Heliyon 7 (2021) e06874

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Consumer sensory evaluation and quality of Sorghum-Peanut Meal-Okra snacks☆

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ARTICLE INFO

Keywords:
Sorghum
Peanut meal
Okra
Jalapeno
Turmeric root
Ginger root

ABSTRACT

Healthful tasty high protein, vegetable, gluten-free snacks are needed for all as well as those sensitive to gluten for in between meals and for after school events. Peanut meal a low value farm by-product was used to increase protein content and to add value for growers. Bile acid binding okra with cholesterol lowering potential and jalapeno, turmeric and ginger with healthy phytonutrients were included to increase vegetable consumption. The objective was to have healthy tasty snacks with ≥24% protein content. Gluten-free, whole grain, high protein, Sorghum-Peanut meal-Okra (SPO) and SPO-Jalapeno, SPO-Turmeric root and SPO-Ginger root snacks were sensory evaluated by 73 volunteers. Physical testing of the snacks included water activity, true and bulk density, texture and proximate analyses. Taste and Odor of the SPO and SPO-Jalapeno snacks were similar and significantly ($p \leq 0.05$) higher than SPO-Turmeric root and SPO-Ginger root. Acceptability of SPO and SPO-Jalapeno snacks were both 88%; this value is quite desirable. Acceptability of SPO-Turmeric and SPO-Ginger were only 56 and 51% respectively. Turmeric and ginger have been reported with many health benefits; however these snacks were not preferred by the tasters. Water activity (Aw) of the snacks tested was SPO (0.42) < SPO-Turmeric (0.52) < SPO-Jalapeno (0.54) < SPO-Ginger (0.62). Water activity indicates that all the snacks were crispy and had longer shelf life. Expansion of these snacks was SPO-Ginger root 84%, SPO-Turmeric root 76%, SPO-Jalapeno 42% and SPO only 14%. Data suggest snacks containing spices were fluffy and would give good presentation in packaging. The objective of attaining protein level was clearly attained, as values ranged 24–26%. These snacks are easy to make in house kitchens or by food companies. These healthy snacks offer a gluten-free, high protein, tasty choice for all, including vegetarians and individuals hypersensitive to gluten.

1. Introduction

Snacks are generally eaten in between meals. Health promoting nutritious snacks would help reduce the risk of many preventable life-style related diseases. Young people often prefer snacks over regular meals (Prepared Foods 2016). For children snacks are important in school and after school events. For the elderly, snacks offer all the essential nutrients and dietary fiber that are not adequately consumed by them from their regular meals (Mother-Jones 2017). Snacks are preferred to be tasty, healthful, flavorful and easy to carry. Consumers do not meet recommended level of whole grain consumption in their daily diets (USDA 2015). The risk of many life style related diseases could be lowered by including whole grains is our diets (Whole Grain Council, 2009). It has been observed that consuming whole grain rye and oats significantly lowered the risk of heart disease (Halnaes et al., 2016). Celiac patients are hypersensitive to gluten. This disease results in impaired intestinal nutrient absorbing lining (Lebwohl et al., 2015). Foods containing less than 20 parts per million, gluten can be labelled as "gluten-free" (FDA, 2014). This gluten level can be validly tested and can be tolerated by most gluten-sensitive individuals (Malgorzata et al., 2017). Gluten sensitivity is increasing worldwide. Low cost meat patties are made by binding meat scraps using microbial transaminase. Transamination of gluten could create hypersensitivity. It is possible that increased industrial pollution has changed gut microbiome resulting in loss of gluten tolerance. In celiac disease loss of proper intestinal function could be multifactorial (Umberto et al., 2013). In US there are 40–60 thousand individuals diagnosed as celiac, there may be many more as undiagnosed. High fat, salt and sugary snacks are not good for healthy

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https://doi.org/10.1016/j.heliyon.2021.e06874
Received 14 August 2019; Received in revised form 3 December 2019; Accepted 16 April 2021
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life style. Children as well as adults do not meet daily required amounts of protein, vegetables and dietary fiber (Mother Jones, 2017). It is desired to have gluten-free, high-protein; tasty, nutritious, vegetable snacks prepared in house kitchens or produced commercially.

