Food Chemistry 111 (2008) 132–138

Contents lists available at ScienceDirect

Food Chemistry

journal homepage: www.elsevier.com/locate/foodchem

Effect of variety and processing on nutrients and certain anti-nutrients in field peas (*Pisum sativum*) ☆

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ARTICLE INFO

Article history:
Received 15 January 2008
Received in revised form 29 February 2008
Accepted 13 March 2008

Keywords:
Dietary fibre
Cooking
Dehulling
Nutrients
Minerals
Peas

ABSTRACT

The effect of variety and processing (soaking, cooking and dehulling) on nutrients and anti-nutrients in field peas (*Pisum sativum*) was investigated. Analysis of variance showed that variety had a significant effect on crude protein, starch, ash, soluble dietary fibre (SDF), insoluble dietary fibre (IDF), total dietary fibre (TDF), trypsin inhibitor activity (TIA), minerals, phytic acid, sucrose and oligosaccharides. Soaking and cooking increased protein content, IDF, TDF, Ca, Cu, Mn and P in peas whereas ash content, Fe, K, Mg, Zn, sucrose and oligosaccharides were reduced. TIA was increased by soaking but reduced by cooking. Cooking was more effective than soaking in reducing oligosaccharides. Dehulling increased crude protein, starch, K, P, phytic acid, stachyose and verbascose content but reduced SDF, IDF, TDF, Ca, Cu, Fe, Mg and Mn.

1. Introduction

Pulses are rich, not only in protein and starch, but also in other nutrients such as fibre, vitamins and minerals, which are well suited to meet the demands of health conscious consumers. Pulses have shown many health benefits such as lower glycemic index for persons with diabetes (Viswanathan et al., 1989) and cancer prevention (Hangen & Bennink, 2002). Research has also indicated that dietary fibre may protect against cardiovascular diseases (Lee, Prosky, & DeVires, 1992). Numerous studies have shown that people with high fibre intakes have blood pressure lower than those with low fibre intake (Brand, Snow, Nobhan, & Truswell, 1990; Kritchevsky, 1982; Scheeman, 1987). Soluble fibre also decreases serum cholesterol and aids in reducing the risk of heart attack and colon cancer (Burkitt, Walker, & Painter, 1974; Kelsey, 1978; Sharma & Kawatra, 1995; Trowell, 1972). A high fibre diet prevents or relieves constipation in humans due to the absorption of water from the digestive track (Hill, 1974). On the other hand, pulses have low protein digestibility, attributed to the presence of antinutrients, some of which also lower the bioavailability of trace elements and proteins (Reddy, Pierson, Sathe, & Salunkhe, 1984; Salunkhe & Kadam, 1989). Trypsin inhibitors, phytic acid and oligosaccharides (raffinose, stachyose and verbascose) are some of the undesirable components in pulses that could limit their protein and carbohydrate utilization.

Consumption of pulses requires pre-treatments such as dehulling, rehydration and heat processing. While these treatments confer some nutritional benefits (Deosthale, 1982), they are reported to alter the content and physical–chemical properties of components (Siljestrom et al., 1986). Domestic cooking methods are known to reduce antinutrient levels and thus improve the nutritive value (Khokhar & Chauhan, 1986) and enhance starch digestibility in pulses (Jenkins et al., 1982). Cooking whole or split peas in boiling water is the most common method used to obtain a palatable product with improved nutritional value. Although studies have been done on chemical composition of raw pea seeds (Wang & Daun, 2004), little information is available on the composition of processed peas. This project was undertaken to determine how variety and processing (soaking, cooking and dehulling) affect nutrients and anti-nutrients of field peas.

2. Materials and methods

2.1. Materials

Samples were selected from Canadian Grain Commission (CGC)'s 2006 harvest survey of the commercially grown crop of field peas submitted to the CGC by producers from across western Canada. Random samples of six pea varieties (n = 4–9 samples for

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doi:10.1016/j.foodchem.2008.03.047

each variety) were cleaned to remove foreign material and damaged seeds prior to being composited on the basis of variety. All the selected samples used in this study were from the same growing region in Saskatchewan, Canada. The six field pea varieties chosen were Nitouche, Keoma, SW Parade, Elipse, Delta and CDC Mozart.

2.2. Processing methods

2.2.1. Soaking

Pea seeds (100 g) were soaked in distilled water at a ratio of 1:4 (seed:water, w/w) at room temperature for 24 h. After draining the water, the soaked seeds were blotted dry, frozen and then freeze-dried. The freeze-dried seeds were ground into flour for further analysis.

2.2.2. Cooking

Cooking time of each sample was determined using an automated Mattson Cooker as described by Wang and Daun (2005). A sample (100 g) was soaked in distilled water 1:4 (seed:water, w/w) for 24 h at room temperature. After draining the water, the sample was transferred into a perforated container and cooked in a boiling water bath for its predetermined cooking time. The cooked sample was then drained, frozen and freeze-dried. The freeze-dried seeds were ground into flour for further analysis.

2.2.3. Dehulling

The Satake TM05C Grain Testing Mill (Satake Engineering Co. Ltd., Hiroshima, Japan) was used to remove the seed coat according to the procedure as described by Wang (2005). Dehulled and undehulled seeds (raw seeds) were ground into flour for further analysis.

