang, J. T. (2004). *Americans and GM food: knowledge, opinion and interest in 2004*. Rutgers University, Food Policy Institute: RR-1104-007.

Helmut Kaiser Consultancy. (2004). *Nanotechnology in food and food processing industry woldwide 2008-2010-2015*. Retrieved May 17, 2011, from <http://www.hkc22.com/Nanofood.html>

Ho, S. S., Brossard, D., & Scheufele, D. A. (2008). Effects of value predispositions, mass media use, and knowledge on public attitudes toward embryonic stem cell research. *International Journal of Public Opinion Research, 20*(2), 171-192.

Ho, S. S., Scheufele, D. A., & Corley, E. A. (2010). Making sense of policy choices: understanding the roles of value predispositions, mass media, and cognitive processing in public attitudes toward nanotechnology. *J Nanopart Res, 12*(8), 2703-2715.

Hossain, F., Onyango, B. M., Adelaja, A. O., Schilling, B. J., & Hallman, W. K. (2002). Consumers acceptance of food biotechnology: willingness to buy genetically modified food products. *Journal of International Food and Agribusiness Marketing, 15*, 53-76.

Huffman, W. E. (2003). Acceptance of (and resistance to) genetically modified foods in high-income countries: effects of labels and information in an uncertain environment. *American Journal of Agricultural Economics, 85*, 1112-1118.

Huffman, W. E., Rousu, M., Shogren, J. F., & Tegene, A. (2004). Consumer's resistance to genetically modified foods: the role of information in an uncertain environment. *Journal of Agricultural & Food Industrial Organization, 2*(2), article 8.

John, D. (2004). *A mini revolution. Food Manufacture.* Retrieved May 18, 2011, from http://www.foodmanufacture.co.uk/news/fullstory.php/aid/472/A_mini_revolution.html

Joseph, T., & Morrison, M. (2006). *Nanotechnology in agriculture and food. A Nanoforum report*. Retrieved May 17, 2011, from http://www.nanoforum.org/dateien/temp/nanotechnology%20in%20agriculture%20and%20food.pdf

Kahan, D. M., Braman, D., Slovic, P., Gastil, J., & Cohen, G. (2009). Cultural cognition of the risks and benefits of nanotechnology. *Nat Nano, 4*(2), 87-90.

Kjærgaard, R. S. (2008). Making a small country count: nanotechnology in Danish newspapers from 1996 to 2006. *Public Understanding of Science, 19*(1), 80-97.

Kjølberg, K., & Wickson, F. (2007). Social and ethical interactions with nano: mapping the early literature. *Nanoethics, 1*(2), 89-104.

Knight, A. J. (2009). Perceptions, Knowledge and ethical concerns with GM foods and the GM process. *Public Understanding of Science, 18*(2), 177-188.

Koivisto Hursti, U. K., & Magnusson, M. K. (2003). Consumer perceptions of genetically modified and organic foods. What kind of knowledge matters? *Appetite, 41*(2), 207-209.

Kulve, H. T. (2006). Evolving repertoires : Nanotechnology in daily newspapers in the Netherlands. *Science as Culture, 15*, 367-382.

Kuzma, J., & VerHage, P. (2006). Nanotechnology in agriculture and food production. Washington, DC: Woodrow Wilson International Center for Scholars.

Lähteenmäki, L., Grunert, K., Ueland, Ø., Åström, A., Arvola, A., & Bech-Larsen, T. (2002). Acceptability of genetically modified cheese presented as real product alternative. *Food Quality and Preference, 13*(7-8), 523-533.

Laing, A. (2005). *A report on Canadian and American news media coverage of nanotechnology issues.* Retrieved May 19, 2011, from <http://www.nanotechproject.org/file_download/files/A%20report%20on%20Canadian%20and%20American%20news%20media%20coverage%20of%20nanotechnology%20issues.pdf>

Lee, C. J., Scheufele, D. A., & Lewenstein, B. V. (2005). Public Attitudes toward Emerging Technologies. *Science Communication, 27*(2), 240-267.

Lewenstein, B. V., Gorss, J., & Radin, J. (2005). The salience of small: nanotechnology coverage in the American press, 1986-2004, *International Communication Association, New York*. New York.

Macnaghten, P., Kearnes, M. B., & Wynne, B. (2005). Nanotechnology, Governance, and Public Deliberation: What Role for the Social Sciences? *Science Communication, 27*(2), 268-291.

Macoubrie, J. (2005). *Pew Project on Emerging Nanotechnology: informed public perceptions of nanotechnology and trust in government*. Retrieved May 18, 2011, from <http://www.pewtrusts.org/our_work.aspx?category=338>

Macoubrie, J. (2006). Nanotechnology: public concerns, reasoning and trust in government. *Public Understanding of Science, 15*(2), 221-241.

Magnusson, M. K., & Koivisto Hursti, U. K. (2002). Consumer attitudes towards genetically modified foods. *Appetite, 39*(1), 9-24.

Marks, L. A., Kalaitzandonakes, N., & Zakharova, L. (2002). On the media roller coaster: will biotechfoods finish the ride? *Choices: The Magazine of Food, Farm and Resources Issues, Spring*, 6-10.

