A Comprehensive Study on Physical Properties of Two Gluten-Free Flour Fortified Muffins

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Abstract

Background: Muffin a Cereal based snacks, has been considered as the most popular breakfast cereals by average Americans now-a-days, because of their unique pleasant taste and easily consumable characteristics. Flour is the main ingredient to prepare muffins and Gluten is the major protein constituent of Wheat flour, which is considered to be responsible for Celiac disease. Life-long Gluten-free diet has been considered as the only effective treatment for Celiac disease.

Aim: The project was aimed to produce gluten free healthy cereal based snacks muffins prepared from two gluten free flours, Rice and Quinoa flour and to conduct a comprehensive study on their physical properties. 100% Wheat flour was used as control. 100% Rice flour was replaced by 25%, 50%, 75% and 100% Quinoa flour to prepare muffin. Physical property measurements including percentage increase/decrease of crest height, moisture and specific gravity, color by Hunter colorimeter and Texture Profile Analysis (TPA) by TAXT. Plus Texture analyzer was done for the final product. The Sensory attributes, appearance, flavor, sweetness, texture and general acceptability, were evaluated by a group of un-trained panelists, using a 9-point Hedonic scale. Sensory and instrumental data were analyzed statistically.

Results: 100% Rice flour and a replacement of Quinoa flour up to 75% to Rice flour was considered as overall consumer acceptable range for gluten free muffins.

Keywords: Rice flour; Quinoa flour; Muffins; Celiac disease; Gluten intolerance

Introduction

Celiac disease (CD) which is a gluten sensitive inflammatory disorder of the small intestine, also known as gluten intolerance, affects genetically predisposed individuals when they ingest gluten proteins from wheat, barley and rye. CD results due to an intolerance to gliadin and glutenin proteins. In 2006, the American Dietetic Association updated its recommendations for a gluten-free diet. The only effective treatment [1] for celiac disease is a life-long gluten-free diet. Gluten-free breads and cookies are principally based on flour from rice or maize with low content and poor-quality proteins. CD patients, especially children on a strict gluten-free diet, are undernourished because of the reduced intake of energy which is largely taken from wheat-based foodstuffs in a current western diet [2]. Recently, the use of two pseudo cereals (non-grass family) in particular amaranth and quinoa have been considered for the preparation of gluten-free snack foods. Amongst those Quinoa was our main consideration. Quinoa has excellent reserves of protein and high lysine content, an important amino acid for tissue growth, so the protein is more complete compared to other grains. High lysine content in quinoa raises the biological value of this protein. Nutritionally, Quinoa is a super grain and the World Health Organization has rated Quinoa as equivalent to milk as it contains high levels of potassium, riboflavin, B6, niacin and thiamin along with magnesium, zinc, copper and manganese and some folate. Therefore, Quinoa flour alone or fortified with other gluten free flour can replace Wheat flour and can represent a healthy alternative for people with CD.

Keeping in view of the above, the current study was aimed to produce a gluten free healthy muffin from gluten free flours, considering muffins are an important part of a daily breakfast. Rice flour and Quinoa flour were used as gluten free flour. Rice flour is naturally gluten-free, rich in carbohydrates and low in fat. This study examined the effects of substitution of Rice flour with Quinoa flour at 25%, 50%, 75% and 100% on the physical, textural, and sensory characteristics of gluten free muffins. 100% Whole wheat flour was used as control flour composition to prepare muffin.

Materials and Methods

Muffin formulations and preparations

Muffin recipe was a combined modifications [3,4] and contained the following ingredients : pure granulated white sugar (Domino Foods, Inc, Yonkers, NY, USA), salt (IGA brand, IGA Inc., Chicago, IL, USA), double-acting baking powder (Clabber Girl, Co., Terre Haute, IN, USA), 100% pure canola oil (Safeway brand, Safeway Inc., Pleasanton, CA, USA), natural 2% reduced fat milk (Safeway brand, Safeway Inc.), fresh large eggs as Table 1.

