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Gluten Free Tortillas of Finger Millet (*Eleusine coracana*) fortified with Chickpea (*Cicer arietinum*)

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ABSTRACT

Objective: The objective of the study is to formulate, optimize, and perform a sensory acceptability study on chickpea fortified finger millet tortillas.

Introduction: Researches have shown potential health benefits of finger millet in many health conditions due to its nutritional content. However, the absence of gluten in finger millet flour prevents binding properties required to formulate tortillas.

Methods: We developed a gluten free flour composition of tortilla consisting of chickpea fortified finger millet flour (30% w/w chickpea flour). We further optimized it with 2% sugar, 4% of glycerin and 15% of starch (rice, potato, and tapioca) to enhance functional and sensory properties.

Results: The results showed that there was no significant difference in chemical and nutritional content of tortillas with different starches but some physical differences were observed. The descriptive sensory analysis was conducted that eliminated tortillas with tapioca starch due to least likeability. The sensory acceptability study showed that overall likability was slightly higher for tortillas with potato starch in comparison to rice starch which correlated with higher scores for taste, texture, and aroma of the tortillas with potato starch. On the other hand, the appearance of the rice starch was preferred in comparison to tortillas with potato starch which correlated with the smooth and spreadable characteristics of rice starch.

Conclusion: The results indicated that incorporation of potato starch results in the formulation of chickpea fortified finger millet tortillas with acceptable textural and sensory properties which would be a gluten-free, nutrient-dense alternative to traditional tortillas.

Keywords
Finger millet; Chickpea; Celiac disease; Tortilla; Starch; Gluten-free; *Cicer arietinum*; *Eleusina coracana L.*

INTRODUCTION

Millets are a good source of phytochemicals, micronutrients, and essential amino acids except for lysine and threonine. There have been studies that have shown potential health benefits in many conditions such as diabetes, cardiovascular disease, aging, cancer, and celiac disease.[1] There are six types of most common and important millets, amongst them finger millet has the highest amount of calcium, potassium, sodium, dietary fiber, and iron.[2] Millets are ancient grain that had been cultivated as early as 2700 BC in China, continue to be stapled in India, and eastern and central Africa while in developed countries millets are used as cattle feed.

The nutrition composition of millets is comparable to other cereals and they are superior source in terms of dietary fiber, minerals, B-vitamins, starch properties and physiological action.[2] Studies were conducted on 76 varieties of finger millet from all over the world for years and the nutritional composition of finger millet determined; it consists of 73 to 82% of carbohydrate, 4 to 8% of protein, 1 to 4.5% of lipid, 200 to 450 mg calcium, 5 to 15 mg iron, 0.4 to 4 mg B-vitamins, 3 to 12% crude fiber and seven essential amino acids.[3] The carbohydrate composition of finger millet consists of 15 to 20% of dietary fiber and 2 to 4.5% free sugar and mostly starch consisting of amylose, amylopectin, and other starch fractions.[2,4] Finger millet is also a very good source of micronutrients especially calcium and iron. According to Gopalan, it has 344 mg% of calcium, 3.9 mg% of iron and 283 mg% of phosphorus in comparison to other cereal grains and millet.[5]

Finger millets are very versatile grain that can be used in many different types of foods and processes including fermented, germinated, puffed, milled and baked or cooked into food products. Traditionally finger millet was considered poor man's food and used to make staples like unleavened bread, porridge, finger millet balls, and some non-alcoholic as well as alcoholic drinks. In the last two decades, the properties of finger millet have been in the limelight which has contributed to a renewed interest and commercial products in the market. There are nearly 40 processed foods that have been documented most of which are in India.[3]

Chickpea (*Cicer arietinum* L.) is a Leguminosae family legume that originated in Asia, it contains high amount of protein (23-27%) and lipids (5.8-6.2%) compared to other legumes.[6] Chickpea is high in lysine which makes it an excellent protein enhance in tortillas with finger millet which is a deficit in lysine. The combination on finger millet flour and chickpea would be a perfect match to fulfill the requirement of all the basic macro and micronutrients. The struggle in the formulation of the tortilla is the absence of gluten in these flour. However, the specific amino acids content of chickpea has characteristic of high foam expansion and stability in comparison to other legumes which is beneficial in gluten-free product development.[7]

The growing trend of ethnic food in the United States has peaked the demand of tortillas; making the tortilla industry the fastest growing sector in the baking industry in U.S. Tortillas were commonly made with wheat and/or corn flour; the budding tortilla industry opens up opportunities to explore various legumes and millets as alternative ingredients to the gluten-free landscape. However, studies for optimization of tortilla made of millet and chickpea are limited. We aim to study the formulation and optimization of finger millet tortillas fortified with chickpea flour that could be an alternative to a traditional flour tortilla.

