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Enhancing the Nutritional Quality of Flour Tortillas: An Investigation of Consumer Receptivity to a Fortified Tortilla Product.

Anna M. R. Hayes
Henrietta Schmoll School of Health
Department of Nutrition and Exercise Sciences
St. Catherine University
2004 Randolph Avenue
Saint Paul, MN 55105

Faculty Advisor: Teri L. Burgess-Champonux, PhD, RD, LD

Abstract

The majority of U.S. adults consume less than the recommended amount of whole grains, dietary fiber, and vegetables on a daily basis. Increased intake of these foods is linked with reduced risks of developing chronic diseases, such as heart attack, cardiovascular disease, and stroke. With increased prevalence of such chronic health conditions and inadequate intakes of whole grains and vegetables, the need for an appealing enriched food product is evident. Over the past decade, the tortilla industry has been the fastest-growing sector of the U.S. baking industry; therefore, enhancing the nutritional content of tortillas could result in healthier food products acceptable to consumers. This research aimed to determine the effects of altering the flour component and adding a legume ingredient, specifically lentils, on the sensory attributes and overall characteristics of flour tortillas. Sorghum, an ancient whole grain variety, is rich in antioxidants, dietary fiber, and iron. Lentils, a type of grain legume, are high in fiber, B vitamins, minerals, proteins, and complex carbohydrates. Ten phases of bench-top product development using standardized preparation techniques were completed, resulting in two optimal fortified tortilla product formulations. Sensory evaluations were conducted among college students and instructors (n=35) for sensory attributes and overall likeability of four samples: two fortified tortilla products, a commercial tortilla made with refined flour, and a commercial health-enhanced tortilla. Results indicate that fortified tortilla products enhanced with pureed cooked lentils and sorghum flour are acceptable among the sampled population. Future research opportunities include conducting sensory evaluations among a larger population, optimizing product formulation for use in commercial production, extending product shelf life, and further enhancing nutritional qualities of tortillas by reducing sodium and fat content.

Keywords: Tortillas, Whole Grains, Fiber, Legumes, Nutrition

1. Practical Application

This research aimed to investigate the best incorporation of lentils and sorghum flour, two nutritionally beneficial ingredients, into soft-shell tortillas. After optimal tortilla formulas were developed, the tortillas were evaluated by adult consumers in a college setting. Findings indicate that a nutritionally enhanced tortilla product is acceptable in comparison to a commercial refined tortilla product among the sampled population.

2. Introduction

Presently, the typical American adult lifestyle is characterized by the overconsumption of food calories and a lack of physical activity.[1] Each individual's dietary habits and food intake are impacted by a variety of components—

including factors such as age and race/ethnicity, environmental setting, industry and media, and social and cultural norms and values. Currently, an abundance of calorically-dense, nutritionally-deficient foods in conjunction with limited access to healthier options and decrement in motivation to maintain healthy nutrition behaviors all contribute to the current dietary habits of U.S. adults.[1] Specifically, recent trends show that the majority of the U.S. adult population consumes less than the recommended amount of whole grains and dietary fiber on a daily basis, and fewer than 5 percent of Americans obtain the average recommended 3 ounce amount of whole grains per day.[2] The 2010 Dietary Guidelines recommend individuals consume at least half of their grains as whole grain varieties and to replace refined grains with whole grains.[1] Increased intake of whole grains is of utmost importance to the adult population, as this dietary habit has been associated with the reduced risk of high blood pressure, coronary heart disease, diabetes, and, potentially, certain cancers.[3]

Additionally, very few Americans obtain the recommended amounts of vegetables in their daily diets. The average U.S. adult consumes only 59 percent of the daily recommended 2½ cups of vegetables.[1] Increased consumption of vegetables has been linked with a reduced risk of developing many chronic diseases, including cardiovascular disease, heart attack, and stroke. One notably concerning health complication is metabolic syndrome (MetS), a condition which approximately 27 percent of the U.S. adult population have been diagnosed.[4] MetS is characterized by the presence of central obesity, dyslipidemia, hyperglycemia, and hypertension and it can also be a strong predictor of type 2 diabetes mellitus, cardiovascular disease, and all-cause mortality. The majority of people diagnosed with MetS have dietary patterns characterized by the frequent consumption of soft drinks, refined grains, corn tortillas, and pastries along with minimal consumption of dairy products, seafood, and whole grains.[4,5] With the increasing prevalence of chronic health conditions and diseases in conjunction with inadequate intakes of whole grains and vegetables observed among adult populations in the U.S., the need for an acceptable whole grain- and vegetable-enhanced product is evident.[1,4,6]

