MOISTURE CONTENT EFFECT ON EXTRUDED PEA (*PISUM SATIVUM* L.) PRODUCT PHYSICAL PROPERTIES

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Abstract
From legume seeds it is possible to make new products with different physical properties such as size and hardness by using extrusion-cooking. Peas are products that normally need a rather long cooking time, but extrusion-cooking can make them more usable in daily human diet. As protein based food products in markets are less represented than those based on carbohydrates, but for balanced diet protein intake is essential, our aim was to ensure availability of such products, so experiments were carried out in order to establish optimal moisture content for grey pea (*Pisum sativum* L.) flour extrusion.
Three grey pea (*Pisum sativum* L.) based products were obtained with different water amount added before extrusion, and their size, volume mass and colour was analyzed in order to ascertain what amount of water is best for such products.
Results show significant differences for size, volume mass and colour changes, establishing that the best of the products was the one with 9.00 ± 0.01 g·100g^{-1} added water. This product had better characteristics than others, where 11.00 ± 0.01 g·100 g^{-1} and 7.00 ± 0.01 g·100 g^{-1} water was added. The products with 9.00 ± 0.01 g·100 g^{-1} added water were by more than 100 g·L^{-1} lighter than other products, also colour changes compared to non extruded pea flour were fewer than for other samples and their size was the biggest of all obtained products, averagely 11 ± 1mm.
Key words: extrusion-cooking, pea, size, moisture.

Introduction

Extruded products are popular, since they are ready-to-eat, of crispy texture, nicely shaped and coloured. However, they are often regarded as junk food because of their composition mainly based on carbohydrates and fat (Hirth et al., 2014).

The design of extruded snacks and breakfast cereals involves complex molecular transformations such as gelatinization and melting of the mostly starch based raw materials. The raw material has to be sheared, mixed, cooked and expanded to generate the desired product structure. Extrusion cooking is a high pressure, high-temperature, short-time (HTST) process, which can apply the amount of thermal and mechanical energy to raw materials in a relatively short period of time. The short residence time should reduce the undesirable reactions (e.g. degradation or chemical reaction of protein) (Hirth et al., 2014).

The food industry is using HTST technology such as extrusion-cooking for many applications including inactivation of microorganisms and toxins, changes of texture and flavour, improvement of digestibility (Boye et al., 1997) to produce food with high quality attributes and enhanced food safety (Gould, 1995; Jung et al., 2011; Knorr, 1999).

The extent of protein unfolding and exposure of hydrophobic patches would increase with the increase in extent of heating (Boye et al., 1997; Tang et al., 2009). Privalov et al. (1989) estimated that proteins lose almost all secondary and tertiary structures when the temperature exceeds 80 °C, and would adopt a configuration that approaches a fully unfolded, random coil conformation. Thus, these heat-induced changes in protein conformation and polypeptide interactions could dictate the degree of exposure of susceptible peptide bonds and influence the type of peptides generated during enzymatic hydrolysis (Chao et al., 2013), where the amount of added water may play a significant role.

There is an increased interest in utilizing the pea (*Pisum sativum* L.) protein as an alternative for soy protein that has a dominating advantage in the market. The pea is one of the valued crops in the world market (Adebiyi and Aluko, 2011; Tian et al., 1999); like other legume seeds, the pea seed is characteristically rich in proteins (18–30%) with a well-balanced amino acid profile, especially a high content in lysine (Schneider and Lacampagne, 2000). In addition to providing amino acid nutrition level, the ultimate success of using pea protein as a promising food ingredient and an alternative to soy proteins depends largely on its functional properties, including solubility, viscosity, water- and oil-binding properties, gelatinization, foaming and emulsifying properties. To date, pea protein products are very limited in food applications (Liang and Tang, 2013).