McCombs, M. (2004). *Setting the agenda: the mass media and public opinion*. Cambridge, UK: Polity Press. 184 pp.

Moerbeek, H., & Casimir, G. (2005). Gender differences in consumers' acceptance of genetically modified foods. *International Journal of Consumer Studies, 29*(4), 308-318.

Moon, W., & Balasubramanian, S. K. (2001). A multi-attribute model of public acceptance of genetically modified organisms, *2001 Annual meeting, August 5-8, Chicago, IL with number 20745.*: Agricultural and Applied Economics Association.

Moon, W., & Balasubramanian, S. K. (2004). Public attitudes toward agrobiotechnology: the mediating role of risk perceptions on the impact of trust, awareness, and outrage. *Applied Economic Perspectives and Policy, 26*(2), 186-208.

National Nanotechnology Initiative. (2011a). The national nanotechnology initiative strategic plan: http://www.nano.gov/sites/default/files/pub_resource/2011_strategic_plan.pdf.

National Nanotechnology Initiative. (2011b). Supplement to the president's FY 2010 budget.

Nisbet, M. C., Scheufele, D. A., Shanahan, J., Moy, P., Brossard, D., & Lewenstein, B. V. (2002). Knowledge, reservations, or promise? A media effects model for public perceptions of science and technology. *Communication Research, 29*(5), 584-608.

O'Fallon, M. J., Gursoy, D., & Swanger, N. (2007). To buy or not to buy: Impact of labeling on purchasing intentions of genetically modified foods. *International Journal of Hospitality Management, 26*(1), 117-130.

Pew Project on Emerging Nanotechnologies. (2007). *Awareness of and attitudes toward nanotechnology and federal regulatory agencies.* Retrieved May 18, 2011, from http://wwwpewtrusts.org/our_work.aspx?category=338

Pew Project on Emerging Nanotechnologies. (2009). *Nanotechnology, synthetic biology, & public opinion.* Retrieved May 18, 2011, from <http://www.nanotechproject.org/process/assets/files/8284/presentation.pdf>

Pollard, T. M., Steptoe, A., & Wardle, J. (1998). Motives underlying healthy eating: using the Food Choice Questionnaire to explain variation in dietary intake. *J Biosoc Sci, 30*(2), 165-179.

Priest, S. H. (2001). Misplaced Faith. *Science Communication, 23*(2), 97-110.

Renn, O., & Roco, M. (2006). Nanotechnology and the need for risk governance. *Journal of Nanoparticle Research, 5*(2), 153-191.

Resurreccion, A. V. A., Galvez, F. C. F., Fletcher, S. M., & Misra, S. K. (1995). Consumer attitudes toward irradiated food: results of a new study. *Journal of food protection, 58*(2), 193-196.

Roco, M. C. (2003). Broader social issues of nanotechnology. *Journal of Nanoparticle Research, 5*, 181-189.

Roco, M. C. (2011). *National nanotechnology investment in the FY2012 budget.* Retrieved May 19, 2011, from http://www.aaas.org/spp/rd/rdreport2012/12pch23.pdf

Sanguansri, P., & Augustin, M. A. (2006). Nanoscale materials development - a food industry perspective. *Trends in Food Science & Technology, 17*(10), 547-556.

Satterfield, T., Kandlikar, M., Beaudrie, C. E. H., Conti, J., & Harthorn, B. H. (2009). Anticipating the perceived risk of nanotechnologies. *Nature Nanotechnology, 4*(11), 752-758.

Scheufele, D. A., Corley, E. A., Dunwoody, S., Shih, T. J., Hillback, E., & Guston, D. H. (2007). Scientists worry about some risks more than the public. *Nat Nano, 2*(12), 732-734.

Scheufele, D. A., Corley, E. A., Shih, T. J., Dalrymple, K. E., & Ho, S. S. (2009). Religious beliefs and public attitudes toward nanotechnology in Europe and the United States. *Nature Nanotechnology, 4*(2), 91-94.

Scheufele, D. A., & Lewenstein, B. (2005). The Public and Nanotechnology: How Citizens Make Sense of Emerging Technologies. (6), 659-667.

Scheufele, D. A., & Tewksbury, D. (2007). Framing, agenda setting, and priming: The evolution of three media effects models. *Journal of Communication, 57*(1), 9-20.

Schummer, J. (2004). Societal and Ethical Implications of Nanotechnology: Meanings, Interest Groups, and Social Dynamics. *Research in Philosophy and Technology. Nanotech Challenges, Part 1, 8,* 56-88.

Siegrist, M. (2008). Factors influencing public acceptance of innovative food technologies and products. *Trends in Food Science & Technology, 19*(11), 603-608.

Siegrist, M., Cousin, M. E., Kastenholz, H., & Wiek, A. (2007). Public acceptance of nanotechnology foods and food packaging: The influence of affect and trust. *Appetite, 49*(2), 459-466.

Siegrist, M., Stampfli, N., & Kastenholz, H. (2009). Acceptance of nanotechnology foods: a conjoint study examining consumers' willingness to buy. *British Food Journal, 111*(6-7), 660-668.

Siegrist, M., Stampfli, N., Kastenholz, H., & Keller, C. (2008). Perceived risks and perceived benefits of different nanotechnology foods and nanotechnology food packaging. *Appetite, 51*(2), 283-290.

