ASSESSING CONSUMER DEMAND FOR INTERMEDIATE WHEATGRASS, A NEW SUSTAINABLE GRAIN

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Nima Homami

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ABSTRACT

Intermediate wheatgrass (IWG), also known as Kernza, is a perennial grain crop that has been lauded as a more sustainable alternative to conventional annual grain crops. The environmental benefits of IWG relative to annual crops include improved water quality, increased soil carbon storage, and enhanced biodiversity. Despite the environment benefits of IWG, consumer demand for it remains poorly understood. Aiming to fill this gap in the literature, we conducted a BDM auction to assess consumers' willingness to pay for breads made using IWG before and after being presented information about its environmental benefits. We also elicited sensory evaluations from consumers to assess the sensory perception of IWG breads before and after being presented this information. Our findings point to the importance of environmental information in a successful marketing strategy for IWG and the need for caution when incorporating IWG into food products to meet consumers' high sensory expectations.

BIOGRAPHICAL SKETCH

Nima is a second year Master's student studying applied economics at Cornell's Dyson School. His research interests are in the fields of sustainable agriculture, social and economic resilience, international development, and their interlinkages. His interest in perennial agriculture began with a summer internship at the Land Institute, a non-profit research institute based in Salina, Kansas. The experience has led him to believe in the potential of perennial crops to radically transform agriculture and has inspired this thesis.

DEDICATIONS

To my parents, who've sacrificed so much for me to be here.

ACKNOWLEDGMENTS

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IWG	Intermediate Wheatgrass, also known as Kernza
WTP	Willingness to Pay

CHAPTER 1

INTRODUCTION

The topic of sustainability has recently received significant attention from policy makers, the private sector and civil society organizations, and become central to the United Nation's 2030 development agenda (*Transforming our world*, 2015). The U.N. Brundtland Commission defines sustainable development as "meeting the needs of the present without compromising the ability of future generations to meet their own needs" (*Sustainability*, n.d.). Achieving sustainable development will necessarily require reimagining agriculture to have a lower environmental footprint, to provide long-term livelihood security, and to be resilient to the effects of climate change (*Sustainable Development Goals: Background*, n.d.). Currently, however, agriculture's ability to be sustainable is constrained by numerous problems. For one, there is agriculture's overdependence on tillage, which is causing destructive topsoil loss through erosion (Montgomery, 2007) and is leading to significant long-term losses in crop productivity (Bakker et al., 2007; Montgomery, 2007). Additionally, current grain production systems are notoriously "leaky" in that they do not do a good job retaining agro-chemicals, such as nitrates, that are applied to the soil (Moss, 2008). These agro-chemicals ultimately end up accumulating in surface and groundwater (Howarth et al., 2002) where they are unavailable to crops and cause harm to the natural environment (Vitousek et al., 1997) and to human health (Ward et al., 2018). Conventional tillage-based agricultural systems also have a lower stock of soil carbon than other, less tillage-intensive systems (Guo & Gifford, 2002), which has adverse consequences for soil fertility (Lal, 2004). Tillage-based agricultural systems, moreover, with their lower stock of soil carbon than no-till systems, sequester less atmospheric carbon dioxide (Lal, 2004), which is an important contributor to climate change. Many of the problems with agriculture today can be traced back to its dependence on annual grain crops, which require more tillage, retain fewer nutrients, contribute more to soil degradation, and contribute to higher levels of atmospheric carbon dioxide than perennial grain crops (Pimentel et al., 2012; Asbjornsen et al., 2014).

Perennial grain crops differ from annual grain crops in that they are seeded once and usually do not have to be reseeded again for three to five years (Pimentel et al., 2012). Annual grain crops, in contrast, must be reseeded at the start of every new growing season. Currently, perennial crops play a negligible role in global cereal grain production with more than 99% of it accounted for by annual crops (*FAO STAT: Data*, 2018). A major reason for the current low production value of perennial grain crops is their low yields (Ryan et al., 2018). Despite their low production value, perennial grain crops have many potential environmental benefits, which become evident by analyzing other perennial cropping systems. Perennial forage systems, for example, promote biodiversity, prevent soil erosion and mitigate environmental contamination issues relative to annual cropping systems (Putnam et al., n.d.). Other perennial cropping systems promote increases in the stock of soil carbon (Guo & Gifford, 2002). The demonstrated advantages of perennial over annual crops have motivated the development of perennial grain breeding programs to close the yield gap between perennial and annual grains and increase the economic viability of perennial grain agriculture (Jungers et al., 2019).

One milestone of research into perennial grains was the introduction of domesticated Intermediate wheatgrass (*Thinopyrum intermedium*; hereafter, IWG). Initially introduced to North America for forage production and conservation plantings in the early 1900s (Hendrickson et al., 2005), IWG was selected as a prime candidate for domestication as a perennial grain crop in the 1980s based on its high seed productivity and favorable agronomic and culinary characteristics (Wagoner, 1990). In 2003, The Land Institute, a non-profit research institute committed to perennializing agriculture, picked up on this research and started an ambitious IWG breeding program that continues to this day (*Our Work: Kernza® Grain*, n.d.). In comparison to major annual grain crops, including corn (Zea mays L.), wheat (Triticum aestivum L.), rice (Oryza sativa L.) and soybean (Glycine max (L.) Merr.). IWG grows a much more extensive root system, allowing it to capture and use water more efficiently (de Oliveira et al., 2018) and preventing soil nutrients from “leaking” into surface and groundwater (Jungers et al., 2019). Land planted to IWG also has up to 15 times more root carbon per hectare than land planted to annual wheat (Sprunger et al., 2018), improving soil health and having the potential for increased soil carbon storage (Culman et al., 2013; Liebig et al., 2018). Compared with annual grains, IWG can also enhance wildlife habitat (Ogle et al., 2011), which raises the biodiversity and recreational value of land on which it is grown. In recent years, grain from improved IWG lines developed at The Land Institute, trademarked as ‘Kernza®’, has been successfully incorporated into commercial food products in local and regional food systems, which has generated substantial interest from consumers, farmers, and food industry firms (Kunzig, 2011; Bitman, 2013; Haspel, 2019).

The increase in public awareness about IWG has accompanied a more general increase in public awareness about environmental issues related to agriculture and sustainable production systems. According to Nilsen, just 22% of consumers globally were willing to pay more for an eco-friendly product in 2011 relative to conventional products (Reints, 2019). Yet, only four years later this figure more than doubled, crossing the 50% threshold (Ibid.). Another study published in 2019 by the research firm CGS, found that 68% of global consumers rate sustainability as important with 35% indicating they would pay 25% more than the original price for products produced sustainably (*The Results are in*, 2019). Further research found that during the years 2013 to 2018, sales of sustainability-marketed products grew 5.6 times faster than those of products conventionally marketed (Reints, 2019). In more than 90% of product categories, "the sustainability-marketed products outperformed their conventional counterparts" (Ibid.). These trends point to the growing importance of sustainability to consumers, and the potential for a more sustainable grain like IWG to command a significant price premium over traditional, annual grains.

Aware of these trends, many private stakeholders have already begun investing in IWG as a way of meeting their commitments to sustainability. Examples include General Mills and Patagonia Inc. (Scott, 2016; Hyslop, 2019), which are both currently promoting new lines of IWG-based products including breakfast cereal and craft beer (Figure 1). Bakers across the country have also been experimenting with IWG (*Our Work: Kernza® Grain*, n.d.). While there is interest among growers, food processors, and retailers in supplying IWG products, the underlying consumer demand for IWG remains poorly understood with no studies to date addressing the topic. This study addresses this gap in the literature, focusing specifically on artisanal bread.

This study focuses on the premium bread market, where there is already ongoing research into developing a consumer product made using IWG (Banjade et al., 2019; Marti et al., 2015, 2016; Rahardjo et al., 2018). It is, moreover, a promising market for IWG because of its size, valued in the U.S. at more than a billion dollars (Conway, 2017; *Understanding the Opportunities in Bakery*, n.d.). Moreover, the premium bread market is growing fast, with a compound annual growth rate in sales of specialty breads and baked goods in the U.S of 12.5% from 2014 to 2017 (Shahbandeh, 2018). If IWG bread is shown to compete well with other specialty breads already found in this market, this will provide evidence for the grain's overall potential as a consumer product. This can have widespread ramifications for the food industry, for agriculture, and for the environment.

Figure 1: On the left is an image of Patagonia Provision's "Long Root Ale" introduced in 2016 (Rainey, 2016), and on the right General Mills' Honey Toasted breakfast cereal introduced in 2019 (Christenson, 2019).

We designed and implemented an economic experiment to examine the demand for IWG bread in the consumer premium bread market. The experiment entailed eliciting the willingness to pay (WTP) for bread using various levels of IWG as ingredient, from a sample of residents of upstate New York using a Becker–DeGroot–Marschak (BDM) auction. In the experiment, we used two breads containing different fractions of IWG (15% and 25%) and two control breads containing no IWG (whole wheat and spelt). WTP data was collected from subjects before and after they received information that summarized IWG's environmental benefits, and before and after they tasted the breads. An additional sensory evaluation by the (untrained) subjects was performed both in the presence and absence of the environmental information about IWG (i.e. labeled and unlabeled).

Building on the central question of what is the consumer demand for IWG, the specific research questions this study poses are the following: Will consumers pay relatively more for the IWG breads than for the control breads when presented with the environmental label? Will consumers pay relatively more for the IWG breads if all the breads are unlabeled? Before environmental labeling, how does consumers' sensory perception of the IWG breads compare to their sensory perception of the other breads? After labeling? What is the effect, if any, of environmental labeling on how much consumers like and will pay for the IWG breads?

Our findings suggest that environmental labeling raises the WTP for the IWG breads and enables them to be competitive with the non-IWG control breads in terms of retail prices, especially among pro-environment consumer segments. We find that the sensory liking of the IWG breads tends be lower relative to the control breads, especially for breads that contain a higher fraction of IWG. The labeled IWG breads also appear to have a higher sensory liking than the unlabeled IWG breads, especially for pro-environment consumers and breads that contain a lower fraction of IWG. These findings point to the importance of environmental information in a successful marketing strategy for IWG and the need for caution when incorporating IWG into food products to avoid failing to meet consumers' high sensory expectations.

CHAPTER 2

LITERATURE REVIEW

This literature review first examine studies evaluating the potential effects of environmental labeling on willingness to pay (WTP) for consumer products. Next, it discusses the use of experimental auctions to study consumer demand for product attributes, Third, it examines empirical and theoretical studies designed to understand how environmental labeling might affect sensory perception. Finally it reviews the existing empirical evidence of determinants of demand of food products using IWG as an ingredient.. The section concludes with a discussion of this study's contribution to the literature.

There is a large number of studies from different contexts analyzing the impacts of environmental labeling on consumer WTP and most show evidence for some positive effects on prices, albeit there is considerable heterogeneity in the magnitude. Teuber et al. (2016) revealed a premium for bread that enhanced biodiversity of around 35% relative to conventional bread in an experimental auction conducted in Germany. Kima et al. (2016), in a choice experiment conducted in South Korea, found a premium for “low carbon” labeled apples of up to 54%. Other case studies from South Africa (Owusu-Sekyere et al., 2019), China (Zhao et al., 2018), and Italy (Lombardi et al., 2017) have obtained similar findings on consumer WTP for products that emit less carbon and use less water. These studies, nevertheless, also demonstrate that the effect of environmental labeling on WTP is moderated by a variety of individual-specific variables, such as general attitudes towards environment, professional occupation, or socio-economic background. It can also be moderated by consumers’ perceptions of the effectiveness of their consumption decisions in shaping environmental outcomes (Lombardi et al., 2017; Zhao et al., 2018). Even when the environmental label has an effect on consumers’ WTP, it may not be the dominant effect driving consumers’ product valuations. For example, Grunert et al. (2014) in another choice experiment evaluating six different food products, found after sampling more than 4,000 respondents from six European countries that while consumers did positively value a product’s environmental attributes, their measured importance was still on aggregate only one-half that of price and one-fifth that of nutrition attributes. The results also demonstrated heterogeneity in the importance of environmental attributes across product types with, for example, environmental attributes being more important for chocolate and less important for soft drinks. In summary, the literature on the effect of environmental labeling points to the existence of some positive effects on consumer WTP. However, the size of this effect is conditional on the type of consumer, product and information presented.

