



Development of gluten-free cracker snacks using pulse flours and fractions

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ABSTRACT

With nearly two million North Americans suffering gluten intolerance, the objective of this study was to develop gluten-free, pulse-based cracker snacks that exploit the anti-allergenic and health-enhancing nature of pulses ingredients. Nine commercially available pulse fractions (chickpea, green and red lentil, yellow pea, pinto and navy bean flours and pea protein, starch and fibre isolates) were evaluated in a model cracker formulation. Early prototype crackers exhibited light colour, good flavour, and crisp texture. Based on its acceptability data, processing characteristics and consultation with an industry partner, the chickpea cracker formulation was advanced to a commercial-scale processing trial. The physical and nutritional characteristics of these pulse crackers were similar to existing products on the market. The products were scored highly during consumer acceptance testing. Interestingly, the % daily values per serving of iron in the chickpea crackers were 3–6 times higher than existing products. Based on these findings, pulse-based, gluten-free crackers have good potential for both consumer appeal and imparting health benefits.

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1. Introduction

The world snack food market was valued at \$66 billion USD in 2003 with baked goods, cookies and crackers, meat snacks, and popcorn accounting for about 22% of these sales (Hodgen, 2004). In Canada, the snack food industry includes manufacturers of potato chips, corn chips, popped popcorn, pretzels, extruded cheese snacks, seed snacks, mixed nuts, peanuts, and others. In 2003, 89 Canadian snack food manufacturers produced \$1.6 billion worth of snack products including \$160 million (9.8%) for export. The growth rate of the market is about 6.2% annually (AAFC, 2003). This market is relatively saturated, however, room remains for niche products high in nutrients such as fibre, protein, and omega-3 fatty acids, or gluten-free. Statistics show that the gluten-free market has grown by 27% since 2001, and this growth rate is projected to continue until at least 2010 (Heller, 2006). With about 1% of North Americans suffering from gluten intolerance, there is an opportunity to develop specialty products for this market.

Pulses are annual, leguminous, edible seeds that grow in pods and encompass a wide range of sizes, shapes, and colours. Although they are leguminous, oilseeds such as soybeans and peanuts, and vegetable crops such as green beans and green peas are not included in the definition of pulses. Pulses are a staple food essential to human diets in many parts of the world, and have significant cultural and historical importance. Over the past 20 years, the Canadian pulse crop industry has grown to become the world's

largest exporter of dry peas and lentils and a major exporter of coloured beans (AAFC, 2005). With an annual production of 4–4.5 million tonnes, approximately 75% of Canadian pulse production is exported to about 150 countries around the world.

Pulses are now recognized as a food choice with significant potential health benefits. Pulses contain complex carbohydrates (dietary fibres, resistant starch, and oligosaccharides), high protein with a good amino acid profile (high lysine), important vitamins and minerals (B-vitamins, folates, and iron), as well as antioxidants and polyphenols. Pulses are also gluten-free and have a low glycemic index, characteristics with benefits for people with diabetes, cardiovascular disease, and celiac disease. Taken together, pulse production and snack industry statistics highlight a great opportunity to develop and introduce a healthy, gluten-free cracker made with pulse ingredients.

Historically, crackers were a matter of convenience for people on the run, namely Jews fleeing from Egyptian slavery. Because they were too rushed to allow their dough to rise, “matzoh” was the result. Early crackers, or “biscuits” as the English called them, were handmade, hard-baked products made from flour and a little moisture (Zohary, 1982). The low level of moisture, decreased even further with baking, left no medium for mold growth. Since these crackers were made with little fat, rancidity was not a concern. Crackers remain a versatile food, and manufacturers are moving to meet consumer demand by providing an increased variety of low-fat and convenient options. Consumer desire for healthy snacks is resulting in an increasing variety of products that are low-fat, low-salt, and low- or no-cholesterol.

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Crackers are defined as thin, crisp wafers or biscuits, usually made of unsweetened and unleavened dough. Crackers can be divided into three main categories based on their differences in ingredients and methods of production (Shukla, 1994). Soda crackers (also called saltines or cream crackers) make up the bulk of sales. They are produced using a sponge and dough system whereby a portion of the ingredients are mixed together and allowed to ferment for 16–20 h. During this time, changes occur in the mixture that contribute to textural and flavour properties. The remainder of the ingredients is added to the sponge and the dough is allowed to rest and ferment for another 3–6 h prior to baking. The second category is snack (sprayed) crackers. These crackers are usually chemically leavened using sodium or ammonium bicarbonate in the presence of a food grade acid for a period of 30 min to 4 h. The last category is flavoured (savory) crackers. These crackers have added flavours, such as cheese or spices, are usually fermented, and are often produced in a manner similar to soda crackers. After the rest period, dough for all three cracker types is sheeted, laminated, docked, and baked. The dough is usually sheeted to about 2 mm and cooked at 200–300 °C for 2–5 min.