2.3. Chemical analysis

Nitrogen was determined by the Dumas combustion method using a Leco FP-428 nitrogen analyzer (AOAC, 1998). Moisture and ash content were determined gravimetrically by AACC methods 44-17 and 08-16, respectively (AACC, 2000). Starch was determined colourimetrically by the method AACC 76-13 (AACC, 2000). Soluble, insoluble and total dietary fibre contents were determined by sequential enzymatic digestion according to AACC method 35-05 (AACC, 2000). Minerals were determined by atomic absorption spectrophotometry (Gawalko, Nowicki, Babb, & Tkachuk, 1997).

Trypsin inhibitor activity (TIA) was determined colourimetrically using a spectrophotometer at 410 nm (Smith, Megen, Twaalfhoven, & Hitchcock, 1980). Phytic acid was extracted and separated by ion-exchange chromatography according to the method of AOAC (1998) before being quantified colourimetrically using a spectrophotometer at 500 nm (Latta & Eskin, 1980). Oligosaccharides were determined by high performance anion exchange chromatography (HPAE) with pulsed amperometric detection (PAD) (Wang & Daun, 2004).

2.4. Statistical analyses

All statistical analyses were conducted using the Statistical Analysis System (v.9.1.3, SAS Institute, Cary, NC). The analysis of variance (ANOVA) for the main effects (variety and treatment) and interaction (variety × treatment) was determined using GLM procedure. The least significant difference (LSD) test ($p < 0.05$) was used to determine differences between means and the Duncan multiple range test was also used to separate means and significance was accepted at $p \leqslant 0.05$. All the treatments and determinations were carried out in duplicate.

3. Results and discussion

Analysis of variance showed that variety had a significant effect on protein, starch and ash content in field peas (Table 1), confirming the results reported by Wang and Daun (2004). Processing techniques also displayed a significant effect as shown in Table 1. The interactive effect of variety x treatment (soaking or cooking) on ash content was significant whereas there was no effect of variety x treatment (soaking, cooking or dehulling) on protein and starch content (Table 1). Soaking resulted in 2.6% to 5.0% increase in protein content while cooking caused a 3.0% to 6.7% increase in protein content (Table 2). Starch content was increased 0.8–2.3% by soaking and 2.4–6.7% by cooking, respectively (Table 2). The increases in protein and starch in soaked or cooked seeds may be attributed to the loss of soluble solids during soaking or cooking. This would increase the concentration of protein and starch in soaked or cooked seeds. Dehulling (removal of seed coat) resulted in a significant increase in the protein (5.4–10.4%) and starch content (7.6–11.8%) for all the varieties. Seed coat (hull) contains very little protein and starch, and its removal means that there is proportionally more protein and starch in dehulled seeds. Results from this study confirmed Edijala (1980) who reported that soaking, cooking and decortication resulted in an increase in protein content for six cowpea varieties.

Soaking resulted in reduction in ash content (1.0–7.7%) (Table 2). The variety Nitouche showed the highest reduction in ash content during soaking whereas Eclipse had the lowest reduction. Cooking significantly reduced ash content in the six pea varieties ranging from 23.2% to 34.4%. Similar results had been reported by Akinyele (1989) for cowpeas. The decrease in ash content might be attributed to diffusion of certain minerals into the soaking or cooking water. Haytowitz and Matthews (1983) reported that cooking in boiling water caused great losses in minerals for cooked pulses. Dehulling had little effect on ash content in the six pea varieties (Table 2).

Analysis of variance showed that both variety and treatment had a significant effect on insoluble dietary fibre (IDF) and total dietary fibre (TDF) content (Table 1). Soluble dietary fibre was affected by cooking or dehulling but was not affected by soaking (Table 1). Variety × cooking had a significant effect on IDF and TDF but had little effect on SDF (Table 1). There was no significant effect of variety × soaking or dehulling on SDF, IDF and TDF. Table 3 shows values of SDF, IDF and TDF as affected by different processing treatments. SDF content decreased significantly in the cooked peas compared to the raw peas, which agrees with data presented by Vidal-Valverde and Frias (1991) who suggested that a softening of soluble fibres occurred with the cooking process, reducing its content. However, Kutos, Golob, Kac, and Plestenjak (2003) found that SDF for beans was increased by cooking. The lowest content of SDF for cooked peas was determined in the variety Delta (13.9 g kg^{-1} dry matter) and the highest SDF content was in the variety Nitouche (17.8 g kg^{-1} dry matter) (Table 3). The IDF content was slightly higher in soaked peas (142.4–154.8 g kg^{-1} dry matter) than that in raw seeds (127.6–149.7 g kg^{-1} dry matter). Cooking significantly increased IDF content for all pea varieties (162.9–194.2 g kg^{-1} dry matter) as compared to the raw samples. This increase may be due to protein–fibre complexes formed after possible chemical modification induced by the cooking of dry seeds (Bressani, 1993). Soaking or cooking increased TDF in peas (Table 3). The TDF contents in raw peas were in the range of 142.6–168.3 g kg^{-1} dry matter, while TDF varied from 157.5 to 172.8 g kg^{-1} dry matter for soaked peas and from 177.2 to 208.8 g kg^{-1} dry matter for cooked peas, respectively. The IDF fraction in raw peas formed the majority of TDF, ranging from 88.6% to 90.2%, while the fraction of SDF ranged from 9.5% to 11.1%. These results agree with data of Su