1.1. Sorghum

Sorghum (*Sorghum bicolor)*, a cereal grain, is the one of the important cereal crops (https://sorghumgrowers.com/2011/07/21/ten-things-you-may-not-know-about-sorghum/). It is drought tolerant and versatile as food, feed and fuel. In the United States food usage of sorghum is on the rise as it is gluten-free (Thomson 2017). World production of sorghum in 2020 is estimated to be 60 million metric tons. Major sorghum production counties in million metric tons are USA 8.9, Nigeria 6.9, Ethiopia 5.2, Mexico 4.5, India 4.4, China 3.6, and Argentina 2.4 (http://www.worldagriculturalproduction.com/crops/sorghum.aspx).

1.2. Peanuts

Peanuts (*Arachis hypogaea*) in US are used in various ways (roasted, peanut butter, confectionary, oil, flour and protein). Over 50 percent of the world production of peanuts is crushed for its oil for various consumer uses. Peanut world production in 2017 was over 47 million metric tons per year (FAO STAT United Nations, 2017). About 23 million tons of peanuts result in estimated 12 million tons of peanut oil and peanut meal. Peanut meal contains 44% protein (Table 1). Peanut meal is used as animal feed as it is extracted using organic solvents. Higher protein foods can be produced using food grade peanut meal obtained using heat and compression extrusion. That would result in a significant additional value addition to peanut crops. Atli Arnarson (2019) reported peanuts as an excellent source of vitamins (biotin, niacin, folate, E, thiamin) and minerals (copper, manganese, phosphorus and magnesium). China produces 17.2 million metric tons of peanuts, with India in second place at 9.2, followed by United States as 3.3 and Nigeria at 2.4; Sudan and Myanmar, 1.6 each (FAO Stat Peanut Production, 2017) (see Table 2).

1.3. Okra

Okra (*Abelmoschus esculentus*) is an important vegetable crop. It offers mucilaginous consistency after cooking. Okra binds bile acids which has the potential of lowering fat absorption and reducing cholesterol (Kahlon and Smith 2007). Okra is high in dietary fiber and polyphenols and many vitamins (Gemede et al., 2015). World production of okra in 2017 was 9.6 million tons. Top okra producing countries in million tons are India 6.0, Nigeria 2.1, Sudan 0.3, Mali, Cote d'Ivoire and Niger 0.2, Pakistan and Cameroon 0.1 (FAO Stat Okra Production, 2017).

1.4. Turmeric root

Turmeric (*Curcuma longa*) is the spice that gives curry its yellow color. It has been used in India for thousands of years as a spice and medicinal herb. Turmeric contains curcumin, which has powerful anti-inflammatory and anti-oxidant properties (Goel et al., 2001; Aggarwal and Harikumar 2009). Curcumin has the potential to lower the risk of lifestyle degenerative diseases such as heart disease, cancer and arthritis (Gunnars 2018). The global annual production of turmeric is around 1.1 million tons. India dominates producing 0.87, China 0.10, Myanmar 0.05 and Nigeria and Bangladesh 0.04 million tons each (Tamil Nadu Agricultural University, 2013).

1.5. Ginger root

Ginger (*Zingiber officinale)* is a popular ingredient in cooking, and especially in Asian and Indian cuisine. It has also been used for many centuries for medicinal purposes. Possible health benefits include relieving nausea, loss of appetite, motion sickness, pain and inflammation (Mao et al., 2019). Ginger is high in dietary fiber, iron, vitamin C and potassium (Ware and Weatherspoon 2017). In 2017, global production of ginger was 3.0 million tons. Top ginger producing in million tons are countries India 1.1, China 0.6, Nigeria 0.4, Nepal 0.3, Indonesia 0.2 (Factfish Statistics World Ginger Production 2017).

