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Extrusion Processing and Evaluation of an Expanded, Puffed Pea Snack Product

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Abstract

The use of grain legumes such as dry field pea (*Pisum sativum*) as major ingredients in snack foods may help to increase the nutritional appeal of these foods. Pea based expanded snack foods were developed using formulations varying in pea flour, pea fiber and pea starch and extrusion processing temperature. The products' physical characteristics, including shear strength, bulk density and expansion index, were characterized. The incorporation of pea fiber had the greatest effect on the texture of the final product whereas the addition of pea flour only slightly affected the physical properties of the product. Temperature also had an effect on the physical properties bulk density and expansion ratio but had no significant effect on the shear strength of the extrudates. Objective texture tests indicated that pea based puffed sample characteristics were comparable to commercial samples made of corn ingredients. The feasibility and quality of pea flour, starch and fiber as functional ingredients in snack food products was demonstrated.

Keywords: Extrusion; Pea; Snack; Fiber; Textures

Practical Application

Dry pea based ingredients such as flours, fibers and starches can be used as functional ingredients in many food applications such as extrusion processing. The addition of pea ingredients in snack food formulations can help to increase the nutritional profile of the product while maintaining textural quality attributed to these snack products.

Introduction

Similar to other pulse crops, dry field peas are nutritionally dense and recognized as a staple food source in many regions of the world. Among their health and wellness attributes, peas are associated with being a good source of slow release carbohydrates and dietary fiber [1] as well rich in proteins which compromise approximately 26-31% of the cotyledon [2]. Due to their impressive macro- and micro-nutrient content, pulses are often recommended for regular dietary consumption by health organizations [3] as their intake is associated with control and prevention of coronary heart disease, diabetes, obesity and colon cancer [1-3]. Despite their nutritional benefits, peas are under consumed in North America. This is due to several factors including lengthy preparation times and lack of use in convenient food product applications.

In order to increase consumption of peas in North America, the formulation of a convenient product is necessary. The snack food market is the ideal channel to introduce such a product. With increased consumer emphasis on health and wellness, the snack food market is undergoing metamorphosis and continues to steadily grow with the introduction of new snack foods [4,5] boasting reduced fat and sugar and increased protein and fiber. Peas are an ideal ingredient in this market being high in protein and fiber as well as naturally low in sugar, sodium and fat. The concept of using pulses in snack food products is not a novel idea. Deep fried pulses such as chickpea are commonly consumed in India as a snack food [1].

Extrusion processing is one method to produce snack foods. Under high temperature, high pressure conditions it is possible to create a product with a desirable crispy, aerated textural structure. Many benefits are associated with extrusion processing including process versatility, lack of effluent, and high throughput. In the case of pulse crops, extrusion has also been found to efficiently reduce the associated antinutrient found within the seed including phytic acid, condensed tannins, polyphenols, protease inhibitors, α-amylose inhibitors and lectins [1,6] while increasing bioavailability of nutrients [1,7].

Several researchers have explored the potential to use pulse ingredients in extruded snack product formulations. Ingredients include common bean (15-45%) blended with corn starch (85-55%) [8], chickpea, Mexican bean, white bean and lentil (10-90%) blended with corn flour (90-10%), pea grits (0-30%) blended with rice (100-70%) [9] and black beans with added sodium bicarbonate [10] pea flour and air classified pea starch [11]. The objective of this work was to produce an aerated snack food made entirely from pea based ingredients, green and yellow pea flours, pea starch and pea fiber analyzed using objective texture evaluation methods to meet the quality attributes of commercially available snack products.

Materials and Methods

Materials

Commercially available whole yellow pea flour, split green pea flour, pea hull fiber (Best Cooking Pulses, Portage la Prairie Manitoba Canada) and native, food grade pea starch (Nutri-Pea Foods, Portage la Prairie Manitoba Canada) were used as the base ingredients of the extruded products. The characteristics of these ingredients are further described in Table 1. Final extruded samples made in this experiment were compared to two corn based commercial samples readily available

