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Research Article

Comparison of the Physical, Textural, Sensory, and Nutritional Properties of Rice Flour and Green Banana Flour on the Acceptability of Gluten-Free Chocolate Chip Oatmeal Bars

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ABSTRACT

Many gluten-free products are lower in fiber and micronutrients and higher in fat and calories than gluten containing foods. The purpose of this study was to determine if green banana flour can be used to enhance the functional properties of gluten-free foods without negatively affecting physical, textural, and sensory properties. Rice Flour (RF), a commonly used gluten-free flour, and novel Green Banana Flour (GBF) were used as substitutes for all-purpose flour in an oatmeal chocolate chip bar recipe (Variation 1: 100% RF, Variation 2: 50%RF/50%GBF, Variation 3: 100% GBF). Objective tests (specific gravity, color, texture, phenolic content), shelf life properties (water activity, moisture content, and microbial assay at 30, 90, and 120 days storage), nutritional analyses, and sensory testing (consumer preference (n=61) for appearance, color, taste, texture, and overall acceptability) were conducted. Significant differences ($p<0.05$) were observed among the phenolic content, color, and hardness (texture). Results show that green banana flour can be used as a gluten-free flour replacer up to 100% level with lower calories, and higher fiber, magnesium, and potassium content, without sacrificing the overall acceptability of the product. Further applications may include its use for diabetes and cancer research due to its health claims of glycemic control and antioxidant capacity.

Keywords: Rice flour; Green banana flour; Resistant starch; Gluten free; Flour replacement; Glycemic control; Fiber; Potassium; Magnesium

INTRODUCTION

The need for gluten-free foods and a rise in their popularity has driven the passing of legislation for gluten-free labeling on products [1,2]. Gluten-free diets are commonly followed by individuals with Celiac Disease and individuals with non-celiac gluten sensitivity as medical nutrition therapy, but the gluten-free diet is also rising in popularity among the general public [3]. Many gluten-free foods tend to be lower in fiber, zinc, iron, magnesium, Vitamin D, Vitamin B, and potassium, and higher in fat and calories than gluten containing foods [4]. This poses a challenge to individuals with Celiac Disease to get the nutrients that they need, especially since they experience intestinal malabsorption. Studies have shown that individuals following a gluten-free diet tend to gain weight, present with micronutrient deficiencies, and have inadequate fiber intake [5].

The growing demand for gluten-free products creates pressure and new opportunities for the food industry and registered dietitians to explore new gluten-free ingredients with enhanced nutritional properties [2]. Rice flour is a conventionally used gluten-free flour, but it does not provide great nutritional quality as it is low in fiber and other nutrients [6]. The purpose of this study was to test the acceptability of green banana flour, a novel gluten-free flour that is high in fiber, potassium, and magnesium. Due to its resistant starch and polyphenol content, green banana flour has the potential to improve gastrointestinal health, aid with glycemic control, and combat many diseases like cancer, diabetes, and cardiovascular disease [7], and its high resistant starch and amylopectin content can allow it to be used as a replacement for gluten flours without altering the texture and structure of products [8].

Past applications of green banana flour include ice cream, pastas, enhanced shakes, and some baked products [9]. Most prior applications have been tested only in beverages, supplements, and energy bars [8]. More research is needed regarding green banana flour as a gluten-free flour replacer, as the removal of gluten affects the structure and texture of baked products. This study was conducted to determine the efficacy, functionality, and consumer

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acceptability of using green banana flour as a gluten-free flour substitution on the physical, textural, and nutritional properties of oatmeal chocolate chip bars.

MATERIALS AND METHODS

Oatmeal bar preparation

The oatmeal bars were made according to the recipe and preparation method outlined in a study by Rankin and Bingham (10). Oatmeal bars were made with enriched, bleached all-purpose flour, eggs, white granulated sugar, dark brown sugar, double acting baking powder, baking soda, vanilla extract, iodized salt, unsalted butter, gluten-free quick cooking rolled oats, semi-sweet chocolate chips, white rice flour (Arrowhead Mills) and/or green banana flour (NuBanaTM N100, International Agriculture Group, Mooresville, NC, USA).