White Rice flour and Quinoa flour were a free gift from Bob’s Red Mill and Whole wheat (General Mills, Inc., Minneapolis, MN, USA) flour was purchased from a local supermarket.

Whole wheat flour was used as control flour and was replaced with White Rice flour and Quinoa flour as gluten free flour replacement. Wheat flour in the control recipe was replaced by 25%, 50%, 75% and 100% Rice flour and Quinoa flours to prepare muffins. Therefore, there were total 6 formulations were tried in terms of flour compositions and...

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Received: June 07, 2013; Accepted: July 27, 2013; Published: August 08, 2013

Citation: Bhaduri S (2013) A Comprehensive Study on Physical Properties of Two Gluten-Free Flour Fortified Muffins. J Food Process Technol 4: 251. doi:10.4172/2157-7110.1000251

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was used to measure height and percent increase/decrease in height was (OHAUS Explorer, MB 45, Pinebrook, NJ).

flour to Rice flour. Moisture was determined by moisture analyzer in moisture content and water activity due to substitution of Quinoa spread chart. All tests were performed in triplicate.

experiment was run at room temperature (at 21.8 ± 2°C). Viscosity was to 5 rpm, and spindle no. 4 (S64) was used for all the experiments. The batter was transferred to a 600-mL Beaker. The spindle speed was set the batter by the weight of an equal volume of water.

A vernier caliper (Monostat Corp., Merenschwand, Switzerland) was carefully removed using a serrated bread knife to expose the crumb for color measurement. Both the crust and crumb color were analyzed by this way.

Texture analysis

The textural properties of muffin were determined using a TA.XT Plus Texture Analyzer (Texture Technologies Corp., Scarsdale, NY) (Stable Micro Systems Ltd.).

Cubes of 2.5 cm were gently cut out of the center of each muffin with a serrated bread knife to expose the crumb for texture measurement. Crumb texture measurement was performed by texture profile analysis (TPA) using a TA-25 MUF1/P36R probe and a TA-90 platform, with pretest speed=5 mm/s; test speed=1 mm/s; post test speed=2 mm/s and distance=10 mm.

Texture analysis program parameters were set as follows: pretest speed=5 mm/s; test speed=1 mm/s; post-test speed=2 mm/s; test distance=5 mm; and distance=10 mm.

Textural variables from force and area measurements [6] were: hardness=peak force (g) during the first compression cycle; cohesiveness=ratio of the positive force area during the second compression to that during the first compression; springiness=height that the sample recovers during the time that elapses between the end of the first bite and the start of the second bite (cm); and chewiness=hardness X cohesiveness X springiness (g cm).

Three muffins from each formulation were used to evaluate textural parameters.

Sensory evaluation

A panel of 20 semi-trained judges of both genders aged 18-50 years evaluated the muffins on a 9-point hedonic scale (1=dislike extremely, 5=neither like nor dislike, 9=like extremely). Muffins were sliced into half and identified by a three-digit random number. The samples were offered to the judges on a white plate at room temperature in individual booths under white light. Panelists were given room temperature water to cleanse the palate before tasting the samples from each formulation. No prior training was provided to panelists. All five samples were served, one at a time, to each panelist. General, appearance, flavor, texture, sweetness and overall acceptability were evaluated using an attribute rating form.

Statistical analysis

Sensory and all other experimental data were analyzed using one-way analysis of variance (ANOVA). P<0.05 was considered significant.

Results and Discussions

Quality of muffin depends mainly on the quality of its batter's physical properties. Changes of pH, Specific gravity, and Viscosity and LST values for all different muffin batters are represented in the Table 2.

A slight increase of pH was observed due to incorporation of

| Ingredients | (% w/w) |
|-------------|---------|
| Flour       | 35.25   |
| White sugar | 15.42   |
| salt        | 0.13    |
| Baking powder (double-acting) | 1.29 |
| Vegetable oil | 13.88 |
| 2% reduced fat milk | 25.31 |
| Fresh large eggs | 8.72 |
| Total       | 100     |

Table 1: Muffin formulations.

they will be designated as F1 (100% Wheat flour), F2 (100% Rice flour), F3 (75% Rice flour+25% Quinoa flour), F4 (50% Rice flour+50% Quinoa flour), F5 (25% Rice flour+75% Quinoa flour) and F6 (100% Quinoa flour) from now.