Table 1
Analysis of variance of variety and treatment (soaking, cooking and dehulling) on composition of field peas

	Mean square			Mean square			Mean square		
	Variety (V)	Soaking (S)	$V \times S$	Variety (V)	Cooking (C)	$V \times C$	Variety (V)	Dehulling (D)	$V \times D$
Composition (g kg^{-1} dry matter)									
Protein ($N \times 6.25$)	176.2***	365.8***	–	211.2***	628.3***	–	228.4***	1969.3***	–
Starch	912.1***	242.6*	–	994.0***	2314***	–	732.3***	13718***	–
Ash	0.98**	5.90**	0.55**	3.19**	280.8***	1.08***	2.06*	0.81**	–
Soluble dietary fiber (SDF)	6.82**	–	–	7.52***	6.41*	–	6.14*	75.6***	–
Insoluble dietary fiber (IDF)	186.8**	700.9***	–	381.7***	9955***	104.5*	124.3*	19482***	–
Total dietary fiber (TDF)	227.5***	621.2***	–	414.1***	9290***	110.8**	148.0**	22222***	–
Minerals (mg/100 g dry matter)									
Ca	154.9***	85.9***	–	194.1***	1466***	50.3*	93.5***	9231***	18.0*
Cu	0.06***	0.03***	–	0.07***	0.18***	0.005*	0.04**	0.01**	–
Fe	0.57**	–	–	0.68**	2.69***	–	0.64**	2.01**	–
K	3789*	23126***	–	6942***	895675***	–	–	12908**	–
Mg	90.3**	–	–	101.5*	247.0*	–	101.3**	2525***	–
Mn	0.11***	–	–	0.11***	0.03**	–	0.11***	0.06*	–
P	–	–	–	–	6831**	–	–	12398***	–
Zn	0.91***	–	–	0.65***	0.71***	–	0.82***	–	–
Sugars (g kg^{-1} dry matter)									
Sucrose	500.1***	449.8***	6.29***	313.5***	2819**	60.2***	644.6***	23.2***	403**
Raffinose	9.34***	1.55**	–	6.19***	54.9***	3.05***	7.28***	3.38***	–
Stachyose	64.7***	40.8***	1.21**	62.5***	1169***	6.72***	72.0***	27.5***	–
Verbascose	58.8***	5.23**	–	57.1***	95.6***	1.38	58.7***	32.9***	0.96**
Phytic acid (g kg^{-1} dry matter)	1.33***	0.43**	–	1.27***	1.44***	–	1.30***	0.41***	0.09**
TIA[A] (mg/g dry matter)	0.25***	0.18***	0.01*	0.06***	8.76***	0.05***	0.23***	0.07***	–

***, **, * = significant at $p < 0.001$, $p < 0.01$ and $p < 0.05$, respectively.
– Blank spaces indicate no significance.
[A] Trypsin inhibitor activity.

and Chang (1995) who reported that the IDF fraction in raw dry beans is 72–90% of the TDF. Bednar et al (2001) observed that IDF represented from 92% to 100% of the TDF for various beans and 99.7% for lentil while SDF represented a small part (0.0–3.2%) of the TDF.

From the nutrition point of view, only thermally processed pulses are important since pulses are never eaten raw. The SDF fractions in cooked samples in the present study ranged from 7.0% to 9.1% of the TDF, with the lowest values found in raw peas. The IDF fraction in cooked peas ranged from 89.3% to 91.1% of the TDF. Heat treatment (cooking) may modify the structure of both cell wall and storage polysaccharides of pulses possibly by affecting the intactness of tissue histology and disrupting the protein–carbohydrate integration, thus reducing the solubility of dietary fibre (Siljestrom et al., 1986). Such changes may adversely affect the beneficial physiological effects. A significant increase in IDF content of peas was observed due to cooking when compared to their raw forms. This increase in IDF may be beneficial as the cellulose content of foods in insoluble fibre has been shown to be closely related to their glycemic responses (Selvendran, 1984). In present study, the IDF fraction which accounted for an average of 89% of TDF in the raw peas, further increased with cooking to 92%. Hence, it is possible that cooked peas may still be effective in reducing the glycemic response despite the reduction in SDF.