There are a variety of methods of measuring consumer WTP, which is instrumental to this study. One approach is to use a hypothetical, stated-preferences survey in which consumers directly state their WTP for a product. The main problem with this approach is that respondents have no incentive to reveal their true valuation of a product (Lusk et al., 2004). Consequently, the responses they give to researchers often diverge strongly from their actual willingness to pay (Fox et al., 1998). The problem of using stated preferences surveys is compounded for environmental goods, for which a large share of consumers indicate they would pay more for environmental goods, but only a minority translate their stated preferences into actual shopping behavior. Researchers have sometimes termed this phenomenon the "30:3" syndrome based on the observation that 30% of individuals say they care about the environmental and ethical impacts of their purchases, yet the market share of green products rarely surpasses 3% (Hobson, 2004). These observations emphasize the need for an incentive compatible process of deriving WTP estimates.

Another approach to measuring WTP is an incentive-compatible experimental auction. In an experimental auction, subjects are given an endowment and asked to bid on the different products being evaluated with the market price being revealed at the end. Subjects' bids govern how much of their endowment is remaining by the end and whether they purchase any of the products. Their bids should in theory proxy for their true WTP because bidding above their true WTP would leave them vulnerable to paying more for something than it is worth to them, while bidding below their true WTP would leave them vulnerable to losing out on an opportunity to pay less for something than what it is worth to them (Becker et al., 1964). The advantage of using an experimental auction over, for example, a non-hypothetical choice experiment, is that an experiment auction directly shows the WTP for each participant, compared to a choice experiment in which the WTP must be estimated using a discrete choice model that relies on a given set of assumptions (Canavari et al., 2019). Experimental auctions, moreover, have been widely applied in the study of WTP for food products, such as pro-environment wine, fair trade chocolate, non-GM potato chips, and organic meats, fruits, and vegetables (Barber et al., 2014).

The two most popular auction methods are the Becker–DeGroot–Marschak (BDM) method and the second-price method (Canavari et al., 2019). In BDM auctions the "winners", i.e. the auction participants who successfully purchase the item being auctioned, are determined by some randomly selected "market price". Auction participants who bid at least the market price purchase the product at that market price using some or all of their initial endowment. Participants who bid below the random market price retain the full value of their initial endowment. On the other hand, in second price auctions the winner is usually the participant with the highest bid and the market price is the value of the second highest bid. Often, when evaluating novel goods in second-price auctions, multiple bidding rounds are used to allow subjects to incorporate market feedback into their valuations (Lusk et al., 2004). The endogenous manner in which the market price is determined in a second-price auction makes it susceptible to overbidding bias, especially in later rounds (Ibid.). Second-price auctions are also not well-suited for off-margin bids, that is, bids which deviate significantly from the second highest bid (Canavari et al., 2019). These problems with the second-price auction merited the use of a BDM auction for this study.

A review of the extant literature suggests that credence attributes, i.e. attributes that affect consumers' confidence in a seller's integrity or credibility, frequently have an effect on consumers' sensory perception of a product (Fernqvist & Ekelund, 2014). As cited in Fernqvist & Ekelund (2014), credence attributes for food products can include information on health, production methods, environmental and social orientation, and product origin. Credence attributes differ from other product attributes, such as taste, in that they cannot be directly evaluated by consumers. Credence attributes affect sensory perception by generating extrinsic cues about a product's sensory performance. These cues elicit expectations from consumers prior to tasting. When these expectations are not met after tasting, consumers subconsciously adjust their sensory perception of the product in the same or opposite direction of its expected sensory performance (Piqueras-Fiszman & Spence, 2015). This discrepancy between expected and actual sensory performance, i.e. the sensory disconfirmation, is what drives the effect of credence attributes on sensory perception.

In what direction consumers will subconsciously adjust their sensory perception of a product when confronted with sensory disconfirmation is also discussed in Piqueras-Fiszman & Spence (2015). After a review of the empirical literature on sensory disconfirmation and the neuro-science literature, we find evidence to support the assimilation-contrast model. This model states that if the discrepancy between expected and actual sensory performance is not excessively large consumers' sensory perception of a product after tasting will be close to the product's expected sensory performance prior to tasting. On the other hand, if the discrepancy between expected and actual sensory performance is excessively large consumers' sensory perception of a product after tasting will deviate strongly from the product's expected sensory performance prior to tasting (Piqueras-Fiszman & Spence, 2015). Thus, if being given information about a product prior to tasting raises a consumer's sensory expectations and the product's true sensory performance is not substantially different from its expected performance, then the consumer's sensory perception of the product is likely to be higher than that of another consumer who had been given no information prior to tasting. On the other hand, if the presented information results in high sensory expectations that diverge strongly from a product's true sensory performance to the extent that the consumer consciously perceives the difference, then information could effectively lower the consumer's sensory perception of the product relative to that of another consumer who had been given no information. Examples of hedonic liking after experiencing a product aligning with expected performance can be found with goods labeled as organic, locally produced, and ethically sourced (Fernqvist & Ekelund, 2014). In some cases, sensory disconfirmation can be extreme enough that it leads to sensory perception moving in the opposite direction of expected performance, such as with smoked-salmon ice cream (Yeomans et al., 2008).

We now shift focus to discussing the nascent literature on IWG's performance as a consumer good. The seminal study by R. Becker et al. (1991) was the first to demonstrate a variety of potential consumer applications for the grain, including as an ingredient in cookies, muffins, cakes, and bread. Becker et al. (1991) reported that IWG as an ingredient in bread, made with a 15% IWG-85% whole wheat flour mix, imparted a distinct, nutty-grain taste. A panel of trained judges rated the bread's overall characteristics between fair and good. The IWG bread, however, lacked some of the baking properties of pure wheat breads forcing the authors to use added wheat gluten to produce a loaf of comparable volume. The shortcomings of using IWG in baked products were later featured in studies in which IWG was shown to be less capable than wheat of forming the kinds of gluten networks that are essential to the baking process (Marti et al., 2015, 2016; Rahardjo et al., 2018). The lack of the gluten forming proteins in IWG resulted in bread that had difficulty rising and was more compact than purely wheat-based breads. This could be expected to deflate consumers' sensory perception of the IWG breads since consumers may perceive them as being less fresh and more difficult to chew (Hager et al., 2012). The literature on IWG's performance as a consumer good thus reveals significant challenges that need to be overcome to meet consumer expectations on quality.

This study's presents several original contributions to the literature. It is the first to examine consumer willingness to pay (WTP) for an IWG product. It is also the first to link information about IWG's environmental benefits with consumers' WTP for and sensory evaluation of an IWG product. Towards this end, we designed and implemented a consumer experiment employing a BDM auction to assess the change in WTP and sensory liking in response to information about IWG. This study will help researchers determine whether IWG can command a price premium from consumers and whether its unique sensory profile is an asset or liability for product development.

CHAPTER 3

EXPERIMENTAL DESIGN

Prior to launching this experiment, we had formed several hypotheses regarding what consumers would be willing to pay for the IWG breads and their sensory perception of the IWG breads. Firstly, we hypothesized that consumers would value the environmental benefits of IWG and consequently pay more for the IWG breads in the presence of information than in the absence of information. We also hypothesized that consumers would pay relatively less for the IWG breads in the absence of information compared to the other control breads because of IWG's relatively inferior baking properties, especially for bread made with a higher fraction of IWG. We hypothesized that consumers would more positively perceive the sensory qualities of the IWG breads after receiving information. This experimental design was conceived as an attempt to elicit a consumer's true willingness to pay for and sensory perception of breads made with IWG, and, enable a comparison with other purely wheat-based breads.

For this experiment we used a BDM auction and a short sensory questionnaire conducted in a controlled lab environment that compared four different bread varieties: two composite IWG-wheat breads and two purely wheat control breads. The IWG-wheat breads were either 15% IWG or 25% IWG (per overall mass of the composite wheat-IWG flour). Every subject was presented information summarizing the environmental benefits of IWG and every subject had the opportunity to taste the breads. The order in which subjects tasted the breads relative to when they received information about the breads was randomized to allow us to assess the effect of tasting on WTP, the effect of information on WTP, and the effect of information on sensory perception. Finally, after the auction and sensory evaluations were completed, subjects filled out a short exit survey soliciting demographic information and information about subjects' purchasing behavior.

The four different bread varieties used in this experiment were a spelt bread, a 15% IWG bread, a 25% IWG bread, and a whole wheat bread. Bread was considered ideal for this kind of study because not only is there a premium market for it, but bread with its simpler ingredients helps better highlight the distinct taste of the IWG. All the breads were sourdough and baked in a wood-fired oven. The decision to use sourdough was based on advice given by collaborators from the Land Institute about the relative suitability of IWG as an ingredient in sourdough breads. The dough for each bread was prepared and baked by a professional baker with experience in making sourdough bread and baking with IWG. The baker was based locally in Ithaca. For all the breads the only ingredients used was a combination of flour, water, yeast and salt. The full recipe is provided in Appendix A.

For the IWG breads we gave the bakers a great deal of liberty in creating a recipe that would produce the "best tasting" IWG bread that would be competitive with existing, purely wheat breads. The IWG breads were made using a mixture of IWG flour and high extract wheat flour. Through a process of trial and error, the bakers found that 25% IWG (per overall mass of the composite IWG-wheat flour) reflected the maximum IWG incorporation rate before the leavening properties of the bread became seriously compromised. 15% IWG reflected the level at which the distinct taste of IWG was noticeable while retaining desirable leavening properties. The IWG grain was sourced from a farm in upstate New York in the summer of 2018 and hammer milled into flour in April of 2019.

As for the control breads, their selection was driven by market research and baker input. The spelt bread was made using a mixture of whole grain spelt flour (50%) and high extract wheat flour. Spelt bread was chosen as one of the control breads because of spelt's potential of competing with IWG in the specialty grain market, where spelt has seen triple digit growth in annual sales (*Spin Trendwatch-Grains*, 2014) and benefited from a growing public interest in so-called "ancient grains" (*2015 Culinary Forecast*, 2014). Spelt bread was also identified by the baker as one of their more popular selling breads. The whole wheat bread was made using 100% high extract wheat flour. Whole wheat bread was selected as one of the control breads because of its ubiquity and familiarity with most American consumers. In 2019 about 192 million Americans were reported to most often consume bread that was whole wheat or multi-grain (*Types of Bread Consumed in the U.S*, 2019). The wheat and spelt flours were both locally sourced and produced organically.

To characterize the nutritional properties of the IWG flour, samples were collected and analyzed for calories, carbohydrates, fat, fiber, ash content, moisture, and protein (Appendix B). This analysis was conducted by Medallion Labs of Minneapolis, MN, a chemical testing laboratory certified in compliance with A2LA Food Testing Program Requirements.