Flour, sucrose, baking powder, and salt were mixed together in a separate bowl, and then were shifted into the wet ingredients at speed 4 for 10 seconds. Muffin pans were filled with the batter (55-65 g each) and were baked for 20 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.

Studies on muffins and muffin batters

Basic physical properties:

Batter specific gravity: Specific gravity of muffin batters (at 21.8 ± 2°C) was measured using a pycnometer (Fisher Scientific, Pittsburg, PA) and was calculated by dividing the weight of a standard measure of the batter by the weight of an equal volume of water.

Batter viscosity: The viscosity of muffin batter was determined [5] using Brookfield DV-H1+Pro Viscometer (Middleboro, MA). Muffin batter was transferred to a 600-mL Beaker. The spindle speed was set to 5 rpm, and spindle no. 4 (S64) was used for all the experiments. The experiment was run at room temperature (at 21.8 ± 2°C). Viscosity was measured immediately.

Line spread test for muffin batters were performed using a line spread chart. All tests were performed in triplicate.

Moisture properties: A study was conducted to know the changes in moisture content and water activity due to substitution of Quinoa flour to Rice flour. Moisture was determined by moisture analyzer (OHAUS Explorer, MB 45, Pinebrook, NJ).

Water activity was determined by a water activity meter (Decagon, Pullman, WA). Moisture was determined by moisture analyzer (OHAUS Explorer, MB 45, Pinebrook, NJ).

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.

Color analysis

The color of muffin crust was measured with a Hunter colorimeter (Hunter Colour-Flex, CFLX 45-2, Hunter Associates Laboratory, Inc., Reston, VA, USA) based on CIE scale in triplicate using, L*, a*, b* color space; L* value measuring black (0)/white (100), a* value measuring green (-)/red (+) and b* value measuring blue (-)/yellow (+). The Hunter colorimeter was calibrated using color standard (white and black) ceramic tiles supplied by the manufacturer. The observations were made using D-65 illuminant and 10° observer. For each replicate, crust color was measured at three random areas. The crust of the muffin was carefully removed using a serrated bread knife to expose the crumb for color measurement. Both the crust and crumb color were analyzed by this way.

Sensory and all other experimental data were analyzed using one-way analysis of variance (ANOVA). P<0.05 was considered significant.

Results and Discussions

Quality of muffin depends mainly on the quality of its batter's physical properties. Changes of pH, Specific gravity, and Viscosity and LST values for all different muffin batters are represented in the Table 2.

A slight increase of pH was observed due to incorporation of

| Flours formulations | Batter pH | Batter Sp. Gravity | Batter Viscosity (cp) | LST (mm/20 min) |
|---------------------|----------|--------------------|-----------------------|-----------------|
| F1                  | 6.5 ± 0.3d | 1.35 ± 0.03d       | 34000 ± 7.07d         | 8.5 ± 0.43d     |
| F2                  | 7.0 ± 0.25d | 1.11 ± 0.01d       | 31116 ± 6.52d         | 38.7 ± 0.26d    |
| F3                  | 7.25 ± 0.05d | 1.12 ± 0.01d       | 34313 ± 6.74d         | 34.88 ± 0.13d   |
| F4                  | 7.25 ± 0.25d | 1.15 ± 0.01d       | 36181 ± 5.48d         | 33.17 ± 0.15d   |
| F5                  | 7.5 ± 0.3c  | 1.18 ± 0.02c       | 38991 ± 12.45c        | 31.61 ± 0.35c   |
| F6                  | 7.5 ± 0.2b  | 1.26 ± 0.02b       | 48470 ± 9.05b         | 24.75 ± 0.66b   |

Table 2: Physical properties of Batters.
Quinoa flour to Rice flour and which compensates the bitterness due to 50% and 75% Quinoa flour in 50% Rice flour+50% Quinoa flour (F4) which means 100% Rice flour and a substitution for Quinoa flour up to 75% to Rice flour are the best overall acceptable composition for a gluten free muffin. However, Flavor is the only attribute whose desirability was not affected considerably by fortification of 100% Quinoa flour (F6) muffins.