1.6. Jalapeno

Jalapeno (*Capsicum annuum)* peppers are good source of phenolics, ascorbic acid, and capsaicin and have high antioxidant activity (Alvarez-Parrilla et al., 2011). Jalapeno is one of the great culinary peppers in the world, finding its way into Tex-Mex dishes, Thai recipes and Spanish foods. This is truly a pepper that has found its niche all over the world. Capsaicin, the chemical that makes chili peppers hot, is thermogenic. It stimulates the fat burning by increasing the metabolism of adipose tissue, generating heat (Ludy et al., 2012). Jalapeno is about 25–30% of the production of all peppers produced in various countries. World top chili producing counties in million tons are China 16.1, Mexico 2.7, Turkey 2.1, Indonesia 1.9, India 1.5, Spain 1.1 and USA 0.9 (World's Top Chili Pepper Producing Countries, 2014). Healthful, tasty, high protein ($\geq$24%), gluten-free snacks were formulated with phytonutrients in order to offer nutritious choice to all and an option for gluten sensitive individuals. In addition, these snacks would increase vegetable consumption and add value for peanut crops. Physical testing of the snacks included water activity, true and bulk density, texture and proximate analyses. The study reported herein included quality testing and sensory evaluation of gluten-free, whole grain, high protein Sorghum-Peanut Meal-Okra snacks.

2. Materials and methods

Whole grain sorghum was purchased from Bob's Red Mill (Bob's Red Mill, Milwauke, OR, 97222 USA). Sorghum flour was prepared by using Blendtec Kitchen Mill Model 91 at medium setting (Blendtec Inc., Orem, UT, 84058 USA). Peanuts, Okra, Jalapenos, Turmeric root and Ginger root were purchased from local food markets. Peanut meal was produced by extracting oil using Vepor Oil Press (Joyfay International, Cleveland, OH, 44103 USA). Okra, Jalapenos, Turmeric root and Ginger root were

Table 1. Proximate composition of Sorghum flour, Peanut meal, Okra, Jalapeno, Turmeric root and Ginger root, as is basis %.

Ingredients	Protein	Crude Fat	Minerals	Total Carbohydrate	DM	Water
Sorghum	7.72 ± 0.12	6.25 ± 0.33	1.31 ± 0.10	73.78 ± 0.28	89.06 ± 0.55	10.94 ± 0.55
Peanut meal	43.46 ± 0.10	16.34 ± 0.07	3.94 ± 0.09	30.13 ± 0.07	93.87 ± 0.02	6.13 ± 0.02
Okra	2.71 ± 0.02	0.56 ± 0.02	0.92 ± 0.02	8.60 ± 0.09	12.79 ± 0.26	87.21 ± 0.26
Jalapeno	1.23 ± 0.03	0.55 ± 0.02	0.62 ± 0.02	6.91 ± 0.03	9.31 ± 0.09	90.69 ± 0.09
Turmeric root	1.52 ± 0.02	1.22 ± 0.03	1.66 ± 0.02	10.63 ± 0.03	15.03 ± 0.07	84.97 ± 0.07
Ginger root	1.12 ± 0.02	0.95 ± 0.05	0.52 ± 0.02	8.09 ± 0.07	10.68 ± 0.21	89.32 ± 0.21

Values are mean ± SD; Nitrogen to protein factors used was 6.25; Dry matter, DM. Total carbohydrate = 100- (crude protein + crude fat + ash + water). Samples were analyzed in triplicates.

Table 2. Dough composition of ancient whole grain gluten-free Sorghum (S), Peanut meal (P), Okra (O) Jalapeno, turmeric root and ginger root snacks, as is basis, %.

Flatbreads	Sorghum	Peanut Meal	Okra	Salt	Jalapeno	Turmeric	Ginger	Water
SPO	32.97	32.97	32.97	1.10	–	–	–	55 ml
SPO-Jalapeno	29.69	29.69	29.69	1.04	9.90	–	–	50 ml
SPO-Turmeric	25.83	25.83	25.83	1.00	–	21.52	–	52 ml
SPO-Ginger	25.83	25.83	25.83	1.00	–	–	21.52	52 ml

Level of Jalapeno, Turmeric root and Ginger root was decided by consensus of laboratory personnel.
Dough was set at room temperature for 30 min.

chopped using Mini-Prep Processor (Cuisinart, East Winsor, NJ 08520 USA). Prepared snacks as well as the ingredients (Sorghum flour, Peanut meal, Okra, Jalapeno, Turmeric root and Ginger root) were analyzed for nitrogen using Leco FP628 analyzer (Leco Corporation, St Joseph, MI, 49085 USA) with AOAC method 990.03, 2000. Crude fat was measured by Soxhlet extraction with petroleum ether using method 963.15, ash using method 923.03 and moisture using method 925.10 (AOAC, 1990). Composition of Sorghum flour, Peanut meal, Okra, Jalapeno, Turmeric root and Ginger root is given in Table 1. Several proportions of various ingredients to formulate snacks were tested. The final composition of the test snacks was determined by the consensus of the laboratory personnel. The dough composition of the snacks was Sorghum flour, Peanut meal and Okra (26–33%), Turmeric root and Ginger root (22%), Jalapeno (10%) and salt (1%). Snack dough was prepared by adding 50–55 ml water to 100g of as is ingredients. Dough was covered with polyvinyl film (Polyvinyl Films, Sutton MA, 011590 USA) and set at room temperature for 30 min.

