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Preference Mapping of Whole Grain and High Fiber Products: Whole Wheat Bread and Extruded Rice and Bean Snack

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PREFERENCE MAPPING OF WHOLE GRAIN AND HIGH FIBER PRODUCTS: WHOLE WHEAT BREAD AND EXTRUDED RICE AND BEAN SNACK

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PREFERENCE MAPPING OF WHOLE GRAIN AND HIGH FIBER PRODUCTS:

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The rise of unhealthy lifestyles and diets among Americans is leading to an influx of health-conscious consumers on the search for more nutritious, health-promoting food options that match their taste preferences. The aim of this research is to determine consumer preferences and specific attributes of whole grain and high fiber products that drive acceptability through descriptive analysis and preference mapping on whole wheat breads and an extruded pinto bean and brown rice flour snack puff.

Commercial whole wheat breads, characterized by 26 appearance, aroma, flavor, and texture attributes, were separated into two distinct groups. The first group consisted of attributes similar to white bread: sweet, moist, and sticky. While the second group, had attributes associated with traditional wheat breads: wheaty, earthy, bitter. Consumers were clustered into three groups for clearer understanding of market segmentation. The first cluster liked all breads equally, while the second liked the breads associated with white bread attributes and the third cluster liked the classic wheat breads more. This was confirmed through partial least squares (PLS) regression, which showed if each attribute positively or negatively affected overall liking for each respective cluster.

In the second study, composite flours were extruded with varying pinto bean flour levels and feed moisture conditions to produce an acceptable puffed snack product. The

level of bean flour affected the majority of the fifteen descriptive attributes, while feed moisture only affected texture and appearance attributes. Consumers found the extruded puffs with up to 15% bean flour to be the most acceptable. Preference mapping and PLS regression showed higher overall liking scores for samples characterized by rice flavor and larger diameter and lower scores for extrudates with higher bean flavor and grittier textures.

Overall, these studies were successful in determining descriptive attributes as well as their relationship to consumer acceptability through preference mapping. These data may be helpful for future researchers when developing new whole grain and high fiber products.

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INTRODUCTION

The USDA recommends that whole grains should make up half of the recommended total grain intake as moderate scientific evidence suggests whole grains, specifically fiber from whole grains, may help lower body weight and reduce the risk of cardiovascular disease (USDA Dietary Guidelines, 2010). While there has been a rise in whole grain products in the market, as seen with the success of the Whole Grains Council's whole grain stamp on over 10,500 different products across 45 countries (Whole Grains Council, 2015), less than 5% of Americans consume this recommended amount (USDA Dietary Guidelines, 2010).

One way to promote consumption of whole grains and high fiber food products, is for food companies to invest in research on these products that maintains desirable sensory properties. In order to determine desirable properties, descriptive analysis and preference mapping techniques are used. Descriptive analysis has been described by Murray et al. (2001) as "undoubtedly one of the most valuable tools in the field of sensory analysis". In generic descriptive analysis, a small trained panel utilizes their own previous experiences and perception to evaluate products qualitatively and quantitatively. Thus, giving intensities for attributes that may not be tested using analytical measures (Murray et al., 2001).

When selecting the samples for this research, both were high fiber products and contained a whole grain. The samples chosen were whole wheat bread and an extruded brown rice/bean flour snack puff. Whole wheat breads were chosen due to their increasing popularity in the marketplace (Atchley, 2013) and relative ease to find multiple commercial varieties. Pinto beans, on the other hand, were chosen to supplement

the brown rice (source of whole grain) due to their dominance in dry bean production and their high fiber, protein, and low fat content, which has been associated with a reduced risk of coronary diseases (Winham and Hutchins, 2007).

Objective and Hypotheses

The overall objective of this research was to use descriptive analysis to evaluate differences among whole grain products and to determine their relationship to consumer acceptability through preference mapping and partial least squares (PLS) regression. Specific aims were to analyze differences among (a) commercially available whole wheat breads and (b) extruded rice and bean flour puff snacks.

This study was not a hypothesis driven study, but a need based study. Due to the urgent need for companies to understand consumer desires, this project was designed to determine complex consumer information in order to create desirable, healthy whole grain and high fiber products. Data obtained from this project, including descriptive attributes and overall acceptance scores, were used to plot preference maps and partial least squares regression. By doing this, desirable and undesirable qualities of whole wheat bread and extruded snack puffs were determined for different consumer segments, as well as identified attributes desired from consumers that are absent in currently available whole wheat breads. These findings will be useful in improving the overall quality of the products and consumer satisfaction.

Organization

This thesis is a compilation of a literature review (Chapter 1) and manuscripts describing two research projects (Chapters 2 and 3), followed by general conclusions. Chapter 1 has been formatted using the guidelines for *Critical Reviews in Food Science and* Nutrition, Chapter 2 for *Cereal Chemistry*, and Chapter 3 for *LWT- Food Science and Technology*. References can be found at the end of each chapter and follow the format of the mentioned journal. Material presented in Chapter 2 has been published, with Chapter 3 to be published in the near future.

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CHAPTER 1. WHOLE GRAIN AND HIGH FIBER HEALTH, CONSUMPTION, AND SENSORY ATTRIBUTES

1.1. Abstract

The addition of whole grains and high fiber offers good sources of protein, fiber, and many micronutrients and may help reduce the risk of obesity, diabetes, and cardiovascular disease. Although many novel products have been launched, consumption of whole grains and high fiber remains low, prompting the need for sensory information. Multivariate statistical techniques, including preference mapping and PLS regression, are useful in determining relationships between descriptive analysis and consumer acceptance tests in order to better understand consumer preferences and market segmentation. A literature search on whole wheat products shows many descriptive analysis studies, yet limited research on consumer acceptance. Further, the available research on consumer preference of whole grain versus refined grain products is inconsistent. For high fiber products, pinto beans have been successfully incorporated into several consumer acceptable products. When used in extrusion, the increase of bean flour will ultimately cause a decrease in expansion and increase in hardness and density, however, decreasing feed moisture may mitigate this. Ultimately, the construct of a preference map from commercial whole wheat breads and a pinto bean and brown rice extrudate is essential to improve consumer acceptability of whole grains and high fiber products and increase their consumption in the diet.

1.2. Introduction

Understanding consumer preferences is a primary goal for product developers. Many large food companies rely on a team of sensory scientists to uncover and discern consumer opinion in order to produce an ideal product for a particular demographic. One area of interest in the food industry is the rise of healthy and functional foods. Consumers are looking for choices that offer health promoting benefits as well as that match their taste preference. One segment of these healthy food choices is those high in whole grains and dietary fiber.

As the United States has seen a decrease in adherence to healthy lifestyles (King et al., 2009) and a shift toward an obesogenic environment, the prevalence of non-communicable diseases like diabetes and cardiovascular disease has increased (Poutanen, 2012). Although obesity is likely caused by an energy imbalance, by consuming more calories than expended, researchers have been evaluating the effects of specific food ingredients in reversing these unhealthy trends. Specifically, whole grains and legumes, which offer good sources of protein, fiber, and many micronutrients may help reduce the risk of obesity, diabetes, and cardiovascular disease (Flight and Clifton, 2006; Grooms et al., 2013; Winham and Hutchins, 2007).

Extrusion, a commonly used technique for the production of cereal and snack food products, has been advantageous in the incorporation of edible beans in the diet (Gujska et al., 2001). Experimental and modeling data have already shown that by subsituting refined grains with their whole grain counterpart, primarily in breads, pastas, ready-to-eat cereal, and other baked goods, consumption of whole grains in children and teen diets significantly increases (Chu et al., 2011; Keast et al., 2011).

Despite the increasing popularity of whole wheat and whole grain breads (Atchley, 2013) and introduction of many novel food products utilizing whole grains and legumes, most Americans still do not meet the recommended intake levels of whole grains and dietary fiber. This is likely due to lack of consumer research on acceptance, as well as research to be able to identify and describe specific attributes of these products. More specifically, there is a lack of research on organoleptic properties determined by a trained panel. By determining these characteristic traits with the use of sensory analysis, manufacturers will have a better understanding of consumers' wants, enabling production of more desirable products.

In this article, the benefits of whole grains and high fiber and their consumption trends in the United States will be introduced, as well as a review of sensory analysis techniques, followed by a discussion of research utilizing sensory methods to produce descriptive attributes and consumer acceptability of bread and extruded products and their subsequent ingredients.

1.3. Whole Grain and High Fiber Contributions to Health and Consumption Trends

Cereal grains are an excellent source of carbohydrates, dietary fiber, and protein and good sources of the B vitamins, vitamin E, and many minerals (Flight and Clifton, 2006). Legumes are also recommended as a good source of protein, fiber, and several micronutrients (Bouchenak and Lamri-Senhadji, 2013). Scientific research has shown that the consumption of whole grains and dietary fiber may be protective against cardiovascular disease (Flight and Clifton, 2006; Hutchins et al., 2012), cancer (Chatenoud et al., 1998), diabetes (Venn and Mann, 2004), obesity (Newby et al., 2007; Rose et al., 2007; Slavin, 2005) and metabolic syndrome (Sahyoun et al., 2006). While

fiber is frequently used in health studies, whole grains also contain many bioactive components that may be protective including antioxidants, vitamins, minerals, lignans, and phenolic compounds (Slavin, 2003).

The USDA recommends that whole grains should make up half of the recommended total grain intake, 3 oz eq per day (USDA Dietary Guidelines, 2010). Despite the rise in whole grain products in the market, as seen with the success of the Whole Grains Council's whole grain stamp on over 10,500 different products across 45 countries, (Whole Grains Coucnil, 2015); the USDA has reported only 5% of Americans consume the recommended amount of whole grains. Further, the USDA recommends intake of dietary fiber be 14g per 1,000 calories, which is about 25g per day for women and 38g for men. However, usual intake is approximately 15g per day (USDA Dietary Guidelines, 2010).

Mean intakes for whole grain measured from 2001-2010 were well below the recommended levels at about 0.61 oz eq/day for adults 19-50y and were largely from yeast breads, ready-to-eat cereals (RTEC), and pastas, cooked cereals, and rice (Mcgill et al., 2015). Similarly, Larson and Story (2010) found that adolescents and young adults were also not meeting the daily intake of whole grains with only approximately 0.6 servings per day. Intakes for fiber were also about half of the recommended intake, ranging from 15-17 g/day (Mcgill et al., 2015; Reicks et al., 2014). These findings for dietary fiber were also consistent with a review of dietary fiber intake in the United States from 1999-2008 that revealed no observable increase in fiber intake over the ten-year period. The study also showed that men had higher total dietary fiber intake, but when energy intake was accounted for, their dietary intake was only 7g per 1,000 kcal as

compared to 8.1g for women. Although grains were found to make up the largest portion of fiber intake at 43.7% (King et al., 2012), the USDA found during that time, there was no increase in dietary fiber although there was an increase of grains contributing to the U.S. fiber supply in 2005 (USDA 2007).

Due to the nutritional benefit and low intake of dietary fiber by Americans, the USDA 2010 Guidelines highlighted dietary fiber as a nutrient of concern (USDA Dietary Guidelines, 2010). Incorporating both whole grains and higher fiber foods has been a major goal of the food industry. While there are a few people who prefer the taste of whole grains, a study in Ireland found the biggest barrier to whole grain consumption was the difference in sensory properties (Mcmackin et al., 2012). In response to this type of consumer, many companies have developed whole grain products with characteristics similar to their refined counterparts such as ConAgra Foods' Ultra Grain (whole-white wheat) and ADM's Kansas Diamond (ultra-fine whole-white wheat) (Food Navigator-USA.com, 2005). Experimental and modeling work substituting refined grains with their whole grain counterparts found the consumption of whole grains in children and teen diets to significantly increase, primarily from breads, pastas, RTEC, and other baked goods (Chu et al., 2011; Keast et al., 2011). It has also been found that snacks make up a significant part of both fiber and whole grain intake, contributing over 20% of fiber and about 26% of whole grain (Mcgill et al., 2015). With an increased pattern in snacking (Kant and Graubard, 2015), ready-to-eat snacks may be the ideal food group for companies to introduce new whole grain and high fiber products.

1.4. Sensory Evaluation and Statistical Analyses

1.4.1. Sensory Methods in the Food Industry

Sensory science is a resource with a wide range of applications that can provide measurements on product differences, attribute intensities, and preferences. In a food company, the role of sensory is not only to service research and development, but also marketing and manufacturing (Sidel and Stone, 1993). One such example is determining the acceptability of reformulated products after shelf-life testing, as done by Capriles et al. (2009) on the stability of rapeseed oil in snack foods.

There are three main types of sensory tests: discriminative, affective, and descriptive. Discrimination tests, including paired comparison, duo-trio, and triangle tests, are the simplest sensory tests used to determine if a difference exists between samples. Lately, companies have been using them for cost reduction and reformulation, especially in order to reduce sodium content in foods and beverages (Kim et al., 2015). Affective tests are conducted to determine overall preference or liking of a product by a sample of consumers that represent the intended population and to quantify results in order to relate them to descriptive analysis. Consumer affective tests usually only require 50-100 consumers (Resurreccion, 1998) and commonly utilize the 15pt interval scales or 9pt hedonic scales. Finally, the last method of sensory analysis and arguably the most valuable is descriptive analysis.

Descriptive sensory analyses are the most sophisticated and valuable tools a sensory scientist can use when identification, quantification, and description of characteristics of food is desired without the use of laboratory equipment. As such, the panelist, after extensive training, becomes a human instrument. This method of analysis

can be used across many platforms of the food industry including reformulation, development of new products, quality monitoring, and determination of the relationship between sensory and instrumental methods (Ares and Gimenez, 2013). There are several different methods of descriptive analysis that employ different techniques in training and scale usage yielding slightly different outcomes. The major approaches are the Flavor Profile, Quantitative Descriptive Analysis (Stone et al.,1974), Texture Profile (Brandt et al., 1963), Sensory Spectrum (Meilgaard et al., 2007), and a generic descriptive analysis (Lawless and Heymann, 2010).

In both research and industry, it is fairly common to use a generic descriptive panel, as researchers are able to modify and combine methods as needed. Generally, there are a few major steps involved in a generic descriptive analysis. First, it is important to recognize the overall success of the panel is dependent on the commitment and motivation of the panelists. Therefore, great care should be taken in recruitment and selection of the panel. The total number of panelists usually depends on availability and budget, however most panels range from six to twenty judges (Heyman et al., 2012; Silva et al., 2014). Panelists should be selected based on the project objective and screened for sensory acuity (Armstrong, 1999). Once a panel has been selected, panelists are exposed to a wide range of product in order to generate an exhaustive list of attributes. If well defined, existing languages from previous studies may also be sought. After consensus on attributes, the panel is trained with unstructured scales in order to produce a common frame of reference for all panelists. Reference standards are commonly used in descriptive panels in order to achieve alignment and improve the performance of the panelists (Murray et al., 2001). For the most effective panel, training should be as

extensive as possible; although limitations may exist to conduct a long training, a positive relationship has been found between the length of panel training and panel performance (Chambers et al., 1994). Ultimately, the trained panel will function as surrogate instruments in the reproducible qualification and quantification of product attributes (Moskowitz, 1996).

Several modifications of descriptive analysis have been made to account for the perceptual change of an attribute over a period of time (Ross et al., 2012). Time scanning descriptive analysis (TSDA) can be useful to negate these changes over time by establishing specific assessment times and temperatures in the protocol (Se et al., 2009). When the effect of time is desired, however, time intensity scaling allows the panelist to focus on changes of a single attribute, commonly astringency and bitterness, over a period of time (Dijksterhuis and Piggott, 2001; Francois et al., 2006).

Due to the extensive training required by most descriptive analyses, establishing a trained panel can be a long and expensive process, so alternatives have been researched in hopes of reducing or eliminating the need to train panelists. The ranking procedure, which is traditionally a discrimination test that serves all the samples simultaneously, does not require extensive training and was useful in determining differences between attributes when the quantitative magnitude was not required (Richter et al., 2010). Similarly, sorting procedures have been found to produce similar results without the need to train panelists (Cartier et al., 2006). Finally, the Optimized Descriptive Profile also presents all samples and references at once and only assesses one attribute at a time. By doing such, it reduces the training time of the panelists by only needing to familiarize the

panelists with reference samples, but unlike the ranking and sorting procedure it does not lose quantitative information on magnitude (Silva et al., 2012; Silva et al., 2013)

1.4.2. Statistical Analyses for Sensory Data

To interpret sensory data, univariate and multivariate statistical analysis techniques are used. Their use will depend on the study and resulting data. One of the most popular statistical methods used for testing the significance of effects from products, assessors, and other variables is analysis of variance (ANOVA) (Piggott et al., 1998).

The purpose of ANOVA is to determine the factors that are responsible for the variation in the response. Once significance has been found, post hoc testing, or multiple comparison testing, is used to statistically compare the averages of the products. Common post hoc tests include, least significant difference (LSD), Tukey's, Bonferroni, Newman-Keul's, and Duncan's (Naes et al., 2010). Traditionally, ANOVAs are used to evaluate differences in products and attributes from acceptance and descriptive data. However, they have also been useful in determining the accuracy of a panel. Although panelists may undergo extensive training, it is possible that panelists will use scales in different ways which may lead to significant sample x panelist interactions (Naes and Langsrud, 1998). Since it is hard to eliminate the differences in sensitivity to attributes between panelists (Tomic et al., 2007), the model is adjusted to use the interaction term in place of the mean square error, and the F-value and LSD values are recalculated (Bayarri et al., 2012). This adjustment has been useful for many studies in determining whether or not samples are still significantly different (Caballero et al., 2003).

