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Physical, Textural and Sensory Characteristics of Gluten Free Muffins Prepared with Teff Flour (Eragrostistef (ZUCC) Trotter)

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Abstract

Since the enrichment of gluten-free cereal products is not mandatory there is a need for improving nutritional content of gluten-free diets by incorporating alternative gluten-free grains that are naturally abundant in nutrients. This study examined the effects of substitution of rice flour (control) with teff flour at 25%, 50%, 75% and 100% on the physical, textural, and sensory characteristics of gluten free muffins. A decrease in height of baked muffins was observed with an increase in the percentage of teff flour. Muffins with 75% and 100% teff flour had very viscous batters with significantly lower line spread tests compared to control rice muffins. Specific gravity was not significantly different between teff muffins, but all teff variations were significantly lower than the control. Textural measurements made using TA.XT Plus Texture Analyzer (Texture Technologies Corp., Scarsdale, NY) showed no significant difference between the control, 25% and 50% teff muffins but the 75% and 100% teff muffins were significantly harder. Springiness was significantly lower when the teff muffins were compared to the control, but no differences were found between teff variations. Substitutions up to 50% with teff flour were acceptable to the panelists. Friedman's rank test showed no significant difference in the overall liking between control, 25% and 50% teff muffins. This study demonstrates that substituting 50% rice flour with teff not only produces acceptable gluten free muffins, but these are more nutritious because of their higher protein (27%), iron (2095%), calcium (25%) and fiber (221%) contents.

Keywords: Teff flour; Gluten-free muffin; Texture; Sensory

Introduction

Celiac disease, also known as gluten sensitive enteropathy, is an autoimmune chronic disease causing inflammation of the upper small intestine in genetically predisposed individuals. It is triggered by ingestion of wheat gliadin and prolamins of rye and barley [1] which release these peptides during digestion and cause flattening of the intestinal mucosa [2] due to loss of normal villi and inflammation [3] leading to mal-absorption of nutrients like iron, folic acid, calcium and fat-soluble vitamins [4,5]. The cornerstone treatment of celiac disease is a lifelong strict withdrawal of wheat, rye, barley and an adherence to a gluten free diet [3]. Many of the gluten-free products are not enriched, and therefore do not provide the same levels of thiamin, riboflavin, niacin [6] iron and folate found in enriched and fortified wheat products [7]. Recent studies have consequently shown nutritional inadequacy of these nutrients associated with the gluten-free diet [8,9]. Since the fortification and enrichment of gluten-free cereal products is not mandatory in the US, there is a need for improving the nutritional content of gluten-free diet by incorporating alternative gluten-free grains that are naturally abundant in these nutrients.

Teff [Eragrostistef (ZUCC) Trotter] is a grain commonly used in Ethiopia. Its small size (1-1.5 mm) prevents the separation of the germ from the endosperm in teff flour [10]. It is reported to have a higher content of iron, calcium, phosphorus, copper, and thiamine compared to other grains like, wheat, barley, and sorghum [11]. It is also reported to be free of gliadin [12,13] and could be suitable for use in the diet of patients with celiac disease [14,15].

The goal of this study was to test the acceptability of gluten free muffins made with teff flour, and to compare the physical, textural and sensory properties of teff muffins with control muffins made with rice flour.

Materials and Methods

Muffin preparation

The muffin formulation [16] is presented in Table 1. Muffins were prepared with 0%, 25%, 50%, 75%, and 100% teff flour as a replacement for rice flour (both flours were provided by Bob's Red Mill, Milwaukie, Oregon). Milk, oil, and egg were mixed together for 1 min at speed 5 with an electric hand mixer (Kitchen Aid Ultra Power 5). Flour, sugar, baking powder, and salt were mixed together in a separate bowl, and then were sifted into with the wet ingredients at speed 4 for 10 seconds. Muffin pans were filled with the batter (65-66 g each) and were baked for 21 minutes or until done at 204°C in a preheated oven. Following a five-minute setting period, muffins were removed from the pans and allowed to cool on wire racks for one hour after which analyses were performed.