Siegrist, M., Wiek, A., Helland, A., & Kastenholz, H. (2007). Risks and nanotechnology: the public is more concerned than experts and industry. *Nat Nanotechnol, 2*(2), 67.

Smith, S. E. S., Hosgood, H. D., Michelson, E. S., & Stowe, M. H. (2008). Americans' Nanotechnology Risk Perception. *Journal of Industrial Ecology, 12*(3), 459-473.

Stephens, L. F. (2005). News Narratives about Nano S&T in Major U.S. and Non-U.S. Newspapers. *Science Communication, 27*(2), 175-199.

Steptoe, A., Pollard, T. M., & Wardle, J. (1995). Development of a Measure of the Motives Underlying the Selection of Food: the Food Choice Questionnaire. *Appetite, 25*(3), 267-284.

Sturgis, P., & Allum, N. (2004). Science in Society: Re-Evaluating the Deficit Model of Public Attitudes. *Public Understanding of Science, 13*(1), 55-74.

Tarver, T. (2006). Food nanotechnology. *Food Technology, 11,* 23-26.

Teisl, M. F., Fein, S. B., & Levy, A. S. (2009). Information effects on consumer attitudes toward three food technologies: Organic production, biotechnology, and irradiation. *Food Quality and Preference, 20*(8), 586-596.

Tenbült, P., De Vries, N. K., Dreezens, E., & Martijn, C. (2005). Perceived naturalness and acceptance of genetically modified food. *Appetite, 45*(1), 47-50.

Tenbült, P., De Vries, N. K., van Breukelen, G., Dreezens, E., & Martijn, C. (2008). Acceptance of genetically modified foods: the relation between technology and evaluation. *Appetite, 51*(1), 129-136.

The Project on Emerging Nanotechnologies. (2011, May 17, 2011). *Nanotech-enabled consumer products continue to rise.* Retrieved May 17, 2011, from <http://www.nanotechproject.org/news/archive/9231>

The White House. (2000). National Nanotechnology Initiative: leading to the next industrial revolution.

Todt, O., Muñz, E., Gonzáles, M., Ponce, G., & Estévez, B. (2008). Consumer attitudes and the governance of food safety. *Public Understanding of Science, 18*(1), 103-114.

Townsend, E., & Campbell, S. (2004). Psychological determinants of willingness to taste and purchase genetically modified food. *Risk Anal, 24*(5), 1385-1393.

Traill, W. B., Jaeger, S. R., Yee, W. M. S., Valli, C., House, L. O., Lusk, J. L., et al. (2004). Categories of GM risk-benefit perceptions and their antecedents. *AgBioForum, 7*(4), 176-186.

Tuorila, H., Cardello, A. V., & Lesher, L. L. (1994). Antecedents and Consequences of Expectations Related to Fat-free and Regular-fat Foods. *Appetite, 23*(3), 247-263.

Vandermoere, F., Blanchemanche, S., Bieberstein, A., Marette, S., & Roosen, J. (2010). The morality of attitudes toward nanotechnology: about God, techno-scientific progress, and interfering with nature. *Journal of Nanoparticle Research, 12*(2), 373-381.

Vilella-Vila, M., Costa-Font, J., & Mossialos, E. (2005). Consumer involvement and acceptance of biotechnology in the European Union: a specific focus on Spain and the UK. *International Journal of Consumer Studies, 29*(2), 108-118.

Waldron, A., Spencer, D., & Batt, C. (2006). The current state of public understanding of nanotechnology. *Journal of Nanoparticle Research, 8*(5), 569-575.

Weaver, D. A., Lively, E., & Bimber, B. (2009). Searching for a Frame News Media Tell the Story of Technological Progress, Risk, and Regulation. *Science Communication, 31*(2), 139-166.

Weiss, J., Takhistov, P., & McClements, D. J. (2006). Functional Materials in Food Nanotechnology. *Journal of Food Science, 71*(9), R107-R116.

Wilkinson, C., Allan, S., Anderson, A., & Petersen, A. (2007). From uncertainty to risk?: Scientific and news media portrayals of nanoparticle safety. *Health Risk & Society, 9*(2), 145-157.

Wolfe, J. (2005). *Safer and guilt-free nano foods.* Retrieved May 18, 2011, from <http://www.foodmanufacture.co.uk/news/fullstory.php/aid/472/A_mini_revolution.html>

Wolfson, J. R. (2003). Social and ethical issues in nanotechnology: lessons from biotechnology and other high technologies. *Biotechnology Law Report*, *22*(4), 376-396.

APPENDIX A

Consent Form

CONSENT FORM

Food Nanotechnology: Understanding the Parameters of Consumer Acceptance

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PURPOSE: Nanotechnology is the understanding and control of materials on a very small scale. The use of nanoscale materials makes possible the production of foods with added benefits such as improved taste, freshness and healthiness. The purpose of this study is to understand consumers' attitudes towards food nanotechnology and their reactions to foods with this technology.

PROCEDURES: I will be asked to taste common foods produced with nanotechnology and to complete questionnaires on my opinions about these foods. Basic demographic information will also be collected. These activities will take ~35 min for me to complete in a single test session.