Soluble dietary fibre (SDF) contents in the dehulled seeds in the six pea varieties were significantly lower than in the raw seeds. Dehulled variety Nitouche had the highest SDF content whereas Delta had the lowest SDF content. Dehulling reduced IDF and TDF significantly in all six pea varieties (Table 3). The decreases observed in TDF content due to dehulling resulted mainly from a decrease in IDF content. The SDF content was low in raw and dehulled peas (Table 3), and dehulling of peas resulted in only marginal decreases

Table 2
Effect of soaking, cooking and dehulling on protein, starch and ash content of peas

Variety	Protein ($N \times 6.25$) (g kg^{-1} dry matter)				Starch (g kg^{-1} dry matter)				Ash (g kg^{-1} dry matter)			
	Raw	Soaking	Cooking	Dehulling	Raw	Soaking	Cooking	Dehulling	Raw	Soaking	Cooking	Dehulling
Nitouche	245.0c[A]	251.5bc (2.9)[B]	257.5b (5.3)	267.0a (9.0)	457.0c	464.5bc (1.5)	468.0b (2.4)	504.5a (10.5)	27.2a	25.1b (−7.7)	20.9c (−23.2)	27.5a (1.1)
Keoma	240.5c	252.0bc (5.0)	255.5b (6.7)	265.0a (10.4)	463.0c	469.0c (1.3)	483.5b (4.3)	515.0a (11.2)	25.3a	25.0ab (−1.2)	18.9b (−25.3)	25.4a (0.4)
SW Parade	229.0c	235.0b (2.6)	237.5b (3.9)	245.5a (7.0)	475.5c	480.5c (0.8)	508.0b (6.7)	532.0a (11.8)	25.9b	25.2c (−2.7)	17.0d (−34.4)	26.3a (1.5)
Eclipse	234.5c	244.5b (4.3)	244.5b (4.7)	249.5a (6.4)	485.0c	496.0bc (2.3)	507.3b (4.5)	538.0a (10.9)	25.3b	25.1b (−0.8)	18.4c (−27.3)	25.8a (2.0)
Delta	240.0c	247.5b (2.9)	248.0b (3.3)	253.5a (5.4)	490.5c	498.0bc (1.6)	506.0b (3.2)	527.0a (7.6)	25.4a	23.9b (−5.9)	19.5c (−23.2)	25.8a (1.6)
CDC Mozart	231.0c	237.0b (2.6)	238.5b (3.0)	248.0a (7.4)	494.5c	503.5bc (2.0)	510.0b (3.2)	535.5a (8.3)	25.8a	24.6b (−4.7)	19.1c (−26.0)	26.3a (1.9)
LSD[C]	9.2	4.2	3.5	3.4	15.6	12.0	7.1	15.6	0.75	0.69	0.39	0.62

[A] Means within a row with the same letter are not significantly different ($p > 0.05$) as determined using Duncan's multiple range test.
[B] Values in parentheses indicate % increase or % decrease (negative sign) over raw values.
[C] LSD = least significant difference ($p < 0.05$).

Table 3
Effect of soaking, cooking and dehulling on soluble, insoluble and total dietary fiber content of peas

Variety	Soluble fiber (g kg^{-1} dry matter)				Insoluble fiber (g kg^{-1} dry matter)				Total dietary fiber (g kg^{-1} dry matter)			
	Raw	Soaking	Cooking	Dehulling	Raw	Soaking	Cooking	Dehulling	Raw	Soaking	Cooking	Dehulling
Nitouche	18.6a[A]	18.1a (−2.7)[B]	17.8b (−7.5)	14.7c (−21.0)	149.7c	154.8b (5.8)	177.8a (18.7)	81.1d (−45.8)	168.3c	172.8b (2.9)	195.6a (16.2)	95.8d (−43.1)
Keoma	17.2a	17.0a (−1.2)	16.0b (−7.0)	12.6c (−26.7)	138.9c	150.2b (8.1)	193.1a (39.1)	84.3d (−39.3)	156.1c	167.5b (7.3)	209.1a (36.0)	96.9d (−37.92)
SW Parade	15.6a	15.3a (−1.9)	14.6b (−6.4)	11.8c (−24.4)	148.0c	153.5b (5.8)	194.2a (31.3)	84.2d (−43.1)	163.9c	168.8b (5.2)	208.8a (27.8)	96.0d (−41.3)
Eclipse	15.5a	15.1a (−2.6)	14.3b (−7.7)	13.5c (−12.9)	131.8c	142.4b (8.0)	162.9a (23.6)	77.1d (−41.5)	149.3c	157.5b (5.5)	177.2a (18.7)	90.5c (−39.4)
Delta	15.0a	14.7a (−2.0)	13.9b (−7.3)	11.0c (−26.7)	127.6c	147.0b (15.2)	175.1a (37.1)	79.3d (−37.9)	142.6c	161.7b (10.2)	188.9a (28.8)	90.3d (−38.4)
CDC Mozart	16.5a	16.0ab (−3.0)	15.6b (−5.5)	13.4c (−20.7)	132.2c	145.1b (9.8)	169.4a (28.2)	80.0d (−39.4)	148.6c	161.1b (6.4)	185.0a (24.4)	93.6d (−37.7)
LSD[C]	3.04	1.93	2.22	4.43	15.1	10.3	7.8	9.5	13.0	11.1	8.7	1.2

[A] Means within a row with the same letter are not significantly different ($p > 0.05$) as determined using Duncan's multiple range test.
[B] Values in parentheses indicate % increase or % decrease (negative sign) over raw values.
[C] LSD = least significant difference ($p < 0.05$).

in their SDF content. Differences in SDF, IDF and TDF contents were significant in the dehulled peas between varieties studied (Table 3). The percentage of SDF to TDF in the dehulled samples ranged from 12.2% to 15.3%, which were significantly higher than in the raw (9.5–11.1%) or cooked seeds (7.0–9.1%). The ratios of IDF to TDF in the dehulled samples were from 84.7–87.8%, which were significantly lower than in the raw (88.6% to 90.2%) or cooked seeds (90.8–92.8%).