Peas contain high levels of protein/amino acids and, accordingly, their potential nutritional value is rather high. However, various anti-nutritional factors in peas interfere with digestive processes, thereby reducing their nutritional value (Gatel and Grosjean, 1990). The major anti-nutritional factors are trypsin inhibitors and, although their levels in peas are 5–20 times lower than in raw soy beans, the amount found in some pea cultivars can be significant and responsible for reduced protein digestibility of pea-

based diets (Al-Marzooqi and Wiseman, 2009). It has been reported (Valdebouze et al., 1980) that the trypsin inhibitor activity (TIA) of winter types was twice that of those sown in spring, and that smooth peas had higher TIA than wrinkled-seeded varieties. Peas also contain appreciable level of starch, although there is considerable variability. For example – the starch content of the smooth seed types is higher than the wrinkled ones (Gatel and Grosjean, 1990). Potentially, peas are a very valuable foodstuff in terms of their energy-yielding potential (French, 1984; Al-Marzooqi and Wiseman, 2009).

The level of trypsin inhibitors may be reduced by heat processing, and the susceptibility of starch to enzymes can be increased by gelatinisation or any other process that destroys the granular structure of starch (Holm et al., 1985); heating also may lead to loss of α-amylase inhibitors (Alonso et al., 2000). Extrusion is a process which involves forcing a material to flow under a variety of controlled conditions to pass through a shaped hole or slot at a predetermined rate. The operating conditions of high temperature, pressure and shear, and low or average water content (all of which can be varied during the process) distinguish extrusion cooking from alternative heating processes and gives the opportunity to ensure that even those low levels of anti-nutritional factors are removed.

It is said (Al-Marzooqi and Wiseman, 2009) that such processing has a limited effect on the nutritional value of peas with low levels of trypsin inhibitors as measured through digestibility of amino acids. However, cultivars with high trypsin inhibitor level may benefit from mild processing (Al-Marzooqi and Wiseman, 2009).

In order to ensure the availability of pea (*Pisum sativum* L.) based products, our aim was to establish the optimal moisture content for grey pea (*Pisum sativum* L.) flour extrusion.

Materials and Methods

Peas (*Pisum sativum* L.) of the variety "Bruno" were used for the experiments. They were milled at "Grauda spēks" Ltd. and 7.00 ± 0.01 g·100 g^{-1}, 9.00 ± 0.01 g·100 g^{-1} and 11.00 ± 0.01 g·100 g^{-1} water was added to flour (moisture – 13.59 ± 0.01 g·100 g^{-1}). Flour and water were carefully mixed in automatic mixer BFJ – I/3 until the mixture was homogenous and extruded with twin screw extrusion-cooker SLG65-III at temperatures 50/150/170 °C and speed 22 Hz. Then the product was dried for 15 minutes in a belt type dryer at 80 °C temperature.

The moisture content (g·100g^{-1}) in the obtained products was determined using ISO 6496:1999. The analyses were done in three repetitions.

The size of the obtained sample pieces (length and height, mm) was measured using the "Electronic

digital outside micrometer 08/03" the analyses were done in ten repetitions. The colour was measured in CIE L*a*b* colour system using Tristimulus Colorimeter, measuring Hunter colour parameters by Colour Tec PCM/PSM. Colour values were recorded as L* (brightness) – the vertical co-ordinate runs from L* = 0 (black) through grey to L* = 100 (white); a* (-a, greenness, +a, redness) – the horizontal co-ordinate that runs from -a* (green) through grey to +a* (red) and b* (-b, blueness, +b, yellowness) – another horizontal co-ordinate that runs from -b* (blue) through grey to +b* (yellow). The samples were milled and filled in a Petri dish. The measurements were repeated ten times on different randomly selected locations at the surface of each sample.

The total colour differences of extruded samples were calculated using the formula (1).

$$\Delta E^* = \sqrt{\left[\left(L^* - L_0^*\right)^2 + \left(a^* - a_0^*\right)^2 + \left(b^* - b_o^*\right)^2\right]}; \quad (1)$$

Where ΔE^* – total colour difference;
L*, a* and b* are the lightness (L), greenness and (a) and blueness (b) values for extruded samples;
L_0, a_0 and b_0 are the corresponding colour values for non extruded pea flour (Papadakis et al., 2000).