RISKS/BENEFITS: The activities I will be participating in pose no forseeable risks to my health. All of the foods I will be asked to taste are common everyday items that are approved for human consumption. Although I will receive no direct benefits from participating in this study, this research will benefit society by providing a better understanding of consumer reactions to nanotechnology.

COMPENSATION: I will receive $ 20 compensation for participating in this study. If I withdraw from the study before completing the session, my compensation will be prorated.

MY RIGHTS AS A RESEARCH SUBJECT/CONFIDENTIALITY: My participation in this study is completely voluntary and I have the right to withdraw at any time without explanation or penalty. The information collected in this experiment will be kept strictly confidential, my identity protected by a code number, and all data kept in a locked filing cabinet or on a pass-word protected computer. Only research staff involved in this study will have access to these files.

AGREEMENT: I have read the above description. All my questions have been answered to my satisfaction and I agree voluntarily to participate. I understand that I have the right to leave the experiment at any time without penalty. I also understand that Rutgers University has made no general provision for financial compensation or medical treatment for any

physical injury resulting from this research. If I have questions about this research, I can contact the Principal Investigator at the number listed above or the Rutgers University Institutional Review Board for the Protection of Human Subjects, Office of Research and Sponsored Programs, 3 Rutgers Plaza, New Brunswick, NJ 08901-8559. Tel: 732-932-0150 ext. 2104 or Email: humansubjects@orsp.rutgers.edu

_____	_____
Name of participant (print)	Date
_____	_____
Signature of Participant	Signature of Investigator

I have received a copy of this statement for my records _____ (initials)

This informed consent form was approved by the Rutgers Institutional Review Board for the Protection of Human Subjects on _____; approval of this form expires on _____.

APPENDIX B

FIZZ Network Ballot for Food Acceptance Taste Test

Welcome to the Sensory Lab!

Thank you for participating in our study on new food technologies.

Introduction to nanotechnology:

Nanotechnology is the application of scientific and engineering principles to make and utilize very small things. How small? Not as small as atoms or molecules, but much smaller than anything you can see. Nanotechnology is different from older technologies because many materials exhibit surprising and useful properties when their size is reduced far enough.

Food companies are developing ways of using nanotechnology in commonly eaten foods to improve their flavor, freshness and healthiness. For example, it is possible to create mixtures of oil and water (like salad dressing) that never separate, to add particles that never sink in liquids, and to add ingredients that won't change the taste of foods. Some of the foods you will taste today are produced using nanoscale materials. We would like your opinion of these foods.

General instructions:

You are going to taste two types of food in this session: tomatoes and chocolate ice cream. You will be served samples of each food one-at-a-time. When you have finished evaluating the first sample, the server will give you the next sample.

Each sample has a 3-digit code number. Make sure the sample code matches the code number on the right side of the computer screen.

Please rinse your mouth thoroughly with water before you taste each sample. Taste the sample and click anywhere on the scale to indicate your liking of the attributes written on the left side of the scale.

When you are done, please turn on the light next to your right knee and we will deliver the next sample.

Subject ID: _____ Date: _____

Tomato samples

This field-ripened tomato was produced WITHOUT the use of nanoscale materials.

Please rinse your mouth thoroughly with water before you begin and in between samples.

Color:

|----------|

Dislike Extremely Like Extremely

Firmness:

|----------|

Dislike Extremely Like Extremely

Juiciness:

|----------|

Dislike Extremely Like Extremely

Sweetness:

|----------|

Dislike Extremely Like Extremely

Tartness:

|----------|

Dislike Extremely Like Extremely

Overall Flavor:

|----------|

Dislike Extremely Like Extremely

Overall Liking:

|----------|

Dislike Extremely Like Extremely

This is a field-ripened tomato. It was wrapped in a package containing anti-microbial nanoparticles that kill harmful microorganisms. The nanoparticles are made from food-grade ingredients that are approved for human consumption.

Please rinse your mouth thoroughly with water before you begin and in between samples.

Color:

|----------|

Dislike Extremely Like Extremely

Firmness:

|----------|

Dislike Extremely Like Extremely

Juiciness:

|----------|

Dislike Extremely Like Extremely

Sweetness:

|----------|

Dislike Extremely Like Extremely

Tartness:

|----------|

Dislike Extremely Like Extremely

Overall Flavor:

|----------|

Dislike Extremely Like Extremely

Overall Liking:

|----------|

Dislike Extremely Like Extremely

Willingness to buy:

1. If this product was available in the market, would you consider buying it?

☐ Yes ☐ No

2. What is the primary reason for your decision to buy or not buy this product?

(Please only check one)

☐ Sensory appeal

☐ Anti-microbial benefit

☐ Nanotechnology in the package

3. If the price of this product was comparable to what I usually pay for tomatoes, I:

☐ Definitely would not buy

☐ Probably would not buy

☐ Maybe/maybe not

☐ Probably would buy

☐ Definitely would buy

This is a field-ripened tomato. It was wrapped in a package containing nanoparticles that keep tomatoes fresher, longer. The nanoparticles are made from food-grade ingredients that are approved for human consumption.

Please rinse your mouth thoroughly with water before you taste the samples.

