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Functional properties of corn and corn–lentil extrudates

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ABSTRACT

Functional properties of corn and corn–lentil extrudates were investigated as a result of extrusion conditions, including feed rate (2.5–6.8 kg/h), feed moisture (13–19% wet basis) and extrusion temperature (170–230 °C). Lentil was used in mixtures with corn flour at a ratio of 10–50% (legume/corn). The water absorption index of extrudates increased with extrusion temperature and feed moisture content and decreased with feed rate and lentil/corn ratio. The water solubility index of extrudates increased with temperature, but decreased with feed moisture content and feed rate. The oil absorption index of extrudates increased with extrusion temperature and decreased with feed rate, feed moisture content and lentil/corn ratio. Generally, the use of lentil flour led to products with lower values for functional properties. Principal component analysis of functional properties discriminated samples with appropriate functionality based on industrial use.

1. Introduction

Grain legumes are important sources of food proteins. In many regions of the world, legume seeds are the unique protein supply in the diet. Very often, they represent a necessary supplement to other protein sources (Duranti & Gius, 1997). Therefore, the dietary importance of legume seeds is expected to increase in the future with increasing protein requirement due to population growth and reduction in consumption of animal protein, especially in the developed countries (Makri, Papalamprou, & Doxastakis, 2005). From the nutritional viewpoint, all legume storage proteins are relatively low in sulphur-containing amino acids, methionine, cysteine and tryptophan, but the amounts of another essential amino acid, lysine, are much greater than in cereal grains (Duranti, 2006). Therefore, with respect to lysine and sulphur amino acid contents, legume and cereal proteins are nutritionally complementary.

Extrusion cooking technology is a versatile and efficient method of converting raw materials into finished food products. It can replace many conventional processes in food and feed industry, because it is unique among heat processes in that the material is subjected to intense mechanical shear; moistened starchy or proteinaceous foods are worked into viscous, plastic-like dough and cooked before being forced through the die. Extrusion has been used to develop various types of snack foods, mainly from corn meal, rice, wheat flour or potato flour, in many shapes and variety of textures. Application of extrusion to legume flours is a relatively new area of investigation with the exception of soy bean (Lazou, Michailidis, Thymi, Krokida, & Bisharat, 2007; Rocha-Guzman et al., 2006).

The suitability of extruded foods for a particular application depends on their functional properties like water absorption, water solubility and oil absorption indexes, expansion index, bulk density and viscosity of the dough (Ali, Hanna, & Chinnaswamy, 1996; Hernandez-Diaz, Quintero-Ramos, Barnard, & Balandran-Quintana, 2007). The effect of extrusion conditions on functional properties of various cereal products (corn, rice and wheat) has been investigated (Artz, Warren, & Villota, 1990; Choudhury & Gautam, 1998; Ding, Ainsworth, Plunkett, Tucker, & Marson, 2006; Ding, Ainsworth, Tucker, & Marson, 2005; Gomez & Aguilera, 1983; Kadan, Bryant, & Pepperman, 2003; Sacchetti, Pinnavaia, Guidolin, & Rosa, 2004). Generally, functional properties of extrudates are related with the molecular modifications that occur during extrusion cooking. Furthermore, the effect of protein addition on the functional properties of cereal based extrudates has been reported previously (Fernandez-Gutierrez, Martin-Martinez, Martinez-Bustos, & Cruz-Orea, 2004; Gujska & Khan, 1991a; Lin, Huff, & Hsieh, 2002; Matthey & Hanna, 1997; Onwulata, Smith, Konstance, & Holsinger, 2001). The most common protein sources used for their production are soy, caseins, whey proteins, native or isolates and to smaller extent vegetable proteins from legumes like beans and chickpeas (except soy) (Anton, Fulcher, & Arntfield, 2009; Balandran-Quintana, Barbosa-Canovas, Zazueta-Morales, Anzaldua-Morales, & Quintero-Ramos, 1998; Singh, Sekhon, & Singh, 2007; Skierkowski, Gujska, & Khan, 1990). So, there is a need for investigation of the functionality of extrudates based on other legume types, because the nutritional value of those products is of great interest.

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The objective of this work was to investigate functional properties (water absorption, water solubility and oil absorption indexes) changes of corn and corn–lentil based extrudates as a function of extrusion conditions (feed rate and extrusion temperature) and material characteristics (moisture content and legume to corn ratio). Furthermore, functional properties were correlated, in order to discriminate samples with desired functionality.