The volume mass (g·L^{-1}) was measured gravimetrically, where each sample was poured up to the mark in a 1L measuring flask and weighed on the balance Precisa 260. The measurements were made at least three times. The hardness (N) was analysed for each sample granule with Texture Analyzer, TA.XT. plus with parameters: pre-test speed 1.5 mm sec^{-1}; test speed 1 mm sec^{-1}; post-test speed 10 mm sec^{-1}, distance 5 mm, selected probe: P/2 DIA stainless steel cylinder. The measurements were made in ten repetitions. The sugar content was determined using ГОСТ 26176-91. The analyses were done in three repetitions.

ANOVA analyses were applied in order to see which moisture content would be the best for further product development.

Results and Discussion

The moisture content in the grey pea flour that was used in experiments was 13.59 ± 0.01 g·100 g^{-1}, so the total moisture content (with added water) in flour before extrusion was 20.59 g·100g^{-1}, 22.59 g·100 g^{-1} and 24.59 g·100 g^{-1}, respectively. All products after extrusion-cooking were dried till 7 ± 1 g·100 g^{-1} moisture. The volume mass was determined in order to examine the aeration of obtained products (Figure 1). The product with added water content 7.00 ± 0.01 g·100 g^{-1} – 280 ± 4 g·L^{-1} was the heaviest, but the lightest was the one with added

water content 9.00 ± 0.01 g·100 g^{-1} – 126 ± 2 g·L^{-1} and 241 ± 5 g·L^{-1} for the sample with 11.00 ± 0.01g·100 g^{-1} added water. Sample with 9.00 ± 0.01 g·100 g^{-1} added water had 153 g (33 g·100 g^{-1}) less volume mass than those products obtained using 7.00 ± 0.01 g·100 g^{-1} added water and by 115 g (42 g·100 g^{-1}) for the sample with 11.00 ± 0.01 g·100 g^{-1} added water.

The explanation for these changes could be that the sample with 7.00 ± 0.01g·100 g^{-1} added water was not moisturised enough. As for the high result obtained using sample with 11.00 ± 0.01g·100 g^{-1} added water, literature states that too mush water can reduce product size and make it harder and heavier (Moscicki, 2011), but does not clearly state the reason for such an effect. Mathematical analysis shows significant differences between product volume mass ($\alpha = 0.05$, $p = 1.64\cdot10^{-8}$).

The size of granules was measured in order to mathematically describe the samples (Figure 2). The sample with largest granule size was the one with

9.00 ± 0.01 g·100 g^{-1} water added; the mean length was 10.3 ± 0.5 mm and the mean width was 11.7 ± 0.8 mm. The same sample had the lowest volume mass. On the other hand, the samples with 7.00 ± 0.01g· 100 g^{-1} and 11.00 ± 0.01g·100 g^{-1} added water were more symmetrical, both having sizes of approximately 7 ± 1 mm; still the distribution of sizes for these products was larger, especially for the sample with 7.00 ± 0.01 g·100 g^{-1} added water – its length was 7 ± 2mm and width 7 ± 1mm, while the sample with 11.00 ± 0.01 g·100 g^{-1} added water measured 7.8 ± 0.8 mm in length and 8 ± 1mm in width. Such fluctuations within driest sample could be caused by too little moisture content, and the flour was not enough hydrated.