Composed of amino acids, proteins are a key macronutrient with versatile roles in the human body.[1,5] The quality of a protein is determined by the protein's digestibility and amino acid composition. A high quality protein contains all the essential amino acids in relatively the same amounts and proportions as required by the human body. In general, foods derived from animal sources (such as meats, cheese, eggs, and milk) provide high quality protein, while foods from plant sources (such as seeds, grains, vegetables, and legumes) provide low quality protein because they lack one or more essential amino acids.[5] However, different plant proteins can be paired in a strategy called protein complementation in order to provide a complete source of all the essential amino acids. Together, such a combination of plant protein foods supply a complete source of high quality protein. Although the majority of U.S. adults obtain adequate amounts of protein in their daily diets,[1,2] the 2010 Dietary Guidelines emphasize incorporating a wider variety of protein foods and making choices that are lower in saturated fat, cholesterol, and calories.[1] Such recommendations afford the need for acquiring high quality proteins from foods that are less calorically-dense. This outcome can readily be achieved through protein complementation in developing a food product made from plant sources of protein.[5]

Grain legumes or pulses include peas, beans, lentils, and chickpeas.[7] These traditional crops are growing in popularity as ingredients or components in food products, as they are excellent sources of fiber, B vitamins, minerals, proteins, and complex carbohydrates.[8,9,10] Such legumes contain approximately 20 to 25 percent protein by weight—double the composition level of wheat[9]—and are generally gluten-free, high in dietary fiber, and free of cholesterol.[7] Although legumes can vary by type and variety, they are all identified as having grown as a seed within a pod.[8] Legumes have notable health benefits, including the ability to enhance glycemic control, reduce heart-related risk factors among individuals with diabetes mellitus,[11] and protect against MetS.[12] However, recent surveys indicate that the majority of U.S. adults consume less than half of the recommended amount of legumes.[13]

As legumes are unique varieties of vegetable plants, their proteins are low in quality and do not contain all the essential amino acids in relatively the same amounts that human beings require.[5,8] However, consuming legumes with cereal grains can provide all of the necessary amino acids, rendering the combination a complete high quality source of protein. In general, legumes and grains are near perfect matches for protein complementation, as one contains the other's lacking amino acid component.

Lentils are a specific type of legume which have been previously used as a blend with other cereal flours in bread and cake products.[9] With rich contents of protein, iron, zinc, selenium, and beta-carotene, increased lentil consumption could help decrease micronutrient deficiency[14]—an expanding concern among the U.S. adult population. Additionally, lentils have distinguished antioxidant and phenolic characteristics,[15] notably those of polyphenols and anthocyanins.[16] A growing body of research suggests that the consumption of lentils could have a major role in preventing diabetes and other chronic-degenerative diseases.[14-16]

Sorghum, also referred to as milo, is an ancient variety of whole grain that is high in antioxidants, dietary fiber, and iron.[17] However, research suggests that by consuming sorghum the body's ability to utilize absorbed nutrients is reduced from 15 percent to 3 percent due to the presence of tannins.[18] The implications of this reduced nutrient bioavailability are two-fold: in cases where overnutrition is a problem, decreased absorption may be desired; however, in cases of nutrient deficiencies decreased absorption is not desirable. This factor must be considered when including sorghum to develop new food products. Alternatively, sorghum's high levels of phenolic compounds and anti-fungal proteins are beneficial, as they provide natural barriers against molding. Flour milled from sorghum is light in color and has a mild flavor with minimal bitter aftertaste, allowing it to be combined with other flours to produce palatable baked products.[17] As Brown (2011) indicates, one notable application of sorghum flour is its traditional use for tortilla-making in some Latin American regions.[8]