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Calories	Whole yellow pea flour	Dehulled green pea flour	Pea fiber	Pea starch
	306 cal/100 g	352 cal/100 g	113 cal/100 g	400 cal/100 g
Total fat	1.84%	1.44	0.62%	<0.01 g
Saturated fat	0.34%	ND	0.19%	ND
Monounsaturated fatty acids	0.41%	ND	0.15%	ND
Polyunsaturated fatty acids	0.98%	ND	0.26%	ND
Trans fats	0%	ND	0%	ND
Available carbohydrates	50.70%	ND	18.70%	ND
Total carbohydrates	66.30%	61.98	84.60%	>98.7%
Total dietary fiber	17.60%	7.8	75.90%	ND
Insoluble dietary fiber	15.60%	7.2	65.90%	ND
Soluble dietary fiber	2.00%	0.6	10%	ND
Protein	21.60%	22.9	8.30%	<1.0 g
Moisture	7.74%	<12	3.56%	<12
Ash	2.55%	2.68	2.96%	<0.2

ND: No Data.

Table 1: Pulse ingredient specifications as provided by suppliers (dwb).

on the market with distinct texture differences. These are referred to as commercial samples 1 and 2. The commercial samples represent the physical variation of extruded snack product quality popular to the North American market. Commercial sample one was representative of a denser product with variable product diameter, length and air cell size. Commercial sample two was representative of a product with greater aeration and more consistent air cell structure, product diameter and length.

Sample processing and preparation

Five formulations, with varying concentrations of whole yellow and split green pea flour, pea fiber and pea starch were formulated on an as is moisture basis. The formulations varied in pea flour and pea fiber and were made up to 100% using pea starch. The formulations included 30% pea flour-0% pea fiber (30-0), 30% pea flour-10% pea fiber (30-10), 40% pea flour-5% pea fiber (40-5), 50% pea flour-0% pea fiber (50-0) and 50% pea flour-10% pea fiber (50-10). Each formulation was run singularly with the midpoint (40-5) processed in triplicate. 100% pea starch was used as the control.

Moisture content of formulations was determined using the American Association of Cereal Chemistry (AACC) moisture air oven method 44-15A [11].

Blends were extruded with an APV co-rotating twin screw extruder (MPF19-25, 2.2 kW motor, 19/25D, APV Baker Ltd. Grand Rapids, MI USA) with a circular die hole of 4.5 mm diameter using a high shear screw configuration as described by Anton et al. [8]. Total moisture content of the blends was adjusted to 15% through the addition of water. Temperature of extrusion was set to 30°C, 70°C and 90°C for the first three of five barrel temperature zones respectively. The effect of temperature on extrudates properties was investigated; temperatures were tested by varying the both the final two barrel temperatures to 110°C, 120°C or 135°C. Screw speed was kept at a constant 240 rpm. Following extrusion, the extrudates were dried in a convection oven at 135°C for 5 minutes, allowed to cool and placed in a polyethylene bag overnight. Texture was analyzed 24 h following drying.

Texture analysis

Texture was analyzed objectively with a Zwick Roell texture analyzer (BDO-FB005TN, Zwick GmbH & Co. KG Germany) using a shear three point bend test. Extrudates were cut into 4 cm lengths and laid across three point bending stand with bar gap set at one millimeter. A Warner Bratzler shear probe was used to stress the samples. The resulting curve was evaluated using test Xpert II v1.41 software (Zwick GmbH & Co., August-Nagael-Strasse). Maximum force (N) indicated by the peak of the curve was used to calculate shear strength. Test conditions used included preload of 1N, and a pre-load speed of 50 mm/min for up to 60 sec. After pre-load, the force was tired. Cycle speed was position controlled at 10 mm/min, standard travel was set to 25 mm, the upper force limit was 1 kN and maximum test time was 1 min.

Physical properties

Expansion ratio was calculated as the cross sectional area of the extrudates divided by the cross sectional area of the die outlet [12]. Ten measurements were taken and results were recorded as the average of these measurements.

Bulk density accounts for expansion of the product in all directions [13] and is measured as mass of product residing in a specified unit of volume [12,14]. Ten 4 mm samples from each extrusion run were weighed and divided by the volume of each sample to calculate the bulk density.

Volume was determined through calculation as

$$Volume = \pi\left(d/2\right)2 \times h$$

Where d=diameter (mm) measured using calipers accurate to 0.1 and h=height of sample (mm)

Shear strength is measured as the shear force (maximum force from texture measurement) required to break a product relative to its cross sectional area and is indirectly related to expansion ratio [15]. Ten measurements of shear strength were taken for each sample to obtain an average result.

