Rheological and qualitative characteristics of pea flour incorporated cracker biscuits

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Summary

The suitability of pea flour for cracker biscuits production was investigated in this study. Pea flour was characterised by high protein (21.46 %) and ash (3.11 %) content and exhibited relatively high emulsifying (37.50 ml/100 ml) and foaming (53.50 ml/100 ml) capacity. The effect of pea flour incorporation to wheat dough (substitution levels 0, 10, 20 and 30 %) on the rheological properties, physical characteristics and sensory parameters of cracker biscuits were also evaluated. Farinographic measurements showed that pea flour addition resulted in increasing of water absorption (from 58.90 to 61.80 %) and dough development time (from 3.55 to 4.50 min), whereas dough stability was decreased (from 6.69 to 3.50 min). It was also found that incorporation of pea flour to cracker biscuits modified physical properties of final products by different ways (decreasing of volume index, width and spread ratio, increasing of thickness). From the sensory evaluation revealed that cracker biscuits prepared from blend flour contained 10 % pea flour showed no significant differences from wheat cracker biscuits. Higher levels of pea flour in the products adversely affected the odour, taste, firmness, colour and overall acceptance of final products.

Keywords: pea, functional properties, rheology, cracker biscuits, quality

Introduction

Legumes have a very specific place from the nutritive point of view and play an important role in nourishment of world population. Pursuant to the Alimentary Codex of the Slovak republic (part three, chapter twelve) as legumes are understood ripe eatable seeds of legume plants: pea (*Pisum sativum* L.), lentil (*Lens culinaris* Med.), common bean (*Phaseolus vulgaris* L.), soya bean (*Glycine max* L.), chickpea (*Cicer arietinum* L.), sweet pea (*Lathyrus* L.) and broad beans (*Vicia faba* L.), which are suitable after processing for consumption (Bojňanská et al., 2012). As good sources of proteins, carbohydrates, several water-soluble vitamins (Sreerama at al., 2012) especially of the B-complex, and minerals such as calcium and iron (Kaur et al., 2007), legumes make a major contribution to human nutrition (Sreerama at al., 2012). The addition of legumes to cereal-based products could be a good means by which to increase the consumption of these products (De la Hera et al., 2012). Furthermore, legume proteins are rich in lysine but deficient in sulphur-containing amino acids, whereas cereal proteins are deficient in lysine but have adequate levels of sulphur-containing amino acids. The combination of cereal and legume proteins would thus provide a better overall balance of essential amino acids, which is very important in a balances diet (De la Hera et al., 2012; Kadam et al., 2012). In addition, the inclusion of legumes in the daily diet has many beneficial physiological effects in controlling and preventing various metabolic diseases such as (Siddiq et al., 2010; Angioloni and Collar, 2012): diabetes mellitus, cardiovascular disease (Arab et al., 2010; De la Hera et al., 2012) and some forms of cancer (Siddiq et al., 2010; Angioloni and Collar, 2012; De la Hera et al., 2012).

Recent papers report the application of legume flours as functional ingredients in some cereal based foods such as (Aguilera et al., 2011): breads (Des Marchais et al.; 2011, Dhinda et al., 2011; Hefnawy et al., 2012), cakes (Gómez et al., 2008; Abou-Zaid et al., 2011; De la Hera et al., 2012), spaghetti (Bahnassey and Khan, 1986; Arab et al., 2010), biscuits (Eissa et al., 2007; Tiwari et al., 2011) and crackers (Bose and Shams-ud Din, 2010; Han et al., 2010; Sedej et al., 2011).

The aim of this study was to investigate the utilisation of pea flour for cracker biscuits production. The chemical composition and functional properties of pea flour were determined. The effect incorporation of pea flour on farinographic properteis of wheat dough, cracker biscuits quality and sensory acceptance were also studied.

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Material and methods

Raw materials

Commercially available fine wheat (type T650) and pea flours purchased from local food market in Slovakia were used in the formulation of cracker biscuits.