Physical measurements

A Vernier caliper (Monostat Corp, Merenschwand, Switzerland) was used to measure height and percent increase/decrease in height was determined from initial and final heights. Initial and final weights were obtained using a top loading electronic balance (OHAUS-Explorer, Pinebrook, NJ). Percent moisture loss upon baking was determined from weight of muffin batter and weight of muffin after baking. Moisture was determined by moisture analyzer (OHAUS-Explorer, Pinebrook, NJ). Specific gravity was measured using a pycnometer (Fisher Scientific, Pittsburg, PA). Line spread test was performed using a line spread chart. All tests were performed in triplicate.

Texture analysis

Texture profile analysis (TPA) of muffins was performed using

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TA.XT Plus Texture Analyzer (Texture Technologies Corp, Scarsdale, NY). The instrument was equipped with a 5 kg load cell and calibrated to a force sensitivity of 1 g. The test was performed on cubes (2.5 cm side) taken from the center of the muffin. The test speed was 5 mm s^{-1} at 75% of the original height; the post test speed was 5 mm s^{-1} and there was a 5 s interval between the two compression cycles. A trigger force of 5 g was selected. The compression of 75% was performed with a 36 mm diameter acrylic cylinder probe, and the cubes were compressed twice. The TPA primary parameters hardness, springiness, and cohesiveness and the secondary texture parameter chewiness were calculated from the curves [17].

Sensory evaluation

The study was approved by the Hunter College Institutional Review Board. Muffins were evaluated by 89 untrained consumers. The panelists had to be at least 18 years of age and not allergic to any food in order to participate in this study. Panelists were informed that they would be evaluating gluten free muffins, and they were presented with control muffin first (coded "000") and then with the other four samples. The order of presentation of the teff muffins was also random. The panelists were asked to evaluate the samples in relation to the control muffin. Appearance, flavor, taste, and overall liking was evaluated using a 5-point hedonic scale, with 1 for "dislike extremely" and 5 for "like extremely". They were also instructed to rank the products in the order in which they liked them, with 1 for "least liked" and 5 for "most liked". They were also asked how often they ate muffins, if they had tried gluten free products before, and if anyone in their family had celiac disease. Water and unsalted crackers were provided to panelists to cleanse their palates between samples. Data acquisition was done using FIZZ software (Biosystems, France).

Nutritional analysis

Nutrient content of muffins was analyzed using Nutritionist Pro software (Axxya Systems, 2007, Stafford, TX). The Nutritionist Pro food database was expanded by adding analysis of teff and rice flour provided by Bob's Red Mill. The calories, fat, fiber, protein, iron, and calcium content of each muffin was analyzed and the changes in nutrients were calculated.

Statistical analysis

Sensory and instrumental data were analyzed using one-way analysis of variance with post-hoc testing by Least Significant Difference (LSD) multiple comparisons using SPSS (version 18 for Windows 2008, SPSS Inc, Chicago, IL). $P<0.05$ was considered significant. Friedman two-way analysis of variance based on ranks was conducted using FIZZ software (Biosystemes, France).

Results and Discussion

Physical measurements

The objective measurements are shown in Table 2. As the percentage of teff flour increased, the muffin batter became more viscous and dense, had low line spreads because of less fluidity, and had low specific gravity. The teff flour muffins also were more compact and had reduced heights and volume. Similar decrease in bread volume was also found when resistant starch (corn, tapioca or a combination) was used in gluten-free bread [18]. Moisture content of the final products revealed no difference between the control, 25%, 50% and 75% teff muffins. Moisture loss was not significantly different between the control, 25% and 50% teff muffins, while the 75% and 100% teff muffins had significantly greater moisture loss.

Texture profile analysis

A typical texture profile analysis curve obtained for muffins is shown in Figure 1 and the primary TPA parameters-hardness, springiness and cohesiveness, and secondary parameter of chewiness are shown in Table 2.

Hardness, defined as the maximum peak force during the first compression cycle (first bite) (Figure 1), was not increased in the 25% and 50% teff muffins when compared to the control, but the 75% and 100% variations were significantly harder. Similar results with an increase in hardness were found in breads prepared with 10%, 20%, and 30% buckwheat flour [19]. However, the substitution of corn and potato starch in gluten-free bread with varying proportions of resistant starch did not significantly change the hardness of bread crumb [20].