2.1. Preparation of snacks

The characteristic shape and design of the snacks was formed by compression of the dough between both cooking surfaces. Snacks were cooked in a 1050 Watts, Chef's Choice KrumKake Express 839 (EdgeCraft Corporation Avondale, PA, 19311 USA). KrumKake Express heat setting was at control dial setting 4 (Range 1–6). Both sides of the cooking surface were lightly sprayed with Pam non-stick cooking spray (ConAgra Foods, Omaha, NE 68103 USA). When the green ready light turned on, 20g snack dough was placed at the center of the lower cooking surface and the upper side was closed and locked. Snacks were cooked for 2 min. Cooking temperature ranged from 185-208 °C as measured by Fluke 61 Infrared thermometer (Fluke Australia Pty Ltd., Baulkham Hills, NSW 2153). Figure 1 shows four kinds of gluten-free whole grain snacks: Sorghum-Peanut Meal-Okra (SPO), SPO-Jalapeno, SPO-Turmeric root and SPO-Ginger root. Cooked snacks were cooled to room temperature and sealed under nitrogen in Ziplock bags (SC Johnson Inc., Pleasanton, CA 94588 USA).

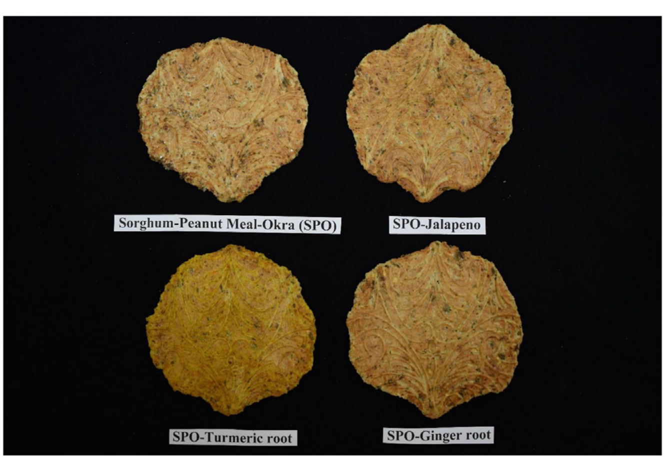

Figure 1. Cooked Flatbreads; top left, Sorghum-Peanut Meal-Okra (SPO); top right, SPO-Jalapeno; bottom left, SPO-Turmeric root and bottom right, SPO-Ginger-root.

2.2. Consumer sensory evaluation of snacks

Informed consent was obtained from all tasters, they were instructed not to participate if have any aversion, allergy or sensitivity to peanuts or any of the ingredients of these snacks. Snacks were cut into four pieces with a pizza cutter. Four kinds of snacks appropriately labelled for their ingredients and were placed in an 8 × 10 inch plate, Sorghum-Peanut Meal-Okra (SPO), SPO-jalapeno, SPO-Turmeric root and SPO-Ginger root as shown in Figure 2. The panelists were instructed to use water as palate cleanser between samples consistently throughout the test and evaluate snacks individually and not on a relative rating. Seventy-three in-house voluntary tasters tested the snacks in four sensory evaluation booths under white lights for Color, Aroma, Taste and Mouth feel on a scale of 1–5 (Like very much = 5, like slightly = 4, neutral = 3, dislike slightly = 2 and dislike very much = 1). The acceptability was evaluated on a scale of 1–2 (Acceptable = 2 and unacceptable = 1).

2.3. Water activity (Aw)

Water activity (Aw) of the gluten-free whole grain Sorghum-Peanut Meal-Okra (SPO) snacks was measured at 25.01 ± 0.02 ^{O}C in triplicate using an Aqua Lab 4TE due point water activity meter (Decagon Devices Inc., Pullman, WA 99163 USA).