Color:

|----------|

Dislike Extremely Like Extremely

Firmness:

|----------|

Dislike Extremely Like Extremely

Juiciness:

|----------|

Dislike Extremely Like Extremely

Sweetness:

|----------|

Dislike Extremely Like Extremely

Tartness:

|----------|

Dislike Extremely Like Extremely

Overall Flavor:

|----------|

Dislike Extremely Like Extremely

Overall Liking:

|----------|

Dislike Extremely Like Extremely

Willingness to buy:

1. If this product was available in the market, would you consider buying it?

☐ Yes ☐ No

2. What is the primary reason for your decision to buy or not buy this product?

(Please only check one)

☐ Sensory appeal

☐ Keeps freshness longer

☐ Nanotechnology in the package

3. If the price of this product was comparable to what I usually pay for tomatoes, I:

☐ Definitely would not buy

☐ Probably would not buy

☐ Maybe/maybe not

☐ Probably would buy

☐ Definitely would buy

Ice cream samples

This ice cream was made without the use of nanoscale materials.

Please rinse your month thoroughly before you taste each sample.

Color:

|----------|

Dislike Extremely Like Extremely

Sweetness:

|----------|

Dislike Extremely Like Extremely

Creaminess:

|----------|

Dislike Extremely Like Extremely

Chocolate flavor:

|----------|

Dislike Extremely Like Extremely

Overall Flavor:

|----------|

Dislike Extremely Like Extremely

Overall Liking:

|----------|

Dislike Extremely Like Extremely

This ice cream contains health promoting nanoparticles that release live cultures (probiotics) into your digestive system. The nanoparticles are made from food-grade ingredients that are approved for human consumption.

Please rinse your mouth thoroughly with water before you taste the samples.

Color:

|----------|

Dislike Extremely Like Extremely

Sweetness:

|----------|

Dislike Extremely Like Extremely

Creaminess:

|----------|

Dislike Extremely Like Extremely

Chocolate flavor:

|----------|

Dislike Extremely Like Extremely

Overall Flavor:

|----------|

Dislike Extremely Like Extremely

Overall Liking:

|----------|

Dislike Extremely Like Extremely

Willingness to buy:

1. If this product was available in the market, would you consider buying it?

☐ Yes ☐ No

2. What is the primary reason for your decision to buy or not buy this product?

(Please only check one)

☐ Sensory appeal
☐ Provides probiotics
☐ Nanotechnology in the product

3. If the price of this product was comparable to what I usually pay for ice cream, I:

☐ Definitely would not buy
☐ Probably would not buy
☐ Maybe/maybe not
☐ Probably would buy
☐ Definitely would buy

This ice cream contains nanoparticles that preserve freshness and prevent ice crystals from forming. The nanoparticles are made from food-grade ingredients that are approved for human consumption.

Please rinse your mouth thoroughly with water before you taste the samples.

Color:

|----------|

Dislike Extremely Like Extremely

Sweetness:

|----------|

Dislike Extremely Like Extremely

Creamy:

|----------|

Dislike Extremely Like Extremely

Chocolate flavor:

|----------|

Dislike Extremely Like Extremely

Overall Flavor:

|----------|

Dislike Extremely Like Extremely

Overall Liking:

|----------|

Dislike Extremely Like Extremely

Willingness to buy:

1. If this product was available in the market, would you consider buying it?

☐ Yes ☐ No

2. What is the primary reason for your decision to buy or not buy this product?

(Please only check one)

☐ Sensory appeal

☐ Preserves freshness and prevents icing

☐ Nanotechnology in the product

3. If the price of this product was comparable to what I usually pay for ice cream, I:

☐ Definitely would not buy

☐ Probably would not buy

☐ Maybe/maybe not

☐ Probably would buy

☐ Definitely would buy

Thank you for your participation in this study.

You have finished the taste test, please turn on the light next to your right knee to let the server know, and give you the questionnaires.

APPENDIX C

Knowledge about Nanotechnology Scale

Subject ID: _____ Date: _____

Knowledge about Nanotechnology Scale

Please indicate if you believe the following statements are true or false. If you are definitely sure that the statement is true, check the "definitely true" box, and if you are definitely sure that the statement is false, check the "definitely false" box. Otherwise, please indicate if you believe that it's likely to be true or likely to be false. If you do not know whether the statement is true or false, please check the "I don't know" box.

1. Nanotechnology involves materials that are not visible to the naked eye.

[ ]	[ ]	[ ]	[ ]	[ ]
Definitely false	Likely false	Likely true	Definitely true	I don't know

2. Nanotechnology involves extremely short amounts of time.

[ ]	[ ]	[ ]	[ ]	[ ]
Definitely false	Likely false	Likely true	Definitely true	I don't know

3. US corporations are NOT using nanotechnology to make food products sold today.

[ ]	[ ]	[ ]	[ ]	[ ]
Definitely false	Likely false	Likely true	Definitely true	I don't know

4. A nanometer is a billionth of a meter.

[ ]	[ ]	[ ]	[ ]	[ ]
Definitely false	Likely false	Likely true	Definitely true	I don't know

Continue on next page

5. Nanotechnology means using very small quantities of materials.

[ ]	[ ]	[ ]	[ ]	[ ]
Definitely false	Likely false	Likely true	Definitely true	I don't know