The objective of this study was to screen and evaluate functionality and characteristics of various commercially available pulse fractions for efficacy in processed baked products. This study focused on the developing a gluten-free cracker snacks utilizing pulse flours and fractions.

2. Materials and methods

2.1. Preliminary ingredient testing and formulation development

Six pulse flours (desi chickpea, green lentil, red lentil, pinto bean, navy bean, and yellow pea), and three yellow pea fractions (protein, fibre, and starch isolates) were examined in the study. All pulse flours and fractions are commercially available in Western Canada. During the preliminary phase of the project, the basic characteristics of the pulse ingredients, and the functionality of the doughs made at various levels of pulse ingredient inclusion, were assessed.

Moisture content of pulse flours and fractions was determined in duplicate using a Sartorius moisture analyzer (Goettingen, Germany).

The colour of each pulse ingredient was measured using a Konica Minolta CM-2500C Spectrophotometer (Mississauga, ON). The colour profile of each ingredient was measured in quadruplicate and reported according to the CIE colour system (International Commission on Illumination) where L^* represents brightness on a scale of 0 (black)–100 (white), a^* represents a scale of +50 (red) to –50 (green), and b^* represents a scale of +50 (yellow) to –50 (blue). Data were subject to one-way analysis of variance to determine if differences between the ingredients were significant.

The distribution of particle size within each pulse ingredient was evaluated. A stacked set of six Tyler sieves with pore sizes of 841, 400, 250, 177, 149, and 125 µm from top to bottom, respectively, was loaded with 100 g of an ingredient. Using a Ro-Tap shaker (Tyler Industrial Products Co., Mentor, OH), the sieves were vibrated for 2 min and the weight of material remaining on each sieve was determined gravimetrically. Measurements were made in duplicate and reported as a percent (w/w basis).

Throughout this phase, the project team observed the doughs made with each pulse ingredient and provided feedback about ease of pulse ingredient use and incorporation into doughs, and dough handling during mixing and sheeting.

Crackers are typically made with soft wheat flour containing 10–12% protein. Wheat gluten plays an important role in development of cracker taste and texture (Tharanathan & Mahadevamma,

2003), and additional ingredients must be used to compensate for a lack of these properties in gluten-free cracker products. As such, the use of other baking ingredients and improvers, including pregelatinized rice starch, modified starch, xanthan gum, carboxy methyl cellulose, hydroxy propyl methyl cellulose, hydrocolloids, surfactants, and maltodextrin was also evaluated during preliminary formulation trials. The effect of these ingredients, however, was minimal. Gluten-free pulse crackers formulated without the baking additives were of reasonable quality. Further product development work proceeded with the use of <1% xanthan gum to simulate a commercial process.

Based on results of preliminary ingredient investigation, a base formulation for pulse-based crackers was developed by focusing on ingredient simplicity to allow for clear identification of the effects of pulse flours and fractions on cracker quality. Ease of later scale-up under commercial conditions was also considered. Ultimately, a popular quick soda cracker formulation was chosen and modified to accommodate the unique characteristics of pulses flours and fractions. Table 1 lists formulations for typical soda crackers containing wheat gluten and the base pulse cracker snack used in the rest of study.

2.2. Bench top-scale processing trial

Once acceptable levels of pulse ingredients were established, the ingredients with best potential to improve or modify the functional and rheological properties of the cracker products, without adversely affecting their sensory attributes, were evaluated in a bench-top processing trial.