Over the past decade, the tortilla industry has reportedly been the fastest-growing sector of the baking industry in the U.S.[19] This trend stems from the continually increasing influence of Hispanic and Latino culture in the U.S., as population projections from the Pew Research Center indicate that the 2005 Hispanic population of 42 million will triple in size by 2050 to 128 million.[20] With this expanding population comes the increasing prevalence of traditional Hispanic foods—such as tortillas. As the popularity of tortillas rises, they could also serve as a viable option for introducing nutritionally enhanced foods. A notable rise in awareness of the potential health benefits associated with tortillas has also increased their popularity. According to Pyler and Gorton (2009), a basic flour tortilla is a flat, circular, and light-colored bread with an average thickness of 1/16 inch and a diameter ranging from 6 to 13 inches.[9] Traditional tortillas are indigenous to Central American countries and have often been consumed as a table bread or with a variety of meat and/or vegetable fillings as burritos, tacos, tamales, and enchiladas.[9,21] Tortillas made with wheat differ from those made with corn, mainly in their methods of processing and preparation. Furthermore, wheat flour tortillas have higher levels of protein, fat, carbohydrates and the three enrichment vitamins (thiamin, riboflavin, and niacin) compared to corn tortillas.[21]

Previous wheat flour tortilla product formulations have yielded favorable incorporations of flavors such as sun-dried tomato, spinach, and other vegetables,[9] indicating the potential for further manipulation of ingredients to create nutritionally enhanced flour tortilla products. Additionally, tortillas have successfully been made using triticale and sorghum in place of wheat or corn as flour components.[21] Four major ingredients comprise the traditional tortilla formulation: flour, water, shortening/oil, and salt.[9,21] Tortillas made with only these ingredients have a shelf life of two to four days due to their high moisture content, rendering them highly susceptibility to molding. In the U.S., most commercial formulations also contain preservatives, chemical leavening agents, emulsifiers, gums, and other ingredients to improve the tortilla products' overall flavor, texture, softness, functionality, and shelf life.[22] For the purposes of this investigation, the majority of such ingredients were not used in attempts to create a more traditional tortilla product. However, xanthan gum was added to the tortilla formula in order to improve texture and sensory attributes of the enhanced product.[17]

One of the primary aims of this research project was to develop a consumer friendly tortilla product that, in comparison to a baseline refined flour tortilla, was 3 times higher in whole grain composition and 3 times higher in dietary fiber content than the control—specifically, increasing the amount from 1 gram to 3 grams. Ideally, this product would provide at least 20 percent of the daily recommended amount of vegetables for adults by incorporating a minimum of ½ cup cooked lentils per serving, which equals 20 percent of the 2½ cup daily recommended amount. Additionally, with its combination of sorghum flour and lentils, this tortilla product would provide a complete source of high quality protein. Such a product enables consumers to obtain a nutritionally dense meal component with one simple choice instead of many. Choosing the enhanced tortilla creates a simpler inclusion of whole grains and vegetables into one's diet by eliminating the necessity to accompany tortillas with vegetable greens and beans. Due to the lack of previous research regarding formulation of flour tortillas with both a whole grain and a vegetable/legume component, exact ingredient production methods and substitution levels required experimentation for optimal application.[7,9] It was hypothesized that the nutritionally enhanced tortilla product would be well-received by sensory panelists due to completing many phases of product development to formulate a tortilla product with acceptable tenderness, taste, and overall texture. Previously, sorghum flour has successfully been individually incorporated in tortilla recipes,[9] but, to the knowledge of the investigator, lentils had not. Furthermore, this project aimed to reveal the best incorporation of both nutritional components in one product.

3. Materials and Methods

3.1Methodology Overview

Independent variables in this project were the alterations to the flour variety and the addition of a vegetable/legume component to a tortilla product through bench-top product development. The baseline recipe.[9,23] was adapted by changing the dry flour component to a mixture of all-purpose (AP) flour and sorghum flour. The inclusion of a lentil vegetable component varied by experimental trial—for some trials the lentil ingredient was added as a puree, while for others it was a dry flour (Appendices A.1. & A.2.). The trial-and-error recipe development process consisted of a series of 10 phases that began during the month of August 2013 in the Research and Development (R&D) test kitchen at Michael Foods, Inc., in Gaylord, MN, and was completed in November 2013 in the Saint Catherine University (SCU) Food Science Lab. Phases 1 to 5 took place at Michael Foods, while Phases 6 to 10 were completed at SCU. Recipe costing was completed for budgetary and planning purposes (Appendix A.3.). Manipulations for the phases involved altering the flour component with different combinations of all-purpose (AP) flour, sorghum flour, and lentils and adjusting the water component (Appendix A.4.). Nutritional analyses were completed using Genesis R&D SQL (Version 10.11.0, 2011, ESHA Research, Inc., Salem, Oregon) and Food Processor Software (Version 10.11.0, 2012, ESHA Research, Inc., Salem, Oregon) to assess whole grain, fiber, and other standard nutrient compositions for each phase of tortillas (Appendix A.5.).