Chemical analysis

Moisture, fat and ash content of flours were determined using a method of Tiwari et al. (2011). Protein content was determined by multiplying the nitrogen content with factor 5.75 (fine wheat flour) and 6.25 (legume flours) (Sudha et al., 2007). Total carbohydrates were calculated by difference (Arab et al., 2010).

Functional properties

Hydration properties: Water holding capacity (WHC) and swelling capacity (SWC) were determined according to method described by Raghavendra et al. (2004). Emulsifying capacity (EC) and foaming capacity (FC) of flours were determined according to the method of Siddiq et al. (2010). The least gelation concentration (LGC) of flours was measured by the method of Kaur and Singh (2005).

Composite flours preparation

Composite flours were prepared using blends of fine wheat flour (wet gluten content: 32.92 ± 0.52 % in dry matter) and pea flour in proportions of 100:0, 90:10, 80:20 and 70:30 (w/w) respectively.

Rheological properties

Rheological properties of doughs were evaluated by using of farinograph (Brabender, Duisburg, Germany) as described Wang et al. (2002). Parameters measured were: water absorption capacity (WA), dough development time (DDT) and dough stability (DS).

Cracker biscuit preparation

Cracker biscuits were prepared from blend wheat-legume flours and other ingredients (water, baking powder, sunflower oil, salt and sugar) according to formulation described by Han et al. (2010). Fine wheat flour was used for preparation of control cracker biscuits. Preparation of cracker biscuits included these operations: mixing of dry and liquid ingredients, 10 min resting of dough, sheeting and laminating of dough and cutting into round shape. The crackers were baked in electric oven at 175 °C for 4 min and cooled to room temperature.

Physical parameters of cracker biscuits

Cracker biscuits were evaluated for their physical properties (volume index, diameter (width), thickness, spread ratio) after cooling at room temperature for 2 h. Volume index of samples was measured by method described with Turabi et al. (2008). The spread ratio was determined by the formula W/T, where W is the average diameter and T is the average thickness of 5 biscuits (Bose and Shams-ud Din, 2010).

Sensory evaluation of cracker biscuits

Sensory evaluation of cracker biscuits was performed using a 5-points hedonic scale method (5 – excellent, 1 - very poor) by 11 trained assessors according to method described by Aziah et al. (2012). A glass of water was provided to cleanse the palate between samples.

Statistical analysis

All analyses were done in triplicate and average values were calculated. Data were presented as mean ± standard deviation. The results were statistically analysed by one-way analysis of variance and means were compared using multiple range test – Fisher's least significant differences procedure at 0.05 levels to describe the significance of differences between control and samples incorporated with different levels of pea flour. Statgraphic Plus, Version 3.1 (Statsoft; Tulsa, Oklahoma, USA) was used as statistical analysis software.

Results and discussion

Chemical composition of flours

Chemical compositon of fine wheat and pea flours are presented in the Table 1. It was concluded that pea flour had considerably higher protein (21.46 %) and ash (3.11 %) content than fine wheat flour (11. 70 % of proteins, 0.45 % of ash). On the other side, fine wheat flour was presented with higher carbohydrate content (72.74 %) in comparison to pea flour (66.38 %).

Table 1. Chemical composition of fine wheat and pea flours

Flour sample	Moisture	Proteins	Fat	Ash	Carbohydrates
	(% in dry matter)				
Fine wheat	13.60 ± 0.02	11.70 ± 0.07	1.51 ± 0.02	0.45 ± 0.04	72.74 ± 2.85
Pea flour	7.92 ± 0.03	21.46 ± 0.50	1.13 ± 0.05	3.11 ± 0.05	66.38 ± 2.41