2.2.1. Processing

The procedure for making the pulse cracker snack is outlined in Fig. 1. All dry ingredients, except sugar, were mixed in a mixer/processor at a high-speed setting for 30 s. The liquid ingredients (water, oil) and sugar were mixed separately for 30 s to form an emulsion. While continuously mixing the liquid ingredients, the dry ingredient blend was gradually incorporated into the emulsion over 3–4 min to form a dough. The mixed dough was rested for 10 min at room temperature to ensure uniform distribution of the liquids. The dough was then passed three times through a set of smooth stainless steel rotating drums (Model 150, Ohtake Noodle Machine Mfg. Co., Tokyo, Japan), gradually narrowing the gap between the rollers to minimize damage to the dough matrix. The roller gap was 6 mm for the first and second passes, and 2 mm on the third pass. After the first pass, the dough was folded into three layers and laminated during the second pass. Circular crackers (67.5 mm diameter) were cut from the dough sheet using a dough cutter, and transferred onto a mesh-wired baking sheet. The crackers were baked in a forced-air convection oven (Garland, Mississauga, ON) at 175 °C for 4 min with minor adjustments to baking time depending on the pulse flours used in the formulation.

Table 1

Formulations for typical soda cracker containing wheat gluten (flour) and the base pulse cracker used in the study.

Ingredients	Typical formula (parts)	Gluten-free formula (parts)
Soft wheat flour	100	
Pulse ingredients ^a		100
Water	25–30	27–33
Chemical leavening agent	0.6–1	0.6–0.8
Oil	6–15	20–27
Salt	1	3–4
Sugar		3–4
Dough conditioning agent	0.5–5	
Hydrocolloid gums		0.6–0.8

^a Yellow pea starch and other pulse flours or fractions.

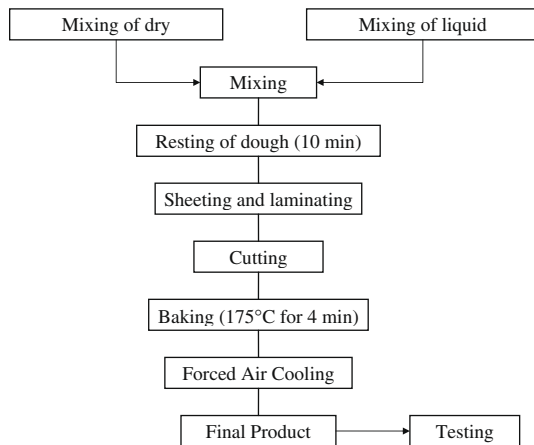


Fig. 1. Schematic diagram of the cracker snack production flow used in bench-top processing.

After baking, the crackers were left in the oven for an additional 2 min with the heat off but with forced air circulation maintained. This process simulated the drying and cooling stages of a tunnel-type commercial baking oven. Baked crackers were then removed from the oven and allowed to cool to room temperature before storage in a sealed plastic container in advance of quality evaluations.

2.2.2. Colour and texture profile analysis of bench top cracker prototypes

Colour attributes of the cracker products were measured as described for preliminary ingredient testing. Texture profile analysis of baked crackers was conducted using an Instron Universal Texture Testing Machine (Model 5565, Instron, Canton, MA) equipped with a “three-point bend rig probe” attachment. Four textural attributes were determined: first break distance (mm), initial slope (MPa; indicates stiffness), peak force (N), and total area of work (J; indicates total energy used). Textural profiles were measured in quadruplicate. Data were subject to analysis of variance to assess the effect of cracker formulation on quality parameters.

2.2.3. Sensory acceptability testing of bench top cracker prototypes

The objective of sensory evaluation during this phase of the project was to gather structured feedback about the acceptability of general characteristics of eight prototype crackers formulated with varying types of pulse ingredients in order to facilitate decision-making about which cracker formulation to move into the next stage of product development and scale-up. Sensory evaluation was conducted using 20 untrained panellists who were asked to score colour, crispiness, flavour, and overall acceptability on 9-point hedonic scales (1 = dislike extremely, 9 = like extremely), and to indicate the one sample they most preferred. Product evaluation was conducted with panellists seated in individual testing booths. Samples were presented simultaneously to allow for overall preference determination. Unsalted soda crackers are commonly used as palate cleansers; however, their use in this study would have compromised the unbiased evaluation of the pulse cracker products. As such, room temperature water infused with the juice of sliced lemons was provided as a palate cleanser. Data were subject to analysis of variance with “formulation” and “panellist” included in the model, and with “panellist” considered a random factor. Where the formulation effect was significant, a Tukey’s test was used for means separation. Correlation analysis was also conducted to assess the direction and strength of the relationship amongst product characteristics.