MATERIAL AND METHODS

Finger millet (*Eleusina coracana L.*) flour and chickpea (*Cicer arietinum*) was procured from Swad Food Products (Skokie, IL, USA). Starches (rice, potato, and tapioca) and glycerin were procured from Ingredion, Inc., (Westchester, IL, USA) and Plant Guru (Plainfield, NJ, USA), respectively. All other ingredients were procured from a local market in Edmond, Oklahoma.

Optimization of the Tortilla Flour

Chickpea is high in protein specifically lysine which makes it an excellent fortifying legume to compliment finger millet which is deficient in lysine. Moreover, according to Bazzi et al, the specific amino acids content of chickpea has characteristic of high foam expansion and stability in comparison to other legumes which is beneficial in gluten-free product development.[8] The combination on finger millet flour and chickpea would not just fulfill the requirement of all the macro and micronutrients but also aid in stability of gluten-free tortillas. The chickpeas were grinded and both flours (finger millet and chickpea) were passed through 60 mesh size (250 microns) to obtain uniform particle size flour. The flours were then combined at the ratio of 70:30 w/w to obtain a protein content of 12.1 g per 100 g flour; 2% of sugar was added to enhance flavor and 4% glycerin to aid in stability. Other ingredients included starch, baking powder, and olive oil. A preliminary experiment was conducted to determine the optimum amount of starch to use in tortillas based on their binding effect of the dough and final tortilla. Four percentage (5, 10 15 and 20%) levels of starch were used. The tests performed were physical appearance and rollability of the tortillas. Tortillas with 5% and 10% starch did not improve their physical appearance and rollability while tortillas with 15% and 20% had similar physical characteristics. Therefore, 15% of starch was selected to keep the quantity of starch low and to help in the binding of the dough.

Processing of Chickpea Fortified Finger Millet Tortilla

A hot-press tortilla-making process was used to make tortillas. Dry ingredients (finger millet flour, chickpea flour, starch, baking powder, sugar, hand salt) were mixed for 1 minute and 30 s on speed 1 in a KitchenAid mixer (KitchenAid, St. Joseph, MI, USA). Olive oil and glycerin were added and mixed for 45 s at speed 1. The sides were scraped down with a spatula and the ingredients mixed further for another 45 s at speed 2 until no clumps are visible. Warm water (38 ^{o}C) was slowly added while mixing at speed 1 and increasing to speed 3 for a total mixing time of 1 minute and 30 s. The dough was kneaded for 30 s with a hook in the mixer, rested for 10 min in a plastic container with a lid to retain moisture. The dough was divided into 60 g balls and stored in a plastic container with a lid until ready to bake.

A tortilla maker (CPP-200 International Chef™ Stainless Steel, Cuisinart Kitchen Appliances, Stamford, CT, USA) was used. The dough balls were pressed for 6 s and baked in for 1 min and 30 s at 204 °C. Tortillas were cooled on a cooling rack for 2 minutes, stored in a re-sealable plastic bag for 2 h before analysis. The tortillas were processed in triplicate. The cooking time was determined by a preliminary experiment using at 204 ^{o}C for 80, 90 and 100 s. The evaluation included color, texture and sensory evaluation.

Physio-Chemical and Nutritional Quality of Flours

Moisture content and ash of finger millet and chickpea flour was determined using American Association of Cereal Chemists (AACC) approved method 44-15.02 and 08-01, respectively. Protein content were determined according to the Association of Official Analytical Chemists (AOCS) method, Ba 4d-90.

Physio-Chemical Characteristics of Tortillas

A 6-inch liquid-crystal display (LCD) digital caliper was used to determine the diameter and thickness of baked tortillas; diameter was the average two perpendicular measurements of 3 baked tortillas and thickness was the average of a stack of 3 tortillas. The weight 3 tortillas were recorded using an analytical balance and the average reported. Moisture content and ash of the tortillas was determined using AACC approved methods 44-15.02 and 08-01, respectively. The color of the tortillas was determined using Hunter Lab MiniSacn XE Plus (Reston, VA, USA) and L, a, b values were reported. Calcium analysis of the baked tortillas was done using flame atomic absorption spectrometry method described by Bazzi, Kreuz, & Fischer[8] and pH of the tortillas was determined using a pH meter model pH-009 (I) pen type that had been calibrated against standard buffers 7 and 4.