Several criteria were followed regarding the timing and location of the experiment, and the method of recruiting subjects. The experiment was organized during the last three weeks of September and the first week of November 2019. Subjects were recruited through a Cornell University-based experimental economics research laboratory's email system. Undergraduate students and individuals younger than 18 were purposefully prevented from participating in the experiment to help ensure the sample would be more representative of working adults. For their participation in the experiment each subject attended one of twelve 40-minute sessions. No more than 24 subjects could be accommodated in each session. All sessions were organized during work hours, 10 AM to 4:30 PM, on a Friday. All sessions were hosted in a facility on Cornell University's campus.

Certain criteria were also followed regarding bread preparation to facilitate bread serving and ensure subjects would be able to state accurately and reliably their WTP and sensory ratings for each bread. To ensure freshness, the breads were freshly baked in the morning of each day of the experiment and sliced an hour before each session. Because serving an entire cross-section may have had a satiation effect on bids as subjects sampled the later breads, only a portion of the top crust was used (Figure 2). The bottom crust was discarded. ~1.5 cm thick slices were used. Each bread variety was labelled with a different letter of the alphabet, from letters "A" through "D". Subjects sampled and bid on the breads in alphabetical order. The letter label for each bread variety rotated across sessions to control for first order and carryover effects that might bias subjects' bids and sensory ratings. Different colored sticky notes were used solely as a mnemonic device for researchers to facilitate bread serving.

Figure 2: Bread varieties used in experiment. A = 15% IWG, B = Whole wheat, C = Spelt, D = 25% IWG

Before beginning the experiment, subjects were given general instruction about the rules and flow of the experiment. Subjects were instructed to take a seat in any one of the twenty-four individual computer terminals each equipped with a privacy shield and a preloaded consent form (Figure 3). They were informed verbally that all decisions they made would be kept strictly confidential, were instructed not to talk with each other, and were told to treat the $25 endowment they would be receiving for their participation in the experiment as money that was already theirs. Subjects were additionally told they would be receiving information about four different varieties of bread and would be given the opportunity to taste each of them. The order in which subjects received information about the breads relative to tasting the breads was randomly determined in advance for each session. Half of the twelve sessions were pre-assigned to the taste-first group, half were pre-assigned to the information-first group (Figure 4). As their names imply, the taste-first group tasted the breads first, while the information-first group received information about the breads first. The purpose of this design was to enable an estimation of the effects of both information and taste on WTP, and the effects of information on sensory perception.

Figure 3: An individual computer terminal where subjects would taste the breads, receive information about the breads, and submit their bids, sensory ratings and all other information relevant to the experiment.

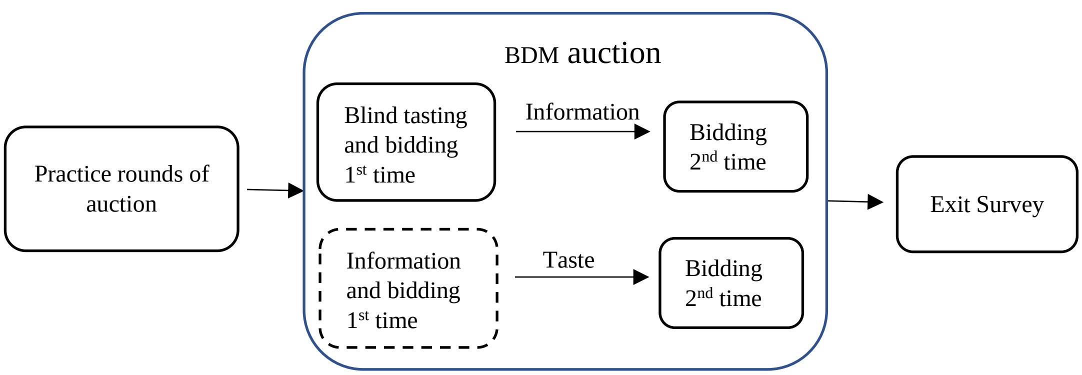

Figure 4: Visualization of experimental flow

After the flow of the experiment was explained to them, subjects were given a brief verbal introduction of the rules of the auction and subjects' optimal bidding strategy. To avoid demand reduction effects, out of a series of auctions subjects were told that only one would be randomly selected to be "binding", i.e. to involve a real-world transaction. To reinforce understanding of the rules and the optimal bidding strategy, practice rounds were used in which subjects bid on a dollar bill and a packet of candy in a hypothetical auction. At the end of the practice rounds there was a login page, in which subjects would have to enter the password we provided them. A login page was used throughout the experiment after each round of bidding to discourage subjects from rushing through the experiment.

After finishing the practice rounds, subjects in the taste-first group then proceeded to taste the breads and fill out a sensory evaluation for each bread. The affective test method was used, which entailed presenting the (untrained) subjects with a questionnaire asking them to indicate how much they liked different attributes of each bread. The affective test method was used because it is the most popular sensory test method utilized in the food industry to assess consumer preference (Chambers & Wolf, 1996). The different attributes being tested were overall liking, liking of taste, liking of appearance, and liking of texture. Subjects evaluated each on a 7-point scale with 1 being least liked and 7 being most liked. Participants had palate cleansers (water and cucumber slices) available to minimize taste bud fatigue and to remove flavor carryover as they moved from one bread to the next.

After filling out a sensory evaluation for each bread, the subjects in the taste-first group were then asked to submit bids for an approximately 1.5 lb. loaf of each bread. Subjects could submit bids no lower than $0 and no higher than $8. Subjects were also asked to indicate their interest in purchasing each bread on a 5-point scale.

After the first round of bidding, the subjects in the taste-first group were then given information about each of the bread varieties. The information subjects received included general, identifying information for each of the breads and information that summarized IWG's environmental benefits. The construction of this information about IWG was the product of a collaboration between researchers from The Land Institute and Cornell University. It also was based loosely on a label already developed by General Mills for a new line of IWG-based cereal (Figure 5). The exact wording of the information presented to subjects is shown in Figure 6. After subjects were presented information they were asked to bid again on each bread.

Figure 5: Environmental claims employed by General Mills for their new line of Honey Toasted breakfast cereal

SPELT- This bread is made of spelt, a common ingredient in traditional-style breads.

WHOLE WHEAT- This bread is made of whole wheat.

15% KERNZA- This bread is made with 15% Kernza flour. Kernza is a perennial grain, which makes it very different from wheat, rye, and other annual grains that need to be replanted every year. Kernza has deep roots that hold the soil and prevent it from being lost due to heavy rain and strong wind. Kernza can protect the quality of our water and help fight climate change by storing carbon from the air securely in the soil.

25% KERNZA- This bread is made with 25% Kernza flour. Kernza is a perennial grain, which makes it very different from wheat, rye, and other annual grains that need to be replanted every year. Kernza has deep roots that hold the soil and prevent it from being lost due to heavy rain and strong wind. Kernza can protect the quality of our water and help fight climate change by storing carbon from the air securely in the soil.

Figure 6: Environmental label used in this experiment

After all the bids had been collected, subjects were told which of their 8 bids (4 bids for each round x 2 rounds) would be treated as binding and whether they had "purchased" the corresponding bread at the random market price. Subjects who purchased the bread would have the market price deducted from their $25 endowment.

The above setup was reversed for the information-first group, with subjects first being given information about each bread, bidding on each bread, tasting each bread, filling out a sensory evaluation, and bidding again on each bread. For the information-first group only, subjects additionally indicated whether their expectations of each bread had been satisfied or not after tasting them. A 5-point scale was used to measure the extent to which subject expectations were met with 1 indicating far short of expectations and 5 indicating far exceeded expectations.

After the auctions, subjects completed an exit survey. This survey asked about demographic information and purchasing habits. Subjects were also asked to report how strongly they agreed with a statement about taking action to reduce their personal environmental footprint. Their responses were measured using a 7-point Likert scale with 1 being most disagree with the statement that they take personal action to reduce their environmental footprint, and 7 being most agree with the statement. A subject's response to this question was used as an index of their propensity for engaging in pro-environment behavior. Highlights from this survey can be found in the section "Data Description".

CHAPTER 4

EMPIRICAL METHODOLOGY

Modeling on the taste-first group was performed first to evaluate the effect of information on WTP. A panel random effect Tobit model was used with bids below $1 censored. The analysis was panel because it entailed a within-subject comparison of bids before and after receiving information. The individual specific disturbance term is assumed to come from a random sample and be uncorrelated with any variation in bread type, information status, or subject attributes. A Tobit model is used to correct for the censored nature of the data at or below $1 by modifying the likelihood function. The justification for using a $1 lower censoring limit is provided in the results section. The specification used for this regression of WTP in the taste-first group is shown below.

$$WTP_{ijs}^{*} = \alpha + \beta_{V2}V_2 + \beta_{V3}V_3 + \beta_{V4}V_4 + \beta_s I + \beta_{VI2}(I * V_2) + \beta_{VI3}(I * V_3) + \beta_{VI4}(I * V_4) + u_i + \boldsymbol{\beta_X X_i} + \varepsilon_{ijs} \quad (1)$$

Where,

$$\varepsilon_{ijs} \sim N(0, \sigma^2)$$
$$WTP = WTP^* \text{ if } WTP^* \geq 1$$
$$= 1 \text{ if } WTP^* < 1$$

In the above specification, WTP_{ijs}^{*} represents the latent willingness to pay for subject -*i*-, bread type -*j*- and information status -*s*-. WTP represents the observed willingness to pay (i.e. subjects' bids) and is shown as a piecewise function of WTP^*. The average effect of information on willingness to pay for all the breads is represented by the coefficient on dummy variable, I, which is assigned a value of 1 when the subject has received information about the breads, 0 otherwise. V_2, V_3, and V_4 are dummy variables corresponding to bread types 15% IWG, 25% IWG, and whole wheat, respectively. Each coefficient on V_2, V_3, V_4 represents the average relative willingness to pay for the corresponding bread compared to the reference spelt control bread when no information about the breads has yet been provided but subjects have tasted the breads. Each coefficient on the interactions of I and V_2 , V_3, V_4 represents the average effect of information on relative willingness to pay for that corresponding bread compared to the reference spelt control bread. The parameter α is a constant that refers to the average willingness to pay for the spelt control bread when no information has yet been provided and subject covariates, X_i, are all evaluated at their base values (i.e. zero). $\boldsymbol{X_i}$ includes standard demographic variables, i.e. age, sex, ethnicity, income and household size, as well as variables associated with premium bread demand, i.e. the frequency of premium bread consumption, where a subject normally shops for bread and whether a subject was hungry when they entered the lab. The coefficients on X_i are estimates of their marginal effects on willingness to pay. The term u_i is an individual-specific random effect used to control for unobserved heterogeneity between individuals. The term ε_{ijs} is an individual, bread type, and information-status specific error term.