2.2.4. Final formulation selection

Colour and texture profile data were used to characterize the final products from each formulation, while acceptability data, observations of each formulation during processing and input from an industry partner were used to select formulations for further product development work. The chickpea flour formulation was advanced to the final phase of the project.

2.3. Commercial-scale processing trial

Commercial-scale processing was conducted at Kinnikinnick Foods Inc. (Edmonton, AB) using a 40 kg batch size with slight, but proprietary, modifications made to the formula to accommodate the requirements of the commercial-scale cracker forming equipment. To assess its suitability for commercial-scale production, the single formulation (chickpea flour based, no additional flavouring) was subject to three forming/docking processes: *four-dot mold-shaping* (4 cm cracker diameter), *one-dot mold-shaping* (4 cm diameter), and *wire-cut shaping* (3.5 cm diameter). After forming, the crackers were baked in a horizontal convection tunnel oven (APV, Peterborough, UK) equipped with three independently controlled temperature zones (Werner Lehara Ltd., Grand Rapid, MI). The oven was heated indirectly and was equipped with a wire mesh belt (33.5 m length × 1.42 m width). Baked crackers were cooled on a forced-air cooling conveyer line for 20 min. All products were packaged in plastic-wrapped trays.

2.3.1. Colour and texture profile analysis of crackers from commercial-scale processing

Colour and texture attributes were assessed as described above. These instrumental data were subject to one-way analysis of variance. Where the effect of formulation was significant, a Tukey’s test was used for means separation.

2.3.2. Consumer acceptability test of the crackers from commercial-scale processing trial

Seventy-eight consumer panellists (18–65 years of age; 44% male, 56% female) were selected on the basis of frequency (at least once per month) of snack cracker consumption. An effort was also made to recruit a substantial and balanced number of panellists who indicated that they regularly consumed gluten-free products. Each panellist evaluated all three samples, and scored shape, crispiness/crunchiness, flavour, and overall acceptability on 9-point hedonic scales (1 = dislike extremely, to 9 = like extremely), and the level of crispiness/crunchiness on a 5-point scale (1 = not crispy/crunchy, to 5 = extremely crispy/crunchy). Additional questionnaire space was also provided in which panellists could provide unstructured commentary about each sample. Samples were presented monadically, with presentation order randomized across panellists. Lemon water was, again, provided as a palate cleanser.

Data were captured electronically using *Compusense five* (v. 4.8, Compusense Inc., Guelph, ON) and subjected to analysis of variance using the General Linear Model in *SAS* (v. 9.1.3, SAS Institute Inc., Cary, NC). Main effects “formulation” and “panellist” were included in the model with “panellist” specified as random factor. Least-squares means were generated for each attribute, and Tukey’s test was used for means separation where the formulation treatment effect was significant. Hedonic score frequencies were also calculated, and unstructured commentary was reviewed.

2.3.3. Nutritional profile analysis of commercial-scale crackers

Nutritional analyses, including proximate analysis, of final crackers were carried out according to the approved official methods of *AACC International* (2000) and *AOAC* (2000) at an independent food testing laboratory.

3. Results

3.1. Preliminary ingredient testing and formulation development

The colour attributes that characterize the various pulse flours and fractions are shown in Table 2. Brightness (L^* value) ranged from 95.27 for pea starch isolate fraction to 81.48 for red lentil flour. As expected, the collective red–green profile (a^* value) ranged from -0.08 for pea starch to 20.47 for red lentil flour, highlighting the obvious redness in the colour profile of the latter ingredient. The collective yellow–blue profile (b^* value) ranged from 2.40 for pea starch to 35.43 for green lentil flour. The higher b^* value of the green lentil flour can be explained by the presence of green coloured hull fragments in the whole-milled flour.

Table 2 also displays the average particle size distribution of the pulse flours and fractions examined in preliminary ingredient investigation. The commercial pulse flours used in the study were ground from the whole seeds, including hulls, according to the manufacturer's product specification. Chickpea flour had the greatest proportion of large particle sizes with 68.5% of flour particles

larger than $250\ \mu\text{m}$. The particle sizes of green lentil and red lentil flours were more evenly distributed, with 79.6% and 67% of particles in the $12\text{--}400\ \mu\text{m}$, respectively. Pinto and navy bean flours had a narrow particle size distribution. In these flours, 63.6% and 63.4% of particles were found in the range of $177\text{--}250\ \mu\text{m}$, respectively. Pea fractions, including flour, starch, protein, and fibre isolates, had smaller particle size. In pea starch and fibre 86.3% and 59.6% of particles, respectively, were smaller than $125\ \mu\text{m}$. Eighty-six percent of pea protein particles were also smaller than $177\ \mu\text{m}$. The particle size distribution of pulse flours and fractions has the potential to substantially affect the palatability of the model crackers.