Qualitative sensory evaluation of the tortillas were conducted for the parameters of appearance, aroma, texture, tenderness, taste, and overall likeability of the tortilla samples served plain. A 9-point hedonic scale with descriptive anchors was used to evaluate each parameter (1 = dislike extremely; 9 = like extremely; Appendix E.5.). This scale had been scientifically validated for use in hedonic testing, which involves rating sensory characteristics according to individual preference; the use of such a scale did not require the standardization of a rating scale and provided a more accurate indication of the preferences of the general consumer population (Meilgaard and others 1999). Two stages of evaluation were conducted as follows:

- Stage 1: Sensory evaluation of initial enhanced products by the R&D staff at MichaelFoods, Inc., in Gaylord, MN (August 21, 2013).
- Stage 2: Sensory evaluation of the final enhanced products by students and facultyinstructors of the Fall 2013 Food Science (FSNU 2900), Topics: Controversiesin Food and Nutrition Science (FSNU 4994), and The Reflective Woman D12 (CORE 1000) courses at Saint Catherine University (October-November 2013).

Additional dependent variables measured for this investigation were the quantitative laboratory measurements of color, moisture/solids, water activity, and texture (force to puncture/break) for tortilla products. Quantitative values obtained through the use of calibrated laboratory instruments provided a more scientifically sound set of results than qualitative sensory evaluations alone. Additional information about the significance and underlying processes for each instrument can be found in the supplementary materials (Appendix B). For phases 1 to 5, analytical tests were conducted in the research and development food laboratory at Michael Foods, Inc. (MFI), in Gaylord, MN. Laboratory resources at the University of Minnesota (UMN) were utilized for quantifying measurement of color, water activity, and texture (force to puncture/break) of the tortilla products from phases 9 and 10. Moisture/solids analysis was not conducted at UMN due to significant discrepancies in instrumentation and methodology. Instrument specifications for all equipment and instruments is included in the supplementary materials (Appendix B.1). Photos of the instruments/equipment and certain stages of their utilization are included in the supplementary materials (Appendices C.1.-C.4.).

3.2 Formulation / Product Development

For recipe formulation and product development, a baseline traditional flour tortilla recipe was made to serve as a standard of reference.[9,23] A series of experimental phases followed, each manipulating the flour component and adding a lentil legume/vegetable component. For phases 1 to 5, a Vulcan™ commercial frying surface was used to cook the tortillas and a PTC Spot Check™ surface thermometer was used to ensure a consistent temperature (400-425°F) was maintained. For phases 6 to 10, a Hamilton Beach™ electric griddle (model 38515) was used to cook the tortillas while maintaining a consistent temperature. The amount of all ingredients in the recipes was measured using a calibrated balance for increased consistency and precision (±0.1 g). Although cost was not a major factor in this project, costing for several formulas was completed (Appendix A.3.). This factor is important in considering the marketing applications of the products developed. Nutritional analyses were also calculated for each phase of enhanced tortillas, noting the amounts of total carbohydrate, protein, and fiber. The nutritional information for phases 1 to 5 was determined using Genesis R&D software (Genesis R&D SQL, Version 10.11.0, 2011, ESHA Research, Inc., Salem, Oregon), while the nutritional information for phases 6 to 10 was determined using Food Processor software (Food Processor Software, Version 10.11.0, 2012, ESHA Research, Inc., Salem, Oregon) (Appendix A.4.).

