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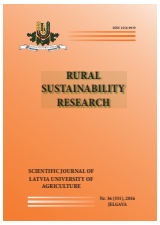

The Characteristics of Extruded Faba Beans (*Vicia faba* L.)

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Abstract. Faba beans (*Vicia faba* L.) are an excellent protein source and should be more present in human diet, but due to their long cooking time, they are rarely used. So, in order to increase the accessibility of faba beans (*Vicia faba* L.), experiments were carried out to obtain new food products. Extrusion-cooking was chosen as the potential thermal cooking process and two different products were obtained. One was made exclusively from faba bean (*Vicia faba* L.) flour, while the second one was produced with a 50% addition of wheat flour to bean flour. Protein content, size, volume mass, pH and starch content for obtained products were analysed in order to characterise the products, as well as to see the differences from non-extruded faba beans (*Vicia faba* L.) and obtained samples. The experiments were carried out using faba beans (*Vicia faba* L.) obtained at Ltd. "Pure Horticultural Research Centre". They were milled at Ltd. "Grauda spēks" and extruded with a twin screw extruder at Ltd. "Milzu". The experiments showed that the extrusion process had decreased the protein content by 9%, but the starch content had risen by 13% with the addition of wheat flour. But, for sample, without added wheat flour differences were not significant. No significant size differences were observed in the obtained samples and pH values had no significant differences between extruded samples.
Key words: faba beans, extrusion, protein, starch, wheat.

Introduction

Of the various possibilities, grain legumes, such as faba beans (*Vicia faba* L.), offer excellent potential for new food production due to their high nutritional value. Faba beans have good protein quality and are also a valuable source of energy due to their starch content (Gatel, 1994; Crepon, 2006; Nalle, V. Ravindran, & G. Ravindran, 2010). Faba beans (*Vicia faba* L.) are widely cultivated and extensively grown in different parts of the world (Chillo *et al.*, 2008). They contain up to 30% of crude protein, approximately 50% of carbohydrate and no more than 15% of crude lipid (Macarulla*et al.,* 2001). Broad beans (*Vicia faba* var. *major*) have their origin in the East, and their consumption is popular worldwide (Haciseferogullari *et al*., 2003). Due to their great resistance to low temperatures, they are, among leguminous plants, the best adapted to colder climates such as the Northern parts of Europe, and represent to the inhabitants of that region a source of energy, protein, folic acid, niacin, vitamin C, magnesium, potassium, iron and dietary fiber (Giménez *et al.*, 2013). In addition, recent advances in the genetic improvement of faba bean varieties have led to the development of a high-yielding line and low tannin varieties (Duc *et al*., 1999; Azaza *et al*., 2009).Moreover, such anti-nutritional factors as trypsin inhibitor levels in faba beans (*Vicia faba* L.) are lower than in common beans (*Phaseolus vulgaris* L.). But as legume seeds are mostly preserved in dry storage at ambient temperature, the main form of deterioration is increased hardness of legumes or loss of cookability, followed by deterioration of colour, texture and loss of nutritive value (Martin – Cabrejas *et al.,* 1997; Yousif & Deeth, 2003). Hardness of legume seeds is commonly described as the "hard-to-cook" phenomenon and is characterized by a requirement for extended cooking time. Hard-to-cook beans need additional energy during preparation and may have inferior nutritional qualities in terms of protein, fats and starch. Long cooking time is also one of the factors responsible for wider underutilization of legume seeds (Deshpande, Sathe, & Salunkhe, 1984; Nasar – Abbas, 2008).Leguminous flours are a good supplement for cereals because not only do they increase protein content but they also improve its biological value (Giménez *et al.*, 2013). Due to