Mathematical analysis shows significant differences between the product size for length $\alpha = 0.05$, $p = 9.26\cdot10^{-5}$, and for width $\alpha = 0.05$, $p = 2.61\cdot10^{-17}$.
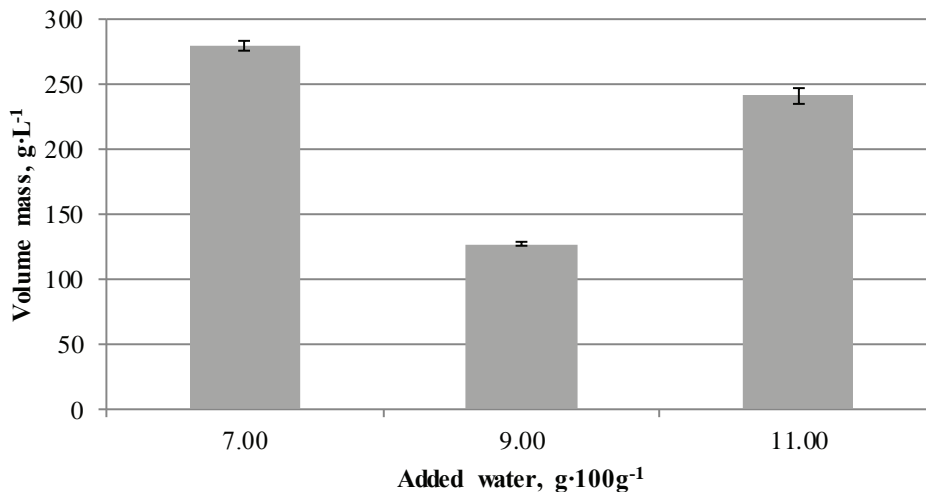

Figure 1. Volume mass of the extruded samples.
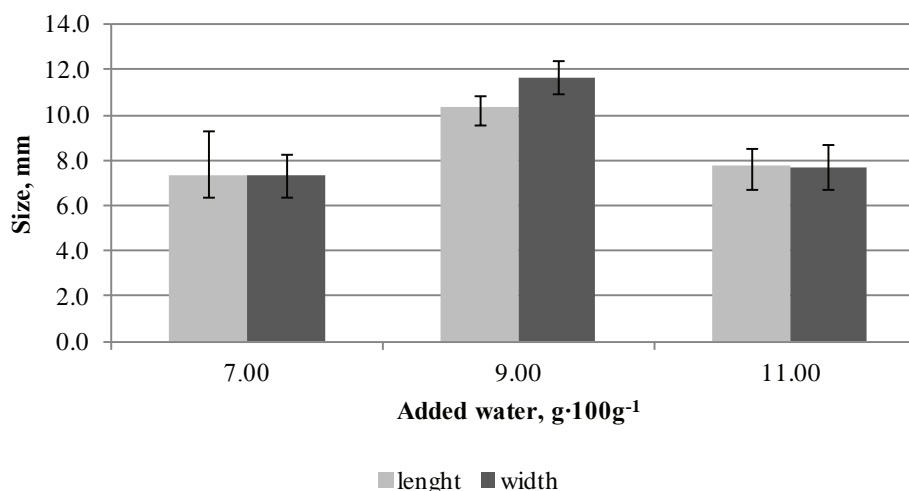

■lenght ■width

Figure 2. The size of the granules of the extruded samples.

Table 1

The colour values for pea flour and extruded samples, and their comparison to pea flour

Sample, added water, g·100g⁻¹	Colour value			Difference from non extruded flour			ΔE*
	L*	a*	b*	ΔL*	Δa*	Δb*	
0[1]	73.7±0.8	-1.8±0.3	14.3±0.3	-	-	-	-
7.00±0.01	67.6±0.9	0.2±0.5	17.9±0.8	-6.1	2.1	3.5	7.4
9.00±0.01	70.1±0.7	-0.1±0.1	17.7±0.7	-3.6	1.7	3.3	2.5
11.00±0.01	65.9±0.9	0.05±0.6	17.2±0.3	-7.8	1.9	2.9	4.2

[1] flour without added water before extrusion

To describe the possible chemical reactions that could occur in products during high pressure and heat treatment, colour is a good indicator. Colour parameters of non extruded pea flour and extruded products are shown in Table 1. As in Maillard reactions protein is bound with sugar in Amadori compounds (Martins et al., 2000), thus reducing protein availability and nutritional value, so they should be avoided if possible or reduced to minimum. As these reactions change the colour of product, colour was analysed in order to establish if there had been significant changes of colour in products.

