AMINO ACID AND DIETARY FIBRE CONTENT OF PEA AND BUCKWHEAT FLOURS

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Abstract
The aim of this study was to investigate amino acid content, biological value and dietary fibre content of conventional and organic pea (*Pisum sativum* L.) and buckwheat (*Fagopyrum esculentum* M.) flours.
Results showed that pea flours contained high amounts of aspartic acid, threonine, serine, glycine, alanine, valine, isoleucine, leucine, tyrosine, phenylalanine, histidine, lysine and arginine while glutamic acid, proline, methionine and tryptophan were found in similar or smaller amounts comparing with wheat flour. The differences of various amino acids between conventional and organic pea flours were insignificant. The content of aspartic acid, threonine, serine, glycine, alanine, valine, histidine, lysine and arginine was high in buckwheat flours in comparison with wheat flour. There were significant ($p<0.05$) differences in the individual amino acid contents across buckwheat flours. Significant ($p<0.05$) variation existed in the content of essential amino acids among samples, whereas the results concerning the proportion of essential amino acids in total amino acids showed insignificant ($p>0.05$) differences between pea flours and buckwheat flours (34.80 – 35.77% and 29.96 – 33.90% respectively). The highest content of lysine was found in pea flours, and it formed about 23% of essential amino acids content. For pea flours the total dietary fibre amount varied between 15.28 g 100 g^{-1} for conventional and 27.24 g 100 g^{-1} for organic pea flour.
Pea and buckwheat flours could be characterised as a good source of dietary fibre with significantly ($p<0.05$) higher content of total dietary fibre comparing to wheat flour.
Key words: pea, buckwheat, amino acids, dietary fibre.

Introduction

Buckwheat *(Fagopyrum esculentum* M.*)* is an old and alternative crop which belongs to *Polygonacea* family. Buckwheat protein has one of the highest amino acid scores of protein in plant food stuffs (Cai, Corke, & Lee, 2004; Qin *et al*., 2010), it is gluten-free (Ikeda, 2002) whereas the protein digestibility of buckwheat is relatively low (Ikeda & Kishida, 1993; Skrabanja, Nygaard, & Kreft, 2000).Due to high lysine content, buckwheat proteins have a higher biological value than cereal proteins (Ikeda, 2002). Buckwheat protein products have been associated with preventative nutrition (Bonafaccia, Marocchini, & Kreft, 2003). Li and Zhang (2001) reported that buckwheat proteins act similarly to dietary fibre by exhibiting cholesterol-lowering and antihy pertension effects and reducing constipation and obesity. A diet rich in dietary fibre decreases risk of cardiovascular diseases, metabolic disorder and type 2 diabetes (Barclay *et al*., 2008; Hopping *et al*., 2010). Health effects of dietary fibre can be substantiated when the intake is high enough – 25-38 g day^{-1} for healthy adults (Slavin *et al*., 2009). The positive health effect of buckwheat *in vivo* is associated especially with its fibre components (Rokka *et al*., 2013). Izydorczyk *et al.* (2014) reported that there are differences in the molecular composition of dietary fibre in buckwheat compared with cereal grains. A diet rich in buckwheat fibre reduced many overweight-related risk factors of cardiovascular diseases in rats (Son, Kim, & Lee, 2008).

Dry peas (*Pisum sativum* L.) have been recognised as nutritious due to their high quality proteins (Boye, Zare, & Pletch, 2010) and nutrient density (Azarpazhooh & Boye, 2012).Field pea is relatively high in protein and lysine and has been suggested as an alternative source to soybean in circumstances where it cannot be used due to intolerance or allergic reactions (Davidsson *et al*., 2001). Combination of pea proteins with low-lysine cereal proteins results in a more nutritionally complete protein (Hood-Niefer & Tyler, 2010). It is known that lysine is the most limited amino acid in the human diet. Less known is the fact that pea can be a valuable source of dietary fibre. The hypoglycaemic effects of legumes have been attributed to their high content of dietary fibre (Trinidad *et al*., 2010). The total dietary fibre measurements of dried peas range from 14 to 26% of dry weight basis (Brummer, Kaviani, & Tosh, 2015), peas are especially rich in insoluble fibre (Wang, Hatcher, & Gawalko, 2008). Dodevska *et al.* (2013) reported that cellulose was the major fibre component in pea samples comprising about 40% of total fibre. The dietary fibre fraction of field pea could be used as a nutritional supplement and functional food ingredient for novel food development (Stoughton-Ens *et al*., 2010).

The background of this study is to investigate the potential of pea and buckwheat flours, their blends in the manufacture of new functional products with increased nutritional value as the first step toward increasing their consumption. The specific aim of this study was to investigate amino acid content, biological value and dietary fibre content of conventional and organic pea (*Pisum sativum* L.) and buckwheat (*Fagopyrum esculentum* M.) flours.

Materials and Methods

Research was performed at the scientific laboratories of Faculty of Food Technology, LatviaUniversity of Agriculture and at the laboratoryof the Institute of Biology, University of Latvia, from September to December, 2015.

Materials

Two pea (*Pisum sativum* L.) flours: conventional (Company 'Fasma', Lithuania) and organic (Farm 'Kaņepītes', Latvia) and three buckwheat (*Fagopyrum esculentum* M.) flours obtained from conventional steamed (Company 'Fasma', Lithuania), organic steamed (Farm 'Kaņepītes', Latvia) and organic (Farm 'Bebri', Latvia) buckwheat seeds were analysed (Table 1). Fine wheat flour as control was purchased from the company 'Dobeles Dzirnavnieks', Latvia.

Table 1

Description of flours

Code	Sample
Control - WF	Wheat flour
CPF	Conventional pea flour
OPF	Organic pea flour
OBF	Organic buckwheat flour
OSBF	Flour of organic steamed buckwheat seeds
CSBF	Flour of conventional steamed buckwheat seeds

Determination of the amino acid content

The content of amino acids was determined the amino acid analyser '*Microtechna Praha AAA339*' according to the requirements of 'Amino acid standard solution for protein hidrolysates – 0.5 µmoles per mL'. The measurements were performed in triplicate.

Determination of the total content of dietary fibre

The total dietary fibre content was determined according to the AOAC Official Method 985.29 'Total dietary fibre in Foods' using equipment '*Fibertec system 1010 Heat Extractor*'. The measurements were performed in triplicate.

Statistical analysis

The results were analysed using the analysis of variance (ANOVA). T-test was applied to compare the mean values, and p-value at 0.05 was used to determine the significant differences. Mean ± standard deviation of three replicates was used.

Results and Discussion

Buckwheat proteins have a high biological value with well-balanced amino acid composition (Cai, Corke, & Lee, 2004) whereas field pea is relatively high in protein and lysine and low in cysteine and methionine (Hood-Niefer & Tyler, 2010). The combination of pea and buckwheat proteins could result in a more nutritionally complete protein. Iqbal *et al.* (2006) concluded that, in order to improve the protein quality of leguminous seeds, their consumption should be combined with cereals.

Pea flours contained high amounts of aspartic acid, threonine, serine, glycine, alanine, valine, isoleucine, leucine, tyrosine, phenylalanine, histidine, lysine and arginine while glutamic acid, proline, methionine and tryptophan were found in similar or smaller amounts comparing with the control sample (wheat flour) (Table 2). Iqbal *et al.* (2006) concluded that aspartic acid and glutamic acid were major unessential amino acids in legume, int.al. green pea