Texture Evaluation

Stretchability and extensibility of the tortillas were evaluated on three replicates of 10 baked tortillas each using a TA-XT2i textural analyzer (Texture Technologies Corp., Hamilton, MA, USA/Stable Micro Systems, Godalming, Surrey, UK).

Stretchability Test

A 60 mm TA-108 Tortilla Fixture and a 20 mm TA-108 acrylic rounded edge probe were used. The test settings included 20 g force, the test speed of 1.70 mm/s; distance 30 mm total before returning to its original position.

Extensibility Test

TA-96 tensile grips were used and the test settings were 5 g force, test speed of 1 mm/s and 25 cm distance. Samples were cut using a stainless steel dog bone template with an average length of 60 mm and samples obtained secured with the tensile grips. The tortilla pieces were pulled up vertically and the maximum peak force values and distance values were recorded.

Nutritional Analysis

Nutritional analysis of the tortillas was performed using Genesis R&D software (ESHA Research, Salem, OR, USA; version 9.12.1.0) at the University of Central Oklahoma.

Sensory Evaluation

Sensory evaluation of the tortillas was conducted at the University of Central Oklahoma in two independent evaluations (duplicate). A descriptive analysis of three sample tortillas (T-Rice, T-Tapioca, and T-Potato) was done by trained panelists consisting of dietetic interns and graduate students, the result of the analysis lead to the elimination of the T-Tapioca treatment. The remaining two samples (T-Rice and T-Potato) were taken further into additional testing and sensory acceptance study. Sensory acceptance study was conducted by students and staff. Institutional review board's (IRB) approval was granted for all stages of this study through the University of Central Oklahoma.

Descriptive Analysis

The dietetic interns and food science graduate students were selected as candidate subjects by personal interview and questionnaire. All candidates had experience working with foods. A tortilla descriptive analysis was evaluated by 8 trained panelists. A modified Spectrum™ method was used.[9] Briefly, flavor (sweet, salty, nutty, bitter, doughy) and texture (roughness, tearability, hardness, fracturability, grittiness) attributes were studied. The panelists were trained in two sessions; in the first four-hour training session the attributes and references on taste, texture, odor, and appearance of the tortillas were defined. Attributes developed by experience in a previous study of the research group of sorghum flour in the research group was referred from a similar study on sorghum flour which accounted for all the characteristics of the finger millet flour and a 15-point numbered absolute scale was used to score perceived intensity. In the second session, the attributes and references were analyzed and refined with standard compounds. The final session, sampling the tortillas were conducted the next day to eliminate panelist fatigue and were provided with three samples of tortillas on a white paper plate with random three-digit numeric codes assigned. The sensory sessions were conducted at 22-24°C, the panelists were provided with unsalted crackers and distilled water to cleanse their palate after each sample in separated booths for all the sessions.

Consumer Acceptance Study

The consumer acceptance study was conducted at the University of Central Oklahoma with fifty (50) untrained panelists and included survey questions on demographics, education, and consumption of tortillas. Tortillas with rice starch and potato starch were the samples in the study. The sample tortillas were placed on a white paper with a three-digit numeric code assigned to each. Samples were given to the panelist one at a time to eliminate bias; unsalted cracker and distilled water were provided to cleanse their palate between tastings. A 9-point hedonic scale ballot was provided to score each sample. The 9-point hedonic scale displayed degrees of like and dislike (1, extremely dislike; 9 extremely like). The attributes tested were appearance, aroma, texture, tenderness, taste, and overall likability. The study was conducted at 22-24 °C temperature room in separated booths.

Statistical Analysis

All the analyses (except nutritional analysis) were conducted in triplicates. Means and standard deviations of all samples were reported for color, moisture, nutrition, and sensory evaluations. One-way ANOVA was performed using the general linear model procedure to identify significant difference ($p<0.05$) among the samples followed by Tukey's test. All statistical analyses were carried out using SPSS (SPSS 20.0, IBM Crop, Armonk, NY, USA) and microsoft excel 2016 MSO, version 16.0.6001.1078.