As compared to the use of pea protein and pea fibre, incorporation of pea starch and other pulse fractions into a dough formula was simpler because additional moisture was not required as for the dough with pea protein and pea fibre. The resulting dough had good mechanical handling property (i.e. mixing and sheeting) and resulting crackers exhibited brighter colour, good flavour and texture.

Table 2

Colour and particle size distribution of pulse flours and fractions assessed during preliminary investigation.

Characteristic	Pulse flours and fractions								
	Chickpea flour	Green lentil flour	Red lentil flour	Pinto bean flour	Navy bean flour	Yellow pea flour	Pea protein isolate	Pea fibre isolate	Pea starch isolate
<i>Colour</i>									
L^*	84.31 cd	82.74de	81.48de	79.85e	88.10b	88.15b	86.48bc	87.00bc	95.27a
a^*	5.69d	7.79c	20.47a	5.34d	2.95e	5.79d	9.16b	2.72e	$-0.08f$
b^*	24.37b	35.43a	33.66a	10.94 cd	9.23d	26.54b	25.05b	12.23c	2.40e
<i>Particle size distribution (%)</i>									
>20, 841 μm	0.39	0.56	1.72	0.72	0.00	0.31	2.07	3.43	0.33
>40, 400 μm	0.64	21.59	26.13	9.50	2.31	0.14	0.05	0.09	0.00
>60, 250 μm	67.43	31.79	36.05	34.58	23.90	1.98	0.76	2.43	0.11
>80, 177 μm	27.55	15.22	14.95	26.04	39.49	16.66	1.26	8.53	2.86
>100, 149 μm	0.25	2.76	1.89	2.20	1.68	28.32	1.04	33.33	9.17
>200, 125 μm	2.06	29.80	14.07	21.59	27.60	33.00	8.54	42.53	27.92
Thru 200, 125 μm	1.69	8.30	5.19	5.38	5.03	19.53	86.29	9.67	59.62

a–f: Across a row, colour characteristic means followed by different letters are significantly different ($P < 0.01$).

Table 3

Colour, texture profile, and acceptability of eight gluten-free snack crackers containing pulse fractions.

Characteristic	Pulse flours and fractions									P-value
	Chickpea flour	Green lentil flour	Red lentil flour	Pinto bean flour	Navy bean flour	Yellow pea flour	Pea protein isolate	Pea fibre isolate		
<i>Colour</i>										
L^*	79.19c	78.24c	75.12d	65.29e	82.02a	81.51ab	79.84bc	79.01c		<0.01
a^*	2.36d	3.25c	23.17a	3.57c	2.19d	2.35d	5.21b	5.34b		<0.01
b^*	34.15d	38.43b	39.61a	15.92 g	16.25 g	35.62c	31.24e	18.29f		<0.01
<i>Texture profile attributes</i>										
First break (mm)	0.47c	0.46c	0.49bc	0.54abc	0.56abc	0.60ab	0.54abc	0.65a		<0.01
Initial slope (MPa)	0.99bcd	1.35a	1.02bc	1.10b	0.81de	0.71e	0.75e	0.86cde		<0.01
Peak force (N)	16.74a	14.70b	13.16c	12.64c	8.72e	10.87d	10.99d	13.67bc		<0.01
Total energy (J)	0.006ab	0.006ab	0.007ab	0.010a	0.005ab	0.009a	0.009a	0.008ab		0.02
<i>Acceptability^A of...</i>										
Colour	6.3	6.2	6.5	6.1	6.0	6.1	6.7	6.7		0.49
Crispiness	6.5	5.8	6.2	6.2	5.7	6.3	6.6	6.7		0.10
Flavour	5.4b	5.5b	5.1ab	5.1ab	3.9a	5.1ab	5.7b	5.5b		<0.01
Overall	4.8ab	5.3ab	4.9ab	5.3ab	4.3a	4.7ab	5.9b	5.7b		<0.01
Frequency of being scored "most preferred" (%)	15	5	10	10	5	15	25	15		–

a–g: Across a row, means followed by different letters are significantly different ($P < 0.01$).