2.4. Density

Bulk density (ρb) of the gluten-free whole grain SPO snacks was measured using Ottawa Sand volume displacement of 10 g sample in triplicate after shaking in a jar of volume 202 ml. The first reading was

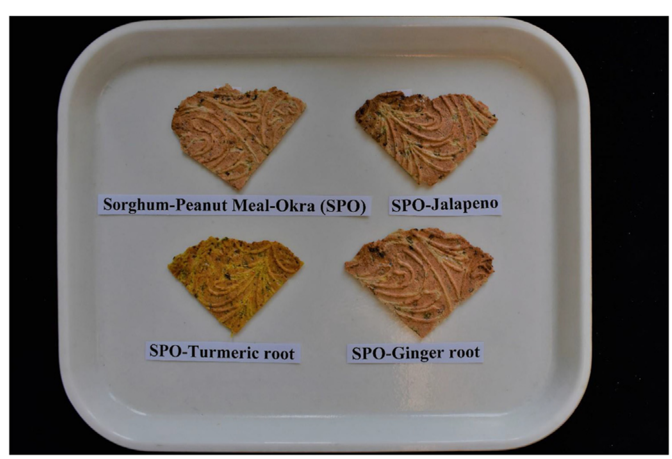

Figure 2. Flatbread samples as presented for sensory evaluation: top left, Sorghum-Peanut Meal-Okra (SPO); top right, SPO-Jalapeno; bottom left, SPO-Turmeric root and bottom right, SPO-Ginger-root. The panelists were instructed to use water as palate cleanser between samples consistently throughout the test and evaluate snacks individually and not on a relative rating.

Table 3. Sensory evaluation of sorghum-peanut meal-okra (SPO) snacks[a,b,c].

Snack	Color	Aroma	Taste	Mouth feel	Acceptability
SPO	4.34 ± 0.77[a]	3.78 ± 0.85[a]	3.88 ± 0.85[a]	4.10 ± 0.94[a]	1.88 ± 0.34[a]
SPO-Jalapeno	4.26 ± 0.77[a]	3.89 ± 1.03[a]	4.00 ± 0.85[a]	3.88 ± 0.85[a]	1.88 ± 0.34[a]
SPO-Turmeric root	4.30 ± 0.68[a]	3.77 ± 0.94[a]	3.03 ± 1.11[b]	3.38 ± 1.11[b]	1.56 ± 0.51[b]
SPO-Ginger root	4.27 ± 0.77[a]	3.89 ± 1.03[a]	3.10 ± 1.20[b]	3.08 ± 1.20[b]	1.51 ± 0.50[b]

[a] Values (mean ± SD) within columns with different superscripts differ significantly ($p \leq 0.05$), n = 73.
[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); Acceptability was on scale of 1–2 (Acceptable = 2 and Unacceptable = 1).
[c] The panelists were instructed to use water as palate cleanser between samples consistently throughout the test and evaluate snacks individually and not on a relative rating.

Table 4. Water activity (Aw), true density (ρt), bulk density (ρb), porosity, expansion, break force and stretchability of sorghum-peanut meal-okra (SPO) snacks.

Snack	Aw	ρt	ρb	Porosity	Expansion	Break Force	Stretchability
SPO	0.42 ± 0.02[d]	1.36 ± 0.02[c]	1.20 ± 0.02[a]	0.12 ± 0.04[c]	1.14 ± 0.04[c]	1821 ± 479[a]	17.59 ± 0.78[a]
SPO-Jalapeno	0.54 ± 0.02[b]	1.39 ± 0.02[a]	0.98 ± 0.05[b]	0.29 ± 0.04[b]	1.42 ± 0.08[b]	1716 ± 138[a]	17.38 ± 0.56[a]
SPO-Turmeric	0.52 ± 0.02[c]	1.38 ± 0.02[b]	0.78 ± 0.09[c]	0.43 ± 0.08[a] 1.76 ± 0.03[a]	1468 ± 146[b]	17.12 ± 0.78[a]	
SPO-Ginger	0.62 ± 0.02[a]	1.38 ± 0.02[b]	0.75 ± 0.03[c]	0.46 ± 0.04[a]	1.84 ± 0.12[a]	1290 ± 191[b]	15.78 ± 0.49[b]