RESULTS AND DISCUSSION

Physical and Chemical Measurements

Moisture, ash, protein, and calcium content of finger millet flour and chickpea flour: The average moisture, ash and protein content of finger millet flour, chickpea flour, potato starch, and rice starch were reported in table 1 the results agree with those of Ozer et al who reported chickpea containing 17.55-23.32% of protein, 2.54-3.41% of ash and 6.39-10.57% of moisture.[10] The results are in agreement with previous reports of finger millet showing approximately 7% protein, 1.7-4.13% ash and 13.2% of moisture.[2,11] The slight variation comparing to literature reports could be explained in part by different varieties of the grains used. There was no significant difference in moisture content of the flours but there were significant differences in ash and protein content. The ash of chickpea flour was higher than finger millet flour which shows there is a higher quantity of minerals in chickpea flour in comparison to finger millet flour. The data for potato starch and rice starch was obtained from their manufacturer. The calcium analysis using flame atomic absorption (FAA) showed that finger millet has 43.553 mg of calcium per 100 g and chickpea has 14.167 mg per 100 g.

Table 1. *Comparison of Moisture, Ash and Protein Content Results of Finger Millet Flour and Chickpea Flour**

Sample	Moisture (%)	Ash (%)	Protein (%)
Finger millet flour	10.7±0.09^a	1.83±0.13^a	5.2
Chickpea flour	10.3±0.11^a	2.41±0.31^b	19.7
Potato Starch	4%	0.21%	<0.1%
Rice Starch	12%	0.24%	0.43%

*Means±standard deviation with different superscripts within columns indicate significant differences among treatments (p<0.05).

Weight, diameter, thickness and bake-off moisture percentage of Tortillas: Table 2 shows the weight, diameter, and thickness of finger millet tortillas made with rice and potato starches. There was a significant difference in weight and diameter but no significant differences in thickness of the tortillas. The weight of the tortillas is indirectly proportional to the bake-off moisture % of the tortillas. The bake-off moisture % of T-Rice tortilla containing rice starch is higher than T-Potato tortilla made with potato starch which shows that more moisture was baked off in the process of making the tortilla in comparison to T-Potato. The moisture bake-off from the tortilla is also a characteristic of starch, it shows that potato starch absorbs and holds more water than rice starch. The potato starch has larger, irregular granules and higher content of phosphate group in comparison to rice starch which has been reported supporting in higher swelling power without disintegration.[12,13]

The diameter and the thickness of the tortillas are indirectly proportional; higher diameter co-relates to lower thickness due to the spreadability of the tortillas. T-Rice had higher spreadability with higher diameter and lower thickness compared to the T-Potato (Table 2). This is in part explained by the small mean diameter of rice starch and unique spreadable characteristics which is valuable in food as well as pharmaceutical applications.[14]

Moisture content, ash and pH: Average moisture content, ash, and pH of two chickpea fortified finger millet tortilla sample (Table 2). There were no significant differences in moisture content, ash or pH of the sample tortilla. It is interesting that the moisture content of the final tortillas was similar despite showing significant differences in bake-off values. In these formulations, the type of starch used did not affect moisture, ash, and pH of the tortillas.

Color: Table 3 shows the average 'L', 'a', and 'b' values which were significantly different in both the samples. The tortillas T-Potato made with potato starch were lighter in color in comparison to T-Rice made with rice starch with a 'L' value of 57.1. The values of 'a' were higher in T-Rice which indicates that it has more redness and values of 'b' T-Potato were higher indicating more yellow color. According to Singh et al, the higher phosphate monoester content in potato starch results in pastes with higher light transmittance whereas higher phospholipids in cereal starch (rice) results in pastes with lower transmittance.[11] According to recent study on gluten free rice flour tortillas, L* value of chapati increased with increase in rice flour concentration from 0% to 20%.[15] The transmittance properties of the starches explain the lighter color of tortillas with potato starch in comparison to tortillas with rice starch. According to Yang, Hattori, Kawaguchi & Takahashi, Maillard reaction occurs between potato starch and

Table 2. *Comparison of Weight, Thickness, Diameter, Moisture, Ash, and Ph Results of Chickpea Fortified Finger Millet Tortillas with Different Starches**

Starch type	Weight (g)	Thickness (mm)	Diameter (mm)	Bake-off moisture (%)	Moisture %	Ash %	pH
T-Rice[1]	46.50±0.39^a	3.28±0.36^a	144±2^a	33.5	26.4±0.09^a	2.86±0.07^a	6.48±0.08^a
T-Potato[2]	49.25±0.94^b	3.61±0.09^a	134±3^b	28.0	26.6±0.04^a	2.86±0.03^a	6.48±0.02^a

*Means (n=3)±standard deviation with different superscripts within columns indicate significant differences among treatments (p<0.05).