Next, a model was fit to the information-first data to evaluate the effect of taste on willingness to pay. A similar panel random effect Tobit model was used with bids below $1 censored. The full specification is shown below.

$$WTP^*_{ijt} = \alpha + \beta_{V2}V_2 + \beta_{V3}V_3 + \beta_{V4}V_4 + \beta_T T + \beta_{V2xT}(T * V_2) + \beta_{V3xT}(T * V_3) + \beta_{V4xT}(T * V_4) + u_i + \boldsymbol{\beta_X X_i} + \varepsilon_{ijt} \quad (2)$$

In the above specification, WTP^*_{ijs} represents the latent willingness to pay for subject -*i*-, bread type -*j*- and tasting status -t-. The coefficients on V_2, V_3, V_4 each represents the average relative willingness to pay for the corresponding bread compared to the reference spelt control bread when subjects have not yet tasted the breads but have received information about them. In this specification dummy variable T substitutes for the dummy variable I of the previous specification. T is assigned a value of 1 when the subject has tasted the breads. The coefficient on T represents the average effect of tasting on WTP for all the breads. The coefficients on the interactions of T and bread type, V_2, V_3 , V_4 , each represents the average effect of tasting on relative WTP for the corresponding bread compared to the reference spelt control bread. Similar to the previous specification, α is a constant that refers to the average willingness to pay for the spelt control bread when subjects have not yet tasted the breads and subject covariates, $\boldsymbol{X_i}$, are evaluated at their base values. The interpretability of the coefficients on $\boldsymbol{X_i}$ is the same as in the previous specification.

Modeling using generalized least squares was also performed to assess the information effect on overall liking and liking of bread taste. The analysis was between-subject in that the sensory ratings of subjects who received information about the different breads before tasting them was compared with the sensory ratings of other subjects who only received information about the different breads after already tasting them and completing their sensory evaluations. The full specification is shown below.

$$S_{ij} = \alpha + \beta_{V2}V_2 + \beta_{V3}V_3 + \beta_{V4}V_4 + \beta_S I + \beta_{V2xS}(I * V_2) + \beta_{V3xS}(I * V_3) + \beta_{V4xI}(I * V_4) + u_i + \boldsymbol{\beta_X X_i} + \varepsilon_{ij} \quad (3)$$

In the above specification S_{ij} may be interpreted as the sensory rating (either overall liking or taste liking) for individual -*i*- bread type -*j*-. The coefficients on V_2, V_3, V_4 each represents the average relative sensory rating of the corresponding bread compared to the reference spelt control bread when no information about the breads has yet been presented. The coefficient on I represents the average effect of information on the sensory rating for all the breads. The coefficients on the interactions of I and bread type, V_2, V_3, V_4 , each represents the average effect of information on relative sensory perception for the corresponding bread compared to the reference spelt control bread. The coefficients on $\boldsymbol{X_i}$ are estimates of their marginal effects on sensory rating. A marginal analysis was later performed to assess the impact of information on absolute sensory liking of the IWG breads.

Modeling using a random effects Tobit model with a lower censoring limit of $1 was performed on second round bids for the information-first and taste-first groups to assess what the relative willingness to pay for the IWG breads would be once variation in sensory performance had been controlled for.

$$WTP_{ij}^{*} = \alpha + \beta_{V2}V_2 + \beta_{V3}V_3 + \beta_{V4}V_4 + \beta_{TF}TF + \beta_S S_{ij} + u_i + \boldsymbol{\beta_X X_i} + \varepsilon_{ijt} \tag{4}$$

In the above specification WTP_{ij}^{*} represents the latent willingness to pay for subject -*i*-, bread type -*j*-. The coefficients on bread type, V_2, V_3, V_4, each represents the average relative willingness to pay for the different breads compared to the reference spelt control bread after controlling for differences in sensory performance. The estimated coefficients on S_{ij} represent the average marginal effect of an improvement in sensory performance on willingness to pay. In the above specification, the estimated coefficients on X_i can be interpreted the same way as in Equations (1) or (2). The dummy TF_i is assigned a value of 1 when subject -*i*- is in the taste-first group, 0 when they are in in the information-first group. An additional comparison of second-round predicted WTP based on the regressions described in Equations (1) and (2) was also performed to assess what the relative premium for the IWG breads might be if they were introduced (as is) into a retail setting.

For every model we ran it on our overall sample, in addition to subsamples of consumers who we identified as either “pro-environment” or “non-pro-environment”.

This kind of segmented analysis allows us to see whether receiving information about the breads elicits a different WTP or sensory response from pro-environment consumers than from the rest of consumers, whether tasting the breads elicits a different WTP response from pro-environment consumers than from the rest of consumers, and whether the IWG beads command a higher relative premium for pro-environment consumers than for the rest of consumers.

CHAPTER 5

DATA DESCRIPTION

In this experiment, 1,768 observations were collected from 221 subjects combined over all 12 sessions. To assess the representativeness of this experimental sample comparisons were made between the experimental sample and the 2019 Food Marketing Institute (FMI) sample of U.S. grocery shoppers, which surveyed over 1700 respondents and was weighted to be representative of the U.S. grocery shopper population (Table 1). Additionally, a nationally representative index of Americans' propensity for engaging in pro-environment behaviors was obtained using data from a 2017 Pew Survey (Anderson, 2017). Pew Survey respondents who indicated that they "always" take actions to reduce their environmental footprint were identified as "pro-environment". The Pew Survey results were highly comparable with our own findings on the fraction of "pro-environment" subjects, who "whenever possible" take action to reduce their environmental footprint. The comparisons between our experimental sample and the national sample are shown in Table 1 and generate several useful insights about the representativeness of our sample.

There are some noticeable differences in the composition of the experimental sample and the national sample. The subjects in the experimental sample skewed much more educated than respondents in the national sample with nearly 4 out of 5 experimental subjects reporting having at least a 4-year degree, compared to around 1 in 2 national sample respondents. We also see a much greater share of women in the experimental sample compared to the national sample (77% versus 54%). The experimental sample also skewed much younger, with nearly half being younger than 35 compared to little more than 1 in 4 for the national sample. With respect to ethnicity, Asians (shown as part of the “other” category) were disproportionately overrepresented in the experimental sample compared to the nation sample. Black and Latin American peoples, on the other hand, were disproportionately underrepresented in the experimental sample compared to the national sample.

There are, as well, some similarities between our experimental sample and the national samples. Comparing the breakdown of each sample belonging to each income tier, we observe that the experimental sample had a similar income distribution as that of the national sample. Based on household composition, as well, we see similarities with only a slight tendency toward single-member and childless households in the experimental sample. Moreover, the share of subjects in the experimental sample who were categorized as “pro-environment” was about equivalent to that of respondents in the Pew sample.

These comparisons are relevant by placing our experimental results in proper context. They show that our experimental sample despite being more educated did not skew wealthier or more “pro-environment” than the rest of the country. Despite being much younger, the experimental subjects also did not appear much more likely to be single and childless than the rest of the country. The comparisons with the national sample demonstrate that our results have greater relevance for subpopulations of American consumers that tend to be younger, more educated, more female, and more Asian than the rest of the country. Based on income, household composition, and propensity to engage in environmental behaviors, the experimental sample does well in representing the overall population of American consumers.

Table 1: Sample Comparison

	Experimental Sample	Nationally Representative Sample
Household Income*		
<$45,000	32%	~30%
$45,000 - $100,000	40%	~41%
$100,000 and up	28%	29%
Schooling		
High school	4%	18%
Some college	18%	33%
4-year degree	44%	31%
Post-graduate degree	35%	18%
Women	77%	54%
Age		
18-24	23%	10%
25-34	26%	18%
35-44	17%	17%
45-54	14%	17%
55-64	18%	17%
65 or older	2%	21%
Ethnicity		
Latin American	7%	16%
Black/ African diaspora	5%	13%
Other	28%	9%
White	68%	63%
Household composition		
Single-member household	29%	25%
2-member household	35%	37%
3-member household	21%	18%
4 or more-member household	15%	20%
Has a spouse	49%	54%
Has a child(ren)	20%	25%
Where mainly buy bread?		
Specialty retailer	19%	-
Wholesale club/Supercenter store	19%	-
Supermarket	63%	-
Premium bread consumption		
Never or rarely consume	33%	-
1-2 meals per week	28%	-
3-5 meals per week	21%	-
1 meal per day/6 meals per week	15%	-
2 meals per day	2%	-
Strongly pro-Environment	19%	20%

Note: Due to rounding error the percentages may not add up to 100. In the nationally representative sample, values from the 2019 FMI Grocery Shopper Survey and 2017 Pew Survey were used.
*In the FMI survey a $40,000 income threshold was used.

For questions subjects might not feel comfortable answering they were given the option of choosing "Prefer not to answer". 19 subjects chose not to indicate their income, 8 chose not to indicate their ethnicity, which created missing values for those observations. To reduce the number of missing values imputed values of income were used for missing observations based on an OLS regression of income on other subject covariates, which gave a high R^2 of 0.55. The new imputed values allowed 18 of the 19 formerly excluded subjects to be included in the final analysis. For ethnicity, a multinomial regression of ethnicity on other subject covariates was not deemed to have high enough statistical power to derive useful imputed values.

Summary statistics on subjects' bids disaggregated by bread type and bidding round were collected (Table 2). The mean second round bid for a loaf of bread in this experiment was $2.18, which was much lower than the breads' $4-6 market price. A tukey mean comparison test revealed no statistically significant differences in the second-round bids across bread varieties. We, moreover, observe that the average second-round bids for the 15% IWG bread and 25% IWG bread in the taste-first group were $0.26 and $0.29 higher than their respective average first-round bids. Statistical t-tests revealed that the second-round bids of subjects in the taste-first group were not significantly different from their first-round bids. With respect to the information-first group, we observe that the average second-round bids for the 15% IWG bread and 25% IWG bread were $0.17 and $0.43 lower than their respective average first-round bids. Statistical t-tests revealed that the second-round bids of subjects in the information-first group for the 25% IWG bread were significantly different from their first-round bids.

Table 2: Summary statistics

			Spelt	Whole Wheat	15% IWG	25% IWG
Taste-first group N=113	Round 1 (Taste only)					
		WTP ($)	2.29	2.2	2.07	1.9
			(0.14)	(0.13)	(0.14)	(0.13)
		Taste liking	5.37	5.39	5.2	4.85
			(0.12)	(0.13)	(0.14)	(0.16)
		Overall liking	5.47	5.57	5.39	5.01
			(0.11)	(0.12)	(0.13)	(0.14)
		Appearance liking	5.81	5.93	5.72	5.29
			(0.1)	(0.09)	(0.1)	(0.13)
		Texture liking	5.57	5.82	5.74	5.24
			(0.13)	(0.1)	(0.1)	(0.13)
	Round 2 (Taste & Info)*					
		WTP ($)	2.2	2.17	2.33	2.19
			(0.15)	(0.16)	(0.16)	(0.16)
		Taste liking	-	-	-	-
			-	-	-	-
		Overall liking	-	-	-	-
			-	-	-	-
		Appearance liking	-	-	-	-
			-	-	-	-
		Texture liking	-	-	-	-
			-	-	-	-
Information-first group N=108	Round 1 (Info only)					
		WTP ($)	2.03	2.11	2.37	2.46
			(0.12)	(0.11)	(0.13)	(0.13)
		Taste liking	-	-	-	-
			-	-	-	-
		Overall liking	-	-	-	-
			-	-	-	-
		Appearance Liking	-	-	-	-
			-	-	-	-
		Texture Liking	-	-	-	-
			-	-	-	-
	Round 2 (Info & Taste)**					
		WTP ($)	2.09	2.18	2.2	2.03
			(0.14)	(0.14)	(0.14)	(0.15)
		Taste liking	5.47	5.49	5.28	4.99
			(0.12)	(0.14)	(0.17)	(0.18)
		Overall liking	5.61	5.68	5.6	5.36
			(0.1)	(0.12)	(0.13)	(0.14)
		Appearance liking	5.91	5.94	5.92	5.52
			0.1	0.1	0.11	0.14
		Texture liking	5.61	5.79	5.66	5.55
			(0.13)	(0.13)	(0.14)	(0.13)
		Short of Expectations (%)	11%	15%	22%	34%
			(3%)	(4%)	(5%)	(5%)

Note: Standard errors in parentheses; sensory ratings were all based on a 7-point scale (1 being least liked, 7 being most liked)

*N = 94 (less than first-round due to missing observations)
**N = 85 (less than first-round due to missing observations)

Mean sensory ratings for the breads by bidding round are also shown in Table 2. A tukey mean comparison test revealed that overall liking, taste liking, and appearance liking for the whole wheat and spelt control breads were higher ($p < 0.05$) than for the 25% IWG bread. Appearance liking and texture liking were also higher ($p < 0.05$) for the 15% IWG bread than for the 25% IWG bread. Satisfaction of sensory expectations was higher for the spelt control bread and 15% IWG bread than for the 25% IWG bread ($p < 0.05$). These trends point to the relatively low consumer sensory valuation of the 25% IWG bread, which contained the highest fraction of IWG of all the breads used in this experiment. Assessing the possible effects of information on sensory perception of the IWG breads, statistical t-tests revealed that overall liking and texture liking of the 25% IWG bread post-information were higher than their overall liking and texture liking pre-information ($p < 0.05$). For 15% IWG bread statistical t-tests revealed that information did not drive a significant change in sensory perception.