3.3 Sensory Evaluations

After several subjectively deemed acceptable combinations of sorghum flour and lentils in a tortilla product were developed, the initial baseline product (control), two enhanced products (phases 4 and 5), and a commercially purchased tortilla product were introduced to a voluntary panel of employees in the R&D department at Michael Foods, Inc., for sensory evaluation (Appendix C.6.a.). Institutional Review Board (IRB) approval was granted for all stages of this study through Saint Catherine University. Participants were asked to first complete a brief survey and then complete a food sensory and taste evaluation of the tortilla products using a semi-structured hedonic scale (Meilgaard and others 1999; Appendices E.3. & E.5.).[24] A ranked scale of 1 ("dislike extremely") to 9 ("like extremely") was used to rate appearance, aroma, texture, tenderness, taste, and overall likeability of the tortilla samples served plain and warmed (Appendix E.4.).

According to Moskowitz and others (2006), the use of a 9-point hedonic scale has been widely researched, utilized, and validated in the scientific literature for measuring product preference and acceptance by consumers.[25] Such a scale is easily understood and provides the optimal number of categories for discrimination, as panelists typically do not use the two extreme ends of the scale (thus 7 points are viable from a 9-point scale).

Upon completion of the initial sensory evaluation, further product development was conducted to refine the enhanced tortilla products in phases 6 to 10 (Appendix C.5.). Additional sensory evaluations were conducted with student and faculty participants at St. Catherine University (Appendix C.6.). Participants were asked to complete a survey and complete a food sensory and taste evaluation of the two final enhanced products (phases 9 and 10), a commercial health-enhanced tortilla, and a commercial refined flour tortilla (Appendices C.6.f.-C.6.i.).

As suggested by Toma and others (2008), demographic and behavioral data were collected from all participants for the parameters of age, gender, race, ethnicity, frequency of vegetable consumption, effort to include whole grains in one's diet, and frequency/manner of tortilla consumption (Appendix E.3.).[26]

3.4 Data Analysis

Data analysis techniques of descriptive statistics, including measures of central tendency, were obtained using IBM SPSS Statistics (SPSS, Version 20.0.0, 2011, IBM, Armonk, New York). One-way Independent Groups ANOVA tests were conducted for the results of the first stage of sensory evaluation data in order to determine the presence of differences in the mean participant ratings for each sensory characteristic between the baseline (control) tortilla product, the commercial tortilla product, and phases 4 and 5 of the enhanced tortilla products ($P<0.05$). One-way Independent Groups ANOVA tests were conducted for the results of the second stage of sensory evaluation data in order to determine the presence of differences in the mean participant ratings for each sensory characteristic between the commercial refined tortilla product, the commercial health-enhanced tortilla product, and phases 9 and 10 of the enhanced tortilla products ($P<0.05$). Measures of central tendency (mean and standard deviation) were calculated for the quantitative analytical tests of texture and color (Microsoft Excel 2013, Version 15.0.4454.1510, Microsoft, Redmond, Washington).

4. Results and Discussion

4.1 Nutrient Analysis Results

Per serving (60 g), the phase 9 tortilla product contained 2.58 g of dietary fiber, while the phase 10 tortilla product contained 2.69 g of dietary fiber (Appendix A.5.c., Food Processor Software, Version 10.11.0, 2012, ESHA Research, Inc., Salem, Oregon). According to the Nutrition Facts Panel information for the commercial refined tortilla product, each serving (60 g) provided 0.88 g of dietary fiber (Appendix A.5.d., http://frescadostortillas.com/products/flour-tortillas/10-chimichanga-flour-tortilla/.). Therefore, the phase 10 tortilla product contained 3 times the dietary fiber content of the commercial refined tortilla product.

4.2 Participants – Demographic Data and Survey Results

Nine (9) staff members and employees from Michael Foods, Inc., participated in stage 1 of sensory evaluations (Appendix D.1.a.). The average participant age was 44 years and the majority of participants were white, had 4+

years of college education, and were currently working full-time. The majority of participants reported consuming tortillas fewer than one time per week, and most consumed tortillas as an ingredient or meal component (as opposed to plain). Self-reported frequency of whole grain and vegetable consumption varied among participants, but most were lower than recommendations from the 2010 Dietary Guidelines; all but one participant had an intake of less than 3 ounces of whole grains daily and less than 2½ cups, or approximately 5 servings, of vegetables per day (HHS & USDA 2010).[1]

Thirty-five (35) students and faculty members from Saint Catherine University participated in stage 2 of sensory evaluations (Appendix D.2.a.). Ages of participants ranged from 18 to 59 years, with an average age of 23 years. All participants were female, and a majority were white with some college/technical school. The majority of participants consumed tortillas as an ingredient or meal component less than one time per week. More participants reported consuming soft regular wheat flour tortillas than soft whole wheat, soft corn, or hard-shell varieties. Self-reported frequency of whole grain consumption varied, with 34 percent of participants reporting daily consumption and 29 percent reporting very infrequent consumption. The majority of participants reported consuming 2 servings of vegetables per day.