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the high levels of lysine in their protein, they are an adequate complement to the protein of cereals (Azaza *et al.,* 2009; Chillo *et al*., 2008). They have great potential in the snack food industry (Smith & Hardacre, 2011). Their addition to wheat dough does not affect their sensory characteristics (Petitot *et al.,* 2010; Giménez *et al*., 2012; Giménez *et al.*, 2013). In wheat products, gluten plays a fundamental role in the formation and characteristics of the dough. Consequently, gluten is the main determining factor of the quality of dough during cooking (Bruneel *et al.,* 2010). The extrusion-cooking method represents an alternative technology that is adequate for the manufacturing of grain products, since it involves the unification of the pregelatinisation and formation steps (Amerayo *et al*., 2011; Marti, Seetharaman, & Pagani, 2010; Sirirat, Charutigon, & Rungsardthong, 2005; Wang *et al*., 1999). Starch contributes substantially to the final structure and quality of dough. As it becomes part of a complex matrix, its modifications and interactions with other components are promoted by the mechanical and thermal processes involved in extrusion cooking (Marti, Seetharaman, & Pagani, 2010). Such modifications allow formation of continuous three-dimensional structures of retrograded amylose and amylose–lipid complex crystals that stabilize the product structure (Amerayo *et al.,* 2011; Marti, Pagani, & Seetharaman, 2011). Most of the extruded products found in the market include corn, rice and wheat as their main ingredient due to its abundance, low cost and high expansion capacity, but little to none are made of legumes or legume and different grain dough mixes (Giménez *et al*., 2013).

Extrusion cooking involves high heat, pressure, and shear forces, which causes clear changes in all physicochemical and functional properties of the flour, depending on a type of raw material and extrusion cooking variables such as feeding rate, feed moisture, screw speed and configuration, die geometry, temperature and time (Sarawong *et al.*, 2014; Brennan *et al*., 2011; Singh, Gamlath, & Wakeling, 2007).

Thus, the aim of this research was to obtain new food products of faba beans (*Vicia faba* L.) and characterize these products' physical and chemical properties, such as protein, starch content, pH and size.

Material and Methods

Experiments were carried out at the Latvia University of Agriculture. Faba beans were provided by Ltd. "Pure Horticultural Research Centre". They were milled at Ltd. "Graudaspēks" with sieve size 1mm, and extruded with a twin screw extruder at Ltd. "Milzu". One sample was made exclusively from beans, but the second one had 50% of wheat flour added to it. Wheat flour was chosen because of its good extrusion qualities, and in pre experiments with other legumes, wheat flour gave good volume increase compared. In order to describe the obtained products, their protein content (LVS EN ISO 5983-2:2009), volume mass, size, pH, and starch content (LVS EN ISO 10520:2001) were analyzed. Protein and starch content was determined for beans as well as for wheat. Volume mass was analysed using 1L baker with marks and scale ACCULAB L-Series. 1L baker was put no scale, tarred and extruded sample was poured in till its mark. Mass was recorded in three repetitions and average was calculated.

In order to do pH measurements, the sample was crushed in mortar until it was homogeneous. Then 10g of sample was weighted till 0.01g in tarred 150mL baker. Water was added till 100mL; the sample was thoughtfully mixed, covered with parafilm and left overnight. Next day the sample was filtrated and pH was measured in filtrate using pH-meter Jenway 3510.

Sample size was measured using electronic slide gauge. Length and width was measured in ten repetitions and average result was calculated.

All results were calculated and given to dry weight.

ANOVA was used as the statistical method to determine significant differences for obtained data, and the statistical analyses were carried out using MS Excel.

Results and Discussion

The protein content (Figure 1) in the faba bean samples decreased from 32.5 ±0.7 g $100g^{-1}$ of the non-extruded samples to 22.2±0.2 g $100g^{-1}$ in the sample with added wheat flour. The extruded faba beans had 31.5±0.5 g $100g^{-1}$protein content on dry matter, but differences between extruded and non extruded beans were insignificant and can be explained by standard division and methods' standard error. Significant decrease ($p=5\cdot10^{-4}$) of protein was observed for the sample obtained from mix of wheat and faba beans.