Further analysis of consumer and descriptive data can be analyzed using several multivariate techniques including Principal Component Analysis (PCA), Cluster Analysis, Partial Least Squares (PLS) Regression, and Preference Mapping. These techniques can be useful in creating a spatial representation of the data for easy interpretation among descriptive, consumer, and instrumental data as well as understanding consumer acceptance. Principal Component Analysis (PCA) analyzes the correlation matrix of a group of observations in order to provide axes, principal components, of the most interesting and important dimensions of variability, which generally can determine between 75 to 90% of the variance with as few as two to three principal components (Naes et al., 2010; Ravi et al., 2011). PCA can be used to visually depict relationships between samples and attributes, determine potential clusters, and relate different sensory methods (Caballero et al., 2003; Miller and Chambers, 2013b; Silva et al., 2013). PCA can also be used to reduce the amount of attributes that adequately describe the product; however, in some cases where the variance between products is great, a reduction is not possible. This was seen in a descriptive study on cooked rice flavors that produced a lexicon of many aromatics as well as the basic flavors of the 33 samples, but lacked the ability to reduce the amount of descriptive attributes (Limpawattana and Shewfelt, 2010). The limitation of PCA is that it is not the most relevant at explaining liking scores, which is where PLS regression is useful. PLS regression easily relates the linear relationship between sensory characteristics and hedonic judgments (Tenenhaus et al., 2005). It is also commonly used in relating instrumental data with sensory data (Limpawattana et al., 2008; Toscas et al., 1999).

An alternative, multi-dimensional, method of relating consumer and descriptive data of a product, is the construction of a preference map from PCA (Cariou et al., 2014; McEwan, 1996). The resulting data from preference mapping can also be useful in determining market demands and expectations as well as predicting product properties for prototype development (Caspia et al., 2006). There are two types of preference mapping: internal and external. Internal preference mapping gives precedence to consumer preferences followed by descriptive information. External preference mapping, however, builds the product map using descriptive information then fits consumer preferences (van Kleef et al., 2006). Since consumers are not always able to specifically describe what they like or dislike in a product, preference mapping gives researchers a tool to better understand them. This technique has been utilized in research on various food commodities including raspberries (Villamor et al., 2013), chocolate milk (Thompson et al., 2004), spreadable cheeses (Bayarri et al., 2012), kefir (Gere et al., 2014), and apples (Bonany et al., 2014), among others.

Through the segmentation of the consumer data using hierarchal cluster analysis, consumers can be separated based on their preferences to provide a clearer understanding of market segmentation (Qannari et al., 1997). Cluster analysis uses computations to group individuals and products according to a measure of similarity (Moskowitz et al., 2012). Clustering is advantageous in differentiating products (Bett-Garber et al., 2001) as well as consumers since they can vary greatly in terms of their likes and dislikes (Arditti, 1997; Miller and Chambers, 2013a).

1.5. Use of Sensory Analysis for the Production of Whole Grain and High Fiber Products

1.5.1. Descriptive Attributes and Consumer Acceptance of Breads

Throughout the years, many studies have used various descriptive analyses to determine freshness (Heenan et al., 2008), identify major compounds (Jiang & Peterson, 2013), evaluate the influence of ingredient (Carson et al., 2000; Collar et al., 2005; Shogren et al., 2003) and processing (Annett et al., 2007; Kihlberg et al., 2004; Kihlberg et al., 2006), to monitor aroma and flavor during storage (Jensen et al., 2011), and to evaluate product characteristics of specialty breads. Lotong et al. (2000) produced a detailed lexicon for describing flavors of wheat sourdough bread including wheaty, yeasty, and sour flavor, which were the most noted attributes in the samples. Descriptive analysis has also been used in determining attributes/lexicons for commercially available breads in Spain (Elía, 2011), Australia (Murray et al., 2002), Norway (Hersleth et al., 2005), and on French bread in Japan (Hayakawa et al., 2010). Common attributes between some of these studies included sweet and salty flavor, moistness, colors of crust and crumb, and chewiness. Unique attributes like pig fat (Elía, 2011) and hay-like (Carson et al., 2000) have also been found to describe breads.

Before 2011, there was no standard method for the sensory analysis of bread and a review of literature found that preparation and attributes evaluated were highly variable (Callejo, 2011). In 2011, Innopan, the Spanish Center of Baking Technology, proposed a method for the sensory analysis of bread by defining a set of 46 descriptors through many sessions of descriptor generation, followed by determination of detailed methodology for measuring aroma, texture, appearance, and flavor attributes (Elía, 2011).

Research on the relation of descriptive attributes with consumer acceptability and subsequent multivariate analyses is limited. Currently, research has been found for composite flours (Charoenthaikij et al., 2010; Ivanovski et al., 2012; Rødbotten et al., 2015) and shelf life of white pan bread (Gámbaro et al., 2004). While there has been no descriptive research on whole wheat breads as they relate to consumer acceptability, there have been studies that examine consumer acceptability of whole wheat versus refined grain bread. Flavor of whole grain products is generally associated with negative sensory attributes, especially bitterness (Bin et al., 2012). Bakke and Vickers (2007) showed that consumers who can taste the bitter compound, 6-n-propylthiouracil (PROP) preferred refined wheat breads. However, a large portion of the consumers, including PROP non-tasters, liked whole wheat and refined breads equally well. In order to attract more consumers to whole wheat, companies have begun utilizing white wheat as breads made from white wheat flour are lighter in color and have been reported to be sweeter and less bitter than red wheat flour (Watts et al., 2012). However, in an evaluation of the acceptance of bread and crackers made from red versus white wheat using descriptive analysis and consumer acceptance, it was found that consumers generally liked the red wheat products better than the white wheat. The authors attributed this to 81% of consumers in the study more frequently consuming traditional whole wheat products that are darker in nature (Challacombe et al., 2011). Similarly, Bakke and Vickers (2011) also found that consumers who prefer whole wheat breads liked breads that were darker in color. This discrepancy of consumer attitudes toward white wheat flours, and whole wheat flours in general, further proves the necessity of research on the descriptive analysis and consumer acceptance of whole wheat breads in the United States.

1.5.2. Dry Bean and Brown Rice Description and Processing Effects of Extrusion

Dry edible beans represent 50% of grain legumes consumed by humans; more specifically, pinto beans account for the majority of the production and consumption of dry edible beans (Camara et al., 2013). Descriptive research on pinto beans is limited to a few studies. A descriptive panel on a no-flatulence pinto bean found color, stickiness, raw bean off flavor, cooked bean aroma, nutty flavor, sweet, bitter, and astringent sensory characteristics (Song et al., 2009). Similar attributes, as well as many other appearance, aroma, flavor, and texture attributes, were also found using the QDA on common beans to determine the affect of radiation (Armelim et al., 2006). Mkanda et al. (2007) related consumer preference with physicochemical and sensory properties of common beans as affected by variety and location and found that beans with sweet taste, soft texture, and cooked-bean flavors were the most preferred, while beans with a bitter taste, soapy and metallic mouthfeel, and hard texture were least preferred.

Several studies have tested consumer acceptability of adding bean flour to various products with some success. Pre-gelatinized flour composed of rice and peeled black bean flours was added to a cookie formula at levels of 15 and 30% in order to improve nutritional characteristics; at these levels, consumers rated the cookies 6.25 and 6.17 on a 9-point hedonic scale, suggesting they liked the cookies slightly (Bassinello et al., 2011). Similarly, Anton et al. (2009b) determined an addition of 25% pinto bean flour to wheat tortillas was acceptable and may appeal to health conscious consumers. Another study determined that a cereal sample, with a 70:30 ratio of rice flour to pinto bean flour, had good overall acceptability (Carvalho et al., 2012). Extruded snack samples made with either defatted or non-defatted pinto bean flour, and coated with a seasoning mix before

testing, were determined to be equally acceptable with no statistical difference in the crispness, taste, and general acceptability of the samples (Gujska et al., 2001).

Although there is limited research on the descriptive analysis of composite flour extrudates, many have studied their physical characteristics. Since sensory attributes produced by a descriptive panel on extruded snacks were found to strongly correlate with instrumental texture analyses (Paula and Conti-Silva, 2014), a review of physical characteristics measured by scientific instruments will serve to predict descriptive results of bean flour/brown rice composite flours.

The addition of bean flour to extruded products has caused several physical effects. First, the addition of bean flour results in a decrease in overall expansion, likely due to the dietary fiber from beans, and an ultimate increase in density (Anton et al., 2009a; Brennan et al., 2013). However, the degree of expansion can also be affected by the particle size and uniformity of the bean flour. Coarse-ground flours were found to cause a lower expansion as compared to finely-ground flour (Nyombaire et al., 2011). Bean flour can also influence the texture of the extrudate by making them harder (Chaiyakul et al., 2009; Estrada-Girón et al., 2015).

Several authors have experimented with altering feed moisture. An increase in feed moisture during extrusion cooking can cause a change in the amylopectin structure, thus reducing the melt elasticity and producing a less expanded product (Ding et al., 2005). This is consistent with results of a primarily brown rice flour composite (90% rice flour, 8% corn starch, 2% potato starch) having reduced expansion values with increased feed moisture. In this same study, the increase in feed moisture also initially caused an increase in hardness of the extrudate, however, beyond 30% feed moisture, the hardness

began to decrease (Liu et al., 2011). Consistent with these results, a descriptive panel found crunchiness, crispness, and diameter to all decrease with increasing feed moisture (Lazou et al., 2010). Scanning electron microscopy was used to confirm these effects of feed moisture and bean addition had an impact on the structural and textural properties of extrudates, as seen by thickening of cell walls and increased pore size (Lazou and Krokida, 2010; Saeleaw et al., 2012). Ultimately, this suggests a decrease or use of the lowest level of feed moisture will help to mitigate the effects of bean flour addition.

1.6. Conclusions

The consumer demand for whole grains and high fiber products is growing, and addition of whole grains and high fiber ingredients into commonly eaten foods like breads and extruded ready-to-eat snacks offers consumers healthy alternatives. Sensory techniques such as descriptive analysis and consumer affective tests have proven to be useful in multivariate statistical analyses in relating hedonic responses with descriptive attributes. Conflicting results on the acceptability of whole wheat and a lack of studies on descriptive attributes of whole wheat breads, especially those found commercially in the United States, suggests further research is needed. Incorporation of dry edible beans at levels around 25-30% in composite flours shows potential in producing a healthier extruded snack when extruded at low feed moisture conditions.

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CHAPTER 2. PREFERENCE MAPPING OF COMMERCIAL WHOLE WHEAT BREADS

2.1. Abstract

Whole wheat breads are becoming a dominant presence in the market. However, the sensory qualities that drive consumer liking have not been well described. The purpose of this study was to identify sensory attributes and consumer acceptance of commercial whole wheat breads. Six whole wheat breads were evaluated for 26 attributes by a trained panel (N=8). Two distinct groups of attributes were noted for the breads: those that were sweet, moist, and sticky versus those with characteristics associated with whole wheat such as wheaty, earthy, and roasted. In the consumer panel (N=75), three clusters were formed. Cluster 1 (n=28) had higher mean hedonic scores for all attributes compared with the other clusters ($p<0.01$), although these consumers did not distinguish well among samples. Significant differences were found in all attributes in clusters 2 (n=33) and 3 (n=14). Cluster 2 preferred samples with sweet flavors and moist, cohesive textures, while cluster 3 preferred samples with earthy, roasted, and whole wheat flavors. A portion of consumers appeared to prefer breads with not only sweet and moist characteristics, but also with some of the more hearty attributes like roasted and fermented. These data may be useful in developing new whole wheat products.

2.2. Introduction

Whole grain breads are becoming increasingly popular in the marketplace today (Atchley 2013). This increasing presence and competition of whole wheat breads allows for products to have different formulas and characteristic traits. By determining these characteristic traits with the use of sensory analysis, manufacturers will have a better understanding of consumers’ wants, enabling production of more desirable products.

The relationship between consumer preference and descriptive data can be formed with the use of preference mapping (McEwan 1996). This technique has been used in other food commodities including raspberries (Villamor et al 2013), chocolate milk (Thompson et al 2004), spreadable cheeses (Bayarri et al 2012), and apples (Bonany et al 2014), among others. The resulting data can be useful in determining market demands and expectations (Caspia et al 2006). Further segmentation of the data using hierarchal cluster analysis can separate consumers based on their preferences (Qannari et al 1997) to realize a clearer understanding of market segmentation.

In recent years, several studies have examined sensory components of whole wheat breads using either pan bread or commercially available bread in other countries. Most studies have focused on specific attributes or types of bread including bitterness (Jiang and Peterson 2013) and freshness (Heenan et al 2008) of commercial breads, soybean flavor in high protein wheat and soy breads (Shogren et al 2003), and sensory attributes of sourdough breads (Lotong et al 2000). Some studies have utilized descriptive analysis in wheat pan bread to monitor changes in aroma and flavor during storage (Jensen et al 2011) and to determine the effect of various farming systems (Kihlberg et al 2004). Additionally, Elia et al (2011) evaluated a descriptive analysis protocol using commercial Spanish breads and Murray et al (2002) developed a lexicon for a variety of Australian store-bought breads. Another study using Norwegian bread looked at the difference between descriptive attributes developed from consumers and trained assessors and asked questions on appropriateness of the bread (Hersleth et al 2005). None of the studies further analyzed the information with consumer preference.

Not only do commercial breads among countries differ greatly, consumer preferences are also different and should be determined. Therefore, the objective of this research was to use descriptive analysis to evaluate differences among commercially available whole wheat breads in the US and determine their relationship to consumer acceptability through preference mapping and partial least squares (PLS) regression.

2.3. Materials and Methods

2.3.1. Whole Wheat Breads

Six whole wheat breads covering brands that were available throughout the US were selected for analysis. Selection was limited to commercial breads declaring 100% whole wheat (Fig. 2.1). A few of the samples' packages included descriptive attributes of the bread on the principal display panel: hearty and delicious for sample 2, lightly sweetened taste, soft, smooth texture for sample 3, and 100% stone ground whole wheat for sample 4. Most of the packages contained nutrition-related statements about not containing high fructose corn syrup or the fiber or whole grain content.

After purchase, all samples were stored at -20˚C for the entirety of the study. When needed, bread was thawed overnight then stored in airtight plastic bags for panel use. The two end pieces from each loaf were removed prior to use.

2.3.2. Descriptive Panel

Trained panelists were recruited through emails, fliers, and social media. Selection criteria included if they liked and regularly consumed whole wheat bread, had no allergies to wheat, soy, or dairy, and had a flexible schedule that would allow them to participate in two 1.5-2 h training sessions per week. Panelists (4 males and 4 females) trained for approximately 13 hours over a course of 8 weeks to develop descriptive

attributes for whole wheat bread and definitive line scales. Training was divided into four phases. In the first phase, panelists sampled the six commercial breads, as well as laboratory-prepared whole wheat and white pan breads (AACC International Approved Method 10-10.03), to develop an exhaustive list of words that described the bread in terms of appearance, aroma, texture, and flavor attributes. Redundant or similar terms were either eliminated or combined by panel consensus. Attributes only detectable by some of the panelists were also eliminated. In phase 2, panelists reanalyzed the commercial breads to determine anchor words and any specific instructions on how to evaluate each descriptor. In the third phase, intensity of each attribute was determined on a subset of samples by general consensus of the trained panel using an unstructured line scale, followed by an individual practice evaluation with remaining samples. Generally, 3 samples were selected to construct the intensity scale and 2 additional samples were selected for individual evaluation. If the panelists were not in agreement over the placement of the two practice samples, the scale would be reevaluated for intensity. In the final phase, panelists assessed the six samples in quadruplicate over two sessions (evaluated each bread twice per session). Evaluation was held in individualized sensory booths with white light. Room temperature water and apples were served as a palate cleanser between samples and panelists were encouraged to expectorate samples to prevent fatigue.

2.3.3. Consumer Panel

Consumers were recruited from the students, faculty, and staff at the University of Nebraska-Lincoln as well as from the surrounding community. Interested consumers were included if they verbally indicated that they liked and regularly consumed whole

wheat bread and had no allergies to wheat, soy, or dairy. Overall, 75 consumers participated in the consumer panel.

Thawed bread samples were cut in half vertically using an electric knife and stored in plastic bags until served. Half slices were served in a completely randomized design presented on white napkins labeled with a random 3-digit code; room temperature water and sliced apples were provided for palate cleansing between samples. Evaluation took place in individual booths under white light. Overall, texture, appearance, and flavor acceptance were evaluated using a 9-point hedonic scale (where 1= dislike extremely and 9= like extremely).

2.3.4. Data Analysis

For the descriptive panel, three-way ANOVA models with interactions were constructed for each descriptor. Main effects in the models were sample, panelist, and replicate, and interaction terms for sample*panelist and panelist*replicate were included. Differences between individual means were calculated by the least significant difference (LSD) procedure in ANOVA models with significant F values for the sample term. For attributes with a significant sample*panelist interaction ($p<0.05$), the F value for sample in the ANOVA model and LSD values were re-calculated using the mean square of the sample*panelist interaction term in place of the mean square error to confirm significance among samples (Carlucci and Monteleone 2001). The mean values of the descriptive data were further evaluated for each sample using principal component analysis (PCA). All data for the descriptive panel were evaluated using SAS software (version 9.2, SAS Institute, Cary, NC USA).

Consumer data were analyzed using a two-way ANOVA with sample and panelist as the factors. For samples with significant *F* values in the ANOVA model, differences between individual means were calculated by the LSD procedure. Initially, all consumers were included in the analysis. The data were then re-analyzed after consumers were clustered into three groups based on their hedonic scores using agglomerative hierarchical clustering using Ward's method. These data were analyzed using SAS software.