4.3 Sensory Evaluation Results

In general, mean ratings for the baseline and commercial tortilla products in stage 1 sensory evaluations were slightly higher than those for the phase 4 and phase 5 tortilla products, and overall likeability for the baseline product was highest with a mean value of 5.8 (Appendix D.1.b.). The phase 4 tortilla product had the lowest ratings for all the parameters with a mean overall likeability rating of 4.0. Since One-Way Independent Groups ANOVA tests indicated general differences in mean ratings among the tortilla products, Tukey HSD tests were completed to determine which specific groups varied. The Tukey HSD tests showed statistically significant differences between mean appearance ratings among the baseline, phase 4, and phase 5 tortilla products. No other statistically significant differences were found.

Results from stage 2 sensory evaluations at Saint Catherine University indicated that the mean sensory characteristic ratings for the commercial refined tortilla product were highest compared to the commercial health-enhanced, phase 9, and phase 10 tortilla products for all parameters except taste (Appendices D.2.b. & D.2.c.). However, mean ratings for the phase 10 tortilla product were generally within a 1-point range of those for the commercial refined tortilla product for all parameters except appearance and texture. Although the commercial health-enhanced tortilla product had the second-highest rating for appearance, it had the lowest ratings for aroma, texture, tenderness, and overall likeability. The phase 10 tortilla product was rated higher in all parameters than the phase 9 product. The amount of lentils in the formula distinguished the phase 9 tortilla product (152 g) from the phase 10 tortilla (190 g). The phase 9 and phase 10 tortilla products had generally low ratings for appearance.

Tukey's HSD tests were also conducted to determine statistically significant differences between mean ratings among groups after One-Way Independent ANOVA tests indicated general differences (Appendices D.2.b. & D.2.c.). Most notably, statistically significant differences were found for mean ratings of appearance, texture, and taste between the commercial refined tortilla and each of the other tortilla products ($P<0.05$). For taste and overall likeability, statistically significant differences for mean ratings were found between the commercial refined tortilla product and both the commercial health-enhanced tortilla product and the phase 9 tortilla product ($P<0.05$); however, no significant differences were found between the commercial refined product and the phase 10 product for these characteristics, and the mean rating for taste was slightly higher for the phase 10 product.

Although the appearances of the nutritionally enhanced developed tortillas (phases 9 and 10) were not rated as high as the commercial products, their ratings for the other sensory attributes indicated that they may be preferred over or comparable to currently existing health-enhanced products (Appendices D.2.b. & D.2.c.). The higher ratings for the phase 10 tortilla product, which incorporated more lentils, than the phase 9 tortilla product suggested that consumers might have enjoyed the characteristics that a legume component (lentils) imparted on final the tortilla product.

4.4 Quantitative Analysis Results

Due to the limited number of samples and financial resources, no tests to assess statistically significant differences were completed for all data collected from analytical testing.

For stage 1 analytical results, the texture value (force to break/puncture the tortilla product) decreased with higher phase of tortilla development, with the baseline tortilla product withstanding 705 grams force (gF) before breaking and the phase 5 tortilla product withstanding 263 gF (Appendix D. Table D.3.a.). This suggested a decreased level of starch structure with lower levels of gluten from the AP flour in the nutritionally enhanced tortilla products. With less AP flour but more sorghum flour and lentils, the tortilla products contained less gluten and thus less structure to withstand force. The average “L,a,b” (L=lightness, a=red-green, b=blue-yellow) color values were similar for the phase 2 through phase 5 tortilla products. The “L” and “a” values differed most between the baseline tortilla product and the phase 2 through 5 tortilla products. Water activity values were similar for all tortilla products, which indicated that approximately the same amount of water was available for microbial growth in each. The baseline tortilla product had approximately 5 percent lower moisture content than the phase 3 through phase 5 tortilla products; no data was available for the phase 2 tortilla product due to insufficient sample available during the time of testing. An increased moisture content in the nutritionally enhanced products indicated increased susceptibility to spoilage.