[1]Chickpea fortified finger millet tortilla with rice starch.

[2]Chickpea fortified finger millet tortilla with potato starch.

Table 3. *Comparison of Color and Texture (Extensibility and Stretchability) Results of Chickpea Fortified Finger Millet Tortillas with Different Starches**

Sample	Color			Bake-off moisture (%)		Ash %	
	L	a	B	Force (g)	Distance (mm)	Force (g)	Distance (mm)
T-Rice[1]	52.56±0.99^a	8.32± 0.15^a	16.64±0.33^a	8.32± 0.15^a	16.64±0.33^a	424.6±38.31^a	3.92±0.75^a
T-Potato[2]	57.09±1.41^b	7.82±0.39^b	17.62±0.83^b	7.82±0.39^b	17.62±0.83^b	372.14±53.77^b	3.82±1.09^a

*Means±standard deviation with different superscripts within columns indicate significant differences among treatments (p<0.05).

[1]Chickpea fortified finger millet tortilla with rice starch.

[2]Chickpea fortified finger millet tortilla with potato starch.

lysine resulting in higher yellowness, which explains the yellower color of tortillas with potato starch in comparison to tortillas with rice starch.[15]

Texture (stretchability and extensibility): T-Rice tortillas were firmer but had an insignificant difference in distance meaning they had similar extensibility. According to Frenholz, a higher force indicates greater stretchability, the higher force on T-Rice suggests that it has the higher stretchability in comparison to T-Potato tortillas with potato starch. However, Frenholz also states that gluten-network in wheat tortillas creates flexibility so, stretchability test may not be a good indicator for a gluten-free tortilla due to the absence of gluten-network.[16]

Table 3 shows the average force and distance of the tortillas testing its extensibility. There was significantly different for force and distance with the lowest value of 1184.93 g. According to Suhendro, a low force value and longer distance of extension indicate soft and extensible tortillas whereas higher force value and shorter rupture distance indicates hard and brittle tortillas.[17] T-Rice made with rice has the low force and long distance whereas T-Potato made with potato has the high force and short distance making indicating T-Rice being softer and more extensible than T-Potato.

Nutrition Analysis

There was no significant difference in nutritional facts of the tortillas since the only difference in the formulation was the use of different starch which had similar properties. The composition of starches is very similar consisting of polymers and minor compound however the physio-chemical properties and functional characteristics are subjected to an aqueous system, biological origin and annealing.[11,14]

Sensory Analysis

Descriptive analysis: Table 4 shows the descriptive analysis for flavor, the only significant difference was in sweetness and doughy after taste of the tortillas. The tortillas with potato starch were the sweetest compared to the tortilla with tapioca starch which has an average score of 1.4 (least sweet comparable to 0.47 or sucrose solution). The doughy profile was high (5.5 scores comparable to butter roll) for tortillas with potato starch while the scores were similar for tortillas with rice or tapioca starch. Overall the highest acceptance scores were observed on tortillas with potato starch compared to those with rice or tapioca starch.

In attributes of texture (Table 4), there was no significant difference across the parameters both in hand and mouth feel the texture. But the scores for roughness and tearability were slightly higher for a tortilla with potato starch which correlates with the physicochemical texture data that indicated it is firmer in comparison to a tortilla with rice starch.

The shape is the only attribute that has significant difference in context of appearance of the tortillas (Table 5). The tortillas with rice starch were rounder than other tortillas with a high score of 14.1. The data indicates that tortillas with rice starch and tortillas with tapioca starch were rounder and smoother than tortilla with potato starch.