^A Scored on 9-point hedonic scales where 9 = like extremely, 8 = like very much, 7 = like moderately, 6 = like slightly, 5 = neither like nor dislike, 4 = dislike slightly, 3 = dislike moderately, 2 = dislike very much, and 1 = dislike extremely.

3.2. Bench-top-scale processing trial

3.2.1. Colour and texture profile of bench-top prototype crackers

Colour and texture profiles of the eight prototype crackers are presented in Table 3. Pulse crackers containing red lentil flour and pinto bean flour had significantly darker colour than other prototype crackers. Lower b^* values of crackers containing navy bean flour and pea fibre isolate fraction indicated slightly greener colour.

A wide range of peak forces was observed: from 8.7 N for the navy bean formulation to 16.7 N for the chickpea formulation. The first break distance attributes of crackers ranged from 0.46 mm (green lentil) to 0.65 mm (pea fibre).

3.2.2. Acceptability of bench-top prototype crackers

Although the colour differences among the prototype crackers were distinct, difference in colour acceptability was not significant (Table 3). About 77% of colour acceptability scores were in the “liking” range (6.0–9.0) of the 9-point hedonic scale, indicating that product colour within the range of samples evaluated in this test, is not likely to be a hindrance to product acceptability.

Difference for acceptability of crispiness was not significant, with mean scores ranging from 5.7 to 6.7 across the treatments. Again, relatively large proportions (about 74%) of scores were in the “liking” range of the hedonic scale. Although several panellists specifically commented on good crispiness of the crackers containing chickpea flour, red lentil flour, pinto bean flour, and pea protein isolate, there were several comments that indicated further investigation of other textural attributes might be warranted. The gluten-free nature of these products may have inhibited development of a texture resembling the wheat-based crackers familiar to many general consumers.

Flavour acceptability mean scores were substantially lower, ranging from 3.9 (pinto bean flour) to 5.7 (pea fibre), than other sensory attributes tested. Forty-five percent of scores were in the “liking” range of the scale, with nearly an equal proportion (42%) in the “disliking” range (1.0–4.0) indicating that flavour is likely to be the greatest challenge to development of a successful pulse-containing cracker. Overall acceptability was heavily influenced by product flavour. Mean overall acceptability scores ranged from 4.3 (pinto bean) to 5.9 (pea protein isolate) with a strong positive relationship to flavour acceptability ($r = 0.82$, $P < 0.01$). Panellists were also asked to indicate the one sample they most preferred, and while an outstanding “winner” was not clearly evident, the cracker containing pea fibre garnered 25% of the most preferred scores.

3.3. Commercial-scale processing trial

3.3.1. Colour and texture profile of commercial-scale crackers

Modification of the chickpea formulation for scale-up did not substantially affect the product colour profile (Table 4) compared to the bench-top prototype product (Table 3). Differences in a^* and b^* values between the four-dot and wire-cut crackers was likely due to the adjustment of baking temperatures required for each cracker style.

Forming process (mold-shaped vs. wire-cut-shaped) significantly affected cracker texture (Table 4). The diameter and thickness of the crackers varied depending on forming process and the thickness of the crackers influenced both first break distance and peak force.

3.3.2. Consumer acceptance of commercial-scale crackers

Differences between the wire-cut and mold-shaped crackers were significant across all characteristics scored on 9-point hedonic scales, while the two styles of mold-shaped crackers were not different from one another (Table 4). The wire-cut-shaped crackers

Table 4

Colour, texture profile, and acceptability of three styles of chickpea snack crackers developed during commercial-scale processing.

Characteristic	Cracker style			P-value
	Four-dot, mold-shaped	One-dot, mold-shaped	Wire-cut-shaped	
<i>Colour</i>				
L*	78.99	79.41	78.95	0.77
a*	1.56b	3.11a	3.11a	<0.01
b*	32.47a	34.00a	22.80b	<0.01
<i>Texture profile attributes</i>				
First break (mm)	0.46a	0.42b	0.21c	<0.01
Initial slope (MPa)	0.62b	0.96a	0.81ab	<0.01
Peak force (N)	4.70c	7.48a	5.17b	<0.01
Total energy (J)	0.002	0.002	0.001	0.08
<i>Acceptability^A of</i>				
Appearance	6.8b	6.9b	5.4a	<0.01
Crispiness/crunchiness ^B	5.8b	6.1b	5.3a	<0.01
Flavour	5.5b	5.4b	4.7a	<0.01
Overall	5.5b	5.5b	4.7a	<0.01
Level of crispiness/crunchiness ^C	2.7	2.8	2.6	0.51

a, b, c: Across a row, means followed by different letters are significantly different ($P < 0.01$).

