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Sensory evaluation of gluten-free quinoa whole grain snacks

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Abstract

Sensory evaluation of quinoa gluten-free whole grain low fat and salt snacks was conducted. The snacks were Quinoa, Quinoa-Cayenne Pepper, Quinoa-Ginger and Quinoa-Turmeric. Cayenne pepper, ginger and turmeric are common spices that contain health promoting nutrients. Cayenne pepper has been associated with enhancing heat production. Ginger has been reported to improve blood flow and prevent joint pains. Turmeric has been observed to have wound healing potential. All the snacks contained 6% corn oil and 2% salt. Snack dough was prepared using 120 mL water for 100 g dry ingredients. About 20 g of snack dough was placed on center of preheated KrumKake Express Baker and cooked for 2 min. Seventy in-house volunteers judged Color/Appearance of Quinoa, Quinoa-Cayenne Pepper and Quinoa-Ginger snacks significantly ($p \leq 0.05$) higher than Quinoa-Turmeric snacks. Odor/Aroma of Quinoa-Ginger snacks was significantly higher than other snacks tested. Texture/Mouth-feel of Quinoa-Cayenne Pepper, Quinoa-Ginger and Quinoa-Turmeric snacks was similar and significantly higher than Quinoa snacks. Taste/Flavor and Acceptance was similar in four kinds of snacks tested. Water activity of all the snacks tested ranged from 0.41–0.55 suggesting that these snacks were crispy with good antimicrobial stability. These snacks would be quite filling due to their expansion of 2.6–3.1 times due to high porosity. Acceptance of snacks tested was Quinoa 79%, Quinoa-Cayenne Pepper 77%, Quinoa-Ginger 73% and

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Quinoa-Turmeric 70%. These snacks contained only 3–4 ingredients and could be made in any house kitchen or commercial production. Acceptance of 70–79% is very desirable. These healthy nutritious gluten-free quinoa snacks offer choice for all including vegetarians and individuals hypersensitive to gluten.

Keyword: Food science

1. Introduction

Snacks play very essential role in our daily food consumption. All school events like recess and physically active activities include snacking. Adopting at early age consumption of healthy snacks could result in habit that would last lifelong. More than 20% of the US population is currently between the ages of 18–34 years. More than one third of these individuals prefer snacks rather than three regular meals daily (Prepared Foods, 2016), http://www.preparedfoods.com/articles/118054. Healthy snacks need to be tasty, flavorful, visually appealing and packed for easy to carry. Nutritious snacks have the potential to prevent obesity related diseases such as: hypertension, heart disease, cancer, diabetes and bone diseases. Bran fraction of whole grains contains fiber and many essential minerals and nutrients. Many of the processed grain products do not contain the bran fraction. Whole grain products are recommended as they contain healthy bran fraction. It is recommended by the Nutrition Policy and Promotion (USDA, 2015a); Dietary Guidelines for Americans (USDA, 2015b), http://health.gov/dietaryguidelines/2015/guidelines/ that more than half of all cereal products consumed should contain whole grains. At all age groups males and females, consumption of refined grains is higher than that of whole grain products. It has been documented that consumption of whole grains products would lower the risk of many preventable lifestyle diseases (Whole Grain Council, 2009). It has been reported that heart disease risk was lowered with the consumption of whole grain rye and oats but not that by wheat (Halnaes et al., 2016). However, many of the snacks on the market contain wheat. There is increasing hypersensitivity to wheat gluten in celiac patients. Healthy nutrient absorbing surface of the gut is needed. This surface is damaged and the needed nutrients cannot be absorbed in celiac patients resulting in many deficiency diseases. Hypersensitivity to foods containing gluten has been on the rise recently. Some of the possible reasons could be use of bacterial transaminase enzyme to glue meat scraps to make meat patties. The transamination of gluten during the digestion process in the gut could make it hypersensitive. Another reason may be that increased pollution and toxins in the environment has resulted in change in the intestinal microbes that have allergic reaction to gluten. In 2014 US Food and Drug Administration (FDA, 2014) has defined foods to be labeled "gluten-free" that contain less than 20 parts per million, gluten http://www.fda.gov/downloads/ForConsumers/ConsumerUpdates/UCM363276.pdf. This is the level many of the individuals sensitive to gluten can tolerate. Higher level than this can be validly tested by the current available analytical techniques. Celiac is an