In odor and overall likability (Table 5), there was no significant differences among the three types of tortillas, but the scores indicated that tortillas with tapioca starch, tortillas with rice starch and tortillas with potato starch had least sweet and musty odor respectively. The panelists preferred tortillas with potato starch with an overall likability score of 11.1 and disliked tortillas with tapioca starch with the least score of 6.9. Due to

Table 4. *Comparison of Flavor and Texture Attributes in Description Analysis of Chickpea Fortified Finger Millet Tortillas with Different Starches*[*]

	Flavor					Texture				
Sample	Sweet[I]	Salty[II]	Nutty[III]	Bitter[IV]	Doughy[V]	Roughness[I]	Tearability[II]	Hardness[III]	Fracturability[IV]	Grittiness[V]
T-Rice[1]	1.6±0.74^{a}	2.3±0.71^{a}	6.5±2.62^{a}	1.3±0.71^{a}	2.9±.099^{a}	5.5±1.07^{a}	12.3±2.38^{a}	8.6±3.96^{a}	7.3±3.20^{a}	5.6±3.99^{a}
T-Potato[2]	2.6±0.92^{b}	2.6±1.51^{a}	6.1±3.18^{a}	1.0 ±0.00^{a}	5.5 ±2.56^{b}	6.1±2.90^{a}	12.5±2.14^{a}	5.8±1.66^{a}	5.9±2.85^{a}	3.1±1.45^{a}
T-TAPIOCA[3]	1.4±0.52^{a}	1.8±0.89^{a}	5.6±2.20^{a}	2.0±1.77^{a}	3.0±1.69^{a}	5.4±1.19^{a}	12.4±1.77^{a}	7.9±3.39^{a}	6.4±2.19^{a}	5.0±3.07^{a}

[*]Means±standard deviation with different superscripts within columns indicate significant differences among treatments (p<0.05).

1. Chickpea fortified finger millet tortilla with rice starch.

2. Chickpea fortified finger millet tortilla with potato starch.

3. Chickpea fortified finger millet tortilla with tapioca starch.

Flavor:

I. Sweet intensity was evaluated on a scale from 1 (not detectable) to 15 (extremely sweet)

II. Salty intensity was evaluated on a scale from 1 (not detectable) to 15 (extremely salty)

III. Nutty intensity was evaluated on a scale from 1 (not detectable) to 15 (extremely nutty)

IV. Bitter intensity was evaluated on a scale from 1 (not detectable) to 15 (extremely bitter)

V. Doughy intensity was evaluated on a scale from 1 (not detectable) to 15 (extremely doughy)

Texture:

I. Roughness intensity was evaluated on a scale from 1 (not detectable) to 15 (extremely rough)

II. Tearability intensity was evaluated on a scale from 1 (easily pulled apart) to 15 (extremely hard to pull apart)

III. Hardness intensity was evaluated on a scale from 1 (extremely easy to bite down) to 15 (extremely hard to bite down)

IV. Fracturability intensity was evaluated on a scale from 1 (extremely easy break) to 15 (extremely hard to break)

V. Grittiness intensity was evaluated on a scale from 1 (absence of gritty particles) to 15 (extremely presence of gritty particles)

Table 5. *Comparison of Appearance Attributes, Odor and Overall Likability in Description Analysis of Chickpea Fortified Finger Millet Tortillas with Different Starches**

Sample	Appearance			Odor		
	Evenness of the color[I]	Shape[II]	Surface[III]	Sweet[I]	Musty[II]	Overall likability[III]
T-Rice[1]	9.8±3.73[a]	14.1±0.35[a]	6.0±2.97[a]	2.0±1.07[a]	6.8±2.36[a]	9.3±2.76[a]
T-Potato[2]	8.3±3.77[a]	8.6±3.02[b]	6.5±3.33[a]	2.1±1.46[a]	5.8±3.69[a]	11.1±3.72[a]
T-TAPIOCA[3]	11.3±2.12[a]	12.5±2.5[a]	5.6±2.06[a]	1.8±1.49[a]	7.3±2.76[a]	6.9±4.32[a]

*Means±standard deviation with different superscripts within columns indicate significant differences among treatments (p<0.05).