6. Nanotechnology allows scientists to arrange molecules in ways that do NOT occur in nature.

[ ]	[ ]	[ ]	[ ]	[ ]
Definitely false	Likely false	Likely true	Definitely true	I don't know

7. A nanometer is about the same size as an atom.

[ ]	[ ]	[ ]	[ ]	[ ]
Definitely false	Likely false	Likely true	Definitely true	I don't know

8. Materials on the nano scale have the same properties as those materials on a bigger scale.

[ ]	[ ]	[ ]	[ ]	[ ]
Definitely false	Likely false	Likely true	Definitely true	I don't know

9. Nano-sized materials behave differently from the same materials when they are on a larger scale.

[ ]	[ ]	[ ]	[ ]	[ ]
Definitely false	Likely false	Likely true	Definitely true	I don't know

Continue on next page

10. Scientists do not understand many of the ways nanotechnology might affect the environment.

[ ]	[ ]	[ ]	[ ]	[ ]
Definitely false	Likely false	Likely true	Definitely true	I don't know

11. It is difficult to predict the effects of nanotechnology on human health.

[ ]	[ ]	[ ]	[ ]	[ ]
Definitely false	Likely false	Likely true	Definitely true	I don't know

12. Foods containing nanotechnology are currently available for sale in the United States.

[ ]	[ ]	[ ]	[ ]	[ ]
Definitely false	Likely false	Likely true	Definitely true	I don't know

13. I have eaten a food containing nanotechnology.

[ ]	[ ]	[ ]	[ ]	[ ]
Definitely false	Likely false	Likely true	Definitely true	I don't know

14. Nanotechnology can be grown into a food.

[ ]	[ ]	[ ]	[ ]	[ ]
Definitely false	Likely false	Likely true	Definitely true	I don't know

15. By law, nanotechnology can only be used in food packaging.

[ ]	[ ]	[ ]	[ ]	[ ]
Definitely false	Likely false	Likely true	Definitely true	I don't know

Continue on next page

16. Humans cannot digest nanotechnology.

[ ]	[ ]	[ ]	[ ]	[ ]
Definitely false	Likely false	Likely true	Definitely true	I don't know

17. Foods containing nanotechnology are required to have special labels.

[ ]	[ ]	[ ]	[ ]	[ ]
Definitely false	Likely false	Likely true	Definitely true	I don't know

18. Nanotech foods cannot be cooked in microwave ovens.

[ ]	[ ]	[ ]	[ ]	[ ]
Definitely false	Likely false	Likely true	Definitely true	I don't know

19. Through the use of nanotechnology, food products are made smaller.

[ ]	[ ]	[ ]	[ ]	[ ]
Definitely false	Likely false	Likely true	Definitely true	I don't know

20. A millimeter is smaller than a nanometer.

[ ]	[ ]	[ ]	[ ]	[ ]
Definitely false	Likely false	Likely true	Definitely true	I don't know

Appendix D

Food Choice Questionnaire

Food Choice Questionnaire

Read each statement starting with **"It is important to me that the food I eat on a typical day"** and decide how you feel about it, and then answer the questions by checking the corresponding boxes. PLEASE ANSWER ALL THE QUESTIONS.

It is important to me that the food I eat on a typical day:

1. Is easy to prepare

[ ]	[ ]	[ ]	[ ]
Not at all important	A little important	Moderately important	Very important

2. Contains no additives

[ ]	[ ]	[ ]	[ ]
Not at all important	A little important	Moderately important	Very important

3. Is low in calories

[ ]	[ ]	[ ]	[ ]
Not at all important	A little important	Moderately important	Very important

4. Tastes good

[ ]	[ ]	[ ]	[ ]
Not at all important	A little important	Moderately important	Very important

5. Contains natural ingredients

[ ]	[ ]	[ ]	[ ]
Not at all important	A little important	Moderately important	Very important

6. Is low in fat

[ ]	[ ]	[ ]	[ ]
Not at all important	A little important	Moderately important	Very important

7. Is familiar

[ ]	[ ]	[ ]	[ ]
Not at all important	A little important	Moderately important	Very important

8. Is high in fiber and roughage

[ ]	[ ]	[ ]	[ ]
Not at all important	A little important	Moderately important	Very important

9. Is nutritious

[ ]	[ ]	[ ]	[ ]
Not at all important	A little important	Moderately important	Very important

10. Is easily available in shops and supermarkets

[ ]	[ ]	[ ]	[ ]
Not at all important	A little important	Moderately important	Very important

11. Cheers me up

[ ]	[ ]	[ ]	[ ]
Not at all important	A little important	Moderately important	Very important

12. Smells nice

[ ]	[ ]	[ ]	[ ]
Not at all important	A little important	Moderately important	Very important

13. Can be cooked very simply

[ ]	[ ]	[ ]	[ ]
Not at all important	A little important	Moderately important	Very important

14. Helps me cope with stress

[ ]	[ ]	[ ]	[ ]
Not at all important	A little important	Moderately important	Very important

15. Helps me control my weight

[ ]	[ ]	[ ]	[ ]
Not at all important	A little important	Moderately important	Very important