^A Scored on 9-point hedonic scales where 9 = like extremely, 8 = like very much, 7 = like moderately, 6 = like slightly, 5 = neither like nor dislike, 4 = dislike slightly, 3 = dislike moderately, 2 = dislike very much, 1 = dislike extremely.

^B Panellists asked to consider both shape and visible texture.

^C Scored on a 5-point scale where 5 = extremely crispy/crunchy, 4 = very crispy/crunchy, 3 = moderately crispy/crunchy, 2 = slightly crispy/crunchy, 1 = not crispy/crunchy.

received lower mean scores for appearance, crispiness/crunchiness, flavour and overall acceptability compared to the one- and four-dot, mold-shaped crackers. Consumer panellists were also asked to score their perception of the level of crispiness/crunchiness. Interestingly, although crispiness/crunchiness acceptability differed among the crackers, no significant difference in the level of this attribute was reported. This may reflect the absence of panellist training on the evaluation of specific product attributes, or it may be a reflection of the lower overall acceptability of the wire-cut-shaped samples influencing perceptions of the complete range of product characteristics scored in the test.

A large proportion of panellists commented that the samples did not look like crackers, especially in mold-shaped crackers that were formed in molds designed for small cookies. At the same time, numerous panellists indicated that they liked the “fancy” appearance of the mold-shaped samples and felt this was a product they could serve to guests. Perhaps a cracker-appropriate mold could be developed to carry this product. The bite-sized format (3.5–4.0 cm diameter) of all the samples was generally appreciated, but the lack of a crisp/crunchy cracker-like texture garnered negative feedback. Texture was apparently preferred when the crackers were presented in the mold-shaped format, and this observation was certainly captured in the scaled data. With the addition of marketing context factors (e.g. packaging and product information), consumers would likely be able to reconcile their assessments of product performance with their expectations about a gluten-free/pulse-based product.

Numerous comments were made about excessive saltiness of all crackers. Adjusting the formulation or adding a seasoning could possibly alleviate this concern, although salt might be required to balance the typically strong flavour of chickpea ingredients. Again, with the addition of product context factors, one could expect that disliking of chickpea-related flavour attributes would be reduced.

In general, where at least 70% of hedonic scores in a consumer taste panel are >6 on a 9-point scale, the potential for product success once modifications are made based on panellists' feedback is

Table 5

Proportion of hedonic scores in the “liking” range (7–9) of the 9-point scales for each pulse cracker characteristic evaluated by consumer panellists ($n = 78$).

Characteristic	Cracker style		
	Four-dot, mold-shaped (%)	One-dot, mold-shaped (%)	Wire-cut-shaped (%)
Appearance	82	86	50
Crispiness/crunchiness	67	71	49
Flavour	63	53	40
Overall acceptability	60	55	40

considered excellent. Both the one- and four-dot, mold-shaped crackers garnered over 80% of scores in this range for appearance acceptability (Table 5). The proportion of acceptance scores of crispiness/crunchiness was also high (71%) for the one-dot cracker and nearly (67%) in the desirable range for the four-dot cracker. The proportion of flavour and overall acceptability scores in the 6–9 range was lower (53–63%), but seasonings/flavourings and the provision of a marketing-based “motivating factor” can probably enhance product performance. When polled on a series of demographic/lifestyle questions, more than 60% of panellists in this study indicated that product functionality (i.e. some actual or implied health benefit) was relevant to food shopping habits. Pulse-based products certainly have potential to benefit from this consumer tendency.

3.3.3. Nutritional profile of commercial-scale crackers

Table 6 shows the nutritional profile of the four-dot mold-shaped crackers produced in the commercial-scale processing trial. Fig. 2 shows Canadian “Nutritional Facts” table of the four-dot, mold-shaped cracker derived from the compositional and nutritional analyses. The compositional and nutritional profile of the pulse crackers from the trial were similar to the existing gluten-free cracker products on Canadian and the US markets, such as Organic Animal Cookie cracker from Nature’s Path Foods (Richmond, BC) and Nut-Thins cracker snacks from Blue Diamond Growers (Sacramento, CA). Based on a single serving size of 28–30 g, the

Table 6

Nutritional composition of the gluten-free cracker produced from the commercial-scale processing trial (Sample name: four-dot, mold-shaped cracker)^a.