The consumer and descriptive data were combined to construct an internal preference map. Initially, PCA was run using panelists' overall acceptance scores for each sample and any respondents whose communality score that was less than 0.50 was removed (Meilgaard et al 2007); sixteen consumer scores were removed from the map. Panelists' factor scores were then rescaled to fall equidistant from the origin. Then, sample means for each descriptor from the descriptive panel were correlated with the factor loadings for sample from the PCA analysis to construct the preference map. PLS regression was also applied to the descriptive and consumer data. Overall acceptance of each cluster was used as the dependent variable and sensory attributes were used as the independent variable. Data were centered and scaled by the software to remove bias associated with the magnitude of variable means. Attributes with solid bars represent those with a variable importance in projection (VIP) higher than 0.8 and significantly contribute to overall liking (Villamor 2013). The preference map was constructed using SAS software and the PLS analysis was applied using XLSTAT 2011 (Addinsoft, Paris, France).

2.4 Results and Discussion

2.4.1. Descriptive Panel

Twenty-six attributes were determined by the trained panel to be used in the final descriptive panel (Table 2.1). Eight of the 26 attributes were found to carry a significant *F* value for the sample*panelist interaction (whole wheat aroma, particulates, doughy, earthy, sour, whole wheat flavor, moistness, and smoothness), indicating that panelists used the scales in different ways for these attributes. However, when the interaction term was used as the denominator in the ANOVA model, the sample term remained significant for seven of the attributes, while doughy flavor no longer showed significant differences among samples.

Differences among attributes for each of the samples are presented in Table 2.2. Samples 1 and 3 were described by sweet flavor and adhesive, cohesive, and moist textures. Sample 4 also had an adhesive texture, but was not as sweet, cohesive, or moist. Darker crust color accompanied by a firm crumb with a lack of smoothness (coarse) containing larger particulates, a fermented aroma, and whole wheat and earthy flavors were seen in samples 2, 5, and 6. Sample 5 was also marked by buttery, roasted, and whole wheat aroma notes, while sample 2 was characterized by sour flavor and smaller pores. Sample 6 was distinguished as having a fruity aroma and springy texture.

Descriptive attributes obtained were similar to those found in other whole wheat bread studies (Annett et al 2007; Callejo 2011). Attributes like doughy, sweet, and bitter flavors were noted at similar levels in wheat bread before long storage (Jensen et al 2011). Hay aroma found in whole wheat pan bread (Kihlberg et al 2004) was described as an earthy flavor in this study.

When PCA was applied to the data, two distinct groups of attributes were noted (Fig. 2.2). The first group included rustic type whole wheat bread characteristics: whole wheat aroma, roasted, bitter, salty, and earthy flavors. These descriptors were associated with samples 5 and 6. The second group contained attributes of undercooked, doughy breads as described by doughy, sweet, moist, and cohesive attributes, which described samples 1 and 3. Samples 2 and 4 were not well described by the attributes in the plot, indicating that either these samples possessed characteristics of both groups of descriptors or there was a lack of descriptive attributes developed by the panel for these breads.

2.4.2. Consumer Panel

Overall, texture, and flavor acceptability had significant differences among samples, but no significant differences were found for appearance (Table 2.3). Excluding appearance, samples 2 and 5 were the least acceptable, while the most liked samples were dependent on the specific attribute. Samples 1 and 3 had no significant difference in flavor, but consumers did prefer the flavor of sample 3 to samples 2, 4, 5, and 6. Consumers preferred the texture of sample 6 to samples 2 and 5 and the overall acceptability of sample 1 to samples 2 and 5.

Based on the hedonic responses, three cluster groups were formed (Table 2.3). Cluster 1 had noticeably higher mean hedonic scores for all attributes compared to the other clusters ($p<0.01$); however, within cluster 1, significant differences among samples were only noted for flavor. This suggests that those in cluster 1 generally liked whole wheat bread and did not distinguish well among different types. Significant differences

were found for all attributes in clusters 2 and 3. Cluster 2 preferred samples 1, 3 and 4 while cluster 3 preferred samples 2, 5 and 6 based on mean values for all responses.

2.4.3. Relationships Between Descriptive and Consumer Panels

An internal preference map was prepared combining scores from the descriptive and consumer data (Fig. 2.3). Consumers were distributed among all four quadrants of the map, with most concentrated in quadrants I (n=24) and IV (n=20). As expected from the liking data, consumers in cluster 1 were distributed among all quadrants of the map (these consumers generally liked all samples; Table 2.3). In contrast, consumers in cluster 2 were mostly found in quadrants I and II, while consumers in cluster 3 were almost exclusively found in quadrants III and IV.

Two distinct groups of attributes were found on the map (Fig. 2.3), with attribute distributions similar to those in Fig. 2.2. Sweet, moist, adhesive and cohesive attributes were found in quadrant I, and the remainder of attributes, including bitter, fermented, earthy, and whole wheat were in quadrant III.

Based on the distribution of panelists, more panelists liked samples with attributes in quadrant I (samples 1 and 3), and few appreciated samples with attributes described in quadrant III (samples 2 and 5). There was a lack of attributes in both quadrants II and IV as well as a lack of consumers in quadrant II. However, quadrant IV contained a large number of consumers. This suggests that many consumers like breads that are sweet and moist, but also contain attributes that are characteristics of hearty whole grain breads.

PLS regression was performed to determine attributes that contributed most to the overall acceptability of whole wheat bread samples (Fig. 2.4). Differences were seen across all three clusters in drivers of overall liking. In the first cluster, high drivers of

liking, those with higher positive coefficients, include fruity aroma, sweet flavor, moist and cohesive texture, and darker crumb color. Cluster 2, the largest cluster, showed doughy and sweet flavor as well as adhesive and moist textures contributed to overall liking, while panelists were very much displeased with whole wheat, earthy, roasted, and bitter notes. Butter, fermented and whole wheat aroma, bitter flavor, and appearance attributes positively affected overall liking in cluster 3, the smallest cluster, while circular appearance and adhesive texture impacted it negatively. In this study, consumer preferences of the samples were driven by a combination of flavor, aroma, appearance, and texture attributes and not just one category of attributes. This is consistent with other descriptive panels that found significance in many attribute categories (Elía 2011; Hersleth et al 2005).

2.5. Conclusion

In this study, a descriptive panel found two main groups of attributes for whole wheat bread: soft and chewy textures coupled with sweet flavors versus whole wheat, earthy, and roasted characteristics. Evaluating the same breads, consumers were grouped into three clusters. Based on the number of consumers in each category that participated in this study, characteristics of whole wheat breads should focus on fulfilling the desires of consumers in cluster 1 and 2. Cluster 1 generally liked all breads and did not distinguish among different types, while cluster 2 liked soft and chewy textures coupled with sweet flavors. Manufacturers looking to re-formulate breads, however, should recognize that regional and demographic differences in liking may exist; studies conducted in other locations or on specific demographics may yield different attributes of importance. Additionally, preference mapping of consumer data with descriptive data

displayed a lack of samples and attributes relating to a portion of consumers. This suggests that many of the consumers in this study liked breads with not only soft, chewy, and sweet flavors, but also some of the whole wheat, earthy, and bitter characteristics associated with whole wheat bread.

2.6. Acknowledgment

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2.7. References

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Table 2.1. Attributes and definitions developed for descriptive analysis

Attribute	Definition	Scale Anchors	Abbreviation
Appearance			
Circular	Pore formation of a circle	Not Circular – Very Circular	Ap_Cir
Crumb Color	Brightness of crumb	Light – Dark	Ap_Crm
Crumb Particulates	Size of particulates in crumb	Small – Large	Ap_Part
Crust Color	Brightness of crust	Light – Dark	Ap_Crst
Pore Size	Size of pores in crumb structure	Small – Large	Ap_Pore
Pore Uniformity	Uniformity of small pores	Very Uniform – Not Uniform	Ap_Unif
Aroma			
Butter	Aroma of butter, slightly rancid	Lacking – Intense	Ar_Butr
Fermented	Aroma associated with fermented dough	Lacking – Intense	Ar_Ferm
Fruity	Characteristic aroma of dried fruit	Lacking – Intense	Ar_Frt
Roasted	Dry, baked aroma	Lacking – Intense	Ar_Rst
Whole Wheat	Characteristic aroma of whole grain	Lacking – Intense	Ar_WW
Flavor			
Bitter	Basic bitter flavor	Lacking – Intense	F_Bitr
Doughy	Flavor associated with uncooked dough	Lacking – Intense	F_Do
Earthy	Dirty, hay-like Flavor	Lacking – Intense	F_Ear
Roasted	Roasted, almost burnt flavor of crumb	Lacking – Intense	F_Rst
Roasted Crust	Roasted, almost burnt flavor of crust	Lacking – Intense	F_RstC
Salty	Basic salty flavor	Lacking – Intense	F_Salt
Sour	Acidic flavor associated with fermentation	Lacking – Intense	F_Sour
Sweet	Basic sugar flavor	Lacking – Intense	F_Swt
Whole Wheat	Characteristic flavor of whole grain	Lacking – Intense	F_WW
Texture			
Adhesiveness	Stickiness of crumb when pushed to roof of mouth	Not Sticky – Very Sticky	T_Adh
Cohesiveness	Ability to form a ball when chewed seven times on molars	Falls Apart – Sticks Together	T_Coh
Crust Texture	Feel of crust texture from touch	Soft – Firm	T_Crst
Moistness	Moistness of crumb surface by touch	Dry – Moist	T_Mst
Smoothness	Perceived firmness by sliding two fingers across crumb surface	Smooth – Coarse	T_Smo
Springiness	Elasticity of crumb by applying pressure to middle of crumb and release	Not Springy – Springy	T_Spr

Table 2.2. Mean intensity ratings from descriptive analysis of whole wheat bread[a]

	Sample					
Attribute	1	2	3	4	5	6
Appearance						
Circular	3.7c	5.5b	6.0b	6.6b	9.5a	9.4a
Crumb Color	7.3ab	6.5b	4.6c	4.1c	7.6ab	8.6a
Crust Color	6.3c	9.4a	6.0c	7.9b	10.4a	9.1ab
Particulates[b]	1.5d	9.3b	1.8d	5.4c	10.9a	11.0a
Pore Size	3.5d	5.6c	5.5c	4.3cd	11.1a	9.5b
Pore Uniformity	3.9e	6.9cd	7.7a	5.8d	10.7a	9.4ab
Aroma						
Butter	4.0c	4.5c	6.1ab	5.1bc	7.1a	5.3bc
Fermented	7.1bc	8.3ab	7.3bc	6.6c	9.5a	9.1a
Fruity	5.4b	4.7b	4.1b	4.4b	5.5b	7.4a
Roasted	5.5c	7.3b	3.9d	5.8c	9.3a	8.0ab
Whole Wheat[b]	6.1b	7.5ab	6.4b	6.4b	8.3a	8.7a
Flavor						
Bitter	5.4a	6.2a	5.0a	4.9a	6.3a	6.4a
Doughy[b]	8.0a	6.1a	7.7a	7.0a	5.5a	5.8a
Earthy[b]	3.8bc	7.3a	2.8c	4.6b	6.5a	7.0a
Roasted	5.1d	6.9bc	4.7d	5.7cd	7.7ab	8.1a
Roasted Crust	6.5cd	7.8b	5.7d	7.4bc	9.8a	8.5b
Salty	4.0bc	5.0b	3.6c	4.6bc	6.8a	4.1bc
Sour[b]	3.0d	6.7a	3.2cd	4.6bc	5.0b	4.4bcd
Sweet	8.6a	5.9bc	9.5a	6.6b	4.8c	6.4b
Whole Wheat[b]	5.5bc	7.9a	4.2c	6.1b	8.3a	8.0a
Texture						
Adhesive	9.6a	6.4cd	9.0ab	9.1ab	7.9bc	5.6d
Cohesive	10.2a	6.9b	10.4a	7.3b	6.9b	6.1b
Crust	5.6cd	9.1a	4.8d	5.6cd	7.5ab	6.8bc
Moist[b]	10.1a	5.2c	10.1a	7.8b	7.5b	6.8bc
Smoothness[b]	2.4c	8.9a	2.2c	4.5b	9.0a	9.7a
Springiness	3.9d	8.2b	6.0c	8.0b	7.7b	10.5a

[a] Attributes evaluated in quadruplicate on a 15 cm unstructured line scale using the anchors in Table 2.1; means within row with different letters are significantly different ($p<0.05$); N=8.

[b] Significant sample*panelist term; significant differences among samples calculate using the mean square of the sample*panelist interaction

Table 2.3. Consumer acceptance of whole wheat bread

Cluster, Sample	Appearance	Flavor	Texture	Overall
All Panelists (n=75)				
1	7.1^{a}	6.8^{ab}	6.4^{ab}	7.0^{a}
2	7.0^{a}	5.9^{d}	6.2^{b}	6.3^{c}
3	6.8^{a}	7.2^{a}	6.6^{ab}	7.0^{ab}
4	7.3^{a}	6.3^{cd}	6.5^{ab}	6.6^{abc}
5	6.9^{a}	6.0^{cd}	6.4^{b}	6.5^{bc}
6	7.3^{a}	6.5^{bc}	6.9^{a}	6.9^{ab}
Cluster 1 (n=28)				
1	7.9^{a}	8.0^{a}	7.6^{a}	7.8^{a}
2	8.0^{a}	7.1^{b}	7.3^{a}	7.4^{a}
3	7.9^{a}	7.9^{a}	7.8^{a}	7.8^{a}
4	7.8^{a}	7.1^{b}	7.5^{a}	7.4^{a}
5	7.9^{a}	7.1^{b}	7.6^{a}	7.7^{a}
6	8.1^{a}	7.5^{ab}	7.8^{a}	7.7^{a}
Cluster 2 (n=33)				
1	7.2^{ab}	6.3^{ab}	6.3^{a}	6.7^{ab}
2	6.3^{cd}	4.9^{c}	5.3^{b}	5.6^{c}
3	6.5^{bcd}	6.8^{a}	6.1^{ab}	6.4^{ab}
4	7.4^{a}	6.5^{a}	6.8^{a}	7.0^{a}
5	5.9^{d}	5.3^{c}	5.3^{b}	5.7^{c}
6	6.8^{abc}	5.5^{bc}	6.3^{a}	6.2^{bc}
Cluster 3 (n=14)				
1	5.7^{c}	5.8^{a}	4.6^{bc}	6.0^{a}
2	6.4^{abc}	5.7^{a}	5.9^{a}	5.7^{a}
3	5.5^{c}	6.7^{a}	5.7^{ab}	6.7^{a}
4	5.9^{bc}	4.3^{b}	3.9^{c}	4.2^{b}
5	7.2^{a}	5.7^{a}	6.2^{a}	6.3^{a}
6	6.8^{ab}	6.7^{a}	6.7^{a}	6.7^{a}

[b] Attributes evaluated on a 9-point hedonic scale (1=dislike extremely; 9=like extremely); means within column and cluster with different letters are significantly different ($\alpha < 0.05$)

Whole wheat flour, water, sugar, wheat gluten, yeast, raisin juice concentrate, wheat bran, molasses, soybean oil, salt, monoglycerides, calcium propionate (preservative), calcium sulfate, DATEM, grain vinegar, citric acid, soy lecithin, whey, soy flour, nonfat milk.

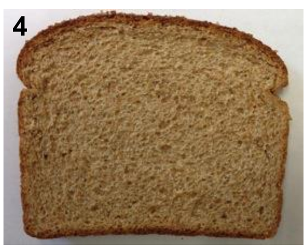
Serving Size	38g
Calories	90g
Sodium	135mg
Total Carb	18g
Dietary Fiber	2g
Sugars	3g
Protein	4g

Whole grains (whole wheat flour, bulgur wheat, rolled whole wheat), water, sugar, wheat gluten, yeast. Contains 2% or less of each of the following: cultured wheat flour, soybean oil, raisin juice concentrate, flaxseed, salt, distilled vinegar, molasses, calcium sulfate, enzymes, ascorbic acid, milk, soy flour

Serving Size	38g
Calories	100g
Sodium	115mg
Total Carb	19g
Dietary Fiber	3g
Sugars	3g
Protein	5g

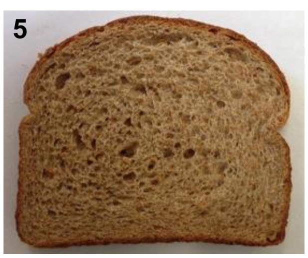
Water, whole wheat flour, wheat gluten, brown sugar, sugarcane fiber, modified wheat starch, inulin, contains less than 2% of each of the following: whole durum flour, soybean oil, honey, wheat bran, cane molasses, salt, yeast, white distilled vinegar, guar gum, DATEM, calcium propionate (preservative), sodium stearoyl lactylate, monocalcium phosphate, monoglycerides, enzymes.

Serving Size	48g
Calories	100g
Sodium	150mg
Total Carb	23g
Dietary Fiber	7g
Sugars	5g
Protein	5g



Whole wheat flour, water, cracked wheat, yeast, wheat gluten, sugar, wheat bran, soybean oil, honey, molasses, raisin juice concentrate, salt, mono- and diglycerides, DATEM, calcium proprionate (preservative), grain vinegar, calcium sulfate, monocalcium phosphate, cornstarch, soy lecithin, citric acid, whey, soy flour, nonfat milk.