Functional properties of flours

In view of the increasing utilisation of legume flours in composite flours for various food formulations their functional properties are assuming greater significance (Kaur and Singh 2005). The results from analysis of functional properties of studied flours are summarised in the Table 2. Hydration parameters (WHC and SWC) are interesting because they can be associated to the amount of water retained by the sample, for example during kneading of dough (De Escalada Pla et al., 2007). Pea flour showed higher WHC (3.87 g/g) than was reported by Boye et al. (2010b), Chau and Cheung (1998) and Aguilera et al. (2011) for legume protein concentrates (0.60-2.70 g/g), different Chinese legume (1.04-1.47 g/g) and Cannellini and Pinta bean (2.20-2.70 g/g) flours. The higher WHC of pea flour may be due to presence of proteins and polysaccharides, which represent the major chemical components of legume flours (Chau and Cheung, 1998; Raghavendra et al., 2004; Arab et al., 2010; Arab et al., 2010; Eltayeb et al., 2011; Appiah et al., 2011). SWC is parameter indicates how much the sample matrix swells as water is absorbed (De Escalada Pla et al., 2007). Pea flour presented in this study showed similar SWC value (3.40 ml/g) as was earlier described for chickpea (3.30 ml/g) and heat treated cowpea (2.31-4,63 ml/g) flours by Kohajdová et al. (2011) and Enwere and Ngoddy (1986). On the other hand, higher SWC values were observed by Benítez et al. (2013) for non-convential legume flours (5.00-5.50 ml/g). The high swelling power suggests the pea flour could be useful in food systems where swelling is required (Appiah et al., 2011).

Table 2. Functional properties of fine wheat and pea flours

Functional parameters	Fine wheat flour	Pea flour
Water holding capacity (g/g)	3.25 ± 0.15	3.87 ± 0.17
Swelling capacity (ml/g)	2.00 ± 0.08	3.40 ± 0.12
Emulsifying capacity (ml/100 ml)	*	37.50 ± 0.08
Foaming capacity (ml/100 ml)	10 ± 0.45	53.50 ± 0.24
LGC (g/100 g)	10	12

*did not form emulsion

LGC may be defined as the lowest concentration required to formation a self-supporting gel. Samples with lower LGC have greater gelling capacity (Boye et al., 2010a). LCG of studied pea flour was 12 %. Similar LGC values (8-14 %) were reported by Siddiq et al. (2010); Boye et al. (2010b) and Kaur and Singh (2005) for bean, chickpea flours and legume protein concentrates. On the other hand Ma et al. (2011) and Butt and Batool (2010) found higher LGC for various legume flours and protein isolates (14-20 %). Variations in gelling properties have associated to the relative ratio of different constituents such as proteins, lipids and carbohydrates in different legume flours (Chau and Cheung, 1998).

EC is defined as the ability of flour to emulsify oil (Kaur and Singh, 2005). Pea flour exhibited EC 37.50 ml/100 ml. Higher EC values were reported by Siddiq et al. (2010) and Sreerama et al. (2012) for different bean (45.60-60.50 ml/100ml), chickpea, horse gram and cowpea flours (48.80-58.10 ml/100 ml). The differences in the chemical compositions and protein solubility might have accounted for the observed differences in EC of legume flours (Sreerama et al., 2012). It was also showed that pea flour exhibited relatively high FC (53.30 ml/100 ml). These results were higher than those found by Siddiq et al. (2010), Kohajdová et al. (2011) and Kaushal et al. (2012) for bean, chickpea and pigeon pea flours (33.00-45.70 ml/100 ml). Appiah et al. (2011) attributed low FC to inadequate electrostatic repulsions, lesser solubility and hence, excessive protein-protein interaction. On the other hand, higher FC may be due to highly hydrated foams.

Rheological properties of wheat-pea dough

Rheological information is valuable in product development (Turabi et al., 2008). Rheological properties of wheat-pea flour blends measured by farinograph are presented in Table 3. Incorporation of pea flour into the fine wheat flour caused an increase in WA from 58.90 to 61.80 %. These results are in agreement with those found by Sadowska et al. (2003), Eissa et al. (2007), Pasha et al. (2011), Des Marchais et al. (2011) and Mohamed et al. (2012). Increasing of WA has been attributed by the ability of proteins to absorb high quantity of water, thus limiting the water availability for the development of the gluten network when in competition with wheat proteins (Des Marchais et al., 2011). Other components such as sugars and fibre may also affect WA of blend flours (Kamaljit et al., 2010; Abou-Zaid et al., 2011). Farinographic measurements also showed that DDT increased as the substitution percentage of pea flour increased, with increasing about 21.1 % for blend flour containing 30 % of pea flour in compare to wheat dough. Similar results were reported by Bahnassey and Khan (1986), Shahzadi et al. (2005), Eissa et al. (2007) and Abou-Zaid et al. (2011). The increase in DDT resulting from pea addition could have been due to the differences in the physico-chemical properties between the constituents of the pea and those of the wheat flours, as has been previously reported by Mohammed et al. (2012). DS which indicates the dough strenght, decreased from 6.69 to 3.50 min. Similar effects on DS were observed by Fenn et al. (2010), Abou-Zaid et al. (2011) and Giménez et al. (2012) when the legume proteins, faba bean, cowpea and broad bean flours were added to wheat dough. In general, the increasing of DDT and reduction in DS could be explaines due to the interactions between non-wheat proteins, fibres and gluten leading to a delay in the hydration and development of gluten in the presence of these ingredients (Dhinda et al., 2011).