As expected, significant differences ($p=7\cdot10^{-5}$) were observed between the extruded and non-extruded samples and the extruded samples with added wheat flour. Decrease of protein in sample with wheat additive was expected, as wheat had 13.8±0.2 g $100g^{-1}$ protein on dry matter. Similar protein decrease was observed by Ai *et al.* (2016) in common bean (*Phaseolus vulgaris* L.) extrudates, where protein also decreased by approximately $1g\cdot100g^{-1}$.

Corn and wheat/barely flours are commonly used for extrusion as they have rather low protein content. In corn flakes protein content is 6.7 g $100g^{-1}$, but in

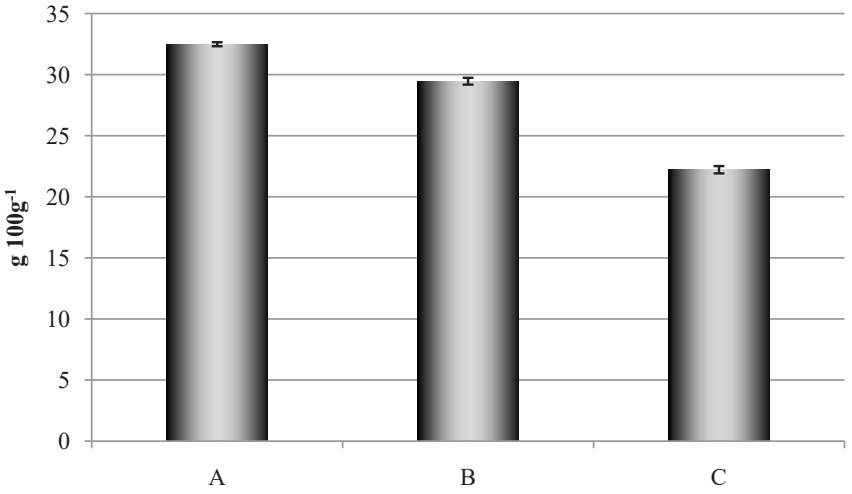

Figure 1. Protein content in non-extruded and extruded faba bean samples
(A – control sample (non-extruded beans); B– extruded sample from 100% faba beans,
C – extruded sample from 50% faba beans and 50% wheat).

wheat/barely flakes – 10.0 g $100g^{-1}$[a], so even 50% of faba beans could be used as additive to increase protein content in commonly used extrudates.

The volume mass (Figure 2) changes were significant ($p=1.6\cdot10^{-13}$) between the extruded and non-extruded samples. A less significant difference ($p=0.02$) was observed between both of the extruded samples. The sample with added wheat flour had a volume mass of 143 ±2 g L^{-1}, but the sample made entirely from faba beans – 148±1 g L^{-1}.

Seeing as the samples with added wheat flour had no big visual difference from the sample that was extruded singularly from faba beans, it can be determined that wheat does not have abig influence on bean extrusion. As the literature suggests (Moscicki, 2011), the size of the extrudate is more influenced by extrusion temperatures and moisture content.

Sizes of extruded samples were similar (Figure 3), approximately 8 mm in both sizes (length and width), but samples with added wheat flour had less data fluctuations compared to samples without additional flour. No significant differences were found between the samples, but the sample size could be improved by changing the extrusion temperature and moisture content of the flour.