Springiness is related to the height that the food recovers during the time that elapses between the end of the first bite and the start of the second bite (Figure 1). Springiness is associated with freshness in a product with a high quality muffin having higher springiness values. Control rice muffin was significantly springier than any variation of teff muffins. There was no difference in the springiness of the various teff muffin variations when compared to each other. Similar results were also found when 10%, 20% and 30% of corn or tapioca starch was incorporated in gluten-free bread with no significant effect on springiness [20].

Cohesiveness is defined as the ratio of the positive force during the second compression to that during the first compression (Figure 1), this parameter is the strength of internal bonds which make up the body of the product. All teff muffins had significantly decreased cohesiveness compared to the control rice muffin, and lower compression energy was required. Typically, a more cohesive product retains more gas, and has a higher volume. No difference was seen in both, cohesiveness and percentage increase in height in control, 25% and 50% teff muffins,

Ingredients (g)	100% Rice (Control)	Teff 25%	Teff 50%	Teff 75%	Teff 100%
Rice flour	200.0	50.0	100.0	150.0	200.0
Teff flour	-	150.0	100.0	50.0	-
Sucrose	47.6	47.6	47.6	47.6	47.6
Baking powder	5.6	5.6	5.6	5.6	5.6
Salt	4.0	4.0	4.0	4.0	4.0
Milk (2% milk fat)	174.2	174.2	174.2	174.2	174.2
Egg	76.0	76.0	76.0	76.0	76.0
Oil	53.4	53.4	53.4	53.4	53.4

Table 1: Formulas for muffins.

but the 75% and 100% teff muffins had decreased cohesiveness and consequently, lower volume. This was most clearly evident in 100% teff muffin, where the decrease in cohesiveness (12.5%) was even visually apparent, as this muffin crumbled easily with simple manipulation.

Chewiness is measured as the product of hardness, cohesiveness and springiness (Figure 1) and is defined as the energy needed to masticate a solid food to a state ready for swallowing. Changes in chewiness parameter varied, a decrease in chewiness was observed with up to 50% substitution, while an increase was seen with 75% and 100% teff muffins.

Sensory evaluation

The mean sensory scores for appearance, flavor, taste and overall liking are presented in Table 2, and the Friedman sum of rank scores are shown in Figure 2.

Appearance of control rice muffins was significantly different from any of the teff muffins, which was excepted since teff flour has a dark brown color. No significant differences were found in flavor, taste and overall liking of control, 25% and 50% teff muffins. Similar results were found when corn flour was substituted with amaranth flour in gluten-free sponge cake [21]. Comparable scores were also obtained when control carrot cake (corn flour) was compared with gluten-free carrot cake, where corn flour was substituted with 64% milled linseed flour [21]. The flavor, taste and overall liking of 75% and 100% teff muffins were rated significantly lower than control, 25% and 50% teff muffins. Mean scores for overall liking for control, 25% and 50% teff muffins were between 4 (like slightly) and 3 (neither like nor dislike), while the mean scores for 75% and 100% teff muffins were between 3 (neither like nor dislike) and 2 (dislike slightly). This data indicates that 50% rice flour can be substituted with teff flour without any significant changes in overall liking of muffins. Increasing beyond 50% substitution with teff flour resulted in unacceptable muffins from sensory point of view. Another study showed that the overall acceptability of cookies supplemented with flax seed flour decreased with increase in flax seed flour from 20% to 30% [22].