Serving Size	40g
Calories	100g
Sodium	130mg
Total Carb	21g
Dietary Fiber	3g
Sugars	3g
Protein	5g



Whole wheat flour, water, cracked wheat, brown sugar, wheat gluten, wheat bran, soybean oil, contains 2% or less of the following: yeast, salt, honey, raisin juice concentrate, dough conditioners (sodium stearoyl lactylate, monoglycerides, azodicarbonamide, enzymes, ascorbic acid, calcium peroxide), distilled vinegar, rolled wheat, calcium propionate (preservative), monocalcium phosphate, calcium sulfate, wheat germ.

Serving Size	34g
Calories	80g
Sodium	190mg
Total Carb	15g
Dietary Fiber	2g
Sugars	3g
Protein	4g

Whole wheat flour, water, wheat berries, wheat gluten, sugar, yeast, sugarcane fiber, honey, unsulphured molasses, contains 2 percent or less of: soybean oil, wheat, nonfat milk, lower sodium natural sea salt, calcium propionate and sorbic acid to retard spoilage, salt, distilled monoglycerides, DATEM (dough conditioner), chichory root fiber, soy lecithin.

Serving Size	43g
Calories	100g
Sodium	105mg
Total Carb	20g
Dietary Fiber	4g
Sugars	3g
Protein	5g

Figure 2.1. Pictures of breads with sample numbers, ingredient statements, and selected nutritional information from the packaging for whole wheat breads used in this study.

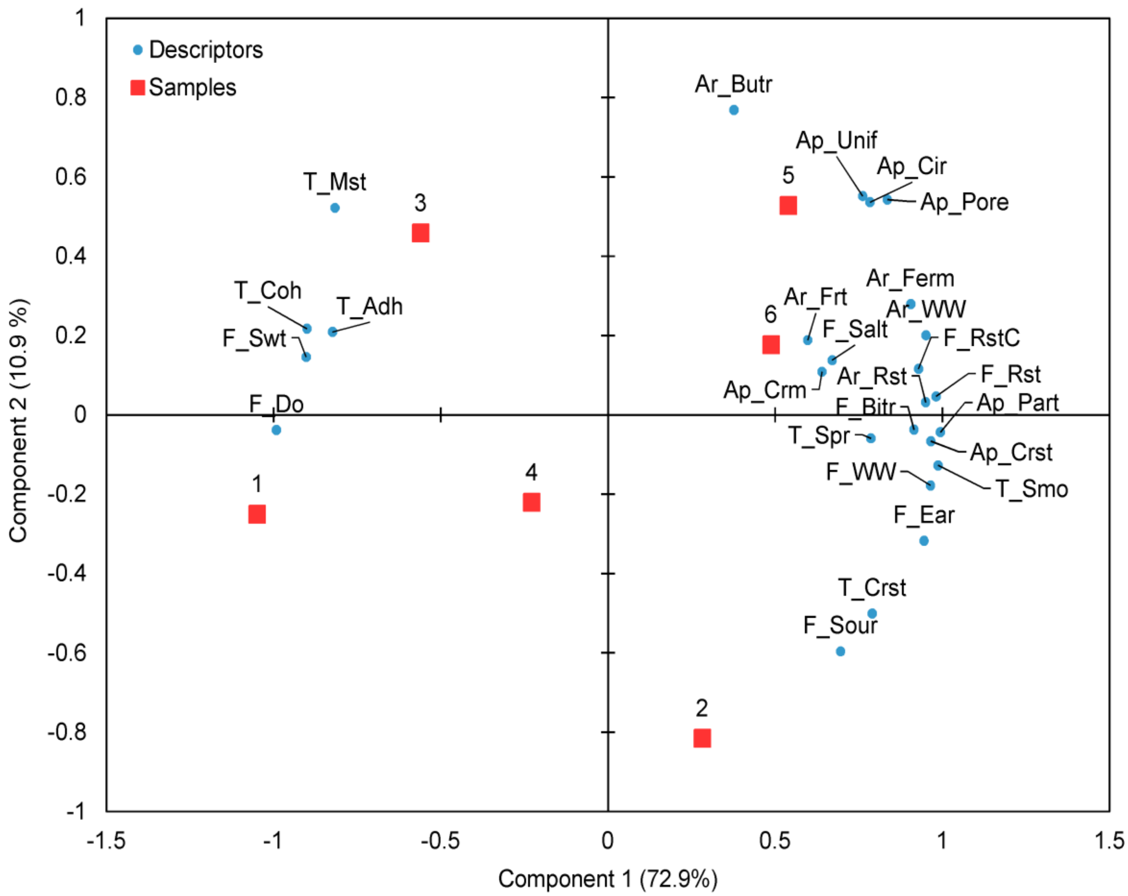


Figure 2.2. Principal component analysis biplot for descriptive whole wheat bread panel; abbreviations in Table 2.1.

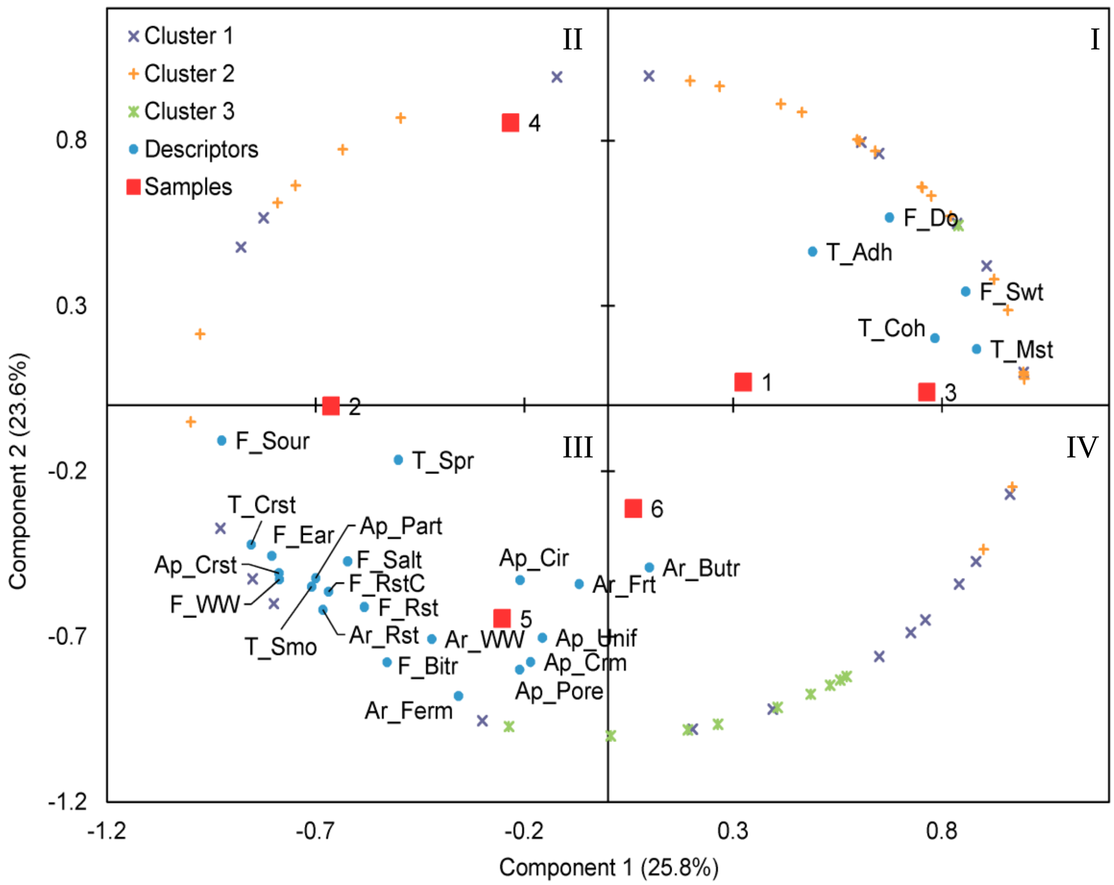


Figure 2.3. Internal preference map of whole wheat bread consumers (n=59), samples, and descriptive attributes; abbreviations as in Table 2.1.

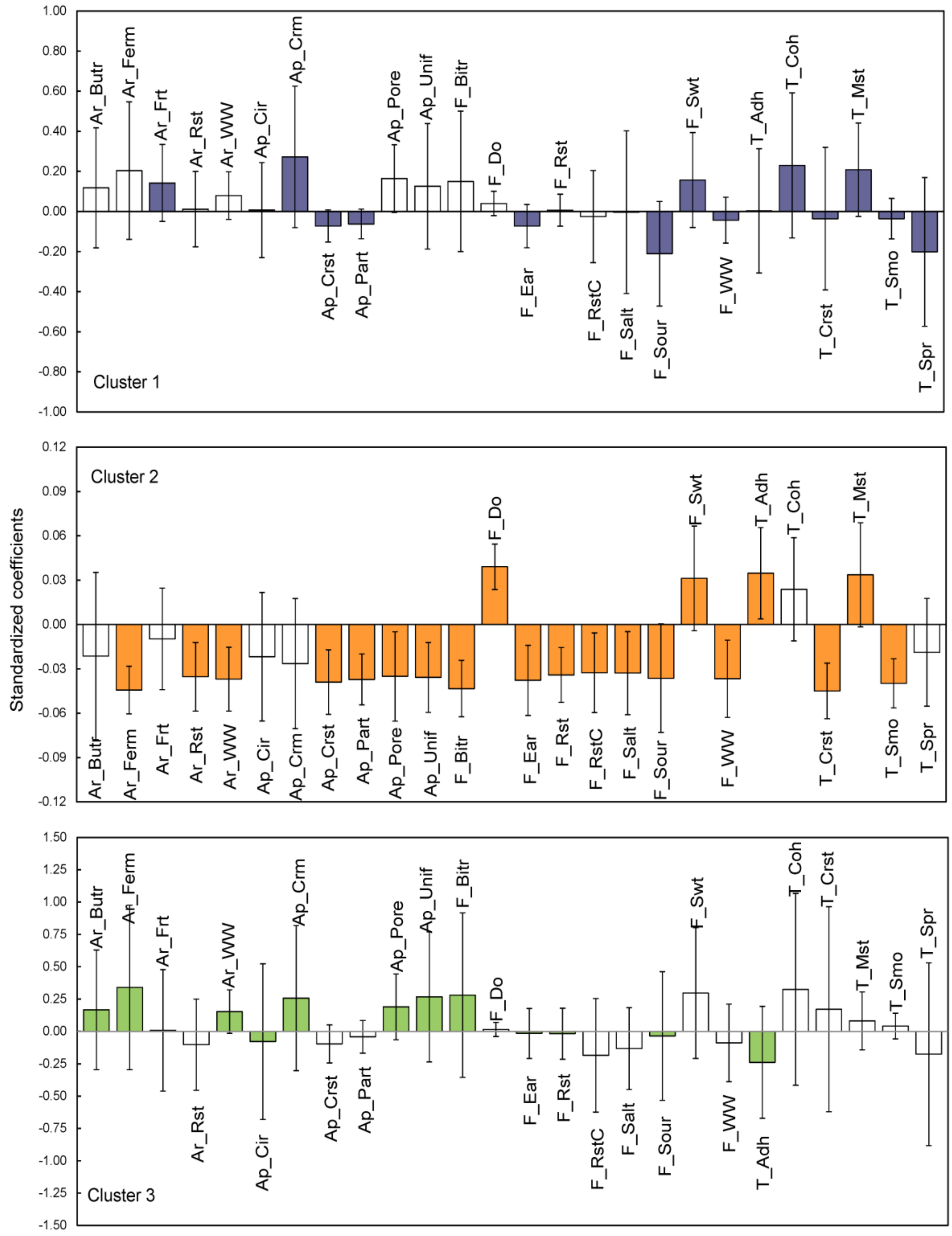


Figure 2.4. Partial least squares regression coefficients of attributes contributing to overall acceptability of whole wheat bread samples in each cluster of panelists; attributes with solid bars represent those with a variable importance in projection of >0.8; abbreviations as in Table 2.1.

CHAPTER 3. PREFERENCE MAPPING OF EXTRUDED BROWN RICE AND PINTO BEAN PUFFS

3.1. Abstract

The use of common beans in the food industry offers unique products with potential health benefits; however, limited research has been done on the sensory qualities that drive consumer likability of these products. The objective of this research was to identify sensory attributes and consumer acceptance of an extruded brown rice and pinto bean snack product. Blends of brown rice and pinto bean flour (0%, 15%, 30%, 45% bean flour) were extruded using a twin-screw extruder at three feed moisture levels (18.3%, 19.5%, and 20.1%). Fifteen sensory attributes were determined by a trained panel (N=8). All attributes were affected by bean flour concentration while uniformity and texture attributes were also affected by feed moisture. In a consumer panel (N=78), which analyzed only the samples extruded at 19.5% moisture, overall acceptability was highest for samples with 0% and 15% bean flour. Preference mapping showed a larger portion of consumers who liked the 0 and 15% bean samples, which were characterized by rice flavor and large diameters. Fewer consumers liked the higher bean samples characterized by bean flavor and crisp texture. These data may be useful in determining an appropriate level for bean inclusion in extruded snacks, as well as extrusion conditions to produce acceptable products.

3.2. Introduction

The rise of unhealthy lifestyles and diets among Americans has led to an influx of health-conscious consumers on the search for more nutritious, health-promoting food options. It was estimated in 2012, that the whole grain and high fiber foods market would reach $27.6 billion by 2017 due to innovative health-focused products with improved tastes driving market growth (Daniells, 2012). Food consumption trends have also shown an increase in snack foods and decrease in main meals (Kant & Graubard, 2015). By incorporating whole grains and high fiber in snack foods, consumers will have more nutritious snack options that can help transition them toward a healthier lifestyle.

Brown rice flour may be useful as a whole grain alternative to the more popular wheat and corn flours currently used in many extruded snacks. Due to its bland taste, light color, and ease of digestion, rice flour is an attractive ingredient for use in extrusion (Kadan, Bryant, & Pepperman, 2003). Further, brown rice is high in dietary fibers and vitamins compared to its polished white rice counterpart (Ohtsubo, Suzuki, Yasui, & Kasumi, 2005).

Common beans (*Phaseolus vulgaris* L.), which represent the third most important legume world wide (Singh, 1999), offer high amounts of dietary fiber, protein, vitamins and minerals. Inclusion of beans in the diet has been shown to reduce the risk of cardiovascular disease, cancer, and diabetes (Hutchins, Winham, & Thompson, 2012; Venn & Mann, 2004). Due to their nutritional and health promoting properties, common beans have been promoted for incorporation in functional foods (Camara, Urrea, & Schlegel, 2013).

Extrusion, a commonly used technique for the production of cereal and snack food products, has been advantageous in the incorporation of legumes in the diet (Gujska et al 2001). Several studies have examined the physical and nutritional impacts of incorporating legumes into extruded products (Anton, Gary Fulcher, & Arntfield, 2009; Nyombaire, Siddiq, & Dolan, 2011; Perez-Navarrete, Gonzalez, Chel-Guerrero, & Betancur-Ancona, 2006) as well as their functional properties (Carvalho et al., 2012; Gujska & Khan, 1991). However, few studies on legume extrudates have included sensory analysis results, which is a useful tool in the development of new products. Simons et al. (2015) determined that extrudates made from pinto, navy, or black beans had acceptable sensory properties with overall acceptability scores higher than 4.5 on a 7-point hedonic scale. Gujska, Duszkiewicz-Reinhard, and Khan (2001) measured the acceptability of seasoned extruded snack samples made with either defatted or non-defatted pinto bean and determined them to be equally acceptable with no statistical differences in the crispness, taste, and general acceptability of the samples. Further, Carvalho et al. (2012) utilized a consumer panel to determine acceptability and purchase intent of an extruded breakfast cereal composed of rice and bean flour in order to improve the diets of adolescents.

The use of consumer data can be correlated with descriptive data to produce preference maps (McEwan, 1996), which can be useful in determining market demands and expectations (Caspia, Coggins, Schilling, Yoon, & White, 2006). Such techniques have been used with many other food commodities. Overall, consumer data on the use of legumes in extruded products are limited and do not incorporate the use of descriptive analysis. Therefore, the objectives of this study were to use descriptive analysis as a tool

to evaluate the organoleptic properties of an extruded brown rice-pinto bean snack and to determine their relationship to consumer acceptance through preference mapping and partial least squares (PLS) regression.

3.3. Materials and Methods

3.3.1. Extruded Snack Puffs

Twelve samples of snack puffs were produced using brown rice flour, varying levels of pinto bean flour and varying levels of feed moisture following a full factorial, completely randomized design. Brown rice flour was obtained from Sage Foods (California) and pinto beans (Poncho variety) from Stateline Bean (Nebraska). Whole pinto beans were ground using a pilot scale hammer mill with a 1 mm screen size (C.S. Bell Co, Ohio, USA) and sieved to pass through a 1 mm screen (US standard mesh no. 20). The sample flour blends were prepared with 0, 15, 30, and 45% pinto bean flour and 1% salt (by total weight after addition of bean flour). Flours were stored at 4°C until extruded.

Samples were extruded on a pilot scale Wenger TX-57 twin screw extruder (Wenger, Sabetha, KS, USA) with a die diameter of 4.08mm. Screw speed was set at a constant speed of 300 rpm with a knife speed of 253 rpm. The barrel temperatures at zone 1, 2, 3 were 80, 90, 110°C, respectively. Flours were fed at a rate of 1.3kg/min; water was injected at different rates yielding final feed moistures of 18.3, 19.5, and 20.1%. Extruded products were dried on a belt drying oven at 103°C for 10 minutes. Samples (Fig. 3.1) were stored in plastic bags at ambient temperature throughout the entirety of the study.