Statistical analysis

Extrudates were evaluated for significant difference ($p<0.05$) using Statistical Analysis Software (SAS, version 9.1) and differences located using a Turkey test adjustment for multiple comparisons. Each formulation blend was run once with exception to the midpoint blend (3) which was run in triplicate. Ten samples were used for texture analysis and the results were recorded as an average.

Results and Discussion

Expansion ratio

Effect of pulse type and concentration: Generally, a greater expansion ratio is more desired in puffed snack foods as this typically indicates a lighter, crisper product. The expansion ratio of pea based snacks ranged from 5.46 to 14.76 for 40-5 and 30-0 split green pea formulation respectively (Table 2). Samples with no added fiber expanded less and whole yellow pea flour resulted in less expansion than the green pea flour that did not contain hull material. It was also observed that expansion ratios when no fiber was included were unaffected by the amount of pea flour use. For example, extrudates made with 30% and 50% split green pea flour were not significantly different with values of 14.76 and 14.36 respectively. Optimal expansion of corn starch was studied by Chinnaswamy and Hanna [15]. It was found that by testing 25% amylose corn starch using a 3 mm die opening with a temperature range of 120-180°C and a moisture of 6%-30%, the best conditions for expansion ratio of corn starch were at 140°C, 14% moisture (db), 150 rpm screw speed and feed rate of 60 g/min yielding an expansion ratio value of 16.1. This value is higher than any achieved with the pea products. Expansion ratio will depend on the extrusion conditions as well as the blend formulations which are being tested.

In terms of other pulse crop extrudates, Berrios et al. [13] achieved expansion ratios of 10.50 to 12.13 for garbanzo beans (chickpeas) and by using fine pin milled black bean flours at 160°C, a feed rate of 25 kg/h and an 18% moisture content produced an expansion ratio of 6.74. Using twin screw extrusion Berrios, Wood, Whitehand and Pan [10] extruded black beans at 200 rpm with an 80 g/min feed rate and a 20% total moisture content expanded to a ratio of 6.70 and was increased to 13.45 with the addition of 0.5% sodium bicarbonate. These values are similar to the range obtained in this study which uses pea flour and pea hull in combination with pea starch. This is expected considering the similar nature of beans, chickpeas and peas in terms of protein, starch and fiber content. Using a twin screw extruder, 160°C process temperature, 500 rpm screw speed, 25 kg/h feed rate, and with two 3.5 mm die openings the expansion ratio of whole pea was 12.45 while the ratio for whole pea with corn starch (Hylon V at 20% of the formulation) increased to 16.46 (Berrios et al, 2008), a value slightly higher than compared to the current study. Split pea flour expanded to a ratio of 20.72 and increased to 24.21 when 20% Hylon V corn starch was added [13]. In this study, the differences between the whole pea and split pea flours may be explained by the difference in the fiber content of the pea flours.

Effect of fiber: As noted above, the addition of whole yellow pea flour, which contained 17.6% total dietary fiber (Table 1), expanded significantly less than the split pea flour; the 30-0 formulations of whole yellow pea flour had an expansion ratio of 7.75 compared to 14.78 for the split green pea flour (Table 2). This fiber effect was also seen for expansion ratios where additional fiber was added to the green split pea flour (Table 2). When pea hull concentrations in 30% split green pea flour formulations were increased from 0% (14.76 expansion ratio) to 10%, expansion was significantly reduced to 5.59 (Figure 1). This trend was also observed at the 50% level. The addition of more fiber to the whole yellow pea flour resulted in decreased expansion with samples containing 50% flour, but no significant differences were seen when fiber was added to extrudates containing 30% yellow pea flour.

When Rampersad et al. [16] extruded cassava and pigeon pea flour, lower expansion ratios were obtained than those found in this study. Using a single screw extruder, a blend moisture content of 12%, temperature profile of 120-125°C, 520 rpm screw speed and 300 g/min feed rate, expansion ratios of 1.68, 1.55, 1.38 and 1.18 were obtained when 0%,5%,10% and 15% pigeon pea flour was added to cassava flour. Clearly, as pigeon pea flour was incorporated, expansion ratio decreased, an effect that was not as clearly seen in the current study, as expansion ratio was more strongly related to the addition of pea hull than pea flour. Differences between the level of fiber in cassava and pigeon pea, differences in theamylose and amylopectin ratios of starch as well as differences in the processing parameters and equipment may explain the discrepancies found between Rampersad et al. [16] and the current study.