Analysis of variance indicated that there was a significant varietal effect on Ca, Cu, Fe, K, Mg, Mn and Zn (Table 1), confirming the findings reported by Wang and Daun (2004). Results showed that potassium (K) was the most abundant element in raw peas ranging from 888.0 to 953.0 mg/100 g (Table 4). Phosphorus (P) in raw peas was found to range from 283.0 to 318.8 mg/100 g. Magnesium (Mg) varied from 117.0 to 128.0, calcium (Ca) from 75.0 to 91.0, iron (Fe) from 4.21 to 5.20, zinc (Zn) from 2.42 to 3.74 mg/100 g. Copper (Cu) ranged from 0.55 to 0.84 and manganese (Mn) from 0.89 to 1.33 mg/100 g. The mineral contents were in the range reported by Wang and Daun (2004) for Canadian field peas and were also comparable with those reported for other pulses (Jagadi, Rundgren, & Ogie, 1987; Salunkhe & Kadam, 1989).

Soaking had a significant effect on Ca, Cu and K while cooking affected all minerals analysed (Table 1). Variety × soaking had little influence on minerals (Table 1). The interactive effect of variety × cooking on Ca and Cu was significant but no effect was found on other minerals. Soaking resulted in a significant increase in Ca (3.1–6.9%) and Cu (9.1–16.7%) but a significant reduction in K (3.2–12.0%) (Table 4). Cooking peas in boiling water resulted in a significant increase in Ca (5.4–33.2%), Cu (13.6–34.3%), Mn (3.0–9.6%) and P (6.8–17.3%). However, cooking resulted in significant losses of Fe (4.6–21.7%), K (34.9–51.6%), Mg (3.8–8.2%) and Zn (3.6–15.5%) (Table 4). Haytowitz and Matthews (1983) reported that cooking in boiling water caused significant loss of K (24%), Cu (15%) and Fe (8%) for pulses. Dehulling had a significant effect on minerals except for Zn (Table 1). Interaction of variety × dehulling only affected Ca levels (Table 1). Dehulling decreased Ca, Cu, Fe, Mg and Mn (Table 4). Similar results were reported by Singh, Rao, Seetha, and Jambunathan (1989) for pigeonpea. K and P content in dehulled seeds were higher than those in the raw seeds.

Trypsin inhibitor activity (TIA) in the raw pea samples ranged from 1.30 to 2.01 mg g^{-1} sample (Table 5). The mean TIA value for the six varieties was 1.65 mg g^{-1} sample, which was in the range reported by Wang and Daun (2004). Analysis of variance showed that both variety and treatment (soaking, cooing or dehulling) had a significant effect TIA and phytic acid (Table 1). The interactive effect of variety x soaking or cooking on TIA was significant but there was no effect on phytic acid (Table 1). Variety × dehulling showed a significant effect on phytic acid. Soaking peas in distilled water resulted in an increase in TIA (3.2–19.3%) (Table 5). Trypsin inhibitors are low molecular weight proteins and as discussed previously protein concentration in the soaked seeds was higher than in the raw seeds. This may be attributed to the higher retention of TIA in soaked seeds. However, the result found in the present study is contrary to the result of Roman, Bender, and Morton (1987) who reported that 28% of TIA in cowpeas was destroyed during soaking. A significant reduction (62.3–77.8%) of TIA was found for all samples after cooking (Table 5). The varieties Keoma and SW Parade showed the highest reduction in TIA after cooking. Cooking has been reported to be effective in inactivating protease inhibitors in pulses (Gatta, Piergiovanni, Ng, Carnovale, & Perrino, 1989; Wang, Lewis, Brennan, & Westby, 1997). Sufficient cooking of peas is necessary to not only soften the peas but also to inactivate or reduce TIA. Thus cooking improves the nutritional quality of peas. However, excessive cooking could result in a loss of nutrients. Dehulling resulted in significant reduction in TIA (5.3–13.1%) for the six pea varieties, indicating that dehulling removed certain amount of TIA. Data from this study indicated that cooking reduced TIA more effectively than soaking or dehulling treatment.

Phytic acid content varied from 6.4 to 8.3 g kg^{-1} dry matter in pea varieties with a mean of 7.3 g kg^{-1} dry matter (Table 5), which was comparable with that reported (Wang & Daun, 2004). Cooking caused a significant reduction (5.3–10.8%) in phytic acid content for the six pea varieties. Similar result had been reported by Ologhobo and Fetuga (1984) in cowpeas. Dehulling increased phytic acid content by 5.3% to 8.0%, indicating that phytate is distributed throughout the cotyledons. This confirmed Beal and Mehta (1985) who reported that the hull or seed coat fraction of pea contained little or no phytate. The high level of phytic acid is of nutritional significance as not only is the phytate phosphorus unavailable to humans, but it also lowers the availability of many other essential minerals (Reddy, Pierson, Sathe, & Salunkhe, 1989).