Unit density was measured according to Ali, Hanna, and Chinnaswamy (1996), with minor modifications, as mass per volume of extrudates measured by rapeseed displacement. Five grams of whole extrudates were placed into a cylindrical canister (9.1 cm in diameter X 9.3 cm in height), and then completely filled with rapeseed. The canister was leveled out and the replaced rapeseed was weighed. Unit density was measured five times for each sample.

Expansion characteristics were measured as radial expansion ratio, axial expansion ratio, and overall expansion ratio. Radial expansion ratio was the cross-sectional diameter (mm) of each extrudate divided by the diameter of the die opening (mm). Radial expansion was averaged from 15 individual pieces from each sample. Overall expansion was the ratio of true solid density to unit density. Axial expansion was the ratio of overall expansion to radial expansion (Ali, Hanna, & Chinnaswamy, 1996). Axial and overall expansions were calculated five times for each sample.

Water absorption index (WAI) and water solubility index (WSI) of extrudates were measured three times per sample according to (Anderson, Conway, & Peplinski, 1970). Color (L*, a*, b*) was measured five times for each ground sample by a Hunter colorimeter (Konika Minolta Chroma Co, Osaka, Japan).

The texture of extrudates was characterized by hardness (N) and jaggedness (N·s). The analysis was performed five times for each sample using a texture analyzer (TA.XT plus, Stable Micro systems, Godalming, UK) with a 5 blade Kramer shear cell probe. Extrudates were added to a height of 4 cm in the canister and cut at a speed of 2 mm/s from a distance of 48 mm. Hardness was the maximum force (N) achieved during the run, and jaggedness was expressed as the linear distance of the force deformation curve.

3.3.2. Descriptive Panel

Panelists were recruited from students, faculty, and staff at the University of Nebraska-Lincoln who were familiar with extruded products and who had a flexible schedule that would allow them to attend 1.5-2 h training sessions weekly over the course of a few months. The selected panelists (six females and two males) trained for approximately 10 hours over a course of two months to develop attributes and definitive line scales for the twelve extruded puff samples. Training was divided into four phases. In the first phase, panelists were presented an assortment of extruded samples to create a comprehensive list of descriptive attributes in terms of appearance, aroma, texture, and flavor. Samples included the final twelve samples used in the study as well as puffed rice cereal, corn extrudates, and a high inulin extrudate. All terms were re-evaluated to eliminate those that were redundant or not detected by all panelists. In the second phase, panelists evaluated a subset of the samples to determine definitions, anchor words, and specific testing instructions for each descriptor. Panelists also suggested potential reference standards. In phase 3, the intensity of each attribute on an unstructured line scale was determined on a subset of the sample through general consensus of the trained panel. Standards were used during this phase to help panelists understand attribute sensations but were not used in the final panel. Panelists were then encouraged to practice the newly defined scale individually. A practice panel was conducted after the third phase to evaluate the success of the training. Following this panel, a review session was conducted to eliminate attributes that were undetected in most samples as well as to eliminate the use of standards in the final panel. In the final phase, all 12 samples were evaluated in duplicate. Evaluation took place in individual sensory booths under white

light. Room temperature water and unsalted crackers were served as palate cleansers between samples. Panelists were asked to expectorate each sample to prevent fatigue.

3.3.3. Consumer Panel

A consumer panel was conducted in the Sensory Analysis Laboratory at the University of Nebraska-Lincoln. Consumers were recruited among the students, faculty, and staff of the University as well as those in the surrounding area. All consenting subjects were asked to taste four samples of extruded puffs, as approved by the UNL Institutional Review Board. The four varying bean flour samples were all produced at the 19.5% feed moisture level. In total, 78 consumers participated in the panel. Three puffs of each sample were served in a completely randomized design in a 2oz cup labeled with a random 3-digit code. Room temperature water and unsalted crackers were provided as a palate cleanser between samples. Evaluation took place in individual booths under white light. Overall, texture, appearance, color, and flavor acceptance were evaluated using a 15-point intensity scale (where 1= dislike extremely and 15= like extremely). Flavor, texture, and odor attributes were also rated for intensity. Consumers were also asked to rate their purchase intent of the product as is or if flavored using an intensity scale. Finally, demographic information, including age and gender, was collected.

3.3.4. Data Analysis

In the descriptive panel, a four-way ANOVA model with interactions was constructed for each descriptor with bean (B), moisture (M), panelist (P), and replicate (R) as the main effects. The interaction terms in the model were BxM, PxR, BxP, MxP, and BxMxP. Since crisp texture was the only attribute to have a significant BxM interaction, the main effects, bean and moisture, were studied for all attributes. Within

each main effect, differences between means were calculated using the least significant difference (LSD) procedure.

For attributes under each main effect with a significant sample term and a significant BxP or MxP interaction ($P<0.05$), the sample F value in the ANOVA was recalculated in order to confirm significance among the samples. In place of the mean square error, the mean square of the BxP or MxP interaction term was used, respectively (Bayarri, Martí, Carbonell, & Costell, 2012; Bernstein & Rose, 2015). Descriptive mean values were further analyzed using principal component analysis (PCA). SAS software (version 9.2, SAS Institute, Cary, NC U.S.A) was used to evaluate all descriptive panel data.

A two-way ANOVA with sample and panelist as the main effects was used to analyze the consumer data. For samples with significant F values in the ANOVA model, differences between means were calculated using the LSD procedure.

To construct the preference map, the consumer and descriptive data were combined. A second PCA was performed on the consumer panelists' overall acceptance scores for each sample. Any respondent whose communality score was less than 0.50 was removed (Meilgaard, Carr, & Civille, 2007). Remaining panelists' factor scores were rescaled to fall equidistant from the origin. The sample factor scores from the second PCA were then correlated with means for each descriptor generated by the trained panel to generate the preference map. Data for the preference map were determined with SAS software.

The descriptive and consumer data were also analyzed by using (PLS) regression using XLSTAT 2011 (Addinsoft, Paris, France). The overall acceptance value for each

sample was used as the dependent variable and descriptive attributes' means were used as the independent variable. To remove bias associated with the magnitude of the variable means, the software centered and scaled the data. Attributes with variable importance in projection higher than 0.8 were considered significant drivers of overall liking (Villamor, Daniels, Moore, & Ross, 2013).

3.4. Results and Discussion

3.4.1. Descriptive Panel

The trained panel evaluated the organoleptic properties of the samples and determined fifteen attributes to be used in the final descriptive panel (Table 3.1). Differences among samples for each attribute under each effect are shown in Table 3.2. The addition of bean flour was found to be a significant factor for all attributes while feed moisture only significantly affected texture and uniformity attributes. Attributes that carried a significant F value for either BxP or MxP interaction signified that panelists used the scales differently. Under the effect of bean, BxP interactions for all attributes except appearance of specks were significant. For moisture, only cell uniformity, shape uniformity, and crisp, gritty, and moutfeel texture were significantly different. When the interaction term was used in place of the mean square error in the denominator of the ANOVA model, only crisp texture under the bean effect, cell uniformity under moisture effect, and toothpack under both were found to no longer being significantly different. Despite selection and training of panelists, it is hard to eliminate the differences in sensitivity to attributes between panelists (Tomic, Nilsen, Martens, & Næs, 2007). Without the use of standards in the final panel, the panelists also had access to a broader

scale, which can lead to interactions in the data and may be responsible for why many of the attributes did have significant differences (Naes & Langsrud, 1998).

The darkness of the extrudates increased as bean flour increased. This may have been attributed to caramelization and Maillard reactions (Lazou, Krokida, & Tzia, 2010). Visual specks, which are likely due to the skins of the beans, may have contributed to the perception of darker color as they also increased with increasing bean flour up to 30%. The diameter assessed by the panel, which is due to the expansion of the extrudate, decreased with increasing bean flour. This may be caused by higher levels of fiber and protein from the pinto beans; thus disrupting cell wall formation and preventing air bubble expansion (Perez-Navarrete et al., 2006).

With the exception of rice flavor, flavor and aroma attributes all increased with increased bean flour. As expected, bean aroma and flavor were significantly different between the 0, 15, and 30% bean flour samples, however no significant difference was seen between the 30 and 45%. Not surprisingly, rice flavor significantly decreased with increasing bean flour for all samples. Bitter and salt flavor also followed the same trend as bean flavor and aroma. Notably, the increase in bean flour also increased the sweetness perception between all samples.

For both uniformity attributes, significant differences were only seen between the low (0 and 15%) and the high (30 and 45%) bean flours. The low levels of bean flour had higher shape uniformity but lower cell uniformity. In contrast, the higher bean flours had higher cell uniformity, but lower shape uniformity. Significant differences were also seen across the three feed moisture levels for shape uniformity with 20.1% feed moisture yielding the most uniform shape.

Textural attributes were affected significantly by both bean flour concentration and feed moisture. When feed moisture was evaluated, crisp texture significantly increased with each increase in feed moisture. These findings contradict those found by Ding, Ainsworth, Tucker, and Marson (2005) where crisp texture of an extruded rice-based snack decreased with increasing moisture content. However, since the values for density found in this study (Table 3.3) align with the trend of increasing density with increasing moisture, it is likely that the trained panelists confused the crispness of the sample as actual hardness. The remaining texture attributes, grittiness and mouthfeel, both significantly increased with increasing bean flour and feed moisture, respectively.

When PCA was applied to the data (Fig. 3.2), a few distinct trends were noticed on the first two components, which together accounted for 78% of the data variability. The first principal component (PC) represented a contrast between extrudates with low percentage of bean flour versus those with higher percentages. Samples containing 30 and 45% bean flour carried positive loadings on PC1 and coincided with eigenvectors for bitter, sweet, and bean flavors, bean aroma, and crisp texture. In contrast, samples containing 0 and 15% bean flour had negative loadings on PC1 and were associated with rice flavor and larger diameter. PC2 separated samples based on feed moisture, showing a trend of increased loading scores with increasing moisture content. Samples extruded at 18.3% moisture, as well as the 30% bean flour at 19.5% moisture, were located on the negative side. The remaining samples extruded at 19.5 and 20.1% moisture lie on the positive side as well as textural attributes including crispness, mouthfeel, and gritty, which were all found to be significantly impacted by feed moisture. When observing the entire PCA, there was a noticeable lack of attributes determined by the trained panel to

describe samples made with 0 and 15% bean flour as compared to the higher bean samples. This suggests that the addition of bean flour into the extrudates took an otherwise bland snack with no describable characteristics and gave it attributes that could be described by the trained panel.

3.4.2. Correlations Between Descriptors and Physical Characteristics

The sensory descriptors found by the trained panel were correlated with measured physical characteristics (Table 3.4). Density and hardness were both strongly correlated with moutfeel, crisp, and gritty textures. Jaggedness was also positively correlated with crisp texture. Similarly, the increase in diameter as measured by the trained panel was negatively correlated with density and positively correlated with radial expansion ratio. Flavor and aroma attributes, with the exception of rice flavor, which had correlation coefficients opposite to those of the others, were also correlated positively with density and hardness and negatively with radial expansion ratio. These findings are consistent with the effects of bean and feed moisture on expansion properties found in other studies (Anton, Fulcher, & Arntfield, 2009; Ding, Ainsworth, Tucker, & Marson, 2005).

WSI and WAI correlations with attributes were inversely related. Attributes associated with higher bean concentration, were positively correlated with WSI and negatively correlated with WAI. This is congruent with research that found WSI to increase with addition of fiber (Kumar, Sarkar, & Sharma, 2010) and wild legume flour (Pastor-Cavada et al., 2011). WAI, however, reflects the porosity of the structure and a decrease in WAI is consistent with higher bulk density due to increased bean flour (Mkandawire, Weier, Weller, Jackson, & Rose, 2015). Thus an attribute like rice flavor,

which denotes low bean flour, would be negatively correlated with WSI and positively correlated with WAI.

Similar to the correlations found with WSI and WAI, color attributes also correlated respective to degree of bean flour addition. The attribute color, defined by the descriptive panel, is highest for darker samples which explains the negative correlation with L* value; however, both represent samples with higher bean flour being darker in color. The values for a* and b* are positively correlated with color suggesting high bean flour samples have more red and yellow hues as compared to samples with lower bean flour.

3.4.3. Consumer Panel

In the untrained consumer panel, samples carried significant differences for all attributes with the exception of crunch intensity and acceptability (Table 3.5). Hedonic responses showed a greater acceptability toward samples with little to no bean flour. For overall acceptability, consumers liked the 0 and 15% bean samples the most. This was also true for overall appearance and overall flavor. For overall color, the only significant difference was seen in the 45% bean sample, which the panelists liked least. Significant differences in overall aroma were seen between 15 and 30%, which consumers found the 15% bean flour to be more acceptable. Intensity data showed no differences in the crunchiness of the samples and small differences in salt flavor between the 0% and 15/30% bean samples. When examining purchase intent, consumers had a greater affinity to purchase the 0 and 15% bean flour samples.

3.4.4. Relationships Between Descriptive and Consumer Panels

To relate consumer liking to the descriptive data, an internal preference map was prepared (Fig. 3.3). One sample loaded in each of the four quadrants on the plot. Attributes were again grouped into two distinct categories, similar to those in Fig. 3.2. Rice flavor, large diameter, and uniform shape were found in quadrant IV with the 15% bean sample; crisp texture was found in quadrant III with the 45% bean sample, and the remaining attributes were found in quadrant II with the 30% bean sample. As mentioned previously, few attributes were determined by the descriptive panel to describe the 0 and 15% bean samples, which is evident by the lack of attributes in either quadrants I or IV. Consumers span the entire map with most concentrated in quadrant I (n=30) and quadrant IV (n=26). However, with most of the consumers located in quadrants I and IV, it suggests that a majority of consumers prefer samples with bland flavor and larger piece size and only a few consumers prefer samples with more describable aroma, texture, and flavor characteristics.

This is in line with previous studies. Choi, Phillips, and Resurreccion (2007) found good acceptability for peanut-rice flour puffs, but noted a pattern of decreasing flavor and texture acceptance when peanut concentration increased over 30%. Lazou, Krokida, and Tzia (2010) also found that overall acceptability generally decreased as lentil flour increased in extruded puffs. For extruded snacks made solely of pinto bean flour, Simons et al. (2015) found overall acceptability, flavor, texture, and appearance to all be acceptable with scores above 4 on a 7-point hedonic scale, but made no comparisons to a control.

Finally PLS regression was performed to determine how each attribute impacted the overall acceptability of the rice-bean extrudate (Fig. 3.4). Shape uniformity was the only attribute that did not contribute significantly to overall liking. High drivers of liking, those with positive coefficients, were large diameter and rice flavor, which is consistent with findings from the preference mapping analyses. Salt flavor and appearance of specks were also found to slightly contribute positively to overall liking. The remaining attributes negatively affected overall liking, with crisp texture having the greatest affect. This highly negative impact of crisp texture also corroborates with the early discussion that the trained panelists confused crispness and hardness attributes. As crisp texture has been found to positively correlate with overall liking in other studies (Lazou et al., 2010).

3.5. Conclusion

In extruded snack products, a descriptive panel found that bean flour concentration affected flavor, appearance, and aroma characteristics, whereas feed moisture affected texture attributes. Overall, extrudates made with 0 and 15% bean flour were bland, only being described with a rice flavor, large diameter, and uniform shape. Samples with higher bean flavors were described by bean aroma and flavor as well as smaller diameter and crispier texture. Most consumers liked the 0 and 15% bean flour extrudates over the extrudates with higher percentages of bean flour. Rice flavor and large diameter were high drivers of liking, which were negatively affected by increasing bean flour beyond 15%. Crispness of the sample, which was impacted by feed moisture, negatively affected overall liking. These findings suggested that the best bean extrudate for consumers would be made with 15% bean flour and extruded at 18.3% feed moisture. It is important to note, however, that regional and demographic differences in liking may

exist; testing in different areas or demographic groups may produce different attributes and acceptance data.