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autoimmune disease and there is no cure for it. The only way to tackle this disease is to avoid consuming gluten containing foods. The whole family has to avoid gluten containing foods even if one family member becomes gluten hypersensitive. Currently snacks available on the market are unhealthy and contain high simple sugars, sodium and saturated fat. Available snacks generally contain wheat that has gluten (Mother-Jones, 2012). Since most individual do not consume one-half the cereals containing whole grains. Consumers need to be educated to buy or prepare in their house kitchens healthy whole grain snacks. The development whole grain gluten-free snacks would meet such a health promoting need. Such snacks should be simple to make containing only a few ingredients including spices that contain disease preventing nutrients.

1.1. Quinoa

Quinoa (*Chenopodium quinoa*) is a pseudocereal, round disc shaped grain smaller but similar to sorghum, cooks like rice and is gluten-free. It is considered perfect food as it contains all nine dietary essential amino acids (histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan and valine). Quinoa is a good source of dietary fiber, minerals and unsaturated fatty acids. The Food and Agricultural Organization of the United Nations (FAO) (2012), Press Release Note No. 6367, 24 October 2012 officially declared that the year 2013 be recognized as "The International Year of the Quinoa" http://www.un.org/News/Press/docs/2012/note6367.doc.htm. FAO intended to focus world attention on the role that quinoa can play in providing food security and nutrition, and in the eradication of poverty.

Ginger (*Zingiber officinale*), turmeric (*Curcuma longa*) and cayenne pepper (*Capsicum annuum* '*Cayenne'*) are common spices that contain several phytonutrients that have been associated with health benefits. Cholesterol lowering, clot prevention, anti-inflammatory, antimicrobial, antioxidant, and anti-neoplastic properties of ginger and turmeric have been reported (Thomson et al., 2002). Skin health benefits of oral and topical turmeric supplements and products have been observed (Vaughn et al., 2016). Higher blood pressure inducing drug was observed to be ineffective in rats when diet contained 4% ginger or turmeric (Akinyemi et al., 2016). Both heat loss and heat production were increased by consuming cayenne pepper (Kobayashi et al., 1998). In overweight and obese individuals hot pepper resulted in increased fat burning and energy expenditure (Inoue et al., 2007). The glycolytic enzymes in the human epithelial cells are activated by active compound capsaicin found in hot chili pepper resulting in increased energy catabolism (Han and Isoda, 2009).

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In the study reported herein, seventy in house volunteers evaluated four kinds of snacks containing gluten-free ancient whole grain Quinoa (QN), QN-Cayenne Pepper, QN-Ginger, and QN-Turmeric.

2. Materials and methods

Whole grain quinoa (tannins removed), cayenne pepper, turmeric powder and ginger powder were purchased from local food stores. Quinoa was milled to fine flour using Blendtec Model 91 Kitchen Mill (Blendtec Orem, UT 84058). Quinoa flour was analyzed for nitrogen, using AOAC method 990.03 (AOAC, 2000) by Leco FP628 analyzer (Leco Corporation, St Joseph, MI); total dietary fiber, using AOAC method 985.29 (AOAC, 2000), crude fat with petroleum ether and an accelerated solvent extractor (ASE 350, Dionex Corp.); ash, using AOAC method 942.05 (AOAC, 1990); and moisture, using AOAC method 935.29 (AOAC, 1990). Composition of Quinoa flour is given in Table 1.

Dough composition of quinoa gluten-free ancient whole grain snacks is given in Table 2. Snacks dough was prepared by adding 120 mL water to 100 g of dry ingredients. Dough was set at room temperature for 30 min. The levels of cayenne pepper, ginger and turmeric were decided by the consensus of laboratory personnel. Snacks were cooked in a 1050Watt, Chef's Choice KrumKake Express 839 (EdgeCraft Corporation Avondale, PA 19311, USA). KrumKake Express with heat control dial settings 1–6 was heated at setting 4 till green ready light turned on. Baking temperature ranged from 185–208 °C as measured by Anritsu Meter AP-710 (Anritsu meter Co., Tokyo, Japan). Cooking surface was lightly greased and 20 g snack dough was placed on the center of heated KrumKake Express baker and cooked for 2 min. Fig. 1 shows four kinds of quinoa gluten-free ancient whole grain cooked snacks. Cooked snacks were cooled to room temperature then vacuum heat sealed in plastic bags by Food Saver 2200 Series (Foodsaver.com).