Even the size of extruded products was smaller than that of non-extruded beans, it should be mentioned that their structure was different and

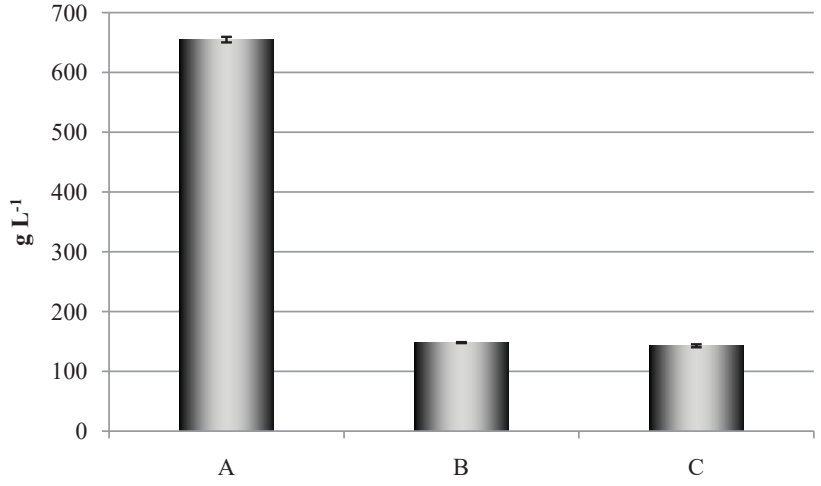

Figure 2. Volume mass of extruded faba beans
(A – control sample (non-extruded beans); B– extruded sample from 100% faba beans,
C – extruded sample from 50% faba beans and 50% wheat).

[a] Conde Nast (2014). *Self NutritionData.* Retrieved August 19, 2016, from http://nutritiondata.self.com/

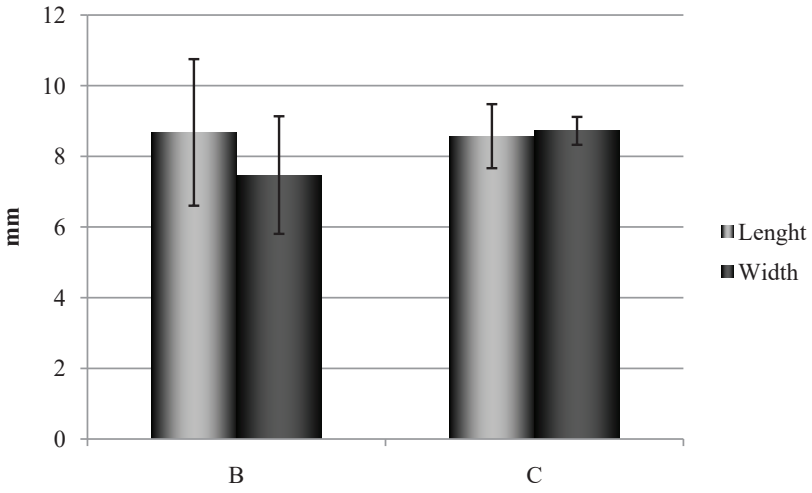

Figure 3. Size of extruded faba bean samples
(A – control sample (non-extruded beans); B– extruded sample from 100% faba beans,
C – extruded sample from 50% faba beans and 50% wheat).

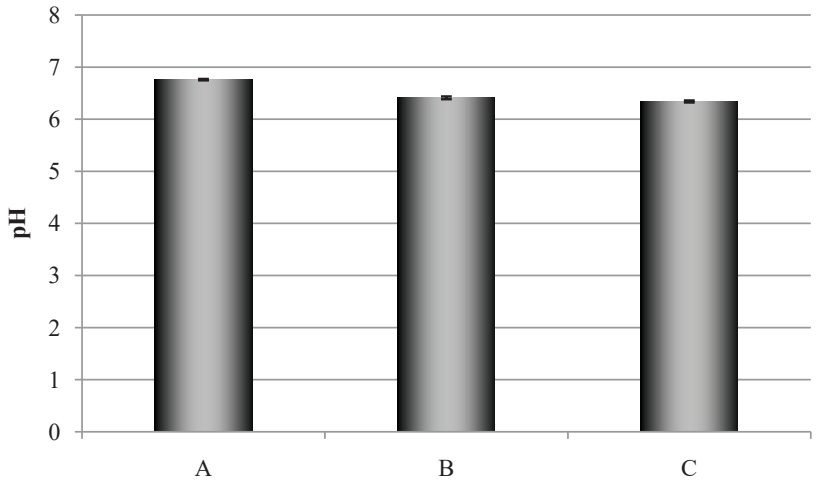

Figure 4. pH of non-extruded and extruded faba bean samples
(A – control sample (non-extruded beans); B– extruded sample from 100% faba beans,
C – extruded sample from 50% faba beans and 50% wheat).