3.6. Acknowledgement

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Table 3.1. Attributes and definitions developed for descriptive analysis of rice-bean extrudates

Attribute	Definition	Scale Anchors 0	Scale Anchors 15	Abbreviation
Appearance				
Cell Uniformity	Uniformity of cells within extrudate	Non-Uniform	Uniform	Ap_CellUnif
Color	Brightness of the sample	Light	Dark	Ap_Color
Diameter	Visual cross length of	Small	Large	Ap_Diameter
Shape Uniformity	Uniformity of curl shape	Non-Uniform	Uniform	Ap_ShpUnif
Speck	Number of brown particulates	None	Many	Ap_Specks
Aroma				
Bean	Characteristic aroma of dry edible beans	Lacking	Intense	Ar_Beany
Texture				
Crisp	Degree of fracturability of sample	Lacking	Intense	T_Crisp
Mouthfeel	Feel of sample during chewing	Smooth	Glassy	T_Mthfeel
Gritty	Perceived presence of hard particles	Lacking	Intense	T_Gritty
Tooth Pack	Amount of sample remaining in teeth	Lacking	Intense	T_Toothpack
Flavor				
Bean	Characteristic flavor of dry edible beans	Lacking	Intense	F_Bean
Rice	Flavor associated with cooked white rice	Lacking	Intense	F_Rice
Salt	Basic salt flavor	Lacking	Intense	F_Salty
Sweet	Basic sweet flavor	Lacking	Intense	F_Sweet
Bitter	Basic bitter flavor	Lacking	Intense	F_Bitter

Table 3.2. Mean intensity ratings from descriptive analysis of rice-bean extrudates

Attribute	Bean Flour (%)				Feed Moisture (%)		
	0	15	30	45	18.3	19.5	20.1
Appearance							
Cell Uniformity[bc]	5.5b	5.3b	7.7a	8.3a	7.6a	6.4a	6.1a
Color[b]	2.1d	5.0c	8.2b	9.3a	6.0a	6.2a	6.3a
Diameter[b]	9.5a	8.7b	5.2c	4.0d	7.1a	6.9a	6.6a
Shape Uniformity[bc]	9.2a	8.6a	6.3b	5.9b	6.5c	7.5b	8.5a
Speck	1.1c	4.0b	8.9a	9.6a	5.9a	6.4a	6.1a
Aroma							
Bean[b]	1.7c	5.2b	8.4a	8.8a	5.9a	6.2a	6.0a
Texture							
Crisp[bc]	8.2a	8.8a	8.8a	9.6a	7.2c	9.0b	10.3a
Mouthfeel[bc]	4.8d	6.8c	7.7b	8.9a	5.3c	7.4b	8.4a
Gritty[bc]	4.2d	6.3c	7.3b	8.3a	5.1c	6.9b	7.5a
Tooth Pack[bc]	6.2a	7.0a	7.5a	7.8a	7.2a	7.4a	6.7a
Flavor							
Bean[b]	1.6c	5.1b	9.6a	10.2a	6.6a	6.6a	6.7a
Rice[b]	10.4a	7.5b	3.4c	2.8d	6.2a	6.0a	5.8a
Salt[b]	4.2c	5.7b	7.1a	7.4a	6.0a	6.3a	6.0a
Sweet[b]	3.9d	5.7c	8.1b	8.8a	6.5a	6.9a	6.5a
Bitter [b]	2.1c	4.9b	7.6a	7.9a	5.5a	5.8a	5.6a

Attributes evaluated in duplicate on a 15 cm unstructured line scale using anchors in Table 3.1; means within a row and effect with different letters are significantly different (<0.05); N=8.

b Significant bean*panelist term; significant differences among samples calculated using the mean square of the bean*panelist interaction term.

c Significant moisture*panelist term; significant differences among samples calculated using the mean square of the moisture*panelist interaction term.

Table 3.3. Physical characteristics of rice-bean extrudate at different flour blends and feed moistures[a]

Feed Moisture/ Bean Flour (%)	Unit Density (g/cm3)	Expansion Ratio			Texture		WSI	WAI	Color		
		Radial	Axial	Overall	Jaggedness ($x10^3$ N·s)	Hardness (N)			L*	a*	b*
18.3											
0	0.10 ± 0.003	2.67 ± 0.05	1.54 ± 0.08	4.11 ± 0.16	1.59 ± 0.09	148 ± 4.83	36.0 ± 0.72	5.21 ± 0.03	78.3 ± 0.24	1.13 ± 0.09	19.4 ± 0.29
15	0.11 ± 0.002	2.69 ± 0.02	1.40 ± 0.03	3.77 ± 0.08	1.71 ± 0.03	150 ± 6.31	37.6 ± 0.88	5.17 ± 0.04	76.4 ± 0.42	2.75 ± 0.17	19.9 ± 0.32
30	0.12 ± 0.002	2.52 ± 0.03	1.53 ± 0.02	3.85 ± 0.01	1.70 ± 0.04	155 ± 6.31	44.0 ± 0.19	4.31 ± 0.03	75.2 ± 0.28	3.65 ± 0.09	20.7 ± 0.27
45	0.12 ± 0.007	2.39 ± 0.02	1.62 ± 0.07	3.88 ± 0.09	1.73 ± 0.03	157 ± 2.91	47.1 ± 1.66	3.84 ± 0.22	72.4 ± 0.34	4.34 ± 0.16	21.6 ± 0.47
19.5											
0	0.11 ± 0.004	2.82 ± 0.02	1.45 ± 0.06	4.08 ± 0.07	2.25 ± 0.13	149 ± 3.67	33.1 ± 0.21	5.69 ± 0.05	78.4 ± 0.21	0.93 ± 0.002	18.8 ± 0.30
15	0.13 ± 0.001	2.80 ± 0.02	1.28 ± 0.01	3.59 ± 0.05	2.19 ± 0.07	152 ± 5.91	35.5 ± 0.70	5.24 ± 0.14	74.2 ± 0.43	3.05 ± 0.21	20.3 ± 0.52
30	0.14 ± 0.001	2.76 ± 0.02	1.33 ± 0.10	3.67 ± 0.13	2.22 ± 0.09	177 ± 5.91	39.0 ± 0.60	4.53 ± 0.04	74.0 ± 0.89	3.63 ± 0.29	20.2 ± 0.98
45	0.13 ± 0.003	2.51 ± 0.03	1.49 ± 0.03	3.73 ± 0.08	2.28 ± 0.10	182 ± 12.9	41.2 ± 1.81	4.25 ± 0.03	72.5 ± 0.46	4.32 ± 0.16	20.8 ± 0.49
20.1											
0	0.12 ± 0.002	2.81 ± 0.03	1.45 ± 0.05	4.07 ± 0.14	2.68 ± 0.17	152 ± 10.9	30.6 ± 1.31	6.06 ± 0.07	77.6 ± 0.30	0.93 ± 0.001	19.4 ± 0.44
15	0.14 ± 0.005	2.81 ± 0.03	1.24 ± 0.05	3.48 ± 0.13	2.53 ± 0.05	153 ± 4.70	32.5 ± 1.20	5.49 ± 0.15	76.0 ± 0.50	2.88 ± 0.23	20.0 ± 0.86
30	0.15 ± 0.007	2.72 ± 0.02	1.37 ± 0.08	3.74 ± 0.08	2.42 ± 0.13	186 ± 4.70	36.6 ± 1.73	4.63 ± 0.17	74.6 ± 0.09	3.63 ± 0.18	20.1 ± 0.59
45	0.16 ± 0.004	2.49 ± 0.01	1.44 ± 0.04	3.57 ± 0.01	2.44 ± 0.05	188 ± 7.90	42.0 ± 1.86	4.30 ± 0.07	74.0 ± 0.27	4.38 ± 0.23	20.8 ± 0.51

[a] Mean Values ± SD; WSI is Water Solubility Index; WAI is Water Absorption Index; L* represents brightness; a* represents greenness-/ redness+; b* represents blueness-/ yellowness+

Table 3.4. Coefficients of correlation between sensory and physicochemical properties of extrudates.

	Density	RER	AER	OER	Jaggedness	Hardness	WSI	WAI	L*	a*	b*
Cell Uniformity	0.18	-0.86***	0.59*	-0.08	-0.42	0.44	0.92***	-0.93***	-0.69*	0.72**	0.80**
Color	0.65*	-0.70*	0.13	-0.57	-0.01	0.76**	0.80**	-0.92***	-0.91***	0.97***	0.87***
Diameter	-0.63*	0.74**	-0.27	0.39	-0.03	-0.80**	-0.78**	0.91***	0.85***	-0.89***	-0.81**
Shape Uniformity	-0.18	0.70*	-0.39	0.19	0.51	-0.42	-0.89***	0.91***	0.68*	-0.73**	-0.74**
Speck	0.66*	-0.65*	0.07	-0.60*	-0.01	0.77**	0.78**	-0.90***	-0.91***	0.97***	0.85***
Bean	0.65*	-0.63*	0.05	-0.61*	-0.02	0.74**	0.77**	-0.90***	-0.91***	0.97***	0.84***
Crisp	0.78**	0.12	-0.43	-0.48	0.88***	0.64*	-0.21	0.02	-0.31	0.29	0.08
Mouthfeel	0.91***	-0.26	-0.31	-0.71**	0.59*	0.87***	0.27	-0.48	-0.71**	0.74**	0.52
Gritty	0.88***	-0.29	-0.29	-0.72**	0.53	0.86***	0.33	-0.54	-0.78**	0.79**	0.57
Tooth Pack	0.35	-0.56	0.10	-0.45	-0.17	0.61*	0.71**	-0.81**	-0.85***	0.84***	0.71*
Bean Flavor	0.64*	-0.68*	0.12	-0.56	-0.04	0.77**	0.80**	-0.92***	-0.89***	0.96***	0.85***
Rice	-0.66*	0.67*	-0.12	0.55	0.00	-0.78**	-0.78**	0.91***	0.89***	-0.96***	-0.84***
Salt	0.63*	-0.62*	0.05	-0.59*	-0.06	0.77**	0.75**	-0.90***	-0.92***	0.96***	0.83***
Sweet	0.63*	-0.68*	0.14	-0.53	-0.05	0.77**	0.81**	-0.92***	-0.89***	0.95***	0.82**
Bitter	0.65*	-0.63*	0.05	-0.60*	-0.02	0.76**	0.76**	-0.89***	-0.91***	0.97***	0.83***

* $P < 0.05$, ** $P < 0.01$ and *** $P < 0.001$; RER, radial expansion ration; AER, axial expansion ratio; OER, overall expansion ratio.

Table 3.5. Consumer acceptance of rice-bean extrudate

	Bean Flour (%)			
Attribute	0	15	30	45
Overall*	8.0a	8.2a	6.9b	5.6c
Appearance				
OA_Appearance*	8.2a	8.2a	6.7b	6.3b
OA_Color*	7.2ab	7.5a	7.0ab	6.6b
Color[3]	5.1c	8.1b	8.3b	9.1a
Aroma				
OA_Aroma*	8.0ab	8.3a	7.4b	7.7ab
Texture				
OA_Texture*	10.1a	9.7ab	9.2b	9.2b
Density[4]	5.5b	4.7b	6.3a	7.0a
Crunch[5]	10.2a	10.1a	10.1a	10.7a
OA_Crunch*	10.4a	10.1a	9.8a	10.1a
Flavor				
OA_Flavor*	7.2ab	7.78a	6.6b	5.5c
Sweetness[1]	4.1a	4.3a	3.8ab	3.3b
Saltiness[1]	3.5b	4.2a	4.1a	3.8ab
Bitterness[1]	3.8c	4.2bc	4.6b	6.5a
Aftertaste*	8.0a	8.5a	6.9b	5.4c
Purchase Intent				
As Is[2]	4.7ab	5.1a	4.1b	3.2c
If Flavored[2]	10.1a	9.8a	8.3b	7.3b

Attributes evaluated on a 15 cm unstructured line scale; means within a row with different letters are significantly different ($P<0.05$). All extrudate samples were prepared at 19.5% moisture level. *Very Undesirable to Very Desirable, 1 Lacking to Intense 2 Very Unlikely to Very Likely, 3 Pale Yellow to Golden Brown, 4 Airy to Dense, 5 Not Crunchy to Very Crunchy

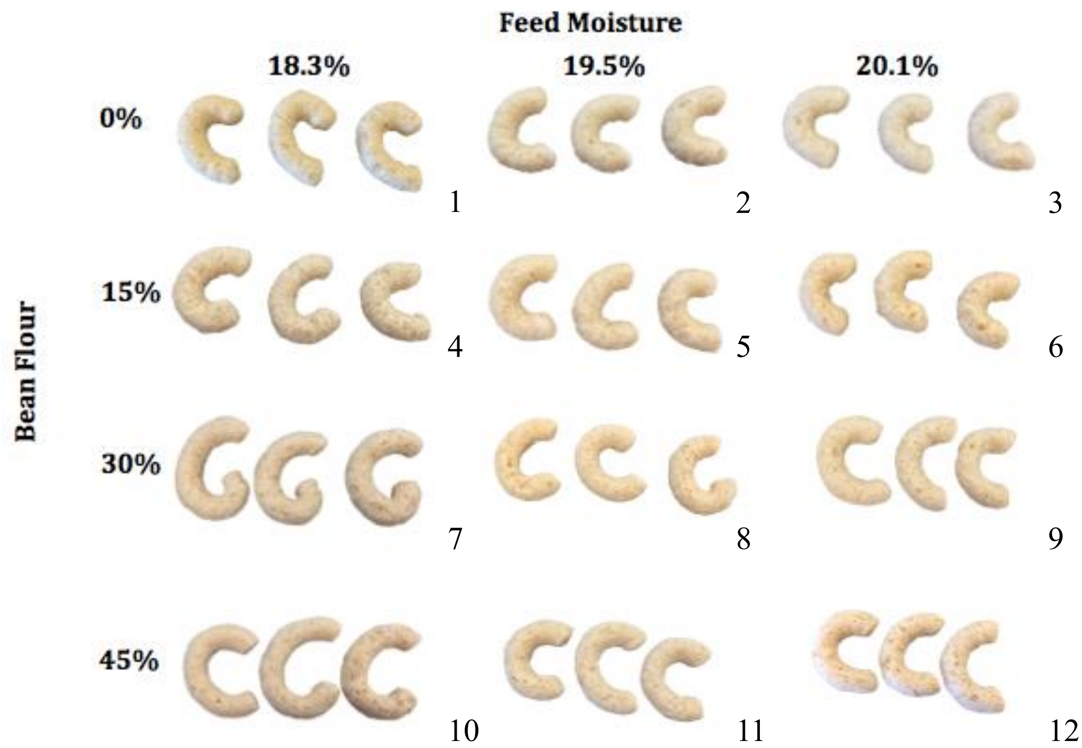

Figure 3.1. Pictures of extrudates prepared at four levels of pinto bean flour (0, 15, 30, 45%) and three levels of feed moisture (18.3, 19.5, 20.1%) with respective sample number.

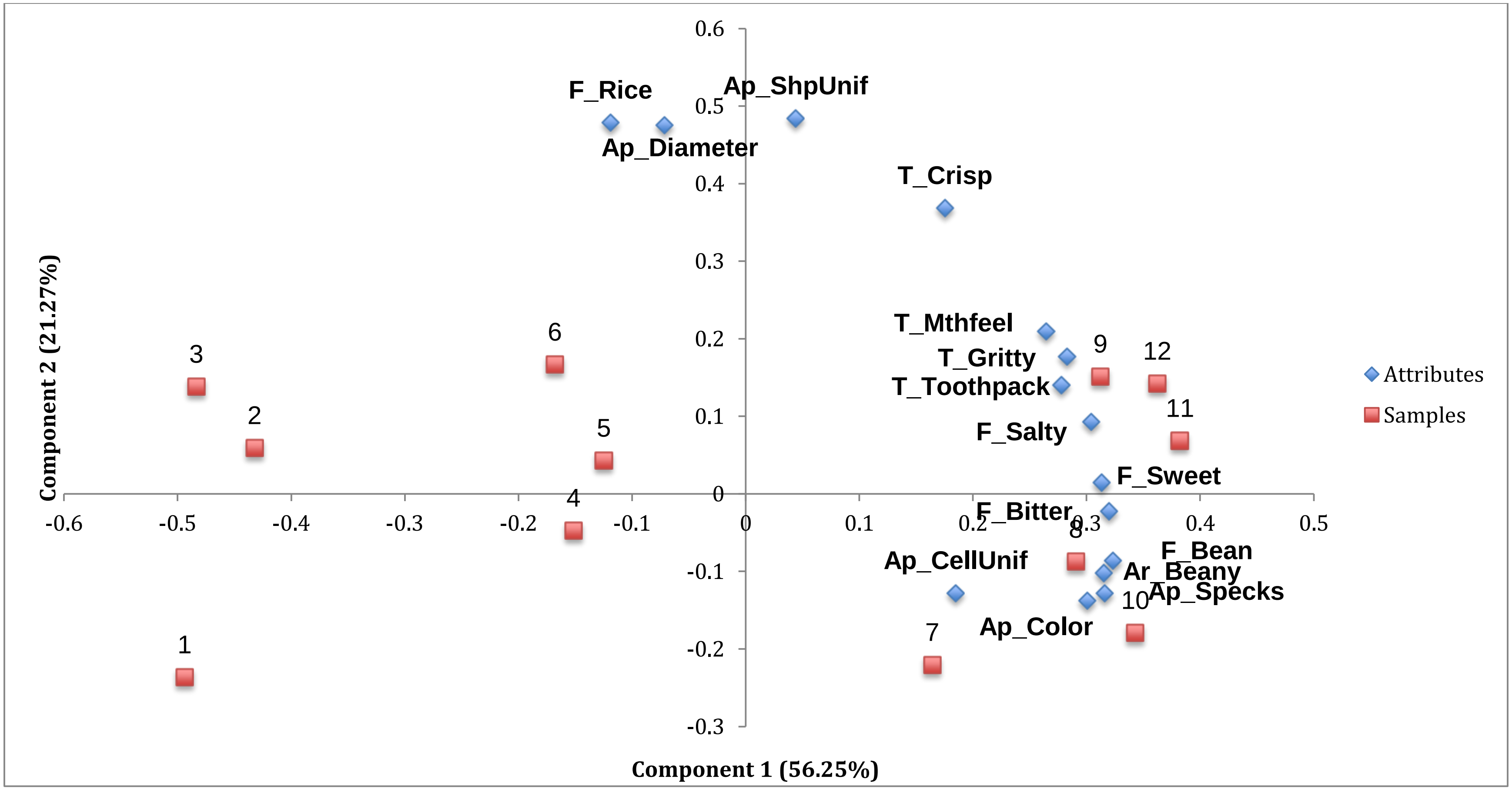

Figure 3.2. Principal component analysis biplot for descriptive whole wheat bread panel; abbreviations in Table 3.1; sample numbers in Figure 3.1.