2.1. Sensory evaluation of snacks

Vacuum packed prepared snacks were opened and cut into four pieces with a pizza cutter. All four snacks were placed in an eight inch by ten inch plate labeled A)

Table 1. Composition of quinoa flour gluten-free ancient whole grain dry matter basis, %.

Ingredients	Protein	Fat	Minerals	Carbohydrates	TDF	DM
Quinoa	14.51 ± 0.19	6.01 ± 0.10	3.38 ± 0.01	76.10	8.51 ± 0.68	89.25 ± 0.06

Values are mean ± SD; Nitrogen to protein factors used was 6.25. Total Dietary Fiber, TDF; Dry matter, DM. Carbohydrate = [100−(Protein + Fat + Ash)]. Samples were analyzed in triplicates.

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Table 2. Dough composition of quinoa gluten-free ancient whole grain snacks as is basis, %.

Snacks	Flour	Oil	Salt	Pepper	Ginger	Turmeric	Water
Quinoa (QN)	92.0	6.0	2.0	–	–	–	120 ml
QN-Cayenne Pepper	91.3	6.0	2.0	0.7	–	–	120 ml
QN-Ginger	86.0	6.0	2.0	–	6.0	–	120 ml
QN-Turmeric	86.0	6.0	2.0	–	–	6.0	120 ml

Quinoa; B) Quinoa-Cayenne Pepper; C) Quinoa-Ginger; D) Quinoa-Turmeric (Fig. 2). Seventy in-house volunteers tasted the snacks in four sensory evaluation booths under white light for Color/Appearance, Odor/Aroma, Taste/Flavor, Texture/Mouth-feel and Acceptance. Tasters were instructed to evaluate each snack individually and not for relative rating. The sensory parameters were evaluated on a scale of 1–5 (Like very much = 5, like slightly = 4, neutral = 3,

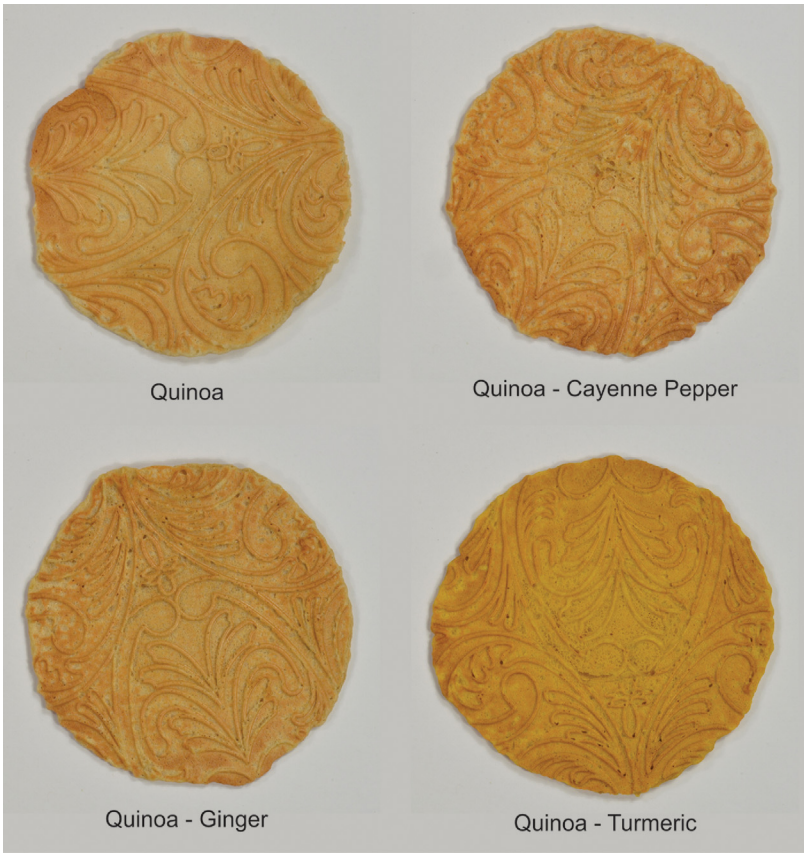

Fig. 1. Four kinds of quinoa gluten-free ancient whole grain cooked snacks.