The least significant changes in products L parameters were found in the sample with 9.00±0.01 g·100 g⁻¹ added water, it got darker only by 3.6 units (8 g 100 g⁻¹), but the biggest changes were found in the sample with 11.00±0.01 g·100 g⁻¹ added water 7.8 units (12 g 100 g⁻¹). As the redness of the samples too could be used as indicator of non-enzymatic browning, but the changes were almost the same for all samples, respectively for the sample with 7.00±0.01 g·100 g⁻¹ added water – it was redder by 2.1 units, but the least for the sample with 9.00±0.01 g·100 g⁻¹ added water – 1.7 units. The same conclusions can be made from the total colour difference ΔE*, where the least changes were observed for the sample with 9.00±0.01 g·100 g⁻¹ added water – only 2.5 units,

while the largest value of ΔE* was ascertained for the sample with 7.00±0.01 g·100 g⁻¹ added water – 7.4 units. Still, these changes probably originated more from other browning processes, as no significant traces of sugar were found in neither the raw material, nor the products.

The hardness of the samples was analysed (Figure 3.) in order to describe crispiness of the granules. The hardness of the sample with 7.00±0.01 g·100 g⁻¹ added water was 35±3 N, but the least significant was of the sample with 9.00±0.01 g·100 g⁻¹ added water – 8±1 N, meaning that the samples with 7.00±0.01 g·100 g⁻¹ added water and 11.00±0.01 g·100 g⁻¹ added water were harder than those with 9.00±0.01 g·100 g⁻¹ added water, which means they are more airy. Similar conclusions can be made for the volume mass.

The sample with 9 g·100g⁻¹ added water is not only the lightest, but also the largest as well as softest, as can also be seen from such parameters as size, volume mass and hardness. It also has the least significant changes in colour values compared to non extruded pea flour.

Conclusions

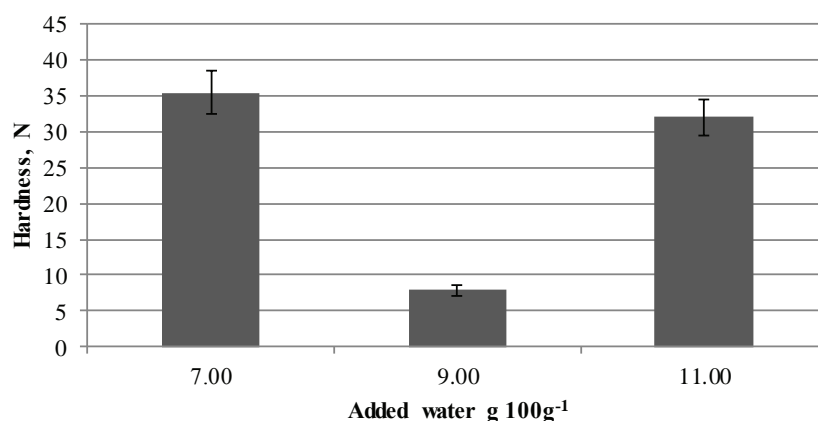In order to produce pea (*Pisum sativum* L.) based food products using extrusion-cooking, the optimal

Figure 3. Hardness of the extruded samples granules.

water amount added to flour is 9.00±0.01 g·100 g^{-1}, as such water amount in temperatures 50/150/170 °C gives products better characteristics than using 7.00±0.01 g·100 g^{-1} water and 11.00±0.01 g·100 g^{-1} water. The volume mass for products obtained using 9.00±0.01 g·100 g^{-1} water was 126±2 g·L^{-1}, by 153 g (33 g·100 g^{-1}) less than volume mass for those products obtained using 7.00±0.01 g·100 g^{-1} added water and by 115 g (42 g·100 g^{-1}) for the sample with 11.00±0.01 g·100 g^{-1} added water.

The size of the products obtained adding 9.00±0.01 g·100 g^{-1} water to flour was 10.3±0.5 mm in length and 11.7±0.8 mm in width, larger than those obtained using 7.00±0.01 g·100 g^{-1}.

The hardness of the sample with 9.00±0.01 g·100 g^{-1} added water was 8±1 N. The colour changes from non extruded flour were the slightest for the sample 9.00±0.01 g·100 g^{-1}.

Acknowledgements

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