Fiber addition was previously found to significantly affect the expansion ratio of lentils. Without apple fiber addition, the expansion ratio was 30.7 while with added fiber this value was only 6.6-8.2 depending on the starch source used [13]. Therefore, the effect of fiber was found to be greater than that of starch source used for lentil extrudates. It was speculated that this effect was due to the decreased level of starch content in the dough due to the replacement of starch with fiber [13].

This effect of bran was also observed by Jin et al. [17] while investigating the extrusion outcomes of yellow corn meal, soy fiber and cane sugar. It was found that using twin screw extrusion with a final barrel temperature of 121°C, a 3.08 mm die opening, 45.4 kg/h feed rate, total moisture content of 20% and a 325 rpm screw speed that as fiber content increased from 0%-20%, the extrudates texture was more compact and less expanded. It was also observed that air cells were

Pea flour type	Formulation (% pea flour-% pea fiber)	Bulk density (g/cm^3)	Shear Strength (N/cm^2)	Expansion Ratio
Green	30-0	0.1 ± 0.02bc	9.94 ± 2.93d	14.76 ± 1.96a
	30-10	0.12 ± 0.03abc	21.03 ± 5.64ab	5.59 ± 1.55d
	40-5	0.12 ± 0.02abc	18.59 ± 3.53cd	5.46 ± 0.86cd
	50-0	0.06 ± 0.01d	5.2 ± 1.3e	14.36 ± 1.75a
	50-10	0.12 ± 0.02abc	25.01 ± 5.23a	5.66 ± 0.84d
Yellow	30-0	0.14 ± 0.02a	21.41 ± 6.01ab	7.75 ± 0.95b
	30-10	0.1 ± 0.01c	20.11 ± 3.69ab	6.98 ± 0.98bcd
	40-5	0.13 ± 0.03ab	24.53 ± 5.38ab	5.94 ± 1.12bcd
	50-0	0.11 ± 0.01abc	14.35 ± 2.52cd	7.63 ± 0.79bc
	50-10	0.12 ± 0.02abc	18.63 ± 2.36bc	5.53 ± 0.68d
Commercial Samples*	1	0.39 ± 0.10	31.24 ± 11.84	ND
	2	0.18 ± 0.02	8.86 ± 4.40	ND

Values represent mean ± standard deviation. Rows within each column with the same letter are not statistically significant ($p<0.05$).
* Results for Commercial samples 1 and 2 are presented for comparison purposes.

Table 2: Bulk density, shear strength and expansion ratio of extrudates made from formulations containing green and yellow pea ingredients.

Figure 1: Images of extruded green pea flour snack (30-0) processed at 135°C (left) as compared to extruded green pea flour snack (30-10) processed at 135°C (right).