CHAPTER 6

RESULTS

Section 1: Information Effect on WTP

A random effect Tobit model was used to show the effect of information on WTP for the taste-first group with a lower censoring limit of $1 being used. The full specification is shown in Equation 1 of the Empirical Methodology chapter. The reason for using \$1 as a lower censoring limit was that bids at or below it corresponded to the bottom 25th percentile of bids, where 3 out of 4 subjects indicated they were "Not Interested" in purchasing the corresponding bread. We, thus, anticipated that for these lower bids, subjects' lack of purchasing intention made it improbable that their bids were proxying for their true WTP, which effectively censored the data at that point.

The results of this model are reported in Table 3. For the overall sample, the coefficients on 15% IWG and 25% IWG dummy variables were negative ($p < 0.05$), which indicates that before the provision of information the WTP for the 15% IWG and 25% IWG breads will be lower than the reference spelt control bread by an estimated \$0.24 and \$0.44, respectively. The coefficients on the IWG dummy variables were more negative for the non-pro-environment group than for the pro-environment group. On the other hand, the coefficients on the interactions of the IWG bread dummy variables and the information dummy variable were positive ($p < 0.05$), which indicates that after the provision of information the relative WTP for the 15% IWG and 25% IWG breads will increase by \$0.38 and \$0.45, respectively. The coefficients on the IWG interaction terms did not vary significantly across the pro- and non-pro-environment groups. We also observe that the coefficient on supercenter or wholesaler was negative ($p < 0.05$), while the coefficient on frequency of bread consumption was positive ($p < 0.01$). This indicates that relative to someone who regularly buys bread at a supermarket, a person who regularly buys bread at a supercenter or wholesaler will be willing to pay \$0.92 less. Additionally, increasing a person's premium bread consumption frequency by 1 tier (out of 5) will raise their

WTP for bread by $0.37. We, moreover, observe that whole wheat bread was not much different from spelt bread with respect its initial WTP and its WTP after receiving information. This is shown by the coefficients on the whole wheat bread dummy variable and on the interaction of the whole wheat bread dummy variable and the information dummy variable, neither of which was statistically significant.

Table 3: Information effect on WTP

	Overall Sample	**Non-pro-environment**	**Pro-environment**
Bread type			
IWG 15%	-0.242*	-0.328	-0.167
	(-2.08)	(-1.81)	(-1.14)
IWG 25%	-0.437***	-0.636***	-0.247
	(-3.71)	(-3.48)	(-1.66)
Whole Wheat	-0.0946	-0.104	-0.0789
	(-0.82)	(-0.59)	-0.53)
Information effects			
Information	-0.124	-0.118	-0.136
	(-1.01)	(-0.63)	(-0.86)
IWG 15%#Information	0.383*	0.370	0.410
	(2.21)	(1.39)	(1.86)
IWG 25%#Information	0.450**	0.462	0.447*
	(2.58)	(1.72)	(2.01)
Whole wheat#Information	0.111	0.180	0.0380
	(0.64)	(0.68)	(0.17)
Income	-0.00931	-0.137	0.140
	(-0.10)	(-0.94)	(1.11)
Woman	-0.0478	0.296	-0.344
	(-0.13)	(0.49)	(-0.77)
White	0.406	-0.0977	0.844
	(1.12)	(-0.17)	(1.74)
Household size	-0.146	0.00911	-0.156
	(-1.05)	(0.05)	(-0.78)
Age	-0.0908	0.0214	-0.235
	(-0.85)	(0.12)	(-1.81)
Primary shopper	0.130	-0.474	0.388
	(0.36)	(-0.89)	(0.73)
Supercenter or wholesaler	-0.916*	-1.563***	-0.331
	(-2.43)	(-2.80)	(-0.67)
Specialty retailer	0.800*	0.203	0.647
	(2.10)	(0.30)	(1.34)
Frequency of consumption	0.368**	0.393*	0.288
	(2.96)	(2.05)	(1.65)
Hungry	0.372	1.026*	-0.259
	(1.25)	(2.35)	(-0.65)
Constant	1.608**	1.815*	1.551
	(2.75)	(2.07)	(1.90)
σ_u	1.366***	1.379***	1.203***
	(12.36)	(8.48)	(8.93)
σ_ϵ	0.779***	0.839***	0.707***
	(30.40)	(21.06)	(21.91)
N	784	416	368

Note: t statistics in parentheses; *p<0.05, ** p < 0.01, *** p < 0.001

Section 2: Taste Effect on WTP

To assess the taste effect on WTP in the information-first group the same Tobit model used in Section 1 was used with taste substituting for information. The full specification is shown in Equation 2 of the Empirical Methodology chapter.

The results of this model are reported in Table 4. For the overall sample, the coefficients on the 15% IWG and 25% IWG dummy variables were positive ($p < 0.001$), which indicates that before tasting the breads the WTP for the 15% IWG and 25% IWG breads will be higher than the reference spelt control bread by an estimated $0.35 and $0.46, respectively. The coefficients on the IWG dummy variables were more positive for the pro-environment group than for the non-pro-environment. On the other hand, the coefficient on the interaction of the 25% IWG bread dummy variable and the taste dummy variable was negative ($p < 0.01$), which indicates that after tasting the breads the relative WTP for the 25% IWG bread will decrease by $0.27. The coefficient on the interaction of the 15% IWG bread dummy variable and the taste dummy variable was not statistically significant, which indicates that relative WTP for the 15% IWG will not change after tasting the breads. The coefficients on the IWG interaction terms were more negative for the non-pro-environment group than for the pro-environment group. We also observe that the coefficients on income, frequency of consumption, household size and primary shopper were positive ($p < 0.05$). This indicates that increasing a person's income by 1 tier (out of 8), which represents an increase of, on average, $15-20,000, will raise their WTP by $0.15. Increasing their premium bread consumption frequency by 1 tier (out of 5) will raise their WTP by $0.20. Increasing their household size by 1 member will raise their WTP by $0.24.

And, relative to someone who is not the primary shopper in their household, a person who is the primary shopper will have a $0.60 higher WTP. We, moreover, observe that whole wheat bread was not much different from spelt bread with respect its initial WTP and its WTP after tasting the breads. This is shown by the coefficients on the whole wheat bread dummy variable and on the interaction of the whole wheat bread dummy variable and the taste dummy variable, neither of which was statistically significant.

Table 4: Taste Effect on WTP

	Overall Sample	**Non-pro-environment**	**Pro-environment**
Bread type			
IWG 15%	0.346***	0.270*	0.464**
	(3.32)	(2.16)	(2.90)
IWG 25%	0.457***	0.423***	0.509**
	(4.40)	(3.40)	(2.90)
Whole wheat	0.0971	0.158	0.0135
	(0.93)	(1.26)	(0.08)
Taste effects			
Taste	0.239*	0.283*	0.161
	(2.11)	(2.10)	(0.83)
IWG 15%#Taste	-0.245	-0.369	-0.0503
	(-1.56)	(-1.95)	(-0.19)
IWG 25%#Taste	-0.507**	-0.592**	-0.368
	(-3.22)	(-3.13)	(-1.38)
Whole wheat#Taste	0.0220	0.0547	-0.0450
	(0.14)	(0.29)	(-0.17)
Income	0.152*	0.234**	0.0831
	(2.18)	(2.79)	(0.85)
Woman	0.0455	-0.184	0.692
	(0.17)	(-0.54)	(1.91)
White	0.371	0.488	-0.527
	(1.37)	(1.66)	(-1.09)
Household size	0.243*	0.128	0.389**
	(2.34)	(0.89)	(2.94)
Age	0.159	0.0636	0.367**
	(1.80)	(0.60)	(2.66)
Primary shopper	0.599*	0.585	0.663
	(2.03)	(1.43)	(1.55)
Supercenter or wholesaler	-0.0155	0.204	-0.960
	(-0.05)	(0.66)	(-1.37)
Specialty retailer	0.421	-0.325	1.394***
	(1.61)	(-0.88)	(3.99)
Frequency of consumption	0.204*	0.372**	0.0689
	(2.14)	(3.08)	(0.55)
Hungry	0.117	0.259	0.153
	(0.57)	(1.01)	(0.53)
Constant	-1.072*	-1.173	-1.547
	(-2.02)	(-1.71)	(-1.95)
σ_u	0.942***	0.869***	0.773***
	(12.56)	(9.78)	(7.44)
σ_ϵ	0.710***	0.661***	0.756***
	(30.58)	(23.66)	(19.35)
N	756	460	296

Note: t statistics in parentheses; * p < 0.05, ** p < 0.01, *** p < 0.001

Section 3: Information Effect on Sensory Liking

To assess the information effect on sensory liking a generalized least square model was used. The full specification is shown in Equation 3 of the Empirical Methodology chapter.

The results of the regressions on overall liking and taste liking are reported here in detail (Table 5). All measures of sensory liking were recorded using a 7-tier scale. For the overall sample, the coefficients on the 25% IWG bread dummy variable were negative ($p < 0.01$) for the regressions on overall liking and taste liking, which indicates that in the absence of information the overall liking and taste liking of the 25% IWG bread are expected to be lower than those of the reference spelt control bread by an estimated 0.4 and 0.5 tiers, respectively. The coefficient on the 25% IWG bread dummy variable was more negative for the non-pro-environment group than the pro-environment group. On the other hand, the coefficients on the 15% IWG bread dummy variable were not significantly different from zero, which indicates that the sensory performance of the 15% IWG bread in the absence of information will not be different from that of the reference spelt control bread. The coefficients on the interactions of the IWG bread dummy variables and the information dummy variable were also not significantly different from zero, which indicates that information has no statistically significant effect on relative overall liking and taste liking for the 15% IWG and 25% IWG breads. This held true for both the pro-environment and non-pro-environment groups.