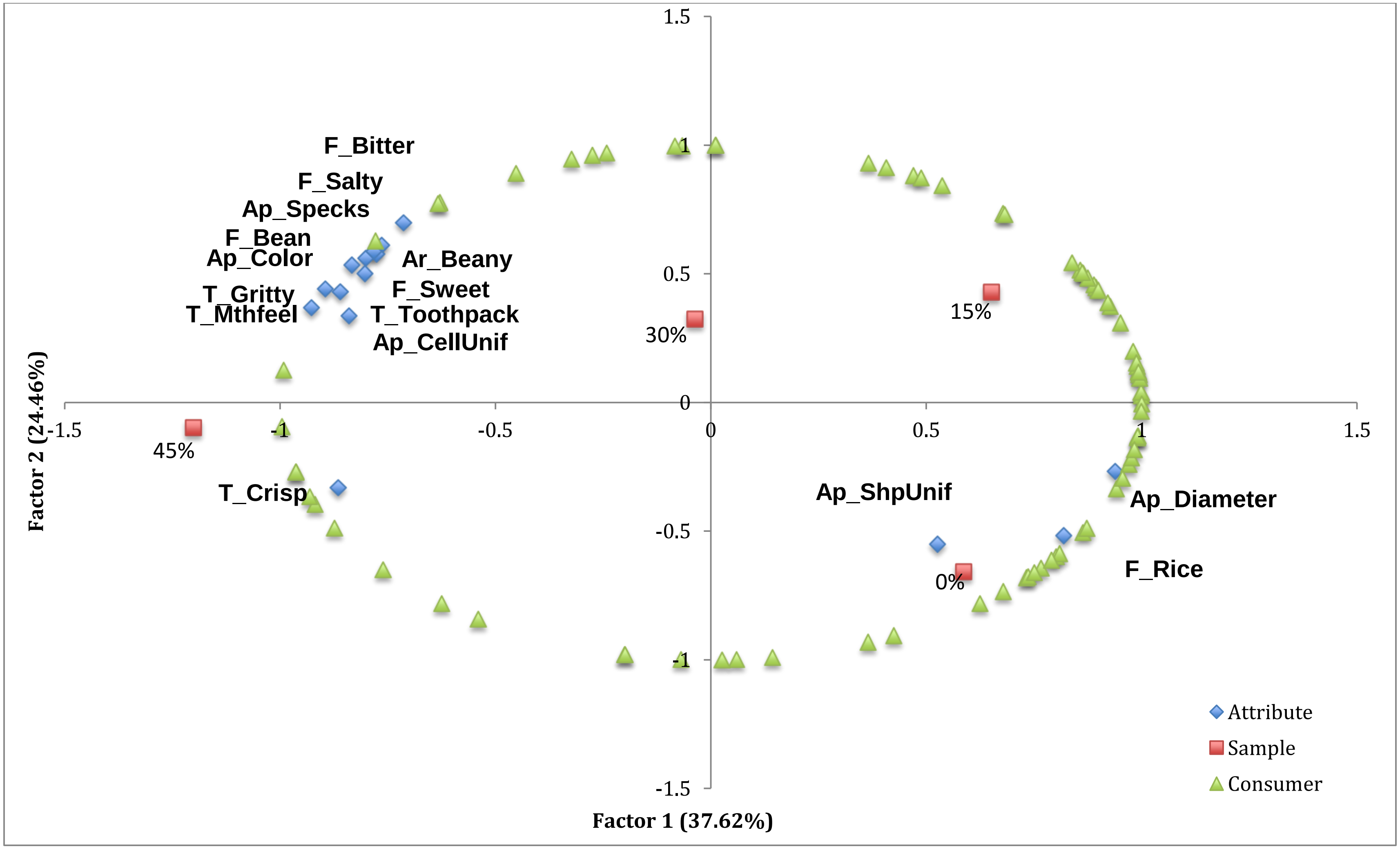

Figure 3.3. Preference map of rice-bean extrudate consumers (n=78), samples, and descriptive attributes; abbreviations in Table 3.1.

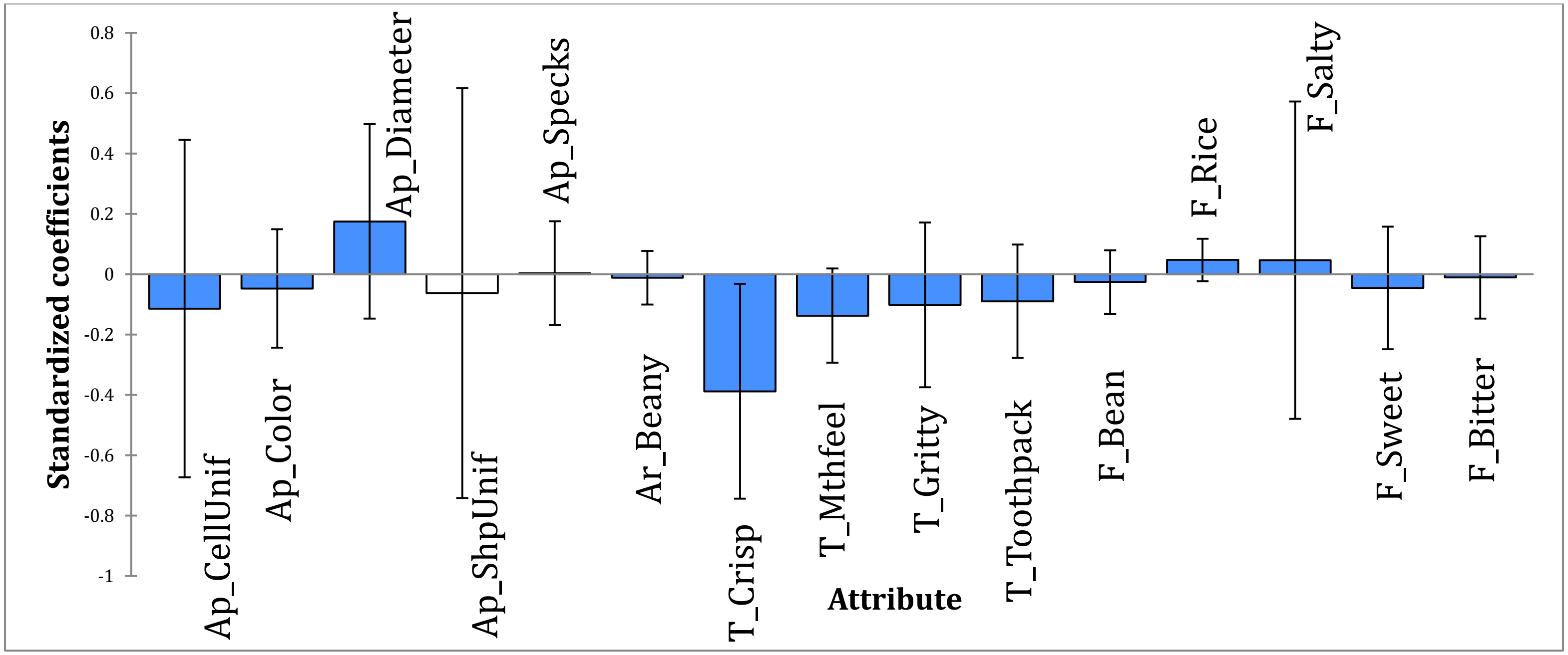

Figure 3.4. Partial least squares regression coefficients of attributes contributing to overall acceptability of rice-bean extrudates; attributes with solid bars represent those with a variable importance in projection of >0.8; abbreviations as in Table 3.1

GENERAL CONCLUSIONS

The present thesis has reported the use of descriptive analysis to evaluate differences among whole grain and high fiber products and to determine their relationship to consumer acceptability through preference mapping and PLS regression. The specific objectives were to analyze (a) commercially available whole wheat breads and (b) extruded rice and bean flour puff snacks.

In the first objective, two main groups of descriptive attributes were found to describe commercial whole wheat breads: soft and chewy textures with sweet flavor, and whole wheat, earthy, and roasted characteristics. Based on the overall acceptance of the samples, consumers were divided into three clusters. In the first cluster, consumers generally liked all breads equally well, while the second cluster liked the soft, chewy, and sweet breads and the third cluster liked the whole wheat, earthy, and roasted breads. Preference mapping confirmed the preferences of each cluster, as well as displayed a lack of samples and attributes that related to small portion of consumers suggesting a portion of consumers would like breads with characteristics from the two groups of attributes.

In the second objective, attributes that described the extrudates were evaluated under the two main effects: bean flour and feed moisture. Levels of bean flour addition affected appearance, flavor, aroma, and texture attributes of the rice-bean puffs, while feed moisture only affected texture attributes. Overall, extrudates made with 0 and 15% bean flour were bland, only being described by a rice flavor, large diameter, and uniform shape. Extrudates made with 30 and 45% bean flour, were described by bean aroma and flavor, small diameter, and crisp texture. Most consumers liked the 0 and 15% bean flour, with rice flavor and large diameter as high drivers of liking. Crispness of the sample,

which increased with increasing moisture, negatively affected overall liking. These findings suggest that consumer acceptable extrudates should be made with up to 15% bean flour and extruded at 18.3% moisture.

Overall, this thesis has determined desirable and undesirable qualities of whole wheat bread and extruded snack puffs for different consumer segments. These findings will be useful in improving the overall quality and consumer satisfaction of whole grain and high fiber food products. It is important to note, however, that regional and demographic differences in liking may exist, so further research on a larger set of products and consumers may prove useful in better understanding consumers and development of successful products.

APPENDICES

Appendix A. Select SAS Code

SAS software (version 9.2, SAS Institute, Cary, NC USA) was used for the code in Appendix A. Statistical differences were determined at p<0.05.

A.1. Descriptive ANOVA

```
data exampleA1;
input rep block panelist sample order attributes;
datalines; [data];
Title2 "LS Panelist Means and Slices";
proc glm data=exampleA1;
class panelist rep sample;
model attributes=  panelist rep sample panelist*rep panelist*sample /SS3;
ODS output ModelANOVA=Anova_pval;
lsmeans sample / pdiff lines;
ODS output lsmeans=ls_sample_means; run;
proc tabulate data=Anova_pval; class Dependent Source; var ProbF;
table Dependent="Characteristic", ProbF*sum=" "*( F=8.2)*Source; run;
```

A.2. Descriptive PCA

```
data exampleA2;
input Block    Order   panelist          Rep      Sample attributes;
datalines; [data];
proc princomp data=exampleA2 plots=(SCREE PATTERN(VECTOR)
SCORE(NCOMP=3));
Title1 "Orginal PCA identify Scores by Sample";
ID sample;
var attributes; run;
proc prinqual data=exampleA2 out=pqualResults n=2 replace mdpref;
    title2 'Multidimensional Preference (MDPREF) Analysis';
    title3 'Optimal Monotonic Transformation of Preference Data';
    id sample;
transform monotone(attributes); run;
proc print data=pqualResults; run;
title1 " Final Principal Component Analysis";
  proc princomp data=pqualResults plots=(SCREE PATTERN(VECTOR)
SCORE(NCOMP=3));
    var attributes; run;
```

A.3. Consumer Panel ANOVA

```
data exampleA3;
input Rep      Block   Judge   Sample Order  attribute;
datalines;
[data];
proc glm;
class Judge     Sample;
model attribute= judge sample;
lsmeans sample/ pdiff lines; run;
```

A.4. Consumer Clustering Method

```
data exampleA4;
input Judge     Dummy x1-x64;
datalines; [data];
proc cluster data=exampleA4 method=ward std pseudo outtree=tree;
id dummy;
var x1-x64;
proc tree data=tree out=clus2 nclusters=2;
id dummy;
copy x1-x64;
proc sort;
by cluster;
proc print;
by cluster;
var dummy;
title2 '3-cluster solution'; run;
```

A.5. Factor Analysis of Consumer Data to Build Preference Map

```
data exampleA5;
input consumers;
datalines;
[data];
proc factor data=exampleA5 nfactors=4 out=prindata;
var consumers;run;
proc print data=prindata noobs; run;
```

A.6. Correlation Between Descriptive Attributes and Physical Measurements

data exampleA6;
input sample physical characteristics sensory attributes;
data; [data];
proc corr;
var physical characteristics;
with sensory attributes; run;

Appendix B. Sensory Panel Ballots

Table B.1. Whole Wheat Bread Descriptive Panel Ballot

Attribute	Question	Special Instructions
Appearance	Please evaluate the appearance attributes	
Pore Size	The PORE SIZE of sample <CODE> is:	
Pore Uniformity	The PORE UNIFORMITY of sample <CODE> is:	
Crumb Color	The CRUMB COLOR of sample <CODE> is:	
Particulates	The CRUMB PARTICULATES of sample <CODE> is:	
Circular	The CIRCULAR APPEARANCE of sample <CODE> is:	
Crust Color	The CRUST COLOR of sample <CODE> is:	
Texture	Please evaluate the texture attributes by touch	Do not taste the sample yet.
Moist	The MOISTNESS of sample <CODE> is:	
Springiness	The SPRINGINESS of sample <CODE> is:	Using index finger, apply pressure to middle of crumb and release
Smoothness	The SMOOTHNESS of sample <CODE> is:	Slide two fingers across crumb surface
Crust	The CRUST TEXTURE of sample <CODE> is:	
Mouthfeel	Please evaluate the texture attributes by mouthfeel	
Cohesive	The COHESIVENESS of sample <CODE> is:	Chew sample 7 times on molars
Adhesive	The ADHESIVENESS of sample <CODE> is:	Push sample to roof of mouth, do not chew

Table B.1. (continued) Whole Wheat Bread Descriptive Panel Ballot

Attribute	Question	Special Instructions
Aroma	Please evaluate the aroma attributes	
Fermented	The FERMENTED AROMA of sample <CODE> is:	
Fruity	The FRUITY AROMA of sample <CODE> is:	
Roasted	The ROASTED AROMA of sample <CODE> is:	
Whole Wheat	The WHOLE WHEAT AROMA of sample <CODE> is:	
Butter	The BUTTER AROMA of sample <CODE> is:	
Flavor	Please evaluate the flavor attributes	Take a bite of apple before beginning each sample
Bitter	The BITTER FLAVOR of sample <CODE> is:	
Whole Wheat	The WHOLE WHEAT FLAVOR of sample <CODE> is:	
Sour	The SOUR FLAVOR of sample <CODE> is:	
Salty	The SALTY FLAVOR of sample <CODE> is:	
Sweet	The SWEET FLAVOR of sample <CODE> is:	
Roasted	The ROASTED FLAVOR of sample <CODE> is:	
Doughy	The DOUGHY FLAVOR of sample <CODE> is:	
Earthy	The EARTHY FLAVOR of sample <CODE> is:	
Roasted Crust	The ROASTED CRUST FLAVOR of sample <CODE> is:	

Scale anchors for each attribute can be found in Table 2.1.

Table B.2. Whole Wheat Bread Consumer Panel Ballot

Screen/ Attribute	Question	Scale
Instruction		
	Today you will evaluate whole wheat bread, one at a time. Evaluate the sample by clicking the box that matches your response to each question. Please take a bite of apple and drink of water before tasting each sample.	
Overall	What is your OVERALL opinion of sample <CODE>	9-pt Hedonic
Appearance	How much do you like or dislike the APPEARANCE of sample <CODE>	9-pt Hedonic
Texture	How much do you like or dislike the TEXTURE of sample <CODE>	9-pt Hedonic
Flavor	How much do you like or dislike the FLAVOR of sample <CODE>	9-pt Hedonic
Comment	Please type any questions you have regarding this product.	

Table B.3. Rice-Bean Puff Descriptive Panel Ballot

Attribute	Question	Special Instruction
Appearance	Please evaluate the appearance attributes	
Cell Uniformity	The CELL UNIFORMITY of the sample is:	Cut 5 pieces of sample and evaluate the cell uniformity between them
Color	The COLOR of the sample is:	
Diameter	The DIAMETER of the sample is:	
Shape Uniformity	The SHAPE UNIFORMITY of the sample is:	
Speck	The amount of SPECKS in the sample is:	Crush sample for evaluation
Aroma	Please evaluate the aroma attributes	
Bean	The BEAN aroma of the sample is:	
Texture	Please evaluate the texture attributes	
Crisp	The CRISPINESS of the sample is:	
Mouthfeel	The MOUTHFEEL of the sample is:	Evaluate the sensation on your tongue as you chew
Gritty	The GRITTINESS of the sample is:	
Tooth Pack	The TOOTH PACK of the sample is:	How much sample sticks to your teeth during chewing
Flavor	Please evaluate the flavor attributes	Evaluate attributes whenever perception of flavor occurs
Bean	The BEAN flavor of the sample is:	
Rice	The RICE flavor of the sample is:	
Salt	The SALTINESS of the sample is:	
Sweet	The SWEETNESS of the sample is:	
Bitter	The BITTERNESS of the sample is:	

Scale anchors for attributes can be found in Table 3.1.