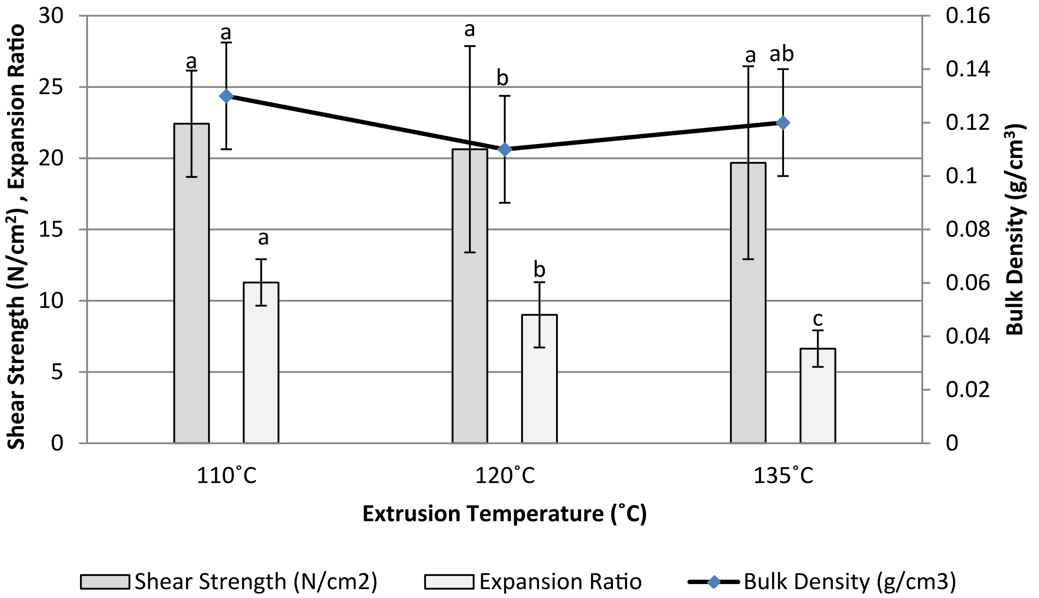

Figure 2: The effect of extrusion processing temperature on mean values of bulk density, shear strength and expansion ratio of pea extrudates (50-0 whole yellow pea formulation). Series with the same letter are not statistically significant (p<0.05).

smaller and more numerous when observed with scanning electron microscopy, and cell walls were seen to be thinner at lower bran contents of 10% than compared to the thicker cell walls observed at 30%. The effect of fiber was more thoroughly explained as the presence of bran causing a limiting effect on the expansion and extensibility of air cell walls and causing bursting of air cell due to an inability to retain steam [17].

While the inclusion of fiber into extruded snacks foods is attractive from a nutritional standpoint, this must be balanced with the impact it has on the ability of the extrudates to expand.

Temperature during extrusion: The effect of temperature (Figure 2) also had a significant effect on expansion ratio. It was found that as temperature of the final two barrels was decreased from 135°C to 120°C to 110°C; the expansion ratio was significantly increased with increments of 6.64, 9.01 and 11.28, respectively, as seen in Figure 2. Falcone and Phillips [14] investigated the extrusion of sorghum and cowpea blends under different conditions. Formulations of 100% sorghum, 67% sorghum-33% cowpea, 33% sorghum-67% cowpea, 100% cowpea, and a temperature range of 160°C -205°C with moisture contents ranging from 13-25% for single screw extrusion with a 7 mm circular die opening using a screw speed of 180 rpm were studied. Their results clearly indicated the role of temperature on extrusion as expansion tended to be greatest at 175°C; however, this was dependent on the formulation of the blend.

Berrios et al. [13] specifically investigated the extrusion of pea flour using 160°C, 500 rpm, 25 kg/h feed rate and two die openings of 3.5 mm diameter and were able to achieve an expansion ratio of 12.45 for whole pea flour, similar to results obtained for this study, while for split pea flour, an expansion ratio of 20.72 was achieved, greater than what was obtained for this study. This difference could be due to processing conditions and equipment differences as well as particle size, composition of peas in terms of fiber, protein and starch content. Starch characteristics could also be a factor as amylopectin exerts a positive effect and amylose a negative effect on expansion ratio [14].

While high expansion ratios have been achieved with higher extrusion temperatures, the lowest temperature (110°C) was preferred in the current study. This would suggest that recommendation of a specific temperature for extruding pulse crops is not possible as there are a number of other factors that need to be considered.

Bulk density

Effect of pulse type and concentration: Changes in bulk density were expected based on the differences in the expansion ratios. Bulk density of the pea extrudates ranged from 0.06 g/cm^3 for the 50-0 green pea sample to 0.14 g/cm^3 for 30-0 yellow pea samples (Table 2). In the absence of added fiber bulk density values for the split green pea extrudates were lower than the corresponding concentration of whole yellow pea extrudates. For green peas the higher flour concentration (50-0) had a lower density than the lower flour concentration (30-0), but no difference due to concentration were seen for the yellow pea flour. This suggested that addition of green pea flour had a positive effect on the final extruded product. Berrios et al (2004) used a twin screw extruder with the parameters of 200 rpm screw speed, 80 g/min feed rate and 20% total moisture content for the extrusion of black bean flour to produce a bulk densities of 0.35, 0.32, 0.33, 0.28, 0.26 and 0.24 g/cm^3 for control, 0.1, 0.2, 0.3, 0.4 and 0.5% sodium bicarbonate addition respectively. These values were all greater than the range of bulk density incurred in the current study utilizing pea flour, pea fiber and pea starch for extrusion. A lower bulk density is generally more desirable considering that it indicates a lighter, crisper final product.