Values (mean ± SD) within columns with different superscripts differ significantly ($p \leq 0.05$), n = 73.
Water activity (Aw) was measured (N = 3) at 25.01 ± 0.02 °C by AquaLab dew point water activity meter 4TE (Decagon Devices, Inc., Pullman, WA).
True density (**ρt**) was determined (N = 5) by AccuPyc II 1340 gas pycnometer (Micromeritics Instrument Co., Norcross, GA 30093) at 21.4 ± 0.4 °C.
The bulk density (**ρb**) of each sample was measured (N = 3) by Ottawa Sand volume displacement by about 10g of sample in triplicate after 15-5-5 min shaking in a jar of 202 cc volume.
Porosity was calculated using the equation [Porosity = 1 – (ρb/ρt)].
Expansion was calculated using the equation [Expansion = (ρt/ρb)].
Break Force, g and Stretchability, mm (n = 14).

taken after shaking for 15 min. Two subsequent readings were taken after additional shaking for 5 min each. True density (ρt) was determined five times at 21.4 ± 0.4 °C using gas displacement pycnometer AccuPycII 1340 (Micromeritics Instrument Co., Norcross, GA 30093 USA). Samples of snacks were dried in triplicate at room temperature for 15 h at 0% relative humidity in vacuum desiccators with anhydrous calcium sulfate (W.A. Hammond Drierite, Xenia, OH 45385 USA). Small pieces of dry samples were compressed into density measuring cylinder of the pycnometer and five true density values were recorded. Porosity and Expansion were calculated as [Porosity = 1- (ρb/ρt)] and [Expansion = (ρt/ρb)].

2.5. Texture analysis

Snack breaking point force (g_f) and stretchability (mm) were measured using TA.XT Plus Texture Analyzer (Texture Technologies Corp., Hamilton, MA 01982 USA). Samples were mounted on TA-108N film fixture using a large Plexiglass probe (n = 14).

2.6. Statistical analysis

Data were analyzed with Minitab software version 14.12.0 (Minitab Inc., State College, PA 16801 USA) using one-way analysis of variance and Tuckey's multiple comparison tests and ($p \leq 0.05$) was considered the criterion of significance. Principle Component Analysis was conducted using SAS OnlineDoc® 9.4. Cary, NC: SAS Institute Inc. 2013.

3. Results and discussion

Color and Aroma of the whole grain gluten-free Sorghum-Peanut Meal-Okra (SPO), SPO-Jalapeno, SPO-Turmeric root and SPO-Ginger root snacks were similar as judged by 73 in-house volunteer tasters (Table 3). Taste, Mouth feel and Acceptability of the SPO and SPO-Jalapeno snacks were similar and significantly ($p \leq 0.05$) higher than SPO-Turmeric root and SPO-Ginger root. These three sensory parameters were also similar between SPO-Turmeric root and SPO-Ginger root snacks. Data suggest that SPO and SPO-Jalapeno snacks were preferred. Water activity (Aw), true density (*ρt*), bulk density (*ρb*), porosity, expansion, break force (g_f) and stretchability (mm) is given in Table 4. Water activity was significantly different between each of the snacks tested: SPO (0.42) < SPO-Turmeric (0.52) < SPO-Jalapeno (0.54) < SPO-Ginger (0.62). At less than 0.6 Aw, all bacterial growth is inhibited; at 0.75 Aw some yeast and molds may grow (Water Activity, Safe foods 360, 2014). Labuza (1980) reported shelf stable dry food with Aw ≤0.6. Data suggests that the snacks tested were shelf stable and crispy. True density (*ρt*) for SPO-Jalapeno snacks was significantly higher than other snacks tested. Values for SPO-Turmeric root and SPO-Ginger root were also significantly higher than SPO-snacks. However, *ρt* values were in a very narrow range 1.36–1.39. Bulk density (*ρb*) for SPO-Turmeric root and SPO-Ginger root were similar and significantly lower than SPO- Jalapeno and SPO snacks. Values for SPO-Jalapeno were also significantly lower