16. Has a pleasant texture

[ ]	[ ]	[ ]	[ ]
Not at all important	A little important	Moderately important	Very important

17. Is packaged in an environmentally friendly way

[ ]	[ ]	[ ]	[ ]
Not at all important	A little important	Moderately important	Very important

18. Comes from countries I approve of politically

[ ]	[ ]	[ ]	[ ]
Not at all important	A little important	Moderately important	Very important

19. Is like the food I ate when I was a child

[ ]	[ ]	[ ]	[ ]
Not at all important	A little important	Moderately important	Very important

20. Contains a lot of vitamins and minerals

[ ]	[ ]	[ ]	[ ]
Not at all important	A little important	Moderately important	Very important

21. Contains no artificial ingredients

[ ]	[ ]	[ ]	[ ]
Not at all important	A little important	Moderately important	Very important

22. Keeps me awake/alert

[ ]	[ ]	[ ]	[ ]
Not at all important	A little important	Moderately important	Very important

23. Looks nice

[ ]	[ ]	[ ]	[ ]
Not at all important	A little important	Moderately important	Very important

24. Helps me relax

[ ]	[ ]	[ ]	[ ]
Not at all important	A little important	Moderately important	Very important

25. Is high in protein

[ ]	[ ]	[ ]	[ ]
Not at all important	A little important	Moderately important	Very important

26. Takes no time to prepare

[ ]	[ ]	[ ]	[ ]
Not at all important	A little important	Moderately important	Very important

27. Keeps me healthy

[ ]	[ ]	[ ]	[ ]
Not at all important	A little important	Moderately important	Very important

28. Is good for my skin/teeth/hair/nails etc

[ ]	[ ]	[ ]	[ ]
Not at all important	A little important	Moderately important	Very important

29. Makes me feel good

[ ]	[ ]	[ ]	[ ]
Not at all important	A little important	Moderately important	Very important

30. Has the country of origin clearly marked

[ ]	[ ]	[ ]	[ ]
Not at all important	A little important	Moderately important	Very important

31. Is what I usually eat

[ ]	[ ]	[ ]	[ ]
Not at all important	A little important	Moderately important	Very important

32. Helps me to cope with life

[ ]	[ ]	[ ]	[ ]
Not at all important	A little important	Moderately important	Very important

33. Can be bought in shops close to where I live or work

[ ]	[ ]	[ ]	[ ]
Not at all important	A little important	Moderately important	Very important

Appendix E

Food Technology Neophobia Scale

Food Technology Attitudes Scale

Please read each of the following statements, and fill in the answer box which best describes your opinion for each statement. You can mark any box from "disagree" to "agree". Please answer all the questions.

1. There are plenty of tasty foods around so we don't need to use new food technologies to produce more.

   [ ] [ ] [ ] [ ] [ ] [ ] [ ]

   Disagree Neutral Agree

2. The benefits of new food technologies are often grossly overstated.

   [ ] [ ] [ ] [ ] [ ] [ ] [ ]

   Disagree Neutral Agree

3. New food technologies decrease the natural quality of food.

   [ ] [ ] [ ] [ ] [ ] [ ] [ ]

   Disagree Neutral Agree

4. There is no sense trying out high-tech food products because the ones I eat are already good enough.

   [ ] [ ] [ ] [ ] [ ] [ ] [ ]

   Disagree Neutral Agree

5. New foods are not healthier than traditional foods.

   [ ] [ ] [ ] [ ] [ ] [ ] [ ]

   Disagree Neutral Agree

6. New food technologies are something I am uncertain about.

[ ] [ ] [ ] [ ] [ ] [ ] [ ]
Disagree Neutral Agree

7. Society should not depend heavily on technologies to solve its food problems.

[ ] [ ] [ ] [ ] [ ] [ ] [ ]
Disagree Neutral Agree

8. New food technologies may have long term negative environmental effects.

[ ] [ ] [ ] [ ] [ ] [ ] [ ]
Disagree Neutral Agree

9. It can be risky to switch to new food technologies too quickly.

[ ] [ ] [ ] [ ] [ ] [ ] [ ]
Disagree Neutral Agree

10. New food technologies are unlikely to have long term negative health effects.

[ ] [ ] [ ] [ ] [ ] [ ] [ ]
Disagree Neutral Agree

11. New products produced using new food technologies can help people have a balanced diet.

[ ] [ ] [ ] [ ] [ ] [ ] [ ]
Disagree Neutral Agree

Continue on next page

12. New food technologies gives people more control over their food choices.

[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Disagree			Neutral			Agree

13. The media usually provides a balanced and unbiased view of new food technologies.

[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Disagree			Neutral			Agree

Appendix F

Food Nanotechnology Attitudes Scale

Food Nanotechnology Attitudes Scale

Please read each of the following statements, and fill in the answer box which best describes your opinion for each statement. You can mark any box from "strongly disagree" to "strongly agree".