Table 3. Effect of pea flour addition on farinographic properties of wheat dough

Pea flour level (%)	WA (%)	DDT (min)	DS (min)
0	58.90 ± 0,30[a]	3.55 ± 0.20[a]	6.69 ± 0.28[a]
10	60.60 ± 0.26[a]	4.00 ± 0.17[b]	4.50 ± 0.12[b]
20	61.37 ± 0.12[b]	4.40 ± 0.00[c]	4.30 ± 0.26[c]
30	61.80 ± 0.10[c]	4.50 ± 0.10[d]	3.50 ± 0.10[d]

[*]mean values in the same column which is not followed by the same letter are significantly different at p = 0.05

Physical properties of pea flour incorporated cracker biscuits

Physical properties of pea flour incorporated cracker biscuits are schowed in the Table 4. It was concluded, that volume index, which is an indicator of cracker volume (Gómez et al., 2008) was reduced from 1.37 (control sample) to 0.98 (sample with 30 % of pea flour). Goméz et al. (2008) and Hemeda and Mohamed (2010) also described reduced volume index for chickpea incorporated wheat cakes. The decreasing of volume index resulting from pea flour addition is most likely due to the combined effect of gluten dilution and mechanical disruption of gluten network structure by the pea particles (Fenn et al., 2010; Mohammed et al., 2012) and the lower ability of the dough to enclose air (Hallén et al., 2004). Incrorporation of pea flour to wheat cracker biscuits also affected diameter, thickness and spread ratio. Cracker biscuits diameters were reduced, while thickness increased with increasing level of pea flour in products. Other researchers (Eissa et al., 2007; Tiwari et al., 2011) also reported similar effect on the thickness and diameter of chickpea, kidney pea and pigeon pea flours substituted wheat biscuits. Biscuits having higher spread ratios are considered most desirable (Hussein et al., 2011; Tiwari et al., 2011; Zucco et al., 2011). It was found that, with increase in level of pea flour spread ratio of crackers decreased. Similar effect on spread ratio was observed after additon different level of pea (Kamaljit et al., 2010) and pigeon pea (Tiwari et al., 2011) flours to wheat cookies and biscuits. This might have been due to greater water retention of flours. For the blends containing legume flours, the increasing number of hydrophilic sites available due to increased protein content compete for the limited free water in dough (Zucco et al., 2011). Rapid partitioning of free water of these hydrophilic sites occurs during dough mixing and increases dough viscosity, thereby limiting cracker biscuits spread and top grain formation during baking (Eissa et al., 2007).

Table 4. Physical properties of pea flour incorporated crackers

Pea flour level (%)	Volume index (cm)	Thickness (T) (cm)	Width (W) (cm)	Spread ratio (W/T)
0	1.37 ± 0.11[a]	0.34 ± 0.05[a]	4.44 ± 0.03[a]	13.06 ± 0.07[a]
10	1.18 ± 0.14[b]	0.36 ± 0.02[b]	4.34 ± 0.04[b]	12.06 ± 0.03[b]
20	1.05 ± 0.10[c]	0.37 ± 0.01[c]	4.33 ± 0.06[c]	11.70 ± 0.04[c]
30	0.98 ± 0.05[d]	0.38 ± 0.02[d]	4.29 ± 0.04[d]	11.29 ± 0.06[d]