Table B.4. Rice-Bean Puff Consumer Panel Ballot

Screen/Attribute	Question	Anchor
Introduction	Today you will evaluate four unflavored snack puff samples, one at a time. Evaluate the samples by clicking on the line scale below to make your selection.	
Appearance	Do not taste the samples yet	
OA_Appearance	The overall APPEARANCE acceptability of the sample is:	Very Undesirable - Very Desirable
OA_Color	The overall COLOR acceptability of the sample is:	Very Undesirable - Very Desirable
Color	The color of the sample is:	Pale Yellow - Golden Brown
Aroma		
OA_Aroma	The overall AROMA acceptability of the sample is:	Very Undesirable - Very Desirable
Off Odor	Do you think there is an off odor?	Yes/No
	(If Yes) The OFF ODOR of the sample is:	Lacking - Intense
Texture	Please eat the sample	
OA_Texture	The overall TEXTURE acceptability of the sample is:	Very Undesirable - Very Desirable
Density[4]	The TEXTURE of the sample is:	Airy - Dense
Crunch[5]	The CRUNCHINESS of the sample is:	Not Crunchy - Very Crunchy
OA_Crunch*	The overall CRUNCHINESS acceptability of the sample is:	Very Undesirable - Very Desirable

Table B.4. (continued) Rice-Bean Consumer Panel Ballot

Screen/Attribute	Question	Anchor
Flavor		
OA_Flavor*	The overall FLAVOR acceptability of the sample is:	Very Undesirable - Very Desirable
Sweetness[1]	The SWEETNESS of the sample is:	Lacking - Intense
Saltiness[1]	The SALTINESS of the sample is:	Lacking - Intense
Bitterness[1]	The BITTERNESS of the sample is:	Lacking - Intense
Off Flavor	Do you think there is an off flavor?	Yes/No
	(If Yes) The OFF FLAVOR of the sample is:	Lacking - Intense
Aftertaste	The overall AFTERTASTE acceptability of the sample is:	Very Undesirable - Very Desirable
Overall	The OVERALL acceptability of the sample is:	Very Undesirable - Very Desirable
Purchase Intent	Please answer the following purchase intent questions	
As Is[2]	How likely are you to purchase this sample as is?	Very Unlikely - Very Likely
If Flavored[2]	How likely would you purchase this sample if it were flavored?	Very Unlikely - Very Likely

Appendix C. IRB Consent Forms

C.1. Whole Wheat Bread Train Panel Consent Form

University of Nebraska Lincoln

IRB# 20130813667 EX
Date Approved: 08/05/2013
Valid Until: 08/04/2018

INSTITUTE OF AGRICULTURE AND NATURAL RESOURCES
COLLEGE OF AGRICULTURAL SCIENCES AND NATURAL RESOURCES
DEPARTMENT OF FOOD SCIENCE AND TECHNOLOGY

Informed consent form

Project: Descriptive evaluation of whole wheat bread

Purpose of the research
This study is being conducted to determine differences in aroma, appearance, texture, flavor, and aftertaste among whole wheat breads available on the market in an effort to develop better tasting whole wheat products.

Invitation to participate
You are invited to participate in this study, which is divided onto two panels: a screening panel and a trained panel. To participate in the screening panel, you should meet the following criteria:

- You are 19 years of age or older
- You like and regularly consume whole wheat bread
- You do not have allergies to wheat, soy, or dairy
- You are willing to provide your name and email address or phone number (which will be kept confidential)
- You have a flexible schedule that would allow for future taste testing in 90 minute segments three times per week for up to four weeks

If you participate in the screening session (described below) and are able to discriminate among whole wheat bread samples, you may be invited to participate in the trained panel. Participation in this panel is voluntary, even if you receive an invitation.

Procedures

Screening panel
In the screening session, you will receive three samples of whole wheat bread via pass-through compartments in booths separated by plywood dividers for privacy. One of the samples will be marked 'R' for reference; the other two samples will be marked with three digit random numbers. One of these two samples will be the same as 'R' and the other will be different. You will be asked to taste all samples and identify the sample that is different from 'R'. Responses will be made by marking the appropriate box on a computer screen. This test will then be repeated 5 times with new samples each time.

Trained panel

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If you are able to correctly identify the different sample at least four out of six times in the screening session, you may be invited to participate in the trained panel. You will be contacted using the information provided prior to the screening panel. At the time of the invitation, the research study personnel will inquire as to your willingness to participate in the trained panel. If you are willing, the research study personnel will then ask for your availability (to identify times when the panel can meet). This information will be kept confidential.

The trained panel will consist of 6-10 training sessions lasting 90 min over a 2-3 week period. In these training sessions, you will be asked to evaluate many whole wheat bread samples. You will be encouraged to expectorate (spit out) samples to prevent fatigue. Training will be divided into four phases:

- Phase 1 (2-3 sessions, 90 min each): Attributes ratings and terminology for whole wheat bread will be developed and refined through open discussions with other panelists and recorded by the research study personnel. As many as 100 descriptors may be generated.
- Phase 2 (2-3 sessions, 90 min each): You will rate breads in an open forum setting with other panelists on line scales for intensity of each of the descriptors developed in phase 1.
- Phase 3 (2-3 sessions, 90 min each): You will evaluate all breads in private booths. Data will be analyzed to determine which descriptors show differences among samples. Descriptors that do not show differences among samples will be eliminated. Data will also be analyzed to determine if you use descriptors and scales in the same way as the other panelists.
- Phase 4 (1 session, 90 min, optional, only performed if a few panelists do not use scales like the rest of the panelists): If you or a few other panelists are identified in phase 3 as not rating samples according to the majority, an additional open forum training session will be conducted. The research study personnel will ask you to focus on descriptors for which there were discrepancies among panelists. The research study personnel will ask one or two panelists that showed good discrimination ability and agreement with the majority to describe each of the attributes in detail and give example ratings for certain samples.

Following training, the descriptive panel will occur. This will be identical to phase 3, except no descriptors will be eliminated.

Potential risks and discomforts

You should not participate in this panel if you have allergies to wheat, soy, or milk. Except for persons having food allergies, risks associated with this study are negligible. If you experience a reaction to an unknown food allergy, you should seek immediate medical attention. Please be aware that any expenses related to your medical treatment will be your responsibility. Please inform at least one of the research study personnel if you do have a reaction to the food product. Only bread purchased from the grocery store and prepared and stored under sanitary conditions will be used in this study. The following ingredients are included in the samples to be tasted (which are typical of store-bought whole wheat breads): Whole wheat flour, sugar, high fructose corn syrup, honey, wheat gluten, yeast, raisin juice concentrate, wheat bran, molasses, soybean oil, cottonseed oil, canola oil, monoglycerides, calcium propionate, calcium sulfate, diacetyl tartrate esters of monoglycerides (DATEM), sodium steroyl lactylate, polysorbate 60,

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azodicarbonamide, ethoxylated monoglycerides, calcium sulfate, ascorbic acid, vinegar, soy lecithin, soy flour, whey, milk, ammonium sulfate.

Potential benefits
Although there are no known benefits directly to you, your involvement in this project may benefit the general public by providing better tasting, healthier foods.

Assurance of confidentiality
Any information obtained in connection with this project and which could be identified with you will be kept strictly confidential. Summary results and statistical data may be reported in scientific journals or presented at scientific meetings; however, you individual responses will be maintained in confidence.

Withdrawal from the study
Participation in this study is voluntary. Your decision whether or not to participate will not affect your present or future relationship with the University of Nebraska-Lincoln. If you decide to participate, you are free to withdraw at any time.

Compensation for participation
Individuals participating in the screening panel will be compensated with a treat, such as a small candy bar. Individuals participating in the trained panel will receive $7 per session.

Offer to answer questions
If you have any questions, please do not hesitate to ask. If you think of questions later, please feel free to contact the research study personnel listed below.

If you have any additional questions concerning the rights of research subjects, you may contact the University of Nebraska-Lincoln Institutional Review Board (IRB), telephone 402-472-6965.

Consent and right to receive a copy
You are voluntarily making a decision whether or not to participate in this research study. By signing this form, you are agreeing to participate, though you may still withdraw at any time. You will be given a copy of this consent form to keep.

Printed name: ______________________

Signature: ______________________ Date: ______________________

Research study personnel and selected contact information

Ashley Bernstein, primary contact	402- 472-2954
Devin Rose, secondary contact	402-472-2802

C.2. Whole Wheat Bread Consumer Panel Consent Form

IRB# 20131214062 EX
Date Approved: 12/20/2013
Valid Until: 12/19/2018

UNIVERSITY OF Nebraska Lincoln

INSTITUTE OF AGRICULTURE AND NATURAL RESOURCES
The Food Processing Center

SENSORY EVALUATION OF WHOLE WHEAT BREAD

Invitation to participate
You are invited to participate in a study of assessing the acceptability of whole wheat bread.

Purpose of the study
This study is being conducted to determine the acceptability of whole wheat bread.

Basis for subject selection
Subjects will be selected based on their willingness to taste whole wheat bread. Individuals with sinus conditions or allergy to a specific ingredient should not participate. You must be 19 years or older to participate.

Potential benefits
There are no potential benefits; however, the results will be used to develop better tasting foods that will have benefit to others in the future.

Explanation of procedures
You will be asked to taste three samples. You will be provided with water and unsalted crackers for rinsing your mouth between samples. This tasting will require about 10 minutes, depending on your speed of tasting. Testing will occur in the Sensory Laboratory located in the Food Industry Complex on the UNL East Campus. You are requested to refrain from smoking, eating, or drinking fluids other than water for one hour prior to each session.

Potential risks and discomforts
Except for persons having food allergies, risks associated with this study are negligible. If you experience a reaction to an unknown food allergy, you should seek immediate medical attention. Please be aware that any expenses related to your medical treatment will be your responsibility. Please inform at least one of the investigators if you do have a reaction to the food product. Only food grade ingredients will be used for preparation of the food to be tasted, and the food will be prepared under sanitary conditions. The following ingredients are included in the samples to be tasted (which are typical of store-bought whole wheat breads): Whole wheat flour, sugar, high fructose corn syrup, honey, wheat gluten, yeast, raisin juice concentrate, wheat bran, molasses, soybean oil, cottonseed oil, canola oil, monoglycerides, calcium propionate, calcium sulfate, diacetyl tartrate esters of monoglycerides (DATEM), sodium steroyl lactylate, polysorbate 60, azodicarbonamide, ethoxylated monoglycerides, calcium sulfate, ascorbic acid, vinegar, soy lecithin, soy flour, whey, milk, ammonium sulfate.

Assurance of confidentiality
Any information obtained in connection with this project and which could be identified with you will be kept strictly confidential. Summary results and statistical data may be reported in scientific journals or presented at scientific meetings; however, individual panelist responses will be maintained in confidence.

IRB# 20131214062 EX
Date Approved: 12/20/2013
Valid Until: 12/19/2018

Withdrawal from the study
Participation in this study is voluntary. Your decision whether or not to participate will not affect your present or future relationship with the University of Nebraska. If you decide to participate, you are free to withdraw at any time.

Compensation for participation
Individuals participating in this taste panel will be compensated with a treat, such as a small candy bar.

Offer to answer questions
If you have any questions, please do not hesitate to ask. If you think of questions later, please feel free to contact the investigator(s) listed below.

If you have any additional questions concerning the rights of research subjects, you may contact the University of Nebraska-Lincoln Institutional Review Board (IRB), telephone 402-472-6965.

YOU ARE VOLUNTARILY MAKING A DECISION WHETHER OR NOT TO PARTICIPATE IN THIS RESEARCH STUDY. YOUR SIGNATURE CERTIFIES THAT YOU HAVE DECIDED TO PARTICIPATE HAVING READ THE INFORMATION PRESENTED. YOUR SIGNATURE ALSO CERTIFIES THAT YOU HAVE HAD AN ADEQUATE OPPORTUNITY TO DISCUSS THIS STUDY WITH THE INVESTIGATOR AND YOU HAVE HAD ALL YOUR QUESTIONS ANSWERED TO YOUR SATISFACTION. YOU WILL BE GIVEN A COPY OF THIS CONSENT FORM TO KEEP.

Printed name: ______________________________

Signature: ______________________________ Date: ______________________

Research study personnel and selected contact information

Ashley Bernstein, primary contact	402- 472-2954
Devin Rose, secondary contact	402-472-2802

C.3. Rice-Bean Puff Trained Panel Consent Form

INSTITUTE OF AGRICULTURE AND NATURAL RESOURCES
COLLEGE OF AGRICULTURAL SCIENCES AND NATURAL RESOURCES
DEPARTMENT OF FOOD SCIENCE AND TECHNOLOGY

Informed consent form

Project: Descriptive evaluation of extruded products

Purpose of the research
This study is being conducted to determine differences in aroma, appearance, texture, flavor, and aftertaste among extruded products.

Invitation to participate
You are invited to participate in this study if you meet the following criteria:

- You are 19 years of age or older
- You do not have allergies to wheat or soy
- You have a flexible schedule that would allow for 2, 45 minute training sessions each week over a 2 month time period.

Participation in this panel is voluntary, even if you receive an invitation.

Procedures
Trained panel
The trained panel will consist of 8-10 training sessions lasting approximately 45 min over a 2-month period. In these training sessions, you will be asked to evaluate many extrudate samples. You will be encouraged to expectorate (spit out) samples to prevent fatigue. Training will be divided into four phases:

- Phase 1 (3-4 sessions, 45 min each): Attributes ratings and terminology for extrudates will be developed and refined through open discussions with other panelists and recorded by the research study personnel. As many as 100 descriptors may be generated.
- Phase 2 (3-4 sessions, 45 min each): You will rate extrudates in an open forum setting with other panelists on line scales for intensity of each of the descriptors developed in phase 1.
- Phase 3 (2-3 sessions, 90 min each): You will evaluate all extrudates in private booths. Data will be analyzed to determine which descriptors show differences among samples. Descriptors that do not show differences among samples will be eliminated. Data will also be analyzed to determine if you use descriptors and scales in the same way as the other panelists.
- Phase 4 (1 session, 90 min, optional, only performed if a few panelists do not use scales like the rest of the panelists): If you or a few other panelists are identified in phase 3 as not rating samples according to the majority, an additional open forum training session will be conducted. The research study personnel will ask you to focus on descriptors for which there were discrepancies among panelists. The research study personnel will ask one or two panelists that showed good discrimination ability and agreement with the majority to describe each of the attributes in detail and give example ratings for certain samples.

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Following training, the descriptive panel will occur. This will be identical to phase 3, except no descriptors will be eliminated.

Potential risks and discomforts
You should not participate in this panel if you have allergies to wheat or soy. Except for persons having food allergies, risks associated with this study are negligible. If you experience a reaction to an unknown food allergy, you should seek immediate medical attention. Please be aware that any expenses related to your medical treatment will be your responsibility. Please inform at least one of the research study personnel if you do have a reaction to the food product. The following ingredients may be included in the samples to be tasted: **Brown rice flour, pinto bean flour, wheat flour, soy, salt.**

Potential benefits
Although there are no known benefits directly to you, your involvement in this project may benefit the general public by providing better tasting foods.

Assurance of confidentiality
Any information obtained in connection with this project and which could be identified with you will be kept strictly confidential. Summary results and statistical data may be reported in scientific journals or presented at scientific meetings; however, you individual responses will be maintained in confidence.

Withdrawal from the study
Participation in this study is voluntary. Your decision whether or not to participate will not affect your present or future relationship with the University of Nebraska-Lincoln. If you decide to participate, you are free to withdraw at any time.

Offer to answer questions
If you have any questions, please do not hesitate to ask. If you think of questions later, please feel free to contact the research study personnel listed below.

If you have any additional questions concerning the rights of research subjects, you may contact the University of Nebraska-Lincoln Institutional Review Board (IRB), telephone 402-472-6965.

Consent and right to receive a copy
You are voluntarily making a decision whether or not to participate in this research study. By signing this form, you are agreeing to participate, though you may still withdraw at any time. You will be given a copy of this consent form to keep.

Printed name: ______________________

Signature: ________________________ Date: ____________________________

Research study personnel and selected contact information

Ashley Bernstein, primary contact	402- 472-2954
Devin Rose, secondary contact	402- 472-2802

C.4. Rice-Bean Puff Consumer Panel Consent Form

University of Nebraska Lincoln

INSTITUTE OF AGRICULTURE AND NATURAL RESOURCES
COLLEGE OF AGRICULTURAL SCIENCES AND NATURAL RESOURCES
DEPARTMENT OF FOOD SCIENCE AND TECHNOLOGY

SENSORY EVALUATION OF EXTRUDATES

Invitation to participate
You are invited to participate in a study of assessing the acceptability of extrudates.

Basis for subject selection
Subjects will be selected based on their willingness to taste extrudates. Individuals with sinus conditions or allergy to a specific ingredient should not participate. You must be 19 years or older to participate.

Explanation of procedures
You will be asked to taste samples of the extrudates. You will be provided with water and unsalted crackers for rinsing your mouth between samples. This tasting will require about 10 minutes, depending on your speed of tasting. Testing will occur in the Sensory Laboratory located in the Food Industry Complex on the UNL East Campus.

Potential risks and discomforts
You should not participate in this panel if you have allergies to wheat. Except for persons having food allergies, risks associated with this study are negligible. If you experience a reaction to an unknown food allergy, you should seek immediate medical attention. Please be aware that any expenses related to your medical treatment will be your responsibility. Please inform at least one of the research study personnel if you do have a reaction to the food product. Only food grade ingredients will be used for preparation of the food to be tasted, and the food will be prepared under sanitary conditions. The following ingredients are included in the samples to be tasted: **Brown rice flour, pinto bean flour, salt.**

Assurance of confidentiality
Any information obtained in connection with this project and which could be identified with you will be kept strictly confidential. Summary results and statistical data may be reported in scientific journals or presented at scientific meetings; however, your individual responses will be maintained in confidence.

Withdrawal from the study
Participation in this study is voluntary. Your decision whether or not to participate will not affect your present or future relationship with the University of Nebraska-Lincoln. If you decide to participate, you are free to withdraw at any time.

Compensation for participation
Individuals participating in this taste panel will be compensated with a treat, such as a small candy bar.

Offer to answer questions
If you have any questions, please do not hesitate to ask. If you think of questions later, please feel free to contact the research study personnel listed below. If you have any additional questions concerning the rights of research subjects, you may contact the University of Nebraska-Lincoln Institutional Review Board (IRB), telephone 402-472-6965.

You are voluntarily making a decision whether or not to participate in this research study. By participating in this panel, you are providing consent to participate. You will be given a copy of this consent form to keep.

Research study personnel and selected contact information

Ashley Bernstein, primary contact	402-472-2954
Devin Rose, secondary contact	402-472-2802

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