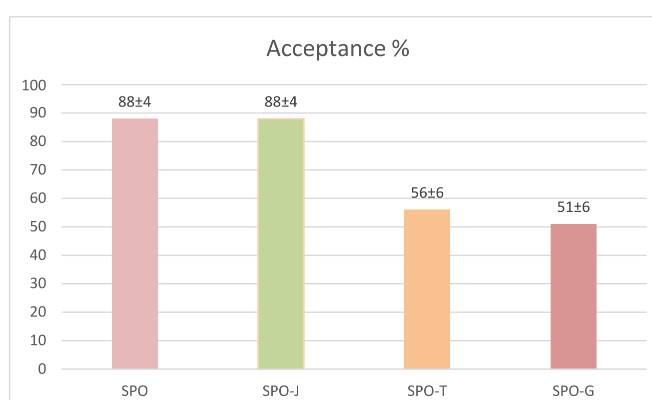

Figure 3. Acceptability of Sorghum-Peanut Meal-Okra (SPO), SPO-Jalapeno (SPO-J), SPO-Turmeric root (SPO-T) and SPO-Ginger root (SPO-G) snacks (n = 73). Values (mean ± SEM) with different letter differ significantly ($p \leq 0.05$).

Table 5. Eigenvalues of the correlation matrix obtained by principal component analysis (PCA) of acceptability and non-acceptability of Sorghum-Peanut Meal-Okra Snacks.

PC	Eigenvalue	Difference	Proportion	Cumulative
1	3.49781085	3.22256651	0.8745	0.8745
2	0.27524434	0.11241653	0.0688	0.9433
3	0.16282781	0.09871082	0.0407	0.9840
4	0.06411699	0.0160	1.0000	

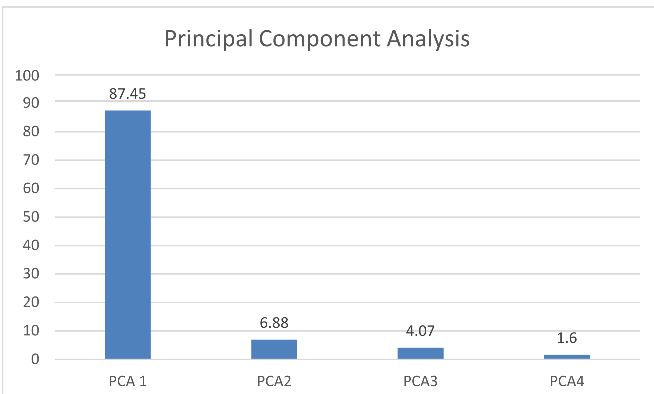

Figure 4. Principal Components plot shows that most of the variance (87.45%) can be explained by the first principal component. The first two principal components contain 94.33% of the information.

parameters (n = 292). Eigenvalues of the Correlation Matrix obtained for Sorghum-Peanut Meal-Okra (SPO) Snacks is given in Table 5.

Principal Component plot shows that most of the variance (87.45%) can be explained by the first principal component (Figure 4). The second principal component still bears some information (6.88%) while the third and fourth principal components can safely be dropped without losing much information. Together, the first two principal components contain 94.33% of the information.

The distribution of the in-house volunteer tasters was Caucasian 31, Asian 28, Hispanic 9, Black 3, American Indian 1, unresponsive 1. The Caucasian, Asian and Hispanic with n = 31, 28 and 9 respectively would give reasonable insight into ethnic preferences of sensory parameters. Other ethnic groups with n = 1–3, their preferences could not be validly considered as representative. Acceptability of sensory parameters by Caucasian, Asian and Hispanic tasters was SPO 87, 89 and 89%; SPO-Jalapeno 84, 96 and 78%; SPO-Turmeric root 61, 54 and 33%; SPO-Ginger root 54, 61 and 22%. Proximate composition of the Sorghum-Peanut Meal-Okra (SPO), SPO-Jalapeno, SPO-Turmeric root and SPO-Ginger root snacks is given in Table 6. On dry matter basis these snacks contained protein (24–26%), fat (16–19%), ash (4–5%) and total carbohydrates (43–46%). The aim of attaining 24% protein was clearly accomplished. In addition to added 1% salt, these snacks contained 3–4% essential minerals. These snacks would add value to peanut meal and increase vegetable consumption. Whole grain, gluten-free, high protein, vegetable snacks offer healthy choice to all as well to those sensitive to gluten.