Table 5: Information Effect on Overall Liking and Taste Liking

	Overall Sample		**Non-pro-environment**		**Pro-environment**	
	Overall Liking	Taste Liking	Overall Liking	Taste Liking	Overall Liking	Taste Liking
Bread type						
IWG 15%	-0.0654	-0.178	-0.0536	-0.196	-0.0784	-0.157
	(-0.41)	(-0.97)	(-0.23)	(-0.74)	(-0.38)	(-0.66)
IWG 25%	-0.439**	-0.533**	-0.679**	-0.732**	-0.176	-0.314
	(-2.73)	(-2.90)	(-2.93)	(-2.77)	(-0.84)	(-1.33)
Whole wheat	0.112	0.0280	0.268	0.250	-0.0588	-0.216
	(0.70)	(0.15)	(1.16)	(0.95)	(-0.28)	(-0.91)
Information effect						
Information	0.167	0.0807	0.118	0.0155	0.277	0.211
	(0.96)	(0.41)	(0.49)	(0.06)	(1.14)	(0.77)
IWG 15%#Information	0.0534	0.0209	-0.103	-0.196	0.297	0.376
	(0.22)	(0.08)	(-0.31)	(-0.51)	(0.88)	(0.99)
IWG 25%#Information	0.210	0.0508	0.404	0.164	0.0202	-0.0300
	(0.86)	(0.18)	(1.20)	(0.43)	(0.06)	(-0.08)
Whole wheat#Information	-0.0158	0.00811	-0.0914	-0.132	0.0276	0.122
	(-0.06)	(0.03)	(-0.27)	(-0.35)	(0.08)	(0.32)
Income	0.0248	0.0306	0.0527	0.0590	0.00791	0.0141
	(0.84)	(0.91)	(1.22)	(1.20)	(0.20)	(0.31)
Woman	-0.0655	-0.269*	-0.0363	-0.234	-0.0950	-0.307
	(-0.59)	(-2.14)	(-0.21)	(-1.20)	(-0.67)	(-1.91)
White	0.394***	0.459***	0.262	0.453*	0.648***	0.563**
	(3.51)	(3.58)	(1.64)	(2.49)	(3.97)	(3.05)
Household size	0.0491	0.0259	0.0262	-0.0132	0.0943	0.0840
	(1.14)	(0.53)	(0.42)	(-0.18)	(1.64)	(1.30)
Age	-0.0890*	-0.0753	-0.167**	-0.182**	-0.0674	-0.0342
	(-2.51)	(-1.86)	(-3.03)	(-2.90)	(-1.48)	(-0.66)
Primary shopper	0.0360	0.0647	0.0367	0.0753	0.0271	0.0295
	(0.31)	(0.48)	(0.22)	(0.40)	(0.16)	(0.16)
Supercenter or wholesaler	-0.209	-0.286*	-0.0288	-0.00771	-0.412*	-0.595**
	(-1.79)	(-2.15)	(-0.19)	(-0.04)	(-2.36)	(-3.01)
Specialty retailer	0.140	0.139	0.0716	0.165	-0.0475	-0.107
	(1.20)	(1.05)	(0.38)	(0.77)	(-0.31)	(-0.62)
Frequency of consumption	0.193***	0.227***	0.228***	0.272***	0.136*	0.149*
	(4.90)	(5.07)	(4.18)	(4.38)	(2.44)	(2.35)
Hungry	-0.0769	-0.0781	-0.103	-0.149	-0.132	-0.103
	(-0.85)	(-0.76)	(-0.78)	(-0.99)	(-1.06)	(-0.73)
Constant	4.881***	4.830***	4.910***	4.822***	4.959***	5.043***
	(22.22)	(19.27)	(15.83)	(13.64)	(16.26)	(14.61)
N	760	760	428	428	332	332

Note: t statistics in parentheses; *p<0.05, ** p < 0.01, *** p < 0.001

We also observe that the coefficients on white and frequency of premium bread consumption were positive ($p < 0.001$) for both overall liking and taste liking, while the coefficient on age was negative for overall liking. This indicates that relative to a non-white person, a white person will have a 0.39 tiers higher overall liking and 0.46 tiers higher taste liking. Increasing a person's frequency of premium bread consumption by 1 tier (out of 5) will increase their overall liking by 0.19 tiers and their taste liking by 0.23 tiers. And, raising a person's age by 1 tier (out of 6), which represents, on average, an increase of 10 years, will reduce their overall liking by 0.09 tiers.

The results of the regressions on overall liking and taste liking were used to conduct a marginal analysis of the effect of information on absolute sensory liking. We observe for the overall sample a significant change only for the 25% IWG bread, whose overall liking increases by 0.38 tiers in response to information. We observe for the non-pro-environment subsample that neither overall liking nor taste liking for the 15% IWG bread showed a significant change in response to information (Table 6). For this same subsample, we observe a significant increase in overall liking and texture liking for the 25% IWG bread after receiving information by about 0.5 and 0.6 tiers, respectively. For the pro-environment subsample, on the other hand, we notice a significant increase in overall liking, taste liking, and appearance liking for the 15% IWG bread after receiving information by about 0.6, 0.6, and 0.5 tiers, respectively. For this same subsample, we notice no significant change in sensory liking after receiving information for the 25% IWG bread. In summary, for the overall sample information evokes a significant increase in overall liking for the 25% IWG bread, for non-pro-environment consumers information evokes a significant increase in overall liking and texture liking for the 25% IWG bread and for pro-environment consumers information evokes a significant increase in overall liking, taste liking, and appearance liking for the 15% IWG bread.

Table 6: Effect of information on sensory liking for pro-environment consumers and non-pro-environment consumers

		Overall sample	**Non-pro-environment**	**Pro-environment**
15% IWG	Overall Liking	0.22	0.01	0.57*
	Taste Liking	0.10	-0.18	0.59*
	Texture Liking	-0.05	-0.21	0.22
	Appearance Liking	0.23	0.04	0.46*
25% IWG	Overall Liking	0.38*	0.52*	0.30
	Taste Liking	0.13	0.18	0.18
	Texture Liking	0.33	0.55*	0.09
	Appearance Liking	0.21	0.30	0.10
	N	190	107	83

Note: *p<0.05, ** p < 0.01, *** p < 0.001

Section 4: Relative Premium for IWG Breads

To assess the relative premium for IWG breads when variation in sensory performance was controlled for a random effect Tobit model was used with a lowering censoring limit of $1. The full specification is shown in Equation 4 of the Empirical Methodology Section. The results are reported in Table 7. The coefficients on the IWG bread dummy variables are positive ($p < 0.05$), which indicates that once controlling for sensory attributes, i.e. taste, appearance, and texture, the IWG breads command a $0.15 to $0.20 premium over the control breads. This translates to about a 5 to 10 percent relative price premium for the IWG breads. The premium rises marginally to $0.20 to $0.25 when only considering the pro-environment group.

A comparison of second-round predicted WTP based on the regressions on WTP in Sections 1 and 2 was also performed to assess what the relative premium for the IWG breads would be if they were introduced as is into a retail setting after consumers had already tasted them and received information about them. For the overall sample a look at the predicted WTP for the four breads after the provision of information and after tasting (Table 8) reveals a 6-7% premium for 15% IWG bread relative to the control breads in the taste-first group. In the information-first group, 15% IWG commands a 5% premium over the spelt control bread. No premium is detected for the 25% IWG bread for either the taste-first or information-first group. For the non-pro-environment subsample, no premium for any of the IWG breads is detected for either the taste-first or information-first subjects. For taste-first subjects in the pro-environment subsample, there is an 11-13% premium for the 15% IWG bread relative to the control breads. For information-first subjects in the pro-environment subsample, the relative premium for the 15% IWG bread rises to 18-19%. There is also a 9-11% premium for the 25% IWG bread relative to the control breads for taste-first subjects in the pro-environment subsample. Information-first subjects in the pro-environment subsample are willing to pay a relative premium for the 25% IWG of 6-8%. These results show the potential for IWG breads to command a price premium, especially if made with less IWG and targeted to pro-environment consumers.

Table 7: IWG Premium Conditional on Sensory Performance

	Overall Sample	**Non-Pro-Env.**	**Pro-Env.**
Sensory Attributes			
Taste Liking	0.380***	0.411***	0.310***
	(10.16)	(8.17)	(5.60)
Appearance Liking	0.0765	0.0442	0.113
	(1.80)	0.75	1.87
Texture Liking	0.190***	0.130*	0.276***
	(4.22)	(2.23)	(3.92)
Bread Variety			
IWG 15%	0.152*	0.0492	0.261*
	(2.08)	(0.49)	(2.48)
IWG 25%	0.186*	0.0647	0.306**
	(2.47)	(0.63)	(2.86)
Whole wheat	0.0605	0.0909	-0.00358
	(0.83)	(0.93)	(-0.03)
Tasting-First	0.158	-0.0330	0.222
	(0.80)	(-0.12)	(0.74)
Income	0.0105	-0.00182	0.0643
	(0.16)	(-0.02)	(0.65)
Woman	0.275	0.657	0.0225
	(1.13)	(1.82)	(0.07)
White	0.305	0.195	0.442
	(1.23)	(0.58)	(1.12)
Household size	-0.0299	-0.0585	0.0579
	(-0.31)	(-0.42)	(0.42)
Age	0.0177	0.0550	-0.0625
	(0.22)	(0.46)	(-0.58)
Primary shopper	0.228	-0.00159	0.393
	(0.88)	(-0.00)	(1.02)
Supercenter or wholesaler	-0.371	-0.443	-0.274
	(-1.40)	(-1.34)	(-0.62)
Specialty retailer	0.610*	0.283	0.721
	(2.42)	(0.75)	(2.04)
Frequency of consumption	0.165	0.205	0.0661
	(1.88)	(1.80)	(0.48)
Hungry	0.209	0.615	-0.304
	(1.03)	(2.22)	(-1.01)
Constant	-2.762***	-2.471	-2.983
	(-5.72)	(-3.93)	(-3.97)
σ_u	1.182***	1.165	1.132
	(15.27)	(11.09)	(10.38)
σ_ϵ	0.607***	0.613	0.581
	(26.72)	(19.75)	(18.01)
N	688	396	292

Note: t statistics in parentheses; *p<0.05, ** p < 0.01, *** p < 0.001

Table 8: Predicted second-round WTP

	Treatment order	Spelt	15% IWG	25% IWG	Whole wheat
Overall Sample	Taste-first	2.02	2.16	2.04	2.04
		(0.16)	(0.16)	(0.16)	(0.16)
	Information-first	2.13	2.23	2.08	2.25
		(0.13)	(0.13)	(0.13)	(0.13)
Non-pro-environment	Taste-first	1.76	1.80	1.58	1.83
		(0.24)	(0.24)	(0.24)	(0.24)
	Information-first	2.03	1.93	1.86	2.24
		(0.15)	(0.15)	(0.15)	(0.15)
Pro-environment	Taste-first	2.29	2.54	2.49	2.25
		(0.21)	(0.21)	(0.21)	(0.21)
	Information-first	2.29	2.70	2.43	2.26
		(0.19)	(0.19)	(0.19)	(0.19)

Note: Standard errors in parentheses

CHAPTER 7

DISCUSSION

Several important findings have emerged through this study. Firstly, we find that the average subject at least somewhat liked the sensory attributes of the IWG breads. Of the four breads used in the experiment, the bread with the worst sensory performance appears to be the 25% IWG, which had a significantly lower overall liking, taste liking, appearance liking, and texture liking than the other breads. Subjects were also more than twice as likely to find the sensory performance of the 25% IWG bread to be underwhelming relative to the other control breads. Our findings show that under blind tasting conditions the 15% and 25% IWG breads had a significantly lower WTP than the completely wheat-based control breads. Noteworthy is that the extent to which subjects disliked the sensory performance of the IWG breads, as shown by their bids and sensory evaluations, varied by their propensity to engage in environmental behavior. Pro-environment consumers in general were more forgiving when it came to taste and penalized the IWG breads less after tasting than non-pro-environment consumers. Overall, these findings on the sensory performance of the IWG breads demonstrate that there is some tradeoff between higher IWG incorporation and sensory performance. It is possible this tradeoff may be partly influenced by the higher bran fractions in the IWG breads (Appendix B), which could be imparting a bitter flavor to the bread. Alternatively, the lower gluten content of IWG could be contributing to a more compact loaf that consumers do not find desirable.