the hardness of the samples was greatly reduced. Consumers are accustomed to certain size products, which have low hardness, thus are easy to chew and consume, usually made from corn or wheat flour, that have good expansion qualities (Moscicki, 2011).

However, the faba bean pH (Figure 4) of the non-extruded samples (6.76± 0.01) was significantly higher ($p=5\cdot10^{-4}$) than the pH of the extruded faba beans (6.41± 0.03) and the faba bean and wheat flour mixture (6.34± 0.02). As for non-extruded wheat flour pH was 6.87 ± 0.01. According to Areas *et al.* (2016), it could be caused by extrusion.

Decrease of pH could be explained by the changed starch rheological state that occurs in extrusion process. Still, the changes were only 0.3 units in the sample without additives and 0.4 units in the sample with added wheat flour. So significance in differences could be caused by method and apparatus uncertainty.

The starch content (Figure 5) was measured before extrusion and for faba beans was 43±2 g $100g^{-1}$ and 61±1 g $100g^{-1}$ for wheat, and no significant changes ($p=0.2$) were found after extrusion between non-extruded samples and extruded samples. As expected starch content increased till 47±2 g $100g^{-1}$ in the sample with added wheat flour. For extrusion maize

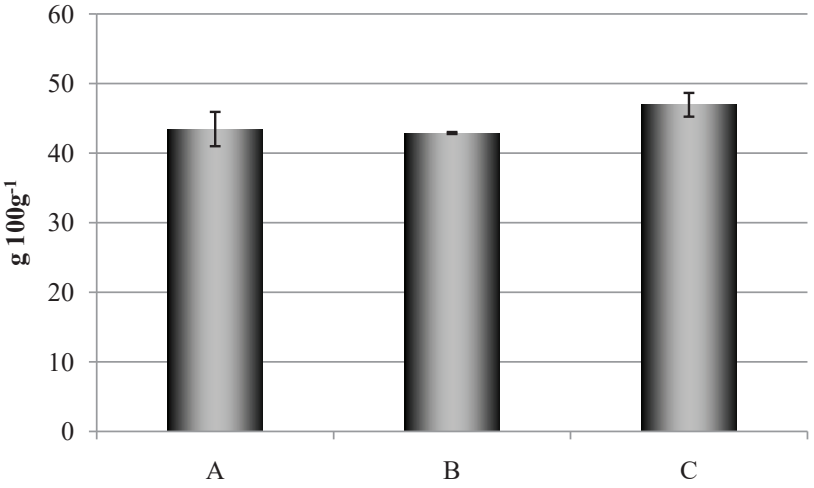

Figure 5. Starch content in non-extruded and extruded faba bean samples (A – control sample (non-extruded beans); B – extruded sample from 100% faba beans, C – extruded sample from 50% faba beans).

and wheat flours are mostly in extrusion cooking (Moscicki, 2011) used due to their high starch content that ensure bigger size of products, less volume mass and less harness, but our experiments showed, that even tough in faba beans are lower than in maize or wheat flour, starch content is enough to make decent extrudates.

Conclusions

Results show that the protein and starch content, which are two of the major nutritional factors, are not lost in the extrusion process of faba beans although their size and volume mass could be improved in order to obtain larger samples. It can be concluded that wheat addition to extrusion mix did not give significant increase to sample size and volume mass, so faba bean flour could be used in extrusion cooking without other additives, as adding wheat flour only decreased protein content for extrudates.

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