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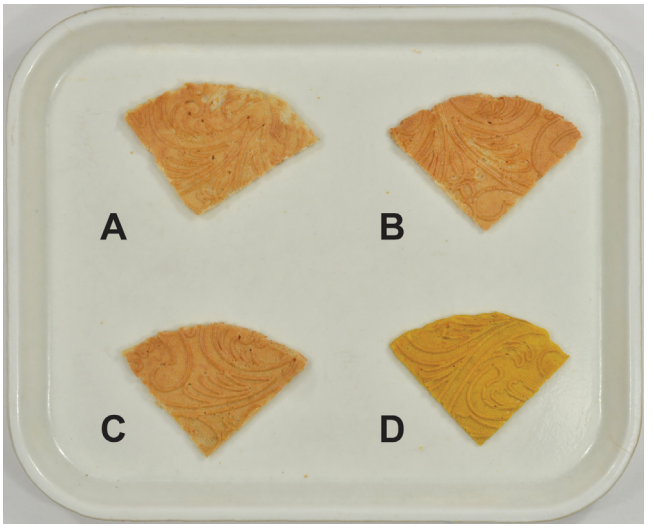

Fig. 2. Four kinds of quinoa gluten-free ancient whole grains snacks as offered for sensory evaluation to the tasters. a) Quinoa; b) Quinoa-Cayenne Pepper; c) Quinoa-Ginger; d) Quinoa-Turmeric.

dislike slightly = 2 and dislike very much = 1); Acceptance was evaluated on a scale of 1–2 (Acceptable = 2 and unacceptable = 1).

2.2. Water activity

Water activity (Aw) of quinoa gluten-free whole grain snacks was measured at 25.01 ± 0.02 °C in triplicate using an AquaLab 4TE dew point water activity meter (Decagon Devices, Inc., Pullman, WA).

2.3. Density

The bulk density (ρb) of quinoa gluten-free whole grain snacks was measured by Ottawa Sand volume displacement of 10 g sample in triplicate after shaking in a jar of 202 cc volume. The first reading was taken after shaking for 15 min, subsequent two reading were taken after shaking for 5 min each time. True density (ρt) was determined five times using gas displacement pycnometer AccuPyc II 1340 (Micromeritics Instrument Co., Norcross, GA 30093) at 21.4 ± 0.4 °C. Samples of each snack were dried in triplicate at room temperature for 15 h at 0% relative humidity in a vacuum desiccator with anhydrous calcium sulfate (W.A. Hammond Drierite, Xenia, OH). After drying, small pieces of samples were compressed into a density measuring cylinder of the pycnometer and five true density values were recorded.

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2.4. Statistical analysis

Data were analyzed with Minitab software (version 14.12.0, Minitab inc., State College, PA) using one way analysis of variance and Tuckey's multiple comparison tests with ($p \leq 0.05$) was considered the criterion of significance.

3. Results and discussion

Results of the taste panel evaluation of quinoa gluten-free ancient whole grain snacks are shown in Table 3. Color/Appearance of Quinoa (QN), QN-Cayenne Pepper and QN-Ginger snacks similar and significantly ($p \leq 0.05$) higher than for QN-Turmeric snacks. Data suggest that light amber brown color was preferred by the tasters than yellow turmeric color of snacks.

Odor/Aroma of the QN-ginger snacks was judged significantly higher than that for other three quinoa snacks tested (n = 70). The Odor/Aroma of dry cooked ginger bioactive compound zingerone (4-(4-hyroxy-3-methoxyphenyl)-2-butanone) was liked very much by the tasters. Ahmad et al. (2015) reported health promoting properties such as anti-inflammatory, antioxidant and many other pharmacological properties of zingerone. Texture/Mouth-feel of QN-Cayenne Pepper, QN-Ginger and QN-Turmeric snacks was similar and significantly better than Quinoa snacks. Data suggest that quinoa snacks that contained spices (Cayenne Pepper, Ginger or Turmeric) significantly improved their Texure/Mouth-feel compared with plain Quinoa snacks. Taste/Flavor and Acceptance of four kinds of Quinoa gluten-free whole grain snacks tested were similar.