When cassava flour and pigeon pea flour were blended in ratios of 100:0, 95:5, 90:10, 85:15 and extruded with a single screw extruder with a moisture content of 12% (db) at 120-125°C and a 520 rpm screw speed using a 300 g/min feed rate [16], it was found that bulk density increased with increasing pigeon pea flour addition; 0%, 5%, 10%, 15% pigeon pea flour had bulk densities of 0.27, 0.29, 0.30 and 0.33 g/cm^3, respectively [16]. The opposite effect was found in the current study, in that the addition of the split green pea flour decreased the bulk density of the extrudates. This could be due to the functionality of cassava as compared to pea starch as the base for extruded snacks as well as differences between pigeon pea and dry field peas in terms of fiber, starch and/or protein content as interactions between these components influence product structure and consequently bulk density. Processing conditions may also have had an effect. The moisture content used in the study by Rampersad et al. [16] was considerably lower (12%) than the 15% moisture content used in the current study.

Fiber: As was the case with expansion ratio, pea hull fiber was found to be more influential than pea flour inclusion in terms of bulk density (Figure 1). The lowest bulk density observed (0.06 g/cm^2) was in the 50-0 green pea sample, where pea flour was added but additional pea hull was not incorporated; (Table 2). Higher bulk densities for the whole yellow pea flour extrudates (no added fiber) were observed in comparison to the green pea extrudates with no added fiber. The presence of fiber increased bulk density, but the amount of fiber did not seem to matter; with 10% added fiber, no differences in bulk density were seen between the two types of flours even though the yellow pea flour contained more fiber initially. In contrast, the study by Jin et al. [16] using yellow corn meal, soy fiber, pure sugar cane in a twin screw extrusion process and a final barrel temperature of 121.1°C, 3.08 mm die opening, 45.4 kg/h feed rate and moisture content of 20% with screw speed of 325 rpm found that as fiber level increased from 0-20%, bulk density decreased however, further increase to 40% fiber caused an increase in bulk density.

Temperature: As temperature decreased from 120°C to 110°C, extrudate bulk density became significantly higher as seen in Figure 2. However, there was no significant difference between the bulk densities of extrudates processed at 135°C and either 120°C or 110 °C. In this case, no inverse relationship was noted between the bulk density and expansion ratio as was shown above. This can be explained based on the rationale that expansion ratio only accounts for expansion from the cross sectional area while bulk density accounts for expansion in all directions. The effect of temperature depends greatly on the material which is being extruded and its physical properties; for instance gelatinization temperatures as well as amylopectin and amylose content will cause different properties of extrudates at different processing temperatures. In the Falcone and Phillips [14] sorghum and cowpea experiment, the lowest bulk density result of 0.26 g/cm^3 was obtained for 100% sorghum at 175°C and 20.5% moisture content. It appeared that as the percent of cowpea incorporated in the blend increased, the temperature required to achieve the lowest bulk density also increased. However, the lowest overall bulk density was achieved at a lower temperature using 100% sorghum.

When bulk density of the test samples was compared to bulk density of commercial samples, commercial sample 1 had a bulk density of 0.39 ± 0.10 g/cm^3 while commercial 2 samples had a bulk density of 0.18 ± 0.02 g/cm^3. The test samples were generally less than both of these commercial samples indicating that the samples produced in this study had a structure that was less dense than those products typically found on the market.

Shear strength

Effect of pea flour, pea hull, temperature, pea type: The shear strength of samples ranged from 5.20 to 25.01 N/cm^2 for samples 50-0 green pea and 50-10 green pea respectively as seen in Table 2. The extruded pea starch control had much greater shear strength values than all other treatments at 34.69 N/cm^2 (Table 2).

The addition of pea fiber had a significant effect on shear strength. The samples with added flour, but with no added pea hull had significantly lower shear strength (Table 2). Jin et al. [17,18] also indicated a similar effect of fiber on shear strength using yellow corn meal, soy fiber, and pure sugar cane subjected to twin screw extrusion, at a temperature of 121.1°C, a 3.08 mm die opening, a 45.4 kg/h feed rate, a moisture content of 20% and a 325 rpm screw speed. They related the breaking strength to the microstructure and suggested that thicker cell walls in the presence of more fiber resulted in greater shear force.

With respect to pea type used, there was no significant difference in shear strength between using the whole yellow pea flour or the split pea flour (Table 2). In terms of temperature, no significant differences were found between extrudates processed at 110°C, 120°C and 135°C (Figure 2) for shear strength.