2. Materials and methods

2.1. Sample preparation

Yellow corn flour was obtained from Marra Bros Mills S.A. (Korinthos, Greece) and lentil flour (with hull) was donated by Agrino-Ev.Ge. Pistiolas S.A (Agrinio, Greece). Chemical composition of raw material is shown in Table 1. The particle size distribution of raw flours was measured by sieve analysis using a set of standard sieves (Fritsch GmbH, Germany) (Table 2) and a digital sieve shaker (Octagon 2000, Endecotts Ltd., UK). Corn and lentil flour were mixed to the desired ratios: 0%, 10%, 30% and 50% legume/corn. Feed mixtures were adjusted to desired moisture content by spraying calculated amounts of distilled water and mixing thoroughly for 15 min. The samples were packed in polyethylene bags and kept in the refrigerator overnight to equilibrate the moisture. Sample moisture content was determined in an oven at 75 °C under a vacuum of 50 mm Hg to constant weight. The feed moisture content levels were 13%, 16% and 19% wb. Corrections in moisture were done in cases of deviation from the set values. The samples were brought to room temperature before extrusion cooking.

2.2. Extrusion cooking

A co-rotating twin screw extruder (Prism Eurolab, model KX-16HC, Staffordshire, UK) was used. The screw geometry was: length 40 cm, diameter 16 mm, maximum rotation speed 500 rpm and die diameter 3 mm. The material was fed into the extruder using a volumetric feeder. The extruder had five temperature control zones. The temperature during extrusion was adjusted by varying the temperature in the barrel, screw and die using electric heaters. The screw speed was set at 200 rpm. The extrusion conditions are shown on Table 3. Steady-state conditions were reached after 20 min, after which samples were collected, air-dried and stored in appropriate laminated bags for further properties measurements.

2.3. Water absorption and solubility indices

The water absorption index (WAI) was determined according to the method of Anderson, Conway, and Peplinski (1970): distilled water (5 mL) was added to ground sample (0.2 g) in a weighed 15 mL glass centrifuge tube. The tube was agitated on a Vortex mixer for 2 min and then centrifuged for 20 min at 700*g*. The supernatant liquid was poured into a tarred evaporating dish. The remaining gel was weighed and the WAI was calculated as:

Table 1
Chemical composition of raw materials (g/100 g).

	Corn	Lentil
Protein	6	28
Lipids	1	1
Total carbohydrates	83	57
Dietary fiber	2	30
Sugar	1	5

Table 2
Particle size distribution of corn and lentil flour.

Screen size (μm)	Corn (% retention)	Lentil (% retention)
630	0.35	1.20
500	0.35	8.78
400	1.40	13.58
315	8.49	15.62
200	61.39	23.70
100	24.82	16.86
90	1.79	1.56
Through 90	1.42	18.70

Table 3
Extrusion processing conditions and raw material characteristics.

Extrusion conditions	Values
Extrusion temperature (°C)	170
	200
	230
Feed rate (kg/h)	2.52
	4.68
	6.84
Material characteristics	
Corn/lentil ratio	0
	10
	30
	50
Feed moisture content (kg/100 kg wb)	13
	16
	19

$$\mathrm{WAI} = \frac{m_g}{m_s}$$

where m_g is the weight of the hydrated gel (g) and m_s is the weight of sample (g).

The water solubility index (WSI) was determined from the amount of dry solids recovered by evaporating the supernatant from the water absorption test as:

$$\mathrm{WSI} = \frac{m_{ds}}{m_s} \cdot 100$$

where m_{ds} is the weight of dry solids from the supernatant (g) and m_s is the weight of the sample (g).

2.4. Oil absorption index

Oil absorption index (OAI) was determined according to the method of Liadakis, Floridis, Tzia, and Oreopoulou (1993): refined corn oil (3 mL) was added to sample (0.5 g) in a graduated 15 mL glass centrifuge tube. The tube was agitated on a Vortex mixer for 1 min, left for 30 min and centrifuge for 20 min at 700*g*; the volume of the free oil was read. OAI was calculated as:

$$\mathrm{OAI} = \frac{V_{oil}}{m_s}$$

where V_{oil} is the volume of oil absorbed (mL) and m_s is the weight of the sample (g).

The results presented are the mean values of four replications.

2.5. Experimental design

This was a 4 (legume/corn ratio) × 3 (feed moisture) × 3 (extrusion temperature) × 3 (feed rate) full factorial experimental design with two replications. The independent variables were: material ratios (0%, 10%, 30% and 50%) (legume/corn); feed moisture content (13%, 16% and 19% wet basis); extrusion temperature (170, 200 and 230 °C) and feed rate (2.52, 4.86 and 6.84 kg/h).