Desirability index for sensory parameters was calculated as percent of tasters judged [like very much + like slightly + ½ (neutral)] Kahlon et al. (2013a); Kahlon et al. (2013b). Desirability index for Quinoa gluten-free whole grain snacks was: Quinoa, QN-Cayenne Pepper, QN-Ginger and QN-Turmeric for Color/Appearance 89%, 93%, 88% and 65%; Odor/Aroma 71%, 71%, 79% and 63%; Taste/Flavor 69%, 65%, 62% and 56%; Texture/Mouth-feel 81%, 71%, 82% and 76%, respectively. Lorenz and Coulter (1991) reported that good quality breads were

Table 3. Results of taste panel of quinoa gluten-free ancient whole grain snacks[ab].

Snacks	Color Appearance	Odor Aroma	Taste Flavor	Texture Mouth-feel	Acceptance
Quinoa (QN)	4.17 ± 0.10[a]	3.51 ± 0.10[b]	3.49 ± 0.12[a]	3.09 ± 0.10[b]	1.79 ± 0.05[a]
QN-Cayenne Pepper	4.34 ± 0.10[a]	3.53 ± 0.10[b]	3.44 ± 0.16[a]	3.70 ± 0.13[a]	1.77 ± 0.05[a]
QN-Ginger	4.24 ± 0.11[a]	3.93 ± 0.12[a]	3.40 ± 0.16[a]	3.97 ± 0.12[a]	1.73 ± 0.05[a]
QN-Turmeric	3.57 ± 0.15[b]	3.41 ± 0.13[b]	3.16 ± 0.14[a]	3.79 ± 0.13[a]	1.70 ± 0.06[a]

[a] Values (mean ± SEM) within columns with different superscript letters differ significantly ($P \leq 0.05$), N = 70.

[b] Sensory evaluation parameters were on a scale of 1–5 (Like very much = 5, like slightly = 4, neutral = 3, dislike slightly = 2 and dislike very much = 1); Acceptance was on scale of 1–2 (Acceptable = 2 and unacceptable = 1).

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baked using wheat flour with 5 and 10% quinoa blend. Schoenlechner et al. (2010) observed that texture and firmness was similar to wheat pasta with combination of buckwheat, amaranth and quinoa (60:20:20). A blend of corn, broad bean and quinoa flour (50:30:20) improved nutritional value of pasta but impaired its sensory quality (Gimenez et al., 2016). Whole grain gluten-free snacks using 86–92% quinoa flour with 70–79% acceptance are reported herein.

Acceptance for Quinoa gluten-free whole grain snacks is shown in Fig. 3. Acceptance of quinoa snacks tested was Quinoa 79%, QN-Cayenne Pepper 77%, QN-Ginger 73% and QN-Turmeric 70%. These acceptance values for four kinds of Quinoa snacks tested were desirable, statistically similar and ranged from 70–79%.

Water activity (Aw), true density (ρt), bulk density (ρb) and expansion (ρt/ρb) of quinoa gluten-free whole grain snacks is shown in Table 4. Water activity of Quinoa and QN-Cayenne Pepper snacks was similar and significantly lower that QN-Ginger and QN-Turmeric snacks. Aw of QN-Turmeric snacks significantly lower than QN-Ginger snacks. Aw data suggests that Quinoa and QN-Cayenne Pepper snacks were crispier and with higher antimicrobial stability than QN-Ginger and QN-Turmeric snacks. Relative crispness and antimicrobial stability of snacks tested was Quinoa = QN-Cayenne Pepper > QN-Turmeric > QN-Ginger. Very crispy snacks with Aw of 0.21–0.27 have been observed by Katz and Labuza (1981). Carrots snacks with Aw of 0.44 were reported to have desired crispness and antimicrobial stability (Adams and Moss, 1997; Dueik et al., 2013).

True density (ρt) values of four kinds of Quinoa gluten-free ancient whole grain snacks tested was similar and values ranged 1.298–1.317. Bulk density (ρb) values for QN-Cayenne Pepper snacks were significantly higher than other three kinds