Table 6. Proximate composition of Sorghum-Peanut Meal-Okra (SPO) snacks, dry matter basis %.

Snacks	Protein	Crude Fat	Ash	Total Carbohydrate	DM %	Water
SPO	26.04 ± 0.09	19.08 ± 1.97	4.12 ± 0.02	42.88 ± 0.54	92.12 ± 0.05	7.88 ± 0.05
SPO-Jalapeno	25.36 ± 0.10	15.81 ± 1.65	4.26 ± 0.05	45.55 ± 0.45	90.98 ± 0.02	9.02 ± 0.02
QPB-Turmeric	24.25 ± 0.12	16.65 ± 0.62	4.61 ± 0.02	46.24 ± 0.31	91.75 ± 0.05	8.25 ± 0.05
QPK-Ginger	23.96 ± 0.09	17.41 ± 1.07	4.40 ± 0.02	44.36 ± 0.42	90.13 ± 0.03	9.87 ± 0.03

Nitrogen to protein factors used was 6.25. Dry matter, DM. Total carbohydrate = 100- (crude protein + crude fat + ash + water). Samples were analyzed in triplicates. Values are mean ± SD, (n = 3).

than SPO snacks. Porosity as well as expansion of SPO-ginger root and SPO-Turmeric root was also similar and significantly higher than SPO-Jalapeno and SPO-snacks. In addition, values for SPO-Jalapeno snacks were significantly higher than SPO snacks. Expansion of SPO-Ginger root 84%, SPO-Turmeric root 76% and SPO-Jalapeno 42% suggests that these snacks were fluffy and would give good presentation in packaging. Break force (g_f) for SPO and SPO-Jalapeno snacks was significantly higher than SPO-Turmeric root and SPO-Ginger root snacks. Data suggest that SPO and SPO-Jalapeno snacks were crispier than SPO-Turmeric root and SPO-Ginger snacks. Stretchability of SPO, SPO-Jalapeno and SPO-Turmeric root snacks was similar and significantly higher than SPO-Ginger snacks. Percent acceptability of Sorghum-Peanut Meal-Okra (SPO), SPO-Jalapeno, SPO-Turmeric root and SPO-Ginger root snacks is given in Figure 3. SPO and SPO-Jalapeno snacks had significantly higher acceptability than SPO-Turmeric root and SPO-Ginger root snacks. Acceptability of SPO and SPO-Jalapeno snacks was 88%. These acceptability values were quite desirable. Acceptability of SPO-Turmeric root and SPO-Ginger root were only 56 and 51% respectively, these snacks require fortification and/or processing modifications. Turmeric root and Ginger root have many health promoting properties (Gunnars 2018; Ware and Weatherspoon 2017), however tasters did not prefer these snacks. Principal Component Analysis was conducted using acceptability vs non-acceptability of four sensory

4. Conclusions

Healthful tasty gluten-free, whole grain, high protein, vegetable Sorghum-Peanut Meal-Okra (SPO) and SPO-Jalapeno, SPO-Turmeric root and SPO-Ginger root snacks were consumer sensory evaluated by 73 volunteers. Acceptability of SPO and SPO-Jalapeno snacks was 88%; these values are quite desirable. Water activity data indicates that the snacks were crispy with longer shelf life. Except SPO, expansion data of snacks suggests good package presentation. Production of these snacks would add value to peanut crops by making food grade product from typical animal feed and increase protein intake and vegetable consumption. These snacks contain only 3–4 ingredients and could easily be made in any home kitchen or commercial establishment. These healthy tasty snacks offer a gluten-free, high protein choice for all, including vegetarians and those sensitive to gluten.

Declarations

Author contribution statement

Talwinder S. Kahlon: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Roberto J. Avena-Bustillos: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Ashwinder K. Kahlon: Performed the experiments; Wrote the paper.

Jenny L. Brichta: Analyzed and interpreted the data; Wrote the paper.

Funding statement

This work was supported by the Agricultural Research Service (2030-44000-010-00D).

Data availability statement

The authors do not have permission to share data.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

Acknowledgements

The authors sincerely thank all the tasters of the sensory evaluation of the gluten-free whole grain high protein vegetable snacks. We dedicate this manuscript to the memory of Mei-Chen (Maggie) Chiu who participated initially in this study. Her unfortunate demise deprived us of a valuable chemist.

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