1. It would feel uncomfortable knowing I was eating nanoparticles.

[ ]	[ ]	[ ]	[ ]	[ ]
Strongly disagree		Neutral		Strongly agree

2. The use of nanoparticles in food production will benefit the producer more than the consumer.

[ ]	[ ]	[ ]	[ ]	[ ]
Strongly disagree		Neutral		Strongly agree

3. Nobody really knows whether widespread, long term exposure to nanoparticles in food will be harmful.

[ ]	[ ]	[ ]	[ ]	[ ]
Strongly disagree		Neutral		Strongly agree

4. Nanotechnology will result in savings for food consumers.

[ ]	[ ]	[ ]	[ ]	[ ]
Strongly disagree		Neutral		Strongly agree

5. Because of a limited budget many people could not avoid buying cheaper food produced using nanotechnology.

[ ]	[ ]	[ ]	[ ]	[ ]
Strongly disagree		Neutral		Strongly agree

6. Nanotechnology will result in convenience foods being more nutritious.

[ ]	[ ]	[ ]	[ ]	[ ]
Strongly disagree		Neutral		Strongly agree

7. Food produced using nanotechnology will be more acceptable than food produced using genetic modification.

[ ]	[ ]	[ ]	[ ]	[ ]
Strongly disagree		Neutral		Strongly agree

8. Food produced using nanotechnology would be unnatural.

[ ]	[ ]	[ ]	[ ]	[ ]
Strongly disagree		Neutral		Strongly agree

Appendix G

Demographics

Demographic Questionnaire

1. What is your age group?

☐ 18-25 ☐ 26-35 ☐ 36-45 ☐ 46-55 ☐ 56-65 ☐ 65+

2. Gender: ☐ male ☐ Female

3**. Please check on box which best describe your occupation.**

☐ Senior managers, science and health professionals and technicians

☐ Clerical, sales, and service workers

☐ Skilled agricultural, building/crafts workers and machinery operator

☐ Day laborers and food service worker

☐ Student ☐ Homemaker ☐ Other (please specify) _____

4. Do you have access to the internet at home: ☐ Yes ☐ No

5. How much personal time do you spend on the internet (either at home or elsewhere)?

☐ 1 More than 5 hr/day
☐ 2 2-5 hr/day
☐ 3 Less than 2 hrs/day
☐ 4 A few hours/week
☐ 5 A few hours/month
☐ 6 Rarely/never

6. To which of the following groups do you consider yourself to belong? You may choose all that apply.

☐ 1 Black or African-American
☐ 2 White
☐ 3 Asian or pacific islander
☐ 4 American Indian or Alaska native
☐ 5 Hispanic or Latino
☐ 6 Other *(please specify):*_____

7. What is the highest education level you have finished? (Please "X" only one answer)

- ☐ 1 6th grade or less
- ☐ 2 8th grade or less
- ☐ 3 Attended some High School
- ☐ 4 High School Graduate or GED
- ☐ 5 Technical School
- ☐ 6 Some College
- ☐ 7 College Graduate
- ☐ 8 Post Graduate Study

***8.* What was the approximate total income, before taxes, of your household last year? (Please "X" only one answer)**

- ☐ 1 Less than $5,000
- ☐ 2 $5,000 - $9,999
- ☐ 3 $10,000 - $19,999
- ☐ 4 $20,000 - $29,999
- ☐ 5 $30,000 - $39,999
- ☐ 6 $40,000 - $49,999
- ☐ 7 $50,000 - $59,999
- ☐ 8 $60,000 - $69,999
- ☐ 9 $70,000 - $79,999
- ☐ 10 $80,000 - $89,999
- ☐ 11 $90,000 - $99,999
- ☐ 12 Over $100,000

Thank you for participating in this study!

Appendix H

Debriefing Statement

Debriefing Statement

Food Nanotechnology: Understanding the Parameters of Consumer Acceptance

Principal Investigator: Dr. William Hallman
Department of Human Ecology
Rutgers University
ASB III, 3 Rutgers Plaza
New Brunswick, NJ 08901-8520
(732) 932-1966 email: Hallman@rci.rutgers.edu

Purpose of the Study: You consented to participate in a study to help us understand consumers' reactions to new food technologies, specifically the use of nanotechnology in food products.

We asked you to taste two food products containing nanotechnology materials. However the foods you tasted did not contain *any* nanotechnology materials. They were purchased from local grocery stores and are no different from the products that are available to purchase any day. We simply used these products as examples to understand how average consumers might react to such products if they were really produced with this technology. We didn't tell you that, because knowing that they weren't really nanotech foods might have influenced your reactions to the products.

If you are unhappy that we didn't tell you that the products really didn't have nanotechnology materials in them and you would like us to delete your data from our study, we will do so. This will not affect your compensation for participating in the study.

Final Report: If you would like to receive a report of this study (or a summary of the findings) when it is completed, contact the primary investigator listed below. Since all data are confidential, you will not be personally identified in any report from this study.

Concerns: If you have any questions about the study, or about the deception involved, please feel free to contact the Principal Investigator, Dr. William Hallman. If you have any questions about your rights as a research subject, you may contact the Sponsored Programs Administrator at Rutgers University at:

Rutgers University Institutional Review Board for the Protection of Human Subjects
Office of Research and Sponsored Programs
3 Rutgers Plaza
New Brunswick, NJ 08901-8559
Tel: 732-932-0150 ext. 2104
Email: humansubjects@orsp.rutgers.edu

This form was approved by the Rutgers Institutional Review Board for the Protection of Human Subjects on _____; approval of this form expires on _____.