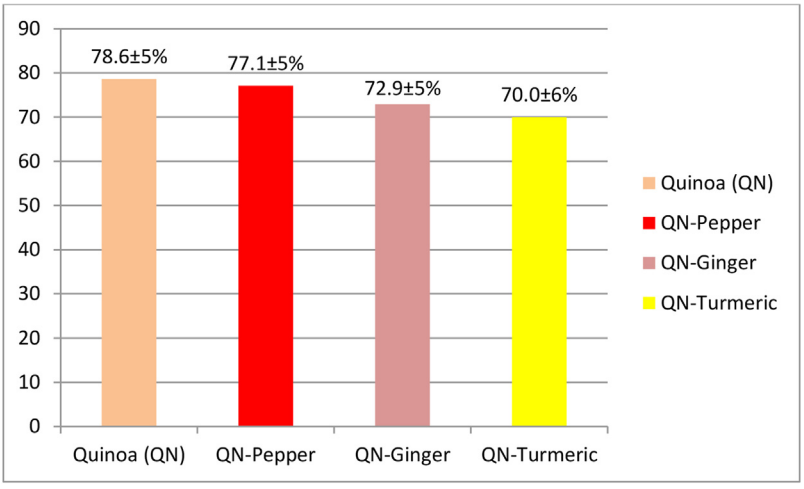

Fig. 3. Percent Acceptance (Y axis = Acceptance %) (± SEM of Quinoa (QN), QN-Cayenne Pepper, QN-Ginger, QN-Turmeric, Gluten-free Whole Grain Snacks (n = 70). No significant difference in acceptance of four kinds of snacks tested.

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Table 4. Water Activity (Aw), True Density (ρt), Bulk Density (ρb) and Expansion of Quinoa. Gluten-free ancient whole grain snacks[abc].

Snacks	Aw	ρt	ρb	Expansion (tρ/bρ)
Quinoa (QN)	0.411 ± 0.003[c]	1.313 ± 0.002[a]	0.461 ± 0.003[b]	2.848 ± 0.001[a]
QN-Cayenne Pepper	0.405 ± 0.003[c]	1.317 ± 0.001[a]	0.500 ± 0.004[a]	2.634 ± 0.002[b]
QN-Ginger	0.548 ± 0.007[a]	1.298 ± 0.007[a]	0.432 ± 0.003[c]	3.005 ± 0.005[a]
QN-Turmeric	0.515 ± 0.002[b]	1.298 ± 0.007[a]	0.418 ± 0.007[c]	3.105 ± 0.005[a]

[a] Values within columns with different superscript letters differ significantly ($P \leq 0.05$).

[b] Water activity (Aw) was measured at 25.01 ± 0.02 °C in triplicate using an AquaLab 4TE dew point water activity meter (Decagon Devices, Inc., Pullman, WA).

[c] True density (ρ*t*) was determined using an AccuPyc II 1340 gas displacement pycnometer (Micromeritics Instrument Co., Norcross, GA) at 21.4 ± 0.4 °C. The bulk density (ρb) of each sample was measured by Ottawa Sand volume displacement by 10 g sample in triplicate after 15-5-5 minutes shaking in a jar of 202 cc volume.

Quinoa snacks tested. Bulk density values for Quinoa snacks were also significantly higher than QN-Ginger and QN-Turmeric snacks. Expansion (tρ/bρ) for Quinoa, QN-Ginger and QN-Turmeric snacks were similar and significantly higher than QN-Cayenne Pepper snacks. It would be expected that fluffier snacks results in lower caloric consumption. Data suggest than Quinoa, QN-Ginger and QN-Turmeric snacks with expansion (fluffiness) of 2.8–3.1 would give desirable presentation in commercial packaging.

4. Conclusions

Four kinds of Quinoa gluten-free ancient whole grain snacks were sensory evaluated by seventy tasters. Acceptance of 86–92% quinoa containing whole grain snacks was Quinoa 79%, QN-Cayenne Pepper 77%, QN-Ginger 73%, and QN-Turmeric 70%. Quinoa protein contains all nine essential amino acids. Hot pepper, ginger and turmeric are common spices with many reported health benefits like heat production, increased blood flow and wound healing. Water activity of Quinoa snacks tested ranged from 0.41–0.55 suggesting that these snacks had acceptable crispness with good antimicrobial stability. Expansion value of 2.6–3.1 suggests that these snacks would be quite filling resulting in lower caloric consumption and offer desirable package commercial presentation. These snacks use only 3–4 ingredients and could be made in any house kitchen or commercial production. Quinoa gluten-free whole grain snacks offer healthy choice for all and option for vegetarians and those hypersensitive to gluten.

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Declarations

Author contribution statement

Talwinder S. Kahlon: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Roberto J. Avena-Bustillos: Analyzed and interpreted the data.

Mei-Chen M. Chiu: Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

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Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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