The commercial sample 1 had shear strength value of 8.86 ± 4.40 N/cm^2 while commercial sample 2 had shear strength value of 31.24 ± 11.84 N/cm^2. The test samples in this study had intermediate shear strength values. Falcone and Phillips [14] compared their sorghum/cowpea blended extrudate force at failure (N) to that of fried or baked commercial corn snacks. The force at failure (N) that was comparable to fried/baked commercial corn snack (~23 N) and was obtained with samples made of 67% sorghum and 33% cowpea processed at 190°C and 23% moisture content (27 N) as well as the 33% sorghum sample blended with 67% cowpea processed at 190°C using a 23% moisture content.

Conclusion

The use of pea flour, pea fiber and pea starch has the potential to be used in many food products as demonstrated here as a puffed, extruded snack food. It was found that expansion ratios and bulk density were improved when fiber levels were low; dehulled green pea flour performed better than whole yellow pea flours with respect the fore-mentioned characteristics. Further product characterization through investigation of bubble frequency and size may further assist in optimizing product texture. Future work in terms of shelf life stability, scale up as well as market research is necessary to create a final marketable product.

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References

1. Tharanthan RN, Mahadevamma S (2003) Grain legumes - a boon to human nutrition. Trends Food Sci Nutr 14: 507-518.
2. Guillon F, Champ MM (2002) Carbohydrate fractions of legumes: uses in human nutrition and potential for health. Br J Nutr 88 Suppl 3: S293-306.
3. Leterme P (2002) Recommendations by health organizations for pulse consumption. Br J Nutr 88 Suppl 3: S239-242.
4. Agriculture and Agri-Food Canada (2013) The Canadian snack food manufacturing industry.
5. Hardacre AK, Clark SM, Riviere S, Monro JA, Hawkins AJ (2006) Some textural, sensory and nutritional properties of expanded snack food wafers made from corn, lentil and other ingredients. J Texture Stud 37: 94-111.
6. Alonso R, Orue E, Marzo F (1998) Effects of extrusion and conventional processing methods on protein and antinutritional factors content in peas seeds. Food Chem 63: 505-512.
7. Abd El-Hady EA, Habiba RA (2003) Effects of soaking and extrusion conditions on anti-nutrient and protein digestibility of legume seeds. LWT 36: 285-293.
8. Anton AA, Fulcher RG, Arntfield SD (2009) Physical and nutritional impact of fortification of corn starch based extruded snacks with common bean (Phaseolus vulgaris L.) flour: Effects of bean addition and extrusion cooking. Food Chem 113: 989-996.
9. Singh B, Sekhon KS, Singh N (2007) Effects of moisture, temperature and level of pea grits on extrusion behavior and product characteristics of rice. Food Chem 100: 198-202.
10. Berrios JDJ, Wood DF, Whitehand L, Pan J (2004) Sodium bicarbonate and the microstructure, expansion and color of extruded black beans. J Food Process Pres 28: 321-355.
11. Hood-Niefer SD, Tyler RT (2010) Effect of protein, moisture content and barrel temperature on the physicochemical characteristics of pea flour extrudates. Food Res Int 43: 659-663.
12. American Association of Cereal Chemists International (1999) Moisture Air-Oven Method (44-15A). American Association of Cereal Chemists. Minnesota.
13. Berrios JDJ, Tang J, Swanson BG (2008) Extruded Legumes patent application. U.S. Patent 0080145483.
14. Falcone R, Phillips D (1988) Effects of feed composition, feed moisture and barrel temperature on the physical and rheological properties of snack-like products prepared from cowpea and sorghum flours by extrusion. J Food Sci 53: 1464-1469.
15. Chinnaswamy R, Hanna MA (1988) Optimum extrusion-cooking conditions for maximum expansion of corn starch. J Food Sci 53: 834-840.
16. Rampersad R, Badrie N, Comissiong E (2003) Physico-chemical and sensory characteristics of flavored snacks from extruded cassava/pigeon pea flour. J Food Sci 68: 363-367.
17. Jin Z, Hsieh F, Huff HE (1995) Effects of soy fiber, salt, sugar and screw speed on physical properties and microstructure of corn meal extrudate. J Cereal Sci 22: 185-194.
18. Obatolu AV, Omueti OO, Adebowale EA (2006) Qualities of extruded puffed snacks from maize/soybean mixture. JFPE 29: 149-161.