For the stage 2 analytical results, the average force to break the phase 10 tortilla product was lowest of the products tested at the University of Minnesota Food Science Lab, withstanding 291 grams force (Appendix D.4.a.). However, no notable differences existed among the phase 9, commercial health-enhanced, and commercial refined tortilla products. “L” color values were similar among the phase 9, phase 10, and commercial health-enhanced tortilla products. This indicated that such products were darker than the commercial refined tortilla. Substantial differences existed between the “a” color values for the phase 9 and phase 10 tortilla products and those for the commercial health-enhanced tortilla product and the commercial refined tortilla product. All the “b” color values among all the tortilla samples were similar. The water activity values were nearly the same (all rounding to 0.95) for the phase 9, phase 10, and commercial health-enhanced tortilla products. The water activity value was slightly lower (0.91) for the commercial refined tortilla product (Appendix D.4.a.). This result may have been due to the presence of additives and preservatives in the commercial refined tortilla product—none of the other tortilla products tested had such components in their formulations. However, all water activity values fell within the range of those typically characteristic of tortillas (0.91-0.95, Appendix B.3.).

4.5 Formulation / Product Development Results

A variety of challenges were faced during recipe formulation and experimentation. The use of lentil flour resulted in harder dough and less cohesive enhanced tortillas.[8] The alterations in starch content, starch structure, and moisture absorption necessitated formulation adjustments in the amount of water component among phases. Good quality tortillas should resist tearing, cracking, and crumbling upon being rolled.[9,22] Therefore, the enhanced tortilla products’ decreased ability to withstand force indicated that they might not closely resemble an ideal tortilla (Appendix D. Tables D.3.a. & D.3.b.). Typically, the protein content of most commercial tortillas ranges from 9 to 11 percent. Previous research indicates that flour with a protein content similar to bread flour is best for tortilla formulation. Since lentils are composed of approximately 20 to 25 percent protein, this increased level of protein affected the enhanced tortilla products by making them less elastic and more crumbly.[9] Despite initial research objectives, incorporating enough lentils in the formula to provide ½ cup of lentils (vegetable) per serving of tortilla was not feasible.

Additionally, whole grain varieties of flour absorb approximately 2 to 3 percent more water than refined flour due to their increased content of pentosans, a group of polysaccharide sugars with a high water binding capacity.[21] Pentosans are 5-carbon pentose rings called hemicelluloses which interact with proteins in doughs to affect bread-making properties, and they absorb 10 times their weight or more in water (setting them apart from starches). The presence of pentosans contributes to oxidative gelation during baking—increasing dough viscosity and decreasing dough extensibility.[9] Despite these challenges, pentosans serve as important sources of soluble and insoluble dietary fiber and have health benefits. In order to offset the changes characterized by increased pentosan content – harder dough and drier/less flexible cooked tortillas – caused by the addition of a whole grain component (in this case, sorghum flour), xanthan gum was added to the tortilla formula.[9,17] Gums such as guar gum and xanthan gum act as water control agents by altering viscosity or by forming gels and helping to stabilize food products. Additionally, particle size was another important factor to consider in evaluating the quality and acceptability of flour tortillas enhanced with whole grain waxy barley.[27] Similar results were found during formulation/product development, as the further extent of cooking and pureeing the lentils, the more readily they were incorporated into the tortilla dough.

Careful manipulation of ingredients was required during mixing, as, during this process, water becomes absorbed by the flour—enabling gluten to develop and gain strength.[8,9] Gluten formation occurs when two types of wheat proteins, gliadin and glutenin, combine after hydration and kneading to create an elastic network that provides the structure for the end product.[8] Over mixing can lead to gluten breakdown, loss of gluten strength, increased stickiness of the dough, and thus an inferior tortilla product. However, since sorghum and lentils do not contain gluten, other sources were required to provide the structure and support for the enhanced tortilla product, and xanthan gum was added.[17]