The major soluble sugars (Table 6) found in peas were sucrose and oligosaccharides (raffinose, stachyose and verbascose), confirming the work of Vose, Basterrechea, Gorin, Finlayson, and Youngs (1976). Sucrose, raffinose, stachyose and verbascose content in the raw peas varied from 25.7–54.3 g kg^{-1} dry matter, 8.3–11.8 g kg^{-1} dry matter, 26.1–36.9 g kg^{-1} dry matter and 10.7–22.2 g kg^{-1} dry matter, respectively (Tables 5 and 6), and are in the same range as previously reported (Reddy et al., 1984; Wang & Daun, 2004). Analysis of variance indicated that both variety and treatment (soaking, cooking or dehulling) had a significant

Table 4
Effect of soaking, cooking and dehulling on minerals of peas

Variety	Raw	Soaking	Cooking	Dehulling	Raw	Soaking	Cooking	Dehulling	Raw	Soaking	Cooking	Dehulling
	Ca (mg/100 g)				*Cu (mg/100 g)*				*Fe (mg/100 g)*			
Nitouche	77.4b[A]	80.3a (3.7)[B]	81.6a (5.4)	37.9c (−51.0)	0.58c	0.65b (12.1)	0.76a (31.0)	0.54c (−6.9)	5.20a	5.11a (−1.7)	4.96b (−4.6)	4.80b (−7.7)
Keoma	83.5bc	86.7b (3.8)	95.0a (13.8)	37.9d (−54.6)	0.66b	0.70ab (6.1)	0.75a (13.6)	0.63b (−4.5)	5.19a	4.96a (−4.4)	4.56b (−12.1)	4.51b (−13.1)
SW Parade	81.8bc	85.0b (3.9)	99.9a (22.1)	41.8d (−48.9)	0.55b	0.60a (9.1)	0.63a (14.5)	0.50b (−9.1)	5.06a	4.90a (−3.2)	3.96b (−21.7)	4.24b (−16.2)
Eclipse	91.0c	96.9b (6.5)	108.8a (19.6)	49.7d (−45.4)	0.70c	0.81b (15.7)	0.94a (34.3)	0.65c (−7.1)	4.21a	4.09a (−2.9)	3.56b (−15.4)	3.63b (−13.8)
Delta	75.0c	79.8b (6.4)	92.0a (22.7)	40.0d (−46.7)	0.84c	0.98b (16.7)	1.09a (29.8)	0.78c (−7.1)	4.81a	4.58a (−4.8)	4.18b (−13.1)	4.18b (−13.1)
CDC Mozart	75.6c	80.8b (6.9)	100.7a (33.2)	41.5d (−45.1)	0.62c	0.70b (12.9)	0.83a (33.9)	0.60c (−3.2)	5.12a	5.01a (−2.1)	4.36b (−14.8)	4.75b (−7.2)
LSD[C]	6.05	4.28	9.95	4.80	0.07	0.11	0.12	0.08	0.93	0.68	0.80	0.81
	K (mg/100 g)				*Mg (mg/100 g)*				*Mn (mg/100 g)*			
Nitouche	902.0b	854.5c (−5.3)	587.5d (−34.9)	966.5a (7.2)	128.0a	129.5a (1.2)	120.5b (−5.9)	106.5b (−16.8)	1.11ab	1.14ab (2.7)	1.18a (6.3)	1.03b (−7.2)
Keoma	890.0ab	861.5b (−3.2)	488.8c (−45.1)	920.5a (3.4)	120.0a	124.0a (3.3)	115.0b (−4.2)	96.5b (−19.6)	1.10b	1.13ab (2.7)	1.2a (9.1)	1.02c (−7.3)
SW Parade	909.5ab	859.0b (−5.6)	440.0c (−51.6)	958.5a (5.4)	121.5a	122.0a (0.4)	111.5b (−8.2)	97.9c (−19.4)	1.33a	1.36a (2.3)	1.37a (3.0)	1.24b (−6.8)
Eclipse	888.0b	794.5c (−10.5)	464.5d (−47.7)	954.5a (7.5)	128.0a	130.8a (2.2)	119.0b (−7.0)	110.5c (−13.7)	1.04b	1.08a (3.8)	1.14a (9.6)	0.92c (−11.5)
Delta	953.0ab	909.5b (−4.6)	599.0b (−37.1)	985.5a (3.4)	117.0a	117.5a (0.4)	109.5b (−6.4)	97.1c (−17.0)	0.89b	0.90b (1.1)	0.94a (5.6)	0.77b (−13.5)
CDC Mozart	910.5ab	801.0c (−12.0)	554.5d (−39.1)	945.3a (3.8)	119.0ab	123.0a (3.4)	114.5b (−3.8)	102.0c (−14.3)	1.29b	1.31ab (1.6)	1.38a (7.0)	1.17c (−9.3)
LSD[C]	57.9	84.4	93.6	87.2	10.7	9.74	16.8	6.59	0.17	0.14	0.21	0.24
	P (mg/100 g)				*Zn (mg/100 g)*							
Nitouche	318.8c	335.0bc (5.1)	361.5ab (13.4)	380.5a (19.4)	3.22a	3.13a (−2.8)	2.92b (−9.3)	3.10a (−3.7)				
Keoma	283.0c	295.0c (4.2)	317.0b (12.0)	368.5a (30.2)	2.78a	2.67a (−4.0)	2.45b (−11.9)	2.71a (−2.5)				
SW Parade	311.5c	318.5c (2.2)	365.5a (17.3)	342.0ab (9.8)	3.74a	3.68a (−1.6)	3.16b (−15.5)	3.70a (−1.1)				
Eclipse	297.8b	300.0b (0.7)	321.0a (7.8)	322.0a (8.1)	2.80a	2.71a (−3.2)	2.37b (−15.4)	2.72a (−2.9)				
Delta	307.5b	314.5b (2.3)	335.0a (8.9)	329.3a (7.1)	2.42a	2.35a (−2.9)	2.18b (−9.9)	2.35a (−2.9)				
CDC Mozart	307.0b	319.3b (4.0)	328.0a (6.8)	356.0a (16.0)	3.03a	2.92ab (−3.6)	2.56ab (−3.6)	2.99a (−1.3)				
LSD[C]	63.0	55.4	54.7	51.7	0.38	0.44	0.46	0.16				