All-purpose flour in the control recipe was substituted with 100% rice flour (Variation 1, RF), 50% rice flour and 50% green banana flour (Variation 2, RF/GBF), and 100% green banana flour (Variation 3, GBF). Substitutions were done on a weight for weight basis. The weight of the ingredients for the control and variations is shown in Table 1.

Butter, sugar, and brown sugar were creamed together. Then, eggs, baking powder, baking soda, vanilla, salt, flour, and oats were added. Ingredients were mixed until they were not dry. Chocolate chips were then added. Next, 37 g of batter was measured per bar and placed in the bar mold. Bars were baked at 350°F for 20 minutes. Bars were left to cool before performing any tests.

Objective measurements

Specific gravity: An aluminum-alloy pycnometer (Cole-Parmer, Vernon Hills, IL) was used to measure the specific gravity of the batter. The measurements were performed in triplicate.

Color analysis: The color of the products was determined by a Hunter colorimeter (HunterLAB Color-Flex EZ, CFLX 45-2, Hunter Associates Laboratory Inc., Reston, VA). The crust, crumb, and middle of the bars were measured. Tests were done in triplicate and color values L*, a*, and b* were recorded. The machine was calibrated with black and white color standards according to the manufacturer's instructions.

Texture analysis: Texture analyses were conducted using the TA-XT Plus Texture Analyzer (Texture Technologies Corp., Scarsdale NY) to determine the hardness and fracturability. A 3-point Bending Rig with an HDP/3PB probe was used with a pre-test speed of 1.0 mm/s, a test speed of 3.0 mm/s, a post-test speed of 10.0 mm/s, and a trigger force of 50g. Measurements were recorded for three bars from every batch.

Total Phenolic Content (TPC)

Extraction method: Antioxidants from the batters and baked products were extracted using a modified method (11). Briefly, methanol was added to dried batter and baked products at a concentration of 1gm/1ml. The mixture was kept on a rotary shaker at speed 5 for 4 hours at room temperature and after 4 hours, the filtrate was centrifuged at 5000 g for 10 minutes and the supernatant was collected. The extraction was done at least three times with the residues and supernatants collected each time. All the collected supernatants were pooled together and were filtered through Whatman No. 1 paper filter and concentrated to a dry mass. The dried mass was dissolved in 1 ml Dimethyl Sulfoxide (DMSO).

TPC determination: Total phenolic content was determined using a modified (12) Folin-Ciocalteu procedure. The batters and finished products were tested, indicating total phenolic content before and after baking. Briefly, 100 µL of the sample extract or a series of gallic acid standards (0 mg/L, 20 mg/L, 40 mg/L, 60 mg/L, 80 mg/L, and 100 mg/L) from the stock solution was mixed with 100 µL of Folin-Ciocalteu reagent (Sigma Chemical Co., St. Louis, Mo., USA). After 10 minutes of incubation, 300 µL of 20% Na_2CO_3 solution was added and the volume was adjusted to 1 mL using deionized water. The mixture was incubated in the dark for 2 hours at room temperature and the absorbance was measured at 750 nm using a spectrophotometer (Bio-Rad Laboratories, Inc., 2000 Alfred Nobel Drive, CA 94547, USA) against a blank sample. The total phenolic content was measured as mg gallic acid equivalents per gram of dry mass (mg GAE/g dry extract) and the values were presented as means of triplicate analysis.

Shelf life analysis

Water activity: Water activity of the samples was determined by a water activity meter (Aqua Lab CX- 1, Decagon Devices, Inc.,

Table 1: Ingredient weights for oatmeal bars.

Ingredients (g)	Control APF	Variation 1 100% RF	Variation 2 50%RF/50%GBF	Variation 3 100% GBF
All Purpose Flour (APF)	95.7	0	0	0
Rice Flour (RF)	0	95.7	47.85	0
Green Banana Flour (GBF)	0	0	47.85	95.7
Eggs			31.3	
Sugar			50.7	
Brown sugar			66.7	
Baking powder			1.4	
Baking soda			1.33	
Vanilla			1.67	
Salt			1	
Butter			74.7	
Oatmeal, ground (quick oats)			74.7	
Chocolate Chips			48	

APF: All Purpose Flour; RF: Rice Flour; GBF: Green Banana Flour

Pullman, WA, USA).

Moisture content: The moisture content was measured with moisture analyzer (OHAUS Explorer, MB 45, MB 120, Pinebrook, NJ, USA).

Microbiological assay: To see the effect on shelf life, a serving of each sample (37 g) from each batch was stored in air-tight Ziploc bags in the freezer at 4°C. Moisture content and water activity were conducted again after 30 days, 90 days, and 120 days of freezer storage. Samples were removed from the freezer and thawed. A microbiological assay was also conducted for test of shelf life at the three time periods given above. Aseptically, 1 g of sample was dispersed in 5 ml of sterile distilled water and mixed with Fischer Scientific Vortex Mixer for 30 seconds. Selective agar plates were inoculated with the water suspensions using separate sterile VRW Inoculating Needles. The plates were incubated at 37°C for 48 h to 72 h in an incubator (Boekel Scientific).

Subjective measurements

Sensory evaluation: Sensory data was collected in regard to appearance, taste, color, texture, and overall acceptability using a 5-point hedonic score card (1=dislike extremely, 2=dislike moderately, 3=neither like nor dislike, 4=like moderately, 5=like extremely). Participants were also asked to rank the samples in order of their preference (1 for “most liked” to 4 for “least liked”). The control and three variations were assigned number codes that were unknown to the panelist and products were presented in a random order. Untrained panelists (n=61) were students, faculty, or guests of Hunter College School of Urban Public Health campus. They were at least 18 years old with no known food allergies. Results were analyzed using FIZZ software.

Nutrient analysis: Nutrient content of the bars was analyzed using Nutritionist Pro Software (Axxya Systems, Woodinville, WA). The calories, fiber, potassium, and magnesium content of the bars were analyzed. A Parr 2600 Bomb Calorimeter (Par, IL) was used to determine the calories per gram by direct calorimetry using 1 g sample. Bomb calorimeter was calibrated with benzoic acid. The bomb calorimeter results were compared to the Nutritionist Pro data.

Statistical analysis: Tests were conducted in triplicate on five different batches for the control and each variation. Objective data was analyzed using SPSS (IBM, Armonk, NY) and sensory data was analyzed with FIZZ (Biosystemes, Couternon, France). Data was analyzed with analysis of variance and multiple comparison LSD post hoc with 95% confidence.

RESULTS AND DISCUSSION

Objective measurements: All objective test results are reported in Table 2.

Specific gravity: There were no significant differences among the specific gravity of the thick batter of the oatmeal bars.

Color properties: Color is one of the first aspects a consumer notices when viewing a food product. Lightness of crust and crumb are commonly studied in baked products, which is indicated by the L value of the top and bottom of the product. An L value closer to 0 indicates a darker color and an L value closer to 100 indicates a lighter color.

There was a downward trend in the lightness with introduction of green banana flour, but the results were not statistically significant. The L values of the middle of the products were statistically significant, with the GBF variations being significantly darker than the control and 100% rice flour ($p<0.001$). There were also

Table 2: Objective test measurements for oatmeal bars.

	Control	RF	RF/GBF	GBF
		Physical Measurements		
Specific gravity	1.26 ± 0.02^{a}	1.25 ± 0.05^{a}	1.24 ± 0.12^{a}	1.25 ± 0.03^{a}
		Color Measurements		
L crust	58.52 ± 3.83^{a}	57.43 ± 4.81^{a}	56.23 ± 1.78^{a}	55.93 ± 2.42^{a}
a crust	10.11 ± 0.65^{a}	9.40 ± 0.75^{b}	9.14 ± 0.93^{b}	7.61 ± 0.72^{c}
b crust	22.70 ± 2.64^{a}	17.87 ± 1.93^{b,c}	20.05 ± 2.59^{b}	16.45 ± 3.44^{c}
L crumb	48.16 ± 2.47^{a}	50.15 ± 3.89^{a}	48.01 ± 3.20^{a}	47.39 ± 2.55^{a}
a crumb	12.24 ± 1.41^{a}	10.47 ± 1.07^{b}	9.86 ± 1.19^{b}	8.38 ± 1.33^{c}
b crumb	22.75 ± 2.09^{a}	18.96 ± 1.59^{b}	17.31 ± 2.83^{b,c}	15.37 ± 3.21^{c}
L middle	55.01 ± 2.18^{a}	55.45 ± 2.79^{a}	47.90 ± 3.40^{b}	48.70 ± 3.33^{b}
a middle	7.81 ± 0.64^{a}	8.06 ± 1.01^{a}	6.78 ± 0.52^{b}	6.79 ± 0.74^{b}
b middle	23.59 ± 2.96^{a}	20.08 ± 3.58^{b}	15.05 ± 1.58^{c}	15.18 ± 1.96^{c}
		Textural Measurements		
Hardness, g	2551.85 ± 998.86^{a}	1747.15 ± 918.05^{b}	1426.34 ± 613.72^{b}	1412.63 ± 400.64^{b}
Fracturability, mm	5.32 ± 2.40^{a}	5.41 ± 2.82^{a}	5.33 ± 2.68^{a}	4.94 ± 1.67^{a}
		Phenolic Content		
TPC before baking, mg GAE/g	0.32 ± 0.03^{a}	0.28 ± 0.12^{a}	0.32 ± 0.07^{a}	0.49 ± 0.12^{b}
TPC after baking, mg GAE/g	0.47 ± 0.08^{a}	0.34 ± 0.14^{b}	0.41 ± 0.06^{a,b}	0.72 ± 0.06^{c}
Increase in TPC from before baking to after baking, %	15.32 ± 9.12^{a1,2}	5.30 ± 3.59^{b}	8.76 ± 3.17^{a1,b}	23.60 ± 7.27^{a2}

Values are means ± standard deviations.
Means in a row with a common superscript are not significantly different at $p<0.05$. TPC, total phenolic content

significant differences in the A values (measure of green-red) and B values (measure of yellow- blue) noted among the products ($p<0.001$).

Color changes during baking are a result of Maillard browning. Maillard reaction is a chemical reaction between reducing sugars and amino acids and is affected by water activity, pH, and temperature, as well as the type of sugars and amino compounds [13]. The different phenolic compounds present in the flours may yield different Maillard Reaction compounds [13]. Another reason for the color differences among the products may be the colors of the raw flours-green banana flour has a green-brown tint, whereas rice flour is white.

Textural properties: Hardness and fracturability were the textural components measured. Hardness is the force needed to attain a given deformation, such as a bite. Fracturability is the force at which the product fractures or breaks. A harder product is more likely to fracture. The control was significantly harder than the gluten-free variations ($p<0.001$). The hardness of the control compared to the variations is due to the presence of gluten. Gluten is formed when wheat proteins gliadin and glutenin combine in the presence of water, forming an important structural matrix [2] and is commonly found in all baked products made from wheat flour.

The introduction of green banana flour produces a less hard and less fracturable product, as seen from the reduced hardness and fracturability of the gluten-free variations, however the results were not statistically significant. Shafi et al [13] also found differences in the hardness and fracturability of the products made with wheat and water chestnut flours. They found the flours with higher fat to produce products with higher fracturability and brittleness. Bhaduri and Navder [12] also observed this and found higher fat to lead to an alteration in the moisture distribution of the product. Hardness and fracturability also typically decrease when moisture increases [14]. This is consistent with results of this study, as the rice flour variation was more fracturable, had a lower percent moisture, and a higher fat content (1.4 g fat per 100 g RF) than the green banana flour variation (0.5g fat per 100g GBF). Since the differences among hardness and fracturability among the gluten-free variations was not statistically significant, green banana flour can effectively be used as a gluten-free flour replacer for rice flour without altering the texture of the product.

Phenolic properties: Significant differences were observed among the means of total phenolic content before baking ($p<0.01$), after baking ($p<0.001$), and the percent change in total phenolic content ($p<0.002$) between before and after baking of the oatmeal bars (Table 2). There was an increase in total phenolic content from before baking to after baking in all products (Figure 1). Protein complexes likely get altered during the mixing of ingredients and

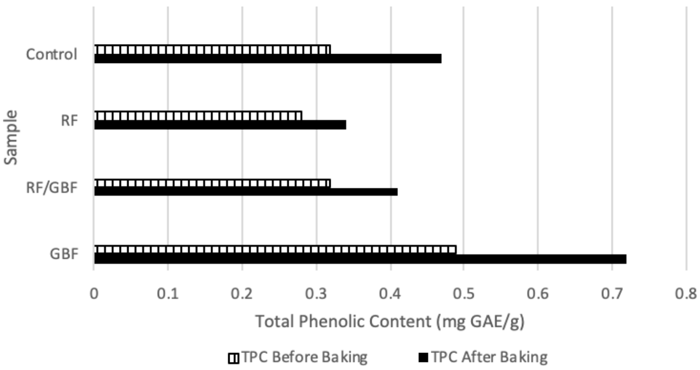

Figure 1: Total Phenolic Content Before and After Baking.

during baking due to Maillard Reaction [15], and research shows that the changes in phenolic content during baking largely depends on the type of polyphenol [16]. Heating elevates antioxidant activities [17], and it was observed that free phenol compounds, especially, phenolic acids increase after baking [18,19].

Phenolic content is directly correlated with free radical scavenging capacity and antioxidant capacity [20-25]. Higher phenolic compounds are found in green banana [26,27]. The total phenolic content of the 100% GBF variation was significantly higher than the control and the other gluten-free variations before and after baking. Rice flour contains phenolic compounds [28,29] but higher phenolic compounds are found in green banana [30]. The 100% Green Banana Flour (GBF) was observed to have the highest amount of total phenolic content compared to other variations (Table 2). Baking produces a Maillard reaction that results in a stronger antioxidant activity. Conversely, it was also observed that the heat treatment and drying process can result in a corresponding decrease of antioxidants [31].

The 100% GBF showed the highest increase of TPC activity after baking (23.6 ± 7.27%), whereas the 100% RF showed the lowest (5.30% ± 3.59%). This is consistent with past research that polished white rice flour is low in phenolic compounds and antioxidant activity [23,32]. The differences in the percent increase of TPC may be due to the varied phenolic profiling of the different flours [13], which suggests greater stability of GBF antioxidants during baking than RF. It is reported that green banana flour is rich in carotenoids and the increase in antioxidant capacity observed after heating may be linked to the release of carotenoids after cooking [33].

Green bananas are also high in phenolic compounds like anthocyanidin and other flavonoids, and as a result have a high antioxidant capacity [20,24,25], [34-37]. Due to its rich polyphenol content, green banana flour has been shown to have the potential to fight many diseases like cancer, diabetes, and cardiovascular disease [15].

Shelf life properties: The water activity and moisture content at Day 0 and after 30, 90, and 120 days of freezer storage are provided in Table 3. Water activity, moisture content, and microbial growth can be used as indices for product quality and shelf life, as high free water content is ideal for the growth of microorganisms [30]. There were significant differences among the water activity of the samples after 30 days ($p<0.001$), 90 days ($p<0.001$), and 120 days ($p<0.014$) of freezer storage.

While there were no statistical differences found among the water activity for all products on the day of formulation (Day 0), the water activity and moisture content of the GBF variations were higher than the 100% RF at all time points. The 100% GBF variation consistently had the highest percent moisture among the products.

Green banana flour is high in amylopectin, which is a branched polysaccharide capable of binding water and causing thickening during cooking [8]. The high fiber content of green banana flour may be a plausible explanation for the higher moisture content observed in these variations, whereas the low fiber content of rice flour may explain why the water activity and moisture percent was lowest in the 100% RF variation.

Rice flour consistently had the lowest water activity and percent moisture, but the results were only significantly different from the control for the percent moisture at 120 days storage. Results from the water activity, moisture percent, and microbial assay analyses show that the gluten-free samples were stable up to 3 months (Day 90) and the control was stable up to 4 months (Day 120). However, the agar plates for the green banana flour variations visibly had less microbial growth than the 100% RF variation. This may have to do with the different phenolic compounds, which increase antioxidant capacity and lend storage stability to the products.

The water activity and percent moisture of the samples follow similar trends, typically decreasing with increased freezer storage time, which is consistent with past research [38]. Exceptions to this pattern may be due to discrepancies when preparing samples for testing. Samples (<1 g) were cut from the middle of the bar, but it may yield more uniform measurements if the entire bar was ground first and then samples were taken.

Subjective measurements

Sensory properties: Hedonic ratings for the acceptability of oatmeal bars with regards to appearance, color, taste, texture, and overall acceptability are shown in Table 4. There were significant differences among the groups for appearance, color, taste, and overall acceptability (Figure 2). There were no statistically significant differences found among the texture of the products. There were no significant differences for overall acceptability among the control and variations with rice flour, but they were all significantly different from 100% green banana flour. Although the acceptability scores for the 100% green banana flour variation were the lowest, the overall acceptability score (3.41 ± 1.10) was over 3 (neither like nor dislike), indicating that the product was

Table 3: Indices of shelf life: Water activity and moisture content at 0, 30, 90, and 120 days

	Control	RF	RF/GBF	GBF
Water activity				
a_w, 0 day	0.59 ± 0.04^a	0.55 ± 0.02^a	0.56 ± 0.0^a	0.59 ± 0.06^a
a_w, 30 day	0.52 ± 0.04^a	0.53 ± 0.02^a	0.61 ± 0.01^b	0.58 ± 0.03^b
a_w, 90 day	0.55 ± 0.00^a	0.55 ± 0.00^a	0.56 ± 0.00^b	0.57 ± 0.00^c
a_w, 120 day	0.50 ± 0.05^a	0.52 ± 0.03^{a,b}	0.55 ± 0.02^{b,c}	0.56 ± 0.01^c
Moisture content				
% moisture, 0 day	6.56 ± 1.23^a	6.08 ± 1.4^a	7.93 ± 0.96^b	8.09 ± 0.38^b
% moisture, 30 day	7.02 ± 0.94^{a1,2}	6.61± 0.59^{a1}	7.78 ± 0.53^{a2,b}	8.26 ± 0.89^b
% moisture, 90 day	6.92 ± 0.64^{a,b,c}	6.48 ± 0.43^{a,b}	6.63 ± 1.08^b	8.15 ± 0.12^c
% moisture, 120 day	6.47 ± 0.32^a	5.57 ± 0.39^b	7.24 ± 0.55^c	7.71 ± 0.34^d

Values are means ± standard deviations.
Means in a row with a common superscript are not significantly different atp<0.05.

Table 4: Sensory measurements for oatmeal bars.

	Control	RF	RF/GBF	GBF
Appearance	4.13 ± 0.74^a	3.85 ± 0.93^a	3.85 ± 0.96^a	3.28 ± 1.08^b
Color	4.08 ± 0.74^a	4.08 ± 0.86^a	3.75 ± 0.91^b	3.21 ± 1.00^c
Taste	4.11 ± 0.71^a	3.95 ± 1.02^{a,b}	3.74 ± 1.12^b	3.31 ± 1.26^c
Texture	3.66 ± 1.17^a	3.34 ± 1.24^a	3.75 ± 1.07^a	3.33 ± 1.22^a
Overall acceptability	4.03 ± 0.91^a	3.84 ± 1.04^a	3.85 ± 0.98^a	3.41 ± 1.10^b

Values are means ± SD (n=61) based on responses of randomly selected, untrained panelists.
All sensory characteristics were evaluated with a 5-point hedonic scale (1=dislike extremely, 2=dislike moderately, 3=neither like nor dislike, 4=like moderately, 5=like extremely)
Means in a row with a common superscript are not significantly different at p<0.05.

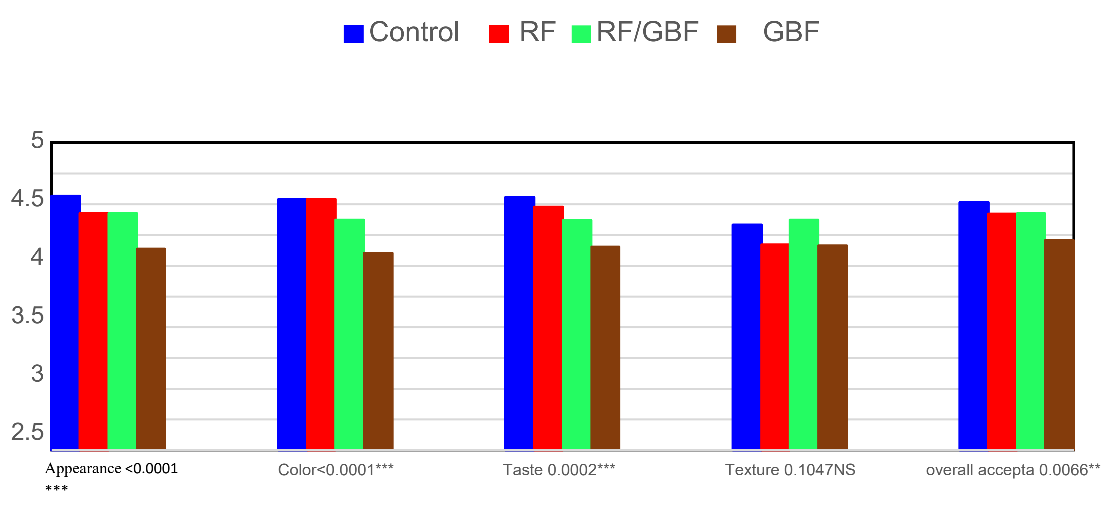

Figure 2: Acceptability Scores from FIZZ Analysis

likeable to some degree. The overall acceptability of the 50/50 RF/GBF variation was not significantly different from the control or 100% rice flour variation.

The Friedman sum of ranks is shown in Figure 3 (Rank 1=Most Liked, Rank 4= Least Liked). The control received the most number 1 ranks and the 100% rice flour and 50/50 RF/GBF variations received a similar distribution of ranks 2 and 3. Although the 100% green banana flour received the most number 4 (least favorite) ranks, there were a handful of people who ranked it as their most liked.

Consumer preference may have been a factor in the ranking of the samples. For example, some people may prefer a crunchy bar and others might prefer a moist, chewier bar. No data was collected with regards to the panelist's preference for cookies or bars in general.

Nutrient analysis

The calorie content of the samples was measured in the lab using a bomb calorimeter and was also calculated using Nutritionist Pro software. As shown in Table 5, the caloric content was significantly different among the samples. The bomb calorimeter values were higher as expected than the Nutritionist Pro values. This expected discrepancy in the calories between bomb calorimeter and Nutritionist Pro is due to the fact that the Bomb Calorimeter determines the physical fuel value by combusting the entire sample, whereas the Nutritionist Pro software reports the physiological fuel value and provides number of calories actually released in the body. This suggests that the human body is not as efficient as the machine and does not fully break down the material it takes in.

The nutrient content from the Nutritionist Pro software per serving size (37 g) of the samples is provided in Table 6. Compared to the 100% rice flour sample, the green banana flour variations had fewer calories due to their higher fiber content. The 100% rice flour variation had significantly less potassium and magnesium, which is consistent with past research studies that show gluten-free flours have poor nutritional quality and high calorie content. In comparison to rice flour, the green banana flour variations had the nutritional advantage of 314% more fiber, 486% more potassium, and 790% more magnesium per serving.

The higher fiber content of the green banana flour variations has important health benefits. Green banana flour is high in resistant starch, which slows down digestion due to insoluble carbohydrates like lignin, cellulose, and hemicellulose [7]. The fermentation of resistant starch in the large intestine also leads to a greater increase in short chain fatty acids like butyrate and acetate which provide many nutritional benefits related to intestinal mucosal cell health [8]. An increase in beneficial bacteria in the gastrointestinal

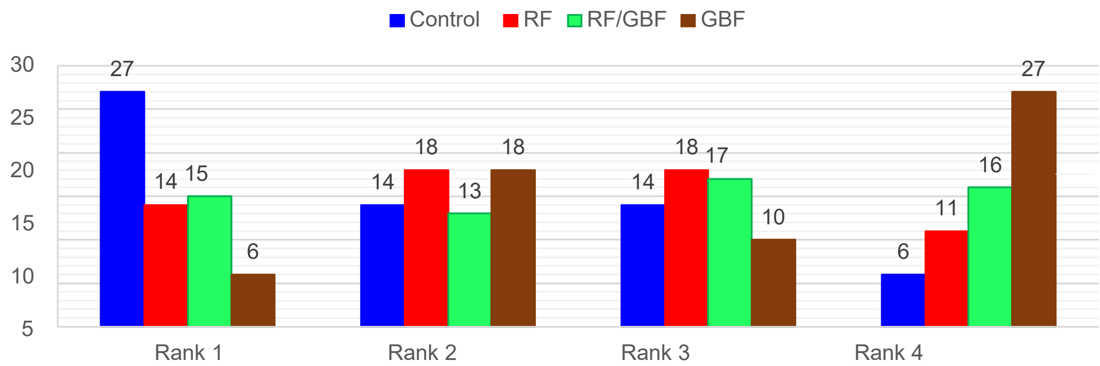

Figure 3: Friedman Sum of Ranks from FIZZ Analysis.

Table 5: Caloric content measured using Bomb Calorimeter Compared to Nutritionist Pro Software.

Bomb Calorimeter	**Control**	**RF**	**RF/GBF**	**GBF**
Calories (kcal/g)	6.12	6.25	6.01	5.73
% Change in Calories	Reference	+ 2.12%	-1.80%	-6.37%
Nutritionist Pro software				
Calories (kcal/g)	4.27	4.27	4.14	4.0
Calories (kcal)/Serving Size of 37 g	158	158	153	148
% Change in Calories	Reference	-	-2.9%	-6.3%

Table 6: Nutrient Analysis of Gluten-Free Chocolate Chip Oatmeal Bars.

Nutrient Content Using Nutritionist Pro Software/Serving Size of 37 g	**RF***	**RF/GBF**	**GBF**
Calories (kcal)	158	153	148
% Decrease in Calories	Reference	3.3%	6.7%
Fiber (g)	0.989	2.54	4.09
% Increase in Fiber	Reference	157%	314%
Potassium (mg)	18.5	63.5	108.5
% Increase in Potassium	Reference	243%	486%
Magnesium (mg)	1.0	4.9	8.9
% Increase in Magnesium	Reference	390%	790%

*For comparison, RF was considered as Reference tract like *Bifidobacterium* and *Lactobacillus* has also been observed following green banana flour consumption [8]. These bacteria help to minimize the number of harmful bacteria in the gut [8], which has a positive effect on gut health, regulating fecal patterns, and reducing the risk of colon cancer and colitis [39]. These effects may also be beneficial for patients with Celiac Disease, nonceliac gluten sensitivity, and Irritable Bowel Syndrome due to their impaired intestinal health and malabsorption [2], [4]. The lower calorie content of green banana flour may also be advantageous to Celiac patients, as BMI has been shown to significantly increase after initiation of the gluten-free diet [40].

CONCLUSION

Green Banana Flour (GBF) is a novel gluten-free flour alternative that is rich in potassium, magnesium, and fiber. It is also lower in calories than rice flour. The results of this study show that green banana flour can be used as a gluten-free flour substitute to enhance the nutritional properties of baked goods. The overall acceptability of the 50/50 RF/GBF variation was not significantly different from the control or 100% rice flour, meaning that even 50% use of GBF can be a nutritional enhancement without altering acceptability. The RF/GBF bar was well received by panelists, and it has 157% more fiber, 243% more potassium, and 390% more magnesium than the 100% rice flour.

Green banana flour's high resistant starch content may make it a suitable replacement for gluten flours in recipes due to its ability to act as a binding agent. Since it is gluten-free it can be used in many gluten-free recipes as an adhesive or binding ingredient, without altering the texture or consumer acceptability.

Future applications of this research may include the use of green banana flour for therapeutic use in cancer, diabetes, and cardiovascular disease patients due to its naturally occurring antioxidants. Green banana flour may also be studied with individuals following gluten-free diets to asses any weight changes or improvements in gastrointestinal bacterial balance. The high potassium content of GBF may also be important for cardiac patients and others following a heart healthy diet. Diabetes patients may also benefit from the use of this flour, as it has been shown to help with glycemic control.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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