Component	Method	Concentration	Unit
Calories, Total	Calculate	445.58	Per 100 g
Omega 3	GC-FID	0.23	%
Omega 6	GC-FID	2.89	%
Omega 9	GC-FID	9.38	%
Fat, Total	AOAC solvent extraction	13.30	%
Saturated fatty acids	AOAC 996.06	1.18	%
Trans-fatty acids	AOAC 996.06	0.00	%
Monounsaturated fatty acids	AOAC 996.06	9.42	%
Polyunsaturated fatty acids	AOAC 996.06	3.12	%
Stearic fatty acids	AOAC 996.06	0.25	%
Cholesterol	AOAC 996.10	1.53	Mg/100 g
Carbohydrate, total	Calculate	70.79	%
Dietary fibre, total	AOAC 992.16/985.29	5.40	%
Sugars	HPLC-RI	6.02	%
Fructose		0.00	%
Glucose		0.00	%
Sucrose		6.02	%
Maltose		0.00	%
Protein	AOAC 981.10/993.13	10.68	%
Vitamin A	HPLC-UV	0.00	IU/100 g
Vitamin A	HPLC-UV	0.00	RE/100 g
Vitamin C	DCP titration	0.00	Mg/100 g
Sodium	ICP-MS	1140.00	Mg/100 g
Calcium	ICP-MS	22.00	Mg/100 g
Iron	ICP-MS	2.80	Mg/100 g
Moisture	Oven-drying at 105 °C	0.86	%
Ash	AOAC 923.02	4.37	%

^a Analyses were conducted by an independent food testing laboratory.

Nutrition Facts

Valeur nutritive

Serving Size 9 crackers (30 g)
Portions 9 craquelins (30 g)

Amount Teneur	% Daily Value % valeur quotidienne
Calories / Calories 135	
Fat / Lipides 4.4 g	7%
Saturated / saturés 0.4 g	2%
+ Trans /trans 0 g	
Cholesterol / Cholestérol 0.5 mg	
Sodium / Sodium 345 mg	14%
Carbohydrate / Glucides 21 g	
Fibre / Fibres 1.6 g	6.4%
Sugars / Sucres 1.8 g	
Protein / Protéines 3.2 g	
Vitamin A / Vitamine A	0%
Vitamin C / Vitamine C	0%
Calcium / Calcium	1%
Iron / Fer	6%

Fig. 2. Canadian “Nutrition Facts” table of the four-dot, mold-shaped cracker produced during commercial-scale processing.

pulse cracker from the trial contained 135 calories compared to 120 and 130 calories in the existing cracker products. All other compositional and nutritional profiles of the pulse crackers from the trial were similar to existing products on the markets except for sodium content, which was 345 mg. The sodium contents of existing products ranged from 80 to 220 mg per serving. The high sodium content of the pulse crackers can be easily adjusted without significantly affecting the quality of the cracker product. The pulse cracker from the trial also contained 6% of daily value of iron per serving which is significantly higher than the existing products’ 0–2% range. The higher iron content demonstrated the health benefit of the pulse ingredients in food system.

4. Conclusions

Gluten-free, 100% pulse-based cracker snacks were developed in this study. Eight prototype pulse crackers were initially examined and included chickpea, green and red lentils, pinto bean, navy bean, and yellow pea flours, and pea fibre protein isolate fractions. Based on the acceptability data, observations of each formulation during processing, and input from an industry partner, the chickpea flour based crackers were advanced to a commercial-scale processing trial. Two commercial cracker-forming processes (mold-shaped, wire-cut) were used to produce cracker products using the chickpea flour formula. Texture and colour profiles, consumer acceptability test, and nutritional analyses were conducted to evaluate the quality of the final products. The physical characteristics of the cracker from the mold-shaped processes (one- and four-dot crackers) were similar to the commercial cracker products currently available on the Canadian market, and were scored highly in consumer acceptance testing. The compositional and nutritional profiles of the crackers were also very similar to the existing cracker products on the market with the exception of the daily values per serving of iron that were 3–6 times higher in the chickpea crackers than existing products on a per serving basis. The pulse-

based, gluten-free cracker products investigated in this project have well-developed potential to both appeal to consumers and to impart health benefits.

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