[A] Means within a row with the same letter are not significantly different ($p > 0.05$) as determined using Duncan's multiple range test.
[B] Values in parentheses indicate % increase or % decrease (negative sign) over raw values.
[C] LSD = least significant difference ($p < 0.05$).

Table 5
Effect of soaking, cooking and dehulling on trypsin inhibitor activity (TIA), phytic acid and sucrose content of peas

Variety	TIA (mg/g dry matter)				Phytic acid (g kg^{-1} dry matter)				Sucrose (g kg^{-1} dry matter)			
	Raw	Soaking	Cooking	Dehulling	Raw	Soaking	Cooking	Dehulling	Raw	Soaking	Cooking	Dehulling
Nitouche	1.30b[A]	1.45a (11.5)[B]	0.49d (−62.3)	1.13c (−13.1)	8.3b	8.2b (−1.2)	7.4c (−10.8)	8.7a (4.8)	50. 4b	40.4c (−19.8)	29.3d (−41.9)	56.5a (12.1)
Keoma	1.71b	1.86a (8.8)	0.38d (−77.8)	1.62c (−5.3)	7.5b	7.4b (−1.3)	7.0c (−6.7)	8.1a (8.0)	46.1a	33.8b (−26.7)	19.0c (−58.8)	46.9a (1.7)
SW Parade	1.64b	1.76a (7.3)	0.38c (−76.8)	1.53c (−6.7)	6.8b	6.7b (−1.5)	6.4c (−5.9)	7.3a (5.9)	54.3a	45.4b (−16.4)	20.5c (−62.2)	56..65a (4.1)
Eclipse	1.56b	1.61a (3.2)	0.42d (−73.1)	1.46c (−6.4)	7.3b	7.2b (−1.4)	6.9c (−5.5)	7.7a (5.4)	32.6a	24.0c (−26.4)	12.5d (−61.7)	33.7a (3.4)
Delta	2.01b	2.26a (12.4)	0.52c (−74.1)	1.90c (−5.5)	6.4b	6.3b (−1.6)	6.0c (−6.3)	6.9a (7.8)	25.7a	20.8b (−19.1)	12.6c (−51.0)	26.7a (3.9)
CDC Mozart	1.66b	1.98a (19.3)	0.43c (−74.1)	1.57c (−5.4)	7.5b	7.4b (−1.3)	7.1c (−5.3)	7.9a (5.3)	29.2a	21.8b (−25.3)	14.4c (−50.7)	29.7a (1.7)
LSD[C]	0.11	0.09	0.04	0.12	0. 36	0.34	0.57	0.50	1.86	1.29	1.22	1.82

[A] Means within a row with the same letter are not significantly different ($p > 0.05$) as determined using Duncan's multiple range test.
[B] Values in parentheses indicate % increase or % decrease (negative sign) over raw values.
[C] LSD = least significant difference ($p < 0.05$).

effect on sucrose, raffinose, stachyose and verbascose content in peas (Table 1). The interaction of variety x soaking displayed a significant effect on sucrose and satchyose (Table 1). Variety × cooking affected sucrose and oligosaccharides while variety × dehulling had an effect on sucrose and verbascose (Table 1). Soaking significantly reduced sucrose (16.4–26.7%) and stachyose content

Table 6
Effect of soaking, cooking and dehulling on oligosaccharides content of peas