Friedman's rank test showed no significant difference in ranking based on liking among control, 25% teff, and 50% teff muffins (Table 2). Muffins prepared with 75% and 100% teff flour received lower rankings. Figure 2 shows a comparison between sum of ranks from panelists who had not (n=50) versus panelists who had consumed (n=39) gluten free products. The gluten-free product consumers found

Characteristic	100% Rice (Control)	25% Teff	50% Teff	75% Teff	100% Teff
Physical measurements of batters and baked muffins					
Line spread (mm)	39.7 ± 5.39	35.4 ± 5.24	26.5 ± 5.37	21.5 ± 7.39	21.6 ± 8.91
Specific gravity	1.14 ± 0.010	1.11 ± 0.049	1.10 ± 0.297	1.09 ± 0.279	1.10 ± 0.310
Moisture (%)	41.9 ± 0.593	41.7 ± 0.568	42.0 ± 0.637	42.1 ± 0.841	42.4 ± 0.728
% increase in height	113.0 ± 4.93	113.2 ± 3.89	113.0 ± 4.48	109.9 ± 4.95	107.6 ± 6.19
% moisture loss	13.8 ± 0.818	13.9 ± 1.46	13.9 ± 0.745	14.4 ± 0 .996	14.7 ± 0.771
Texture profile analysis parameters					
Hardness (N)	562.1 ± 94.5	597.0 ± 95.2	593.3 ± 67.8	687.0 ± 91.72	812.9 ± 128.2
Springiness (mm)	1.38 ± 0.640	1.10 ± 0.392	1.08 ± 0.347	1.06 ± 0.322	0.99 ± 0.307
Cohesiveness	0.830 ± 0.030	0.793 ± 0.025	0.781 ± 0.037	0.750 ± 0.029	0.732 ± 0.016
Chewiness (N.mm)	639.7 ± 324.8	524.6 ±185.1	508.3 ± 174.4	549.6 ±149.5	590.8± 93.66
Sensory evaluation					
Appearance	4.20 ± 0.7	3.83 ± 0.87	3.73 ± 0.85	3.65 ± 1.08	3.62 ± 1.11
Flavor	3.37 ± 0.92	3.49 ± 0.94	3.36 ± 0.96	2.72 ± 1.15	2.55 ± 1.09
Taste	3.33 ± 0.9	3.51 ± 0.98	3.33 ± 1.02	2.65 ± 1.16	2.51 ± 1.10
Overall liking	3.36 ± 0.91	3.47 ± 0.97	3.34 ± 1.04	2.72 ± 1.12	2.61 ± 1.11
Friedman ranking test (sum of ranks)	299.0	295.0	284.0	236.0	221.0

Table 2: Physical measurements, texture profile analysis, and palatability ratings, overall liking, and ranking ratings of muffins.

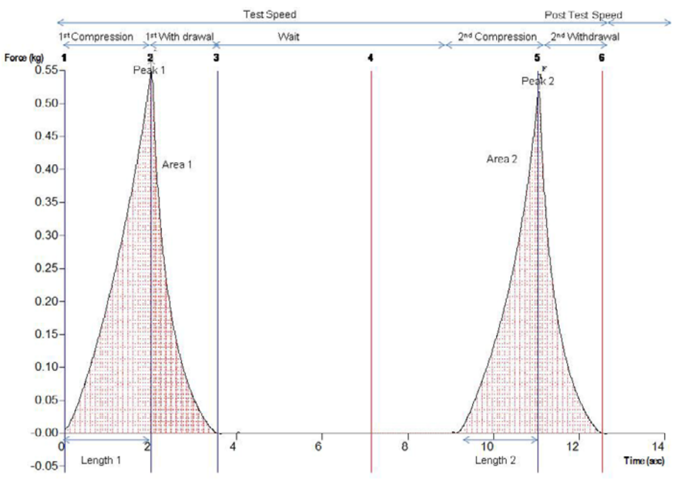

Figure 1: A typical texture profile analysis graph for muffins.

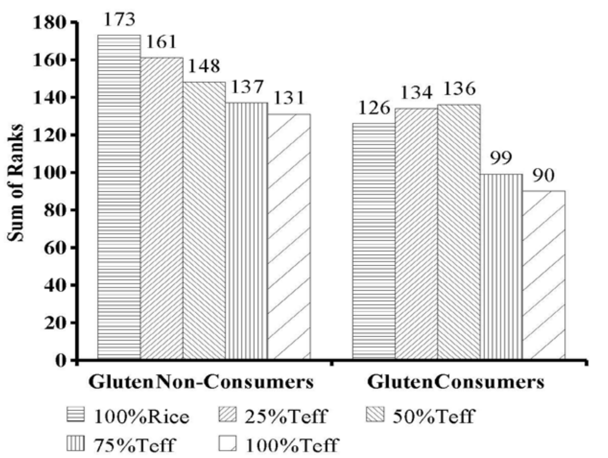

Figure 2: Friedman's sum of ranks test for control rice muffin and teff muffins for non-consumers.