With respect to the effect of information about IWG's environmental benefits on WTP for the IWG breads we found that for all consumers, both pro- and non-pro-environment, receiving information raised their WTP for the IWG breads. The magnitude of this increase was similar in absolute terms for both groups. On average for the entire sample receiving information resulted in a 14% increase in WTP for the 15% IWG bread and a 19% increase in WTP for the 25% IWG bread. For the entire sample, the relative WTP for the 15% and 25% IWG breads compared to the reference spelt control bread increased after receiving information by around $0.38 and $0.45, respectively. From an average WTP for the 15% IWG that was $0.22 less than that of the spelt bread, the average WTP of the 15% IWG bread increased to $0.13 above that of the spelt bread. From an average WTP for the 25% IWG that was $0.39 less than that of the spelt bread, the average WTP of the 25% IWG increased to only $0.01 less than that of the spelt bread. Effectively, information closed the initial WTP gap between the IWG breads and the control breads created by the IWG breads' sensory (under)performance. It also enabled the WTP for the 15% IWG bread to surpass that of the control breads in the second-round of bidding.

Another important finding from this study is that information about IWG can affect the sensory perception of the IWG breads, however, this effect is conditional on the kind of consumer and the type of bread. For pro-environment consumers, results suggest a significant increase in the sensory ratings of the 15% IWG bread in response to information, whereas, for non-pro-environment consumers we see a significant increase in the sensory ratings of the 25% IWG bread in response to information. Applying the assimilation-contrast model of disconfirmed expectations described earlier to these data patterns is challenging since the response to information varies across consumer segments. However, we do observe that for the group we anticipated would be most affected by the information about IWG, i.e. the pro-environment group, that the findings are consistent with the assimilation-contrast model. For the 15% IWG bread where there is low sensory disconfirmation, i.e. where the high expected sensory performance of the IWG bread does not deviate too much from its true sensory performance, we observe an assimilation effect in the form of higher sensory ratings. On the other hand, for the 25% IWG bread where there is high sensory disconfirmation, i.e. where the bread's true sensory performance fails to meet its high expected performance, the assimilation effect attenuates to the extent that information has a null effect on sensory ratings. While show how the assimilation-contrast model would apply to this subsample of consumers, interpreting the findings on the non-pro-environment group is more difficult. It could simply be that non-pro-environment consumers who had tasted the 25% IWG bread without knowing anything about it were excessively harsh in their sensory evaluation of it, perhaps, because they did not know what they were eating and felt it deviated strongly from their expectations of how bread should taste. This may explain why sensory ratings for the 25% IWG bread significantly improved after receiving information.

How receiving information affected the overall competitiveness of the IWG breads with their non-IWG counterparts varied across different consumer segments. For pro-environment consumers there was a large, in excess of 10%, predicted relative premium for the 15% IWG bread after receiving information and after tasting the breads (Table 8). There was also a modest, in excess of 5%, predicted relative premium for the 25% IWG bread. Yet, for non-pro-environment consumers we did not predict a relative premium for any of the IWG breads, and even found evidence they were being outcompeted by the control breads. For the entire sample we detected a modest, in excess of 5%, predicted relative premium for the 15% IWG bread and no relative premium for the 25% IWG bread. When we controlled for variation in the sensory performance of the breads (Table 7), we estimated a more than 5% relative premium for the IWG breads in the entire sample, and a more than 10% relative premium for the for the pro-environment subsample. Importantly, the size of this relative premium was not significantly different between the 15% and 25% IWG bread, indicating that bakers would not gain much from incorporating a higher fraction of IWG into their product. No relative premium was found for the non-pro-environment subsample even if variation in sensory performance could be controlled for. These findings demonstrate the critical importance of information in marketing IWG to consumers, especially more environmentally inclined consumers.

There are several limitations to this study, which should be addressed in future research. Firstly, subjects' bids for all the breads were clearly much lower than their true market price. While this does make predictions on absolute WTP unreliable, it does not seriously undermine our core findings, which are about relative WTP. In other words, is the variation in WTP across information status, tasting status, and bread type that interests us, and the bids perform well in capturing that variation. To address this limitation, future research can study WTP for IGW breads in actual retail setting. Another limitation is the use of a lower censoring limit of $1 in the above Tobit specifications, which could potentially censor some observations that should not have been censored and un-censor some observations that should have been censored. To account for this, we employed alternative specifications with different lower censoring limits (Appendix Tables E, F and G). Regardless of the choice of lower censoring limit, the results are robust. An additional limitation of this study was the use of a within-subject analysis of the estimated effects of information and tasting on WTP, since it creates the potential for carry-over effects biasing our estimates. For instance, tasting first without information could prime consumers to have a very low WTP for the unlabeled IWG breads, which they might then overcompensate for in the second-round of bidding motivated by a feeling of "loser's regret" from not bidding the optimal amount the first time. For this reason, we conducted a between-subject analysis, which revealed our estimates on the effects of information and tasting on WTP to be robust (Appendix Tables C and D). Our sampling design imposed an additional limitation on this study, since it generated a sample that was not entirely representative of the overall population of American consumers. While it is difficult with convenience sampling to generate a truly representative sample, we believe that the estimates obtained in study can be broadly applied to the national context, especially since none of the demographic variables for which the sample does differ from the overall population appear to be significant drivers of WTP or sensory liking. An additional study limitation was the use of an imputed value of income. When the original income variable was used, however, we did not observe significant divergence from our core results, although we did observe a loss in statistical power. Another study limitation is the use of a limited number of "control" bread varieties. This issue is one that cannot be easily resolved in an experimental context, since introducing more bread varieties would also introduce subject fatigue, which would compromise the experimental results. This issue can only truly be resolved in a retail setting, a natural "next step" for this kind of analysis. Bringing IWG bread into a retail setting would also help researchers assess the importance of other IWG attributes, such as its higher protein and fiber content. It would also help researchers understand how variables such as packaging and imagery might affect the receptiveness of consumers to the environmental label.

CHAPTER 8

CONCLUSION

This study, the first of its kind, shows that artisanal premium breads incorporating IWG can be competitively marketed, especially at lower incorporation rates and when targeted to environmentally inclined consumers. This study moreover appears to show that information about the IWG breads provided before tasting is driving up their expected sensory performance, which shifts up subjects' sensory ratings of the breads after tasting them. The positive effect of information on sensory perception seems, however, moderated by a subject's propensity to engage in pro-environment behavior. Four main insights about a successful marketing strategy for IWG can be gleaned from this study: 1) Marketers must not compromise on sensory quality and be very methodical about how much IWG they use in their product formulations, 2) Marketers can raise consumers' sensory perceptions of IWG, especially for pro-environment consumers, by advertising its environmental benefits before tasting, 3) Marketers can realize a relative price premium, especially for pro-environment consumers, if they emphasize the environmental benefits of IWG, 4) Marketers will find that pro-environment consumers respond more favorably to the sensory performance of IWG than other consumers. Future research in marketing IWG food products can build on this study by analyzing the demand of IWG baked goods in real-world retail settings from a variety of sites to assess whether the findings of this study are generalizable. Although this study's findings are preliminary, they offer important insights that highlight the market potential of a new, more sustainable grain with the potential of radically transforming agriculture.

APPENDIX

A: Bread Recipe

The IWG breads in this experiment contained either 15% IWG or 25% IWG based on the total amount of flour in the formula. The remaining flour in each dough was composed of a blend of equal portions of white bread flour (le blond, Les Moulins de Soulanges, Saint-Polycarpe, Qc) and high-extraction stone-ground wheat flour (high extraction, Farmer Ground Flour, Trumansburg, NY). All doughs corresponding to the four bread varieties used in this experiment were hydrated to 75% hydration (based on total flour mass) and contained 2% (by flour mass) of salt. Doughs were naturally leavened with a sourdough starter by pre-fermenting 10% of the flour with an equal mass of water and a small portion (~1 Tbsp) of sourdough culture, overnight (12-16 hours) at room temperature (~76F) before mixing the final dough. Five kilogram batches of dough were mixed in a 20-quart Hobart planetary mixer on first speed for 5 minutes at a desired dough temperature of 76F. Mixed dough was left to bulk ferment in plastic tubs for 3-4 hours with hourly folds to develop strength. The dough was divided into 1.5 lb. loaves, shaped and placed into loaf pans to proof for 1-2 hours at room temperature before retarding overnight in a cooler at 45F. The following morning, loaves were baked in a wood fired stone oven at ~450F for an internal temperature of >200F (30-40 minutes).

B: Nutritional Analysis

The results of the nutrition analysis revealed that a 25-percentage point increase in the IWG incorporation rate resulted in a 15% increase in the ash content per unit of mass. A 25-percentage point increase in the IWG incorporation rate also resulted in a 21% increase in the fiber content. Additionally, every 25-percentage point increase in the IWG incorporation rate increased protein content by 11% on average. These trends point to the higher bran fraction in the IWG breads than the 100% wheat breads, which may be driving the distinct nutty or earthy taste of the former. This also may explain the lower sensory ratings for the IWG breads. The higher protein of the IWG breads could also potentially be a selling point for marketers, however, it is unclear whether the difference in protein is significant enough to impact consumers' purchasing behavior.

Bread Type	**Calories**	**Carbohydrates**	**Total Fat**	**Protein**	**Total Dietary Fiber**	**Moisture**	**Ash**
	(C/100g)	%	%	%	%	%	%
Spelt	228	45.9	1.5	7.8	6.0	43.0	1.8
25% IWG	220	44.1	1.1	8.6	5.6	44.4	1.8
50% IWG	233	44.3	1.9	9.6	6.8	42.1	2.1

C: Between-subject analysis of effect of information on WTP

	Overall Sample	**Non-pro-environment**	**Pro-environment**
Bread type			
IWG 15%	-0.233*	-0.307	-0.159
	(-1.99)	(-1.88)	(-0.97)
IWG 25%	-0.422***	-0.607***	-0.240
	(-3.57)	(-3.67)	(-1.45)
Whole wheat	-0.0943	-0.115	-0.0738
	(-0.81)	(-0.71)	(-0.45)
Information effect			
Information	-0.226	-0.0500	-0.306
	(-1.01)	(-0.16)	(-0.93)
IWG 15%#Information	0.327	0.183	0.577*
	(1.85)	(0.78)	(2.17)
IWG 25%#Information	0.359*	0.410	0.381
	(2.02)	(1.74)	(1.42)
Whole wheat#Information	0.225	0.338	0.0597
	(1.28)	(1.47)	(0.22)
Income	0.0139	-0.00654	0.0764
	(0.21)	(-0.07)	(0.85)
Age	-0.0186	-0.0440	-0.0975
	(-0.24)	(-0.38)	(-0.95)
Woman	0.288	0.616	0.0842
	(1.18)	(1.68)	(0.26)
Household size	0.0126	-0.00253	0.121
	(0.13)	(-0.02)	(0.93)
White	0.504*	0.323	0.790*
	(2.05)	(0.95)	(2.15)
Primary shopper	0.0202	-0.0939	0.0622
	(0.08)	(-0.27)	(0.17)
Supercenter or wholesaler	-0.421	-0.372	-0.476
	(-1.62)	(-1.12)	(-1.19)
Specialty retailer	0.730**	0.341	0.705*
	(2.90)	(0.87)	(2.08)
Frequency of consumption	0.250**	0.305**	0.102
	(2.91)	(2.65)	(0.81)
Hungry	0.252	0.521	-0.131
	(1.27)	(1.87)	(-0.47)
Constant	0.918*	0.731	1.225
	(2.10)	(1.22)	(1.93)
σ_u	1.205***	1.211***	1.109***
	(15.67)	(11.52)	(10.52)
σ_ϵ	0.790***	0.772***	0.789***
	(27.93)	(20.34)	(19.10)
N	760	428	332