Hedonic ratings for product attributes and overall likeability are presented in Table 4. If an attribute score is above 5 (neutral), it was considered to the desirable range [7-9]. Higher percentage of Quinoa flour did not affect too much to the Appearance and Flavor to muffins. Quinoa flour has a uniquely different flavor. Therefore, the Hedonic rating for flavor 7.38 was highest for 100% Quinoa flour (F6) muffin.

But, Quinoa flour has a natural bitter taste, therefore, the attribution for sweetness was considerably lower, 4.76 for 50% Rice flour+50% Quinoa flour (F3), 4.24 for 25% Rice flour+75% Quinoa flour (F4) and 3.76 for 100% Quinoa flour (F6). Which also reduces their overall acceptability and it is 7.42, highest for 100% Rice flour (F2) and 6.52 for 75% Rice flour+25% Quinoa flour (F4) and 4.90, the lowest for 100% Quinoa flour (F6).

Wich means 100% Rice flour and a substitution for Quinoa flour up to 75% to Rice flour are the best overall acceptable composition for a gluten free muffin. However, Flavor is the only attribute whose desirability was not affected considerably by fortification of 100% Quinoa flour to Rice flour and which compensates the bitterness due to 50% and 75% Quinoa flour in 50% Rice flour+50% Quinoa flour (F6).
and 25% Rice flour+75% Quinoa flour (F6) formulations and keep the overall acceptability range to over 5, a neutral range.

Qualities of the muffins are greatly influenced by their appearance due to its Texture. A good muffin should be softer in Texture. There were significant change of textural properties (Table 3) of muffins because of the replacement of Wheat flour with gluten free flours, such as Rice and Quinoa. 100% Wheat flour muffin is very hard (1405.19 g). Hedonic Texture rating is 5.05, might be because of high gluten content. 100% Rice flour muffin is comparably softer (868.27 g) and Hedonic rating for Texture is 7.14, the highest. Hardness increases and Hedonic rating for Texture decreases with the increase of Quinoa flour fortification.

Table 7: Effect of different flour formulations on CIE color.

| Flour formulations | L (a) | Crumb (a) | Crust (b) | Crumb (b) |
|--------------------|-------|-----------|-----------|-----------|
| F1                 | 20.89 ± 0.17 | 50.35 ± 0.46 | 13.72 ± 0.29 | 9.03 ± 0.13 |
| F2                 | 22.43 ± 0.48 | 74.68 ± 0.42 | 17.61 ± 0.44 | 3.06 ± 0.18 |
| F3                 | 21.46 ± 0.31 | 72.45 ± 0.51 | 15.33 ± 0.06 | 4.04 ± 0.22 |
| F4                 | 20.62 ± 0.41 | 71.52 ± 0.36 | 15.03 ± 0.08 | 4.66 ± 0.01 |
| F5                 | 18.58 ± 0.31 | 66.74 ± 0.37 | 14.31 ± 0.06 | 5.08 ± 0.04 |
| F6                 | 15.94 ± 0.13 | 56.59 ± 0.43 | 14.45 ± 0.23 | 5.23 ± 0.19 |

Conclusions

This study shows that, 100% Rice flour and 25% to 75% replacement with Quinoa flour to Rice flour formulations for muffin has the better overall consumer acceptability compared to 100% Quinoa flour muffin, which has the lowest overall consumer acceptability because of the bitter taste of Quinoa flour. 100% Rice flour and 75% Rice flour+25% Quinoa flour formulated muffins are the softest muffins and most acceptable muffin formulations in terms of overall consumer acceptability.

Acknowledgments

1. The work was supported by PSC-CUNY-TRADA-43-29 grant.
2. Thanks to Bob’s Red mill (General Mills, Inc., Minneapolis, MN, USA), for supplying of White Rice flour and Quinoa flour as a free gift.

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