1. Chickpea fortified finger millet tortilla with rice starch.

2. Chickpea fortified finger millet tortilla with potato starch.

3. Chickpea fortified finger millet tortilla with tapioca starch.

I. Evenness of the color intensity was evaluated on a scale from 1 (very even) to 15 (extremely uneven)

II. Shape intensity was evaluated on a scale from 1 (not round) to 15 (perfectly round)

III. Surface intensity was evaluated on a scale from 1 (presence of blistering) to 15 (absence of blistering)

IV. Sweet intensity was evaluated on a scale from 1 (not detectable) to 15 (extremely sweet)

V. Musty intensity was evaluated on a scale from 1 (not detectable) to 15 (extremely musty)

VI. Overall likability intensity was evaluated on a scale from 1 (extremely dislike) to 15 (extremely like)

low score tortillas with tapioca was eliminated from the experiment and tortillas with rice and potato starch continued for testing and sensory acceptability study.

Consumer study: Table 6 shows the average scores from the consumer acceptability test. Appearance is the only attribute that has significant differences with a score of 6.3 for a tortilla with rice starch and 5.6 for a tortilla with potato starch. The overall likability score for a tortilla with potato starch were slightly higher in comparison to a tortilla with rice starch which correlates with the higher score in taste, aroma and texture. In contrast, the appearance and the tenderness score were low for a tortilla with potato starch which correlates with it being smaller, thicker and tougher tortillas from physicochemical testing. According to Wani et al, rice starch has bland taste, smooth, creamy and spreadable characteristics which correspond with lower scores in taste but higher scores in appearance and tenderness of the tortillas with rice starch.[14]

Table 6. *Comparison of Scores from Consumer Acceptance Study of Chickpea Fortified Finger Millet Tortillas with Different Starches**

Sample	Overall likeability	Appearance	Texture	Tenderness	Aroma	Taste
T-Rice[1]	6.0±1.77[a]	6.3±1.51[a]	5.8±1.68[a]	6.0±1.76[a]	5.9±1.39[a]	5.9±1.82[a]
T-Potato[2]	6.3±1.7[a]	5.6±1.70[b]	6.0±1.75[a]	5.9±1.93[a]	6.1±1.51[a]	6.0±1.87[a]

*Means ± standard deviation with different superscripts within columns indicate significant differences among treatments (p<0.05).

1. Chickpea fortified finger millet tortilla with rice starch

2. Chickpea fortified finger millet tortilla with potato starch

Physical, chemical, textural and sensory testing showed differences between tortillas with different starches. The tortillas with rice starch were better in texture and appearance whereas the overall acceptability was higher for tortillas with potato starch due to its flavor neglecting the textural characteristics. The results indicated that incorporation of potato/rice starches may result in the formulation of chickpea fortified finger millet tortillas with acceptable textural and sensory properties which would be a gluten-free, nutrient-dense alternative to traditional tortillas for people with celiac disease and a potential medicinal food for people with diabetes.

The increasing prevalence of obesity and overweight are linked to several health conditions (diabetes, cardiovascular disease, etc.), along with the growing incidences of food allergies are of major concern globally. These health conditions are not only talking toll in the health but also the economy of the people. The change in lifestyle and diet are one of the few measures to reduce risk and manage these conditions. The availability of healthier food choices and the awareness of functional ingredients are of utmost importance. Finger millet is an ancient millet grain that has superior nutritional values and has shown to aid in many health conditions. Formulation of food incorporating finger millet could provide alternative and boost healthier diet leading to better health.

However, the textures of the tortillas with potato starch was not ideal and comparable to commercial tortillas. Further research should include hydrocolloids and emulsifiers (sodium stearoyl lactylate, diacetyl tartaric acid ester of mono- and diglycerides (DATEM), and others) to improve the overall quality of the tortillas. The shelf- life of the tortillas has not been studied in this research, so further research is required in the field of the shelf- life along with research on the effect of high protein flour composition as an alternative of gluten.

CONCLUSION

Nutrient-dense gluten-free chickpea fortified finger millet tortillas optimized with rice and potato starch was analyzed for physical, chemical, textural and sensory properties. The results indicated that incorporation of potato/rice starches may result in the formulation of chickpea fortified finger millet tortillas with acceptable textural and sensory properties producing a gluten-free, nutrient-dense alternative to traditional tortillas for people with celiac disease and a potential medicinal food for people with diabetes. The overall acceptability was higher for tortillas with potato starch due to its flavor but there is room for improvement of the texture of tortillas with potato starch. Further research should include hydrocolloids and emulsifiers to improve overall texture quality and shelf life of the tortillas.

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CONFLICTS OF INTEREST

Dr. Bhargava reports in addition, Dr. Bhargava has a patent composition and process for making millet-based flour useable informed food products pending to the University of Central Oklahoma.

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