Variety	Raffinose (g kg^{-1} dry matter)				Stachyose (g kg^{-1} dry matter)				Verbascose (g kg^{-1} dry matter)			
	Raw	Soaking	Cooking	Dehulling	Raw	Soaking	Cooking	Dehulling	Raw	Soaking	Cooking	Dehulling
Nitouche	9.2a[A]	9.7a (5.4)[B]	7.5b (−18.5)	9.6a (4.3)	27. 6b	25.4b (−8.0)	17.1c (−38.0)	29.2a (5.8)	13.7b	14.5ab (5.8)	10.2c (−25.5)	15.1a (10.2)
Keoma	11.8a	12.8a (8.5)	6.2b (−47.5)	11.9a (0.8)	30.9b	29.8c (−3.6)	14.3d (−53.7)	34.0a (10.0)	10.7c	12.1b (13.1)	6.8d (−36.4)	14.3a (33.6)
SW Parade	9.4b	9.5b (1.1)	4.9c (−47.9)	10.9a (16.0)	28.0b	25.2c (−10.0)	11.7d (−58.2)	30.5a (8.9)	12.7b	13.4b (5.5)	7.4c (−41.7)	16.1a (26.8)
Eclipse	10.6b	11.3a (6.6)	7.4c (−30.2)	11.6a (9.4)	32.4b	28.0c (−13.6)	16.5d (−49.1)	35.6a (9.9)	13.7c	14.7b (7.3)	9.5d (−30.7)	15.9a (16.1)
Delta	11.2b	12.1a (8.0)	9.9b (−11.6)	12.3a (9.8)	36.9b	34.7c (−6.0)	24.3d (−34.1)	39.1a (6.0)	12.8b	14.3a (11.7)	10.8c (−15.6)	14.4a (12.5)
CDC Mozart	8.3a	8.3b (1.2)	6.5c (−21.7)	8.7a (4.8)	26.1b	23.1c (−11.5)	14.2d (−45.6)	27.4a (5.0)	22.2b	22.5b (1.4)	17.0c (−23.4)	24.1a (8.6)
LSD[C]	0.95	0.99	0.87	1.01	0.98	1.22	1.1	1.89	0.95	1.16	1.28	0.90

[A] Means within a row with the same letter are not significantly different ($p > 0.05$) as determined using Duncan's multiple range test.
[B] Values in parentheses indicate % increase or % decrease (negative sign) over raw values.
[C] LSD = least significant difference ($p < 0.05$).

(3.6–13.6%) in the six varieties studied, but raffinose and verbascose content were increased up to 8.5% and 11.7%, respectively. Somiari and Balogh (1993) had reported that soaking cowpeas in distilled water reduced the levels of oligosaccharides. Upadhyay and Garcia (1988) attributed the removal of the oligosaccharides from cowpeas to the differential solubility of individual sugars and their diffusion rates. Cooking in the present study caused a greater reduction in sucrose and oligosaccharide levels than soaking with a mean decrease of 54.4% for sucrose, 29.5% for raffinose, 46.5% for stachyose and 28.9% for verbascose. These observations are in agreement with that reported by Khalil and Mansour (1995) for faba bean and by Wang et al. (1997) for cowpeas. Onigbinde and Akinyele (1983) proposed that the decrease in raffinose, stachyose and verbascose during cooking may be attributed to heat hydrolysis to disaccharides and monosaccharides or to the formation of other compounds. Dehulling resulted in a significant increase in sucrose (12.1%) for variety Nitouche but had a little effect for other varieties studied (Table 5). Raffinose contents in SW Parade, Eclipse and Delta variety were significantly increased by dehulling (Table 6) whereas removal of seed coat had little effect on raffinose content for other varieties. Dehulling had a significant effect on stachyose and verbascose content for the six pea varieties (Table 6). Keoma variety had the highest reduction in both stachyose (10%) and verbascose (33.6%) in dehulled seeds whereas variety CDC Mozart showed the lowest reduction in both stachyose (5.0%) and verbascose (8.6%).

4. Conclusions

Crude protein content in raw field peas found in this study ranged from 229.0 to 245.0 g kg^{-1} dry matter. Starch (457.0–494.5 g kg^{-1} dry matter) accounted for most of the difference in protein content, while the remainder consisted of ash, total dietary fibre, sucrose and anti-nutritional factors (TIA, phytic acid and oligosaccharides). Field peas are a good source of minerals such as Ca, Fe, K, Mn, P and Zn. Oilgosaccharides varied from 50.0 to 61.0 g kg^{-1} dry matter, phytic acid from 6.4 to 8.3 g kg^{-1} dry matter, trypsin inhibitor activity (TIA) from 1.3 to 2.0 mg/g sample. As shown in this study, variety and processing (soaking, cooking and dehulling) affected the composition, minerals and antinutritional factors in field peas. Significant differences in proximate composition, dietary fibre, minerals, oligosaccharides, trypsin inhibitor activity (TIA) and phytic acid content were found among pea varieties. Soaking or cooking increased crude protein content, soluble dietary fibre (SDF), insoluble dietary fibre (IDF), total dietary fibre (TDF), Ca, Cu, Mn and P in peas whereas reduced ash content, Fe, K, Mg, Zn, sucrose and oligosaccharides. Cooking was more effective than soaking in reducing TIA and oligosaccharides. Dehulled seeds had higher crude protein, starch, K, P, phytic acid, stachyose and verbascose content, but lower TIA, SDF, IDF, TDF, Ca, Cu, Fe, Mg and Mn than raw seeds. The information gathered from this study will be beneficial for human nutritionists who wish to incorporate peas into their dietary specifications.

Acknowledgements

We gratefully acknowledge the technical assistance of R. Toews, M. Richardson (Summer student) and K. Jarrin, Canadian Grain Commission, Grain Research Laboratory.

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