*mean values in the same column which is not followed by the same letter are significantly different at p = 0.05

Sensory parameters of pea flour incorporated cracker biscuits

Sensory parameters of pea flour incorporated cracker biscuits are presented in the Table 5. Addition of pea flour concluded in increased hardness of cracker biscuits. The same changes in hardness of biscuits, cakes and breads with various legume flours addition have been reported by Tiwari et al. (2011), Goméz et al. (2008), De la Hera et al. (2012) and Sadowska et al. (2003). The increase in hardness of biscuits might have caused disruption in the well defined protein-starch complex of the dough due to reduction in the wheat structure forming proteins and starch (Dhinda et al., 2012).

Table 5. Sensory parameters of pea flour incorporated cracker biscuits

Sensory parameters	Pea flour level (%)			
	0	10	20	30
Odour	5.00 ± 0.10[a]	4.79 ± 0.07[a]	3.15 ± 0.06[b]	2.18 ± 0.05[c]
Taste	4.90 ± 0.11[a]	4.85 ± 0.08[a]	3.02 ± 0.05[b]	2.46 ± 0.07[c]
Firmness	4.86 ± 0.11[a]	3.05 ± 0.09[b]	2.70 ± 0.03[c]	2.00 ± 0.02[d]
Colour	4.95 ± 0.30[a]	4.69 ± 0.10[a]	3.40 ± 0.22[b]	3.06 ± 0.15[c]
Overall acceptance	4.99 ± 0.07[a]	4.76± 0.12[a]	4.19 ± 0.08[b]	3.98 ± 0.09[c]

*mean values in the same row which is not followed by the same letter are significantly different at p = 0.05

Colour characteristic is a major criterion that affects the quality of the food products (Abou-Zaid et al., 2011). The colour of crackers biscuits was progressively darker as the crackers contained higher levels of pea flour (20 and 30 %). Similar effect was observed by Hallén et al. (2004), Mohammed et al. (2012), Abou-Zaid et al. (2011), Zucco et al. (2011) and Tiwari et al. (2011) for different legumes supplemented breads, cakes, cookies and biscuits. The colour of the cracker biscuits top surface was generated in the baking process possibly due to non-enzymatic browning (Maillard reactions) between reducing sugars and amino acids, but also possibly to starch dextrination and sugar caramelisation (Gómez et al., 2008; Zucco et al., 2011). It was also concluded that higher levels of pea flour (20 and 30 %) caused also significant reduction in taste, odour and overall acceptance of final products due to higher intensity of leguminous taste and odour.

Consculsions

In the recent years, using of legumes in food formulation are assuming a greater importance and have attracted the attention of food processors, marketers and consumers (Benítez et al., 2013). The aim of this study was to investigate the potential of pea flour for cracker biscuits production. Pea flour was presented as a protein and mineral compounds rich raw material with good emulsifying and foaming capacity. It was also found that inclusion of pea flour to wheat dough resulted in increased WA and DDT, whereas DS was reduced. Possible reasons for these effects on the rheological properties of dough might include an effective decrease in wheat gluten content (dilution effect), competition between pea proteins and wheat flour proteins for water and possible proteolytic activity in the pea flours (Hallén et al., 2004). Also it was concluded that incorporation higher levels of pea flour (20 and 30 %) to cracker biscuits significantly reduced volume index, width and spread ratio of final products. As was described earlier (Angioloni and Collar, 2012) as an efficient strategy for elimination of these adversely effects, structuring agents (gluten, hydrocolloids) can be applied into the legume based cereal products. Sensory evaluation showed that no significant differences were observed in odour, taste, colour and

overall acceptance of fine wheat cracker biscuits and cracker biscuits containing 10 % of pea flour. Higher proportions of pea flour adversely modified of sensory parameters of cracker biscuits.
In the generally it could be stated that, substitution percentage and the kind of legume flour used should be experimentally determined in each case depending on the kind of cereal products, and the purpued objectives (nutritional improvement, free-gluten products, special organoleptic characteristics, etc.) (Gómez et al., 2008; Hefnawy et al., 2012).

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