Note: t statistics in parentheses; *p<0.05, ** p < 0.01, *** p < 0.001

D: Between-subject analysis of the taste effect on WTP

	Overall Sample	**Non-pro-environment**	**Pro-environment**
Bread type			
IWG 15%	0.348***	0.266	0.470**
	(3.34)	(1.94)	(2.98)
IWG 25%	0.459***	0.421**	0.514**
	(4.41)	(3.08)	(3.26)
Whole wheat	0.0991	0.155	0.0122
	(0.95)	(1.13)	(0.08)
Taste effect			
Taste	0.219	0.0740	0.333
	(1.01)	(0.25)	(1.01)
IWG 15%#Taste	-0.209	-0.226	-0.228
	(-1.34)	(-1.04)	(1.03)
IWG 25%#Taste	-0.442**	-0.585**	-0.314
	(-2.83)	(-2.70)	(-1.41)
Whole wheat#Taste	-0.0827	-0.0814	-0.0562
	(-0.53)	(-0.38)	(-0.25)
Income	0.0535	0.0133	0.160
	(0.80)	(0.15)	(1.58)
Age	0.0401	0.0388	-0.0459
	(0.51)	(0.35)	(-0.41)
Woman	0.189	0.489	0.117
	(0.78)	(1.45)	(0.33)
Household size	0.0108	-0.00356	0.0391
	(0.11)	(-0.03)	(0.28)
White	0.468	0.406	0.445
	(1.87)	(1.29)	(1.08)
Primary shopper	0.449	0.103	0.845*
	(1.76)	(0.31)	(2.14)
Supercenter or wholesaler	-0.527*	-0.354	-0.773
	(-1.98)	(-1.09)	(-1.70)
Specialty retailer	0.534*	0.216	0.698*
	(2.13)	(0.59)	(2.00)
Frequency of consumption	0.216*	0.314**	0.0605
	(2.52)	(2.83)	(0.46)
Hungry	0.274	0.554*	-0.0699
	(1.38)	(2.10)	(-0.23)
Constant	0.111	0.117	0.0995
	(0.25)	(0.21)	(0.14)
σ_u	1.254***	1.223***	1.202***
	(16.19)	(11.86)	(10.92)
σ_ϵ	0.708***	0.725***	0.673***
	(29.33)	(21.74)	(19.66)
N	780	448	332

Note: t statistics in parentheses; *p<0.05, ** p < 0.01, *** p < 0.001

E: Different Lower Limits Specifications for Information Effect on WTP

	Tobit, ll=0	Tobit, ll=0.5	Tobit, ll=1.5	GLS
Bread type				
IWG 15%	-0.232*	-0.218*	-0.262*	-0.204
	(-2.10)	(-2.00)	(-2.10)	(-1.11)
IWG 25%	-0.414***	-0.415***	-0.389**	-0.378*
	(-3.74)	(-3.79)	(-3.12)	(-2.05)
Whole wheat	-0.0966	-0.0798	-0.0977	-0.0893
	(-0.88)	(-0.74)	(-0.80)	(-0.49)
Information effect				
Information	-0.105	-0.116	-0.0965	-0.102
	(-0.90)	(-1.01)	(-0.74)	(-0.53)
IWG 15%#Information	0.357*	0.353*	0.410*	0.330
	(2.18)	(2.19)	(2.23)	(1.21)
IWG 25%#Information	0.403*	0.395*	0.396*	0.366
	(2.46)	(2.44)	(2.14)	(1.34)
Whole wheat#Information	0.0975	0.0865	0.129	0.0988
	(0.59)	(0.54)	(0.71)	(0.36)
Income	-0.0187	-0.0192	-0.00970	-0.00665
	(-0.22)	(-0.22)	(-0.09)	(-0.20)
Woman	0.00118	-0.00512	0.0896	-0.0301
	(0.00)	(-0.02)	(0.23)	(-0.25)
White	0.538	0.586	0.541	0.420***
	(1.69)	(1.80)	(1.36)	(3.32)
Household size	-0.114	-0.0849	-0.176	-0.0963*
	(-0.94)	(-0.68)	(-1.15)	(-2.00)
Age	-0.115	-0.121	-0.117	-0.107**
	(-1.23)	(-1.25)	(-1.00)	(-2.86)
Primary shopper	0.101	0.128	0.237	0.251*
	(0.31)	(0.39)	(0.59)	(1.98)
Supercenter or wholesaler	-0.575	-0.741*	-0.924*	-0.626***
	(-1.77)	(-2.21)	(-2.23)	(-4.88)
Specialty retailer	0.764*	0.748*	0.855*	0.657***
	(2.25)	(2.16)	(2.07)	(4.89)
Frequency of consumption	0.354**	0.353**	0.380**	0.317***
	(3.23)	(3.15)	(2.80)	(7.28)
Hungry	0.196	0.235	0.407	0.181
	(0.75)	(0.88)	(1.26)	(1.74)
Constant	1.686**	1.593**	1.320*	1.710***
	(3.27)	(3.02)	(2.05)	(7.28)
σ_u	1.211***	1.239***	1.473***	-
	(13.57)	(13.14)	(11.32)	-
σ_ϵ	0.794***	0.766***	0.771***	-
	(34.26)	(33.13)	(27.74)	-
N	784	784	784	784

Note: t statistics in parentheses; *p<0.05, ** p < 0.01, *** p < 0.001

F: Different Lower Limit Specifications for Taste Effect on WTP

	Tobit, ll=0	Tobit, ll=0.5	Tobit, ll=1.5	GLS
Bread type				
IWG 15%	0.352***	0.332***	0.405***	0.330*
	(3.44)	(3.38)	(3.76)	(2.18)
IWG 25%	0.444***	0.430***	0.497***	0.420**
	(4.34)	(4.39)	(4.62)	(2.78)
Whole wheat	0.0916	0.0916	0.109	0.0751
	(0.89)	(0.93)	(1.00)	(0.50)
Taste effect				
Taste	0.196	0.196	0.303*	0.158
	(1.77)	(1.84)	(2.56)	(0.97)
IWG 15%#Taste	-0.221	-0.202	-0.307	-0.216
	(-1.43)	(-1.37)	(-1.89)	(-0.94)
IWG 25%#Taste	-0.514***	-0.496***	-0.531**	-0.480*
	(-3.32)	(-3.34)	(-3.25)	(-2.10)
Whole wheat#Taste	0.0163	0.0206	-0.0545	0.0203
	(0.11)	(0.14)	(-0.33)	(0.09)
Income	0.144*	0.140*	0.152*	0.121***
	(2.11)	(2.11)	(2.05)	(4.21)
Woman	-0.0476	-0.0781	0.143	0.0620
	(-0.18)	(-0.31)	(0.49)	(0.56)
White	0.295	0.330	0.466	0.292*
	(1.11)	(1.27)	(1.62)	(2.57)
Household size	0.222*	0.217*	0.223*	0.226***
	(2.17)	(2.18)	(2.00)	(5.11)
Age	0.122	0.139	0.154	0.0979**
	(1.41)	(1.65)	(1.65)	(2.63)
Primary shopper	0.665*	0.666*	0.455	0.556***
	(2.30)	(2.36)	(1.45)	(4.50)
Supercenter or wholesaler	0.0369	-0.0191	0.00607	0.0231
	(0.13)	(-0.07)	(0.02)	(0.20)
Specialty retailer	0.378	0.386	0.472	0.386***
	(1.46)	(1.54)	(1.70)	(3.50)
Frequency of consumption	0.188*	0.180*	0.197	0.184***
	(2.01)	(1.99)	(1.94)	(4.59)
Hungry	0.105	0.103	0.108	0.131
	(0.53)	(0.53)	(0.49)	(1.54)
Constant	-0.722	-0.694	-1.105	-0.498*
	(-1.40)	(-1.38)	(-1.95)	(-2.08)
σ_u	0.928***	0.903***	0.997***	-
	(13.04)	(12.96)	(11.72)	-
σ_ϵ	0.736***	0.699***	0.690***	-
	(34.19)	(33.48)	(27.85)	-
N	756	756	756	756

Note: t statistics in parentheses; *p<0.05, ** p < 0.01, *** p < 0.001

G: Different Lower Limit Specifications for IWG Premium Conditioning on Sensory Performance

	Tobit, ll=0	**Tobit, ll=0.5**	**Tobit, ll=1.5**	**GLS**
Sensory Attributes				
Taste Liking	0.337***	0.344***	0.373***	0.411***
	(10.00)	(10.30)	(9.17)	(9.61)
Appearance Liking	0.0871*	0.0967*	0.0820	0.0313
	(2.17)	(2.44)	(1.83)	(0.57)
Texture Liking	0.155***	0.154***	0.202***	0.106
	(3.67)	(3.75)	(4.19)	(1.93)
Bread variety				
15% IWG	0.156*	0.159*	0.161*	0.165
	(2.17)	(2.28)	(2.12)	(1.32)
25% IWG	0.183*	0.167*	0.170*	0.199
	(2.48)	(2.34)	(2.17)	(1.58)
Whole wheat	0.0208	0.0287	0.0346	0.0414
	(0.29)	(0.41)	(0.46)	(0.33)
Tasting-First	0.192	0.159	0.177	0.181*
	(1.08)	(0.90)	(0.81)	(1.98)
Income	0.0158	0.0128	-0.0247	0.0102
	(0.27)	(0.22)	(-0.34)	(0.33)
Woman	0.245	0.239	0.407	0.257*
	(1.13)	(1.10)	(1.49)	(2.27)
White	0.282	0.296	0.511	0.273*
	(1.26)	(1.33)	(1.85)	(2.36)
Household size	-0.0267	-0.00906	0.0436	-0.00864
	(-0.31)	(-0.11)	(0.41)	(-0.20)
Age	-0.0194	-0.0119	-0.0217	-0.00695
	(-0.27)	(-0.17)	(-0.25)	(-0.19)
Primary shopper	0.257	0.273	0.232	0.254*
	(1.12)	(1.18)	(0.80)	(2.14)
Supercenter or wholesaler	-0.122	-0.242	-0.354	-0.188
	(-0.53)	(-1.04)	(-1.19)	(-1.56)
Specialty retailer	0.534*	0.521*	0.699*	0.479***
	(2.34)	(2.30)	(2.52)	(4.05)
Frequency of consumption	0.177*	0.171*	0.193*	0.149***
	(2.25)	(2.18)	(1.98)	(3.62)
Hungry	0.109	0.165	0.226	0.147
	(0.60)	(0.91)	(1.00)	(1.56)
Constant	-2.233***	-2.355***	-3.151***	-1.950***
	(-5.24)	(-5.51)	(-5.83)	(-6.14)
σ_u	1.065***	1.062***	1.293***	-
	(16.37)	(16.23)	(13.90)	-
σ_ϵ	0.651***	0.617***	0.582***	-
	(30.11)	(29.21)	(24.51)	-
N	688	688	688	688

Note: t statistics in parentheses; *p<0.05, ** p < 0.01, *** p < 0.001

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