Past research suggests that white and black bean purees can be incorporated into corn tortilla products with reasonable acceptance among consumers.[28-30] Further evidence has indicated that levels of dietary fiber (insoluble and soluble fiber) and protein can be enhanced in corn tortillas.[31] In addition, whole barley flour, soybean flour, and chia seeds have successfully been incorporated in flour tortillas with favorable consumer acceptance,[26,31,32] and growing bodies of evidence suggest consumers may be more willing to pay higher prices for a healthier, higher fiber food option.[33] Yet, an acceptable enhancement of flour tortillas with both a whole grain and a legume/vegetable component, resulting in a final product with more "bang for the buck" and easy inclusion into one's daily diet, has not been developed until now. The variance in receptivity to the phase 9 and phase 10 tortilla products suggested that openness to try new foods and/or familiarity may be the key issues to address when introducing such a nutritionally enhanced product to a new audience. Notably, one participant rated one nutritionally enhanced tortilla products highly and commented, "Yum! I'd eat this all the time. The taste is excellent." Meanwhile, another rated the same product low and commented, "This product is something I'm not familiar with tasting and eating. So it's not my type of food to eat."

Some participants raised concerns about the nutritionally enhanced products' appearance and application (fold ability/bendability) as a tortilla or burrito. These valid concerns highlight some challenges that would need to be addressed before this nutritionally enhanced product could be produced and sold on a commercial scale. However, the fact that the developed nutritionally enhanced tortillas were rated higher than a currently sold commercial health-enhanced tortilla product on average for many sensory attributes suggests a positive market potential (Appendix D.2.c.).

4.6 Comments on Methodology

This study had its set of limitations. Ideally, recipe formulation/product development, both stages of sensory evaluations, and all analytical testing would have been conducted at one location. However, resources did not allow for such consistency to be maintained throughout the entire course of the study. The means of recipe formulation/product development were bench-top and exploratory, and, in order to establish precision and accuracy, certain tortilla characteristics were affected. Namely, to maintain consistent thickness, a tortilla press was used; however, this press did not produce tortillas that were as thin as some consumers desire. This ultimately impacted the participants' ratings of the enhanced tortilla products, as several commented that they were "too thick."

When considering the sensory evaluations, the small participant sample sizes (n=9 and n=35) and the relative similarities in demographics among participants should be noted. Such groups are likely not representative of the entire U.S. population. Additionally, when completing sensory evaluations, some participants did not "check the box" on the sensory evaluation forms to actually rate certain parameters even though they wrote comments. The order in which participants evaluated the tortilla products may have affected their ratings; in efforts to mitigate this, participants were presented with all the samples at one time and could freely choose their own order for testing. This method may have introduced a slight bias of comparison, as one participant commented, "Did not notice difference from sample 583." Furthermore, the tortilla samples were intended to be evaluated when they were slightly warmed, but ensuring that all participants received heated samples simultaneously was a challenge. As the samples were set out and as the participants completed the evaluation, certain samples were able to sit longer and may have become dry. A more scientifically structured random order of presentation in a room where all the tortilla samples could have been served at the same temperature without drying out would have been more ideal testing conditions for the sensory evaluations. Further methods of evaluating the tortillas could involve serving them with other food components, as this is how many consumers typically eat tortillas.

5. Conclusion

This project provides a basis for understanding the amount and correct ratio of sorghum flour and lentils in flour tortillas, a typically highly refined staple food with increasing popularity among the general population of the U.S.[19] Because of potential health and disease risks, it is important for the majority of adults to increase their intake of whole grains, dietary fiber, and vegetables.[3,6] The primary research objectives to develop a consumer friendly tortilla product that, in comparison to a baseline commercial refined flour tortilla, was 3 times higher in whole grain composition and 3 times higher in dietary fiber content, provided a complete source of protein, and yielded an optimal incorporation of sorghum flour and lentils in the formula were achieved with the phase 10 tortilla product. However, the aim to provide at least 20 percent of the daily recommended amount of vegetables for adults by incorporating a minimum of ½ cup cooked lentils per serving was not met. Solutions to challenges with appearance and texture may be required before this nutritionally enhanced tortilla product becomes well-received by the general U.S. population. Potential future research opportunities with nutritionally enhanced tortillas include evaluating the feasibility of commercial production, conducting sensory evaluations with a larger and more diverse group of participants, extending shelf life, incorporating different types of grains and legumes, and improving additional nutritional parameters such as sodium and fat content.

6. References

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