Nutrient/ Serving (1 muffin, 55 g)	100% Rice (Control)	25% Teff	50% Teff	75% Teff	100% Teff
Calories (kcal)	184	184.6	185.3	185.9	186.5
Increase in calories		0.34%	0.69%	1.03%	1.38%
Fat (g)	7.796	7.899	8.001	8.104	8.207
% Increase in Fat		1.32%	2.63%	3.95%	5.27%
Fiber (g)	0.571	1.204	1.838	2.471	3.105
% Increase in Fiber		110.8%	221.9%	332.7%	443.8%
Protein (g)	3.154	3.582	4.01	4.438	4.866
% Increase in protein		13.57%	27.14%	40.71%	54.28%
Iron (mg)	0.304	3.488	6.673	9.857	13.042
% Increase in Iron		1047%	2095%	3142%	4190%
Calcium (mg)	58.894	66.312	73.73	81.148	88.566
% Increase in Calcium		12.59%	25.19%	37.78%	50.38%

[1]Values are means ± standard deviations.
[2]Means in same column with same letters are not significantly different at $P<0.05$ determined by ANOVA
[3] Values were determined with TA.XT Plus Texture Analyzer (5-kg capacity) (Texture Technologies Corp., Scarsdale, NY) equipped with 36 mm diameter acrylic cylinder probe.
[4] Values are means ± standard deviations or sum of ranks
[5]Palatability ratings, overall liking, and ranking ratings of muffins as evaluated by 89 untrained panelists
[6]Muffins were evaluated on a 5-point hedonic scale: 1=dislike extremely, 2=dislike slightly, 3=neither like nor dislike, 4=like slightly, 5=like extremely.
[7]Muffins were ranked using the Ranking Test scale: 1=least liked and 5=most liked.

Table 3: Nutrition information for gluten free muffins.

the 50% teff muffin acceptable whereas consumers who had not tried gluten free products liked the variation only up to 25% level. Panelists who had never consumed gluten free products found no difference between the control and 25% teff but had significantly lower ratings for the 50, 75 and 100% teff muffins. However, panelists who had previously consumed gluten-free products ranked the 50% teff muffins highest and no significant difference was found between the control, 25 and 50% teff muffins.

Nutrition analysis

Results of nutrition analysis are presented in Table 3. Substitution of rice flour with teff flour at all levels increased fiber (111-444%), iron (1047-4190%), and calcium (30-50%) content of the muffins. This is important since adequate amounts of these nutrients are usually lacking in the gluten-free diet and recent studies have shown nutritional inadequacy associated with these diets [7,8]. In addition, since many gluten free products are neither enriched, fortified nor naturally rich sources of fiber and micronutrients [7], celiac disease patients do not meet recommended nutrient intakes [23,24]. Another study demonstrated that nutrient profile of the gluten-free diet was improved by incorporating quinoa grain in the diet grains [25]. This present study showed that incorporation of teff flour at 50% level produced gluten free muffins that were an excellent source of iron and a good source of dietary fiber.

Conclusions

Since the overall acceptability was unchanged and the substitution of rice flour with teff flour improved nutritional content, our results show that replacing rice flour up to 50% with teff produces acceptable muffins. Nutrition analysis showed that substitution of rice flour up to 50% with teff produces muffins that are excellent source of iron and good source of dietary fiber. Since many gluten free products are neither naturally rich nor enriched or fortified this study confirms that teff flour substitution improves the nutritional value of gluten-free muffins.

This study could be useful to dietetics professionals who can recommend teff flour as an alternative for patients with celiac disease. The apparent improved nutritional profile could benefit the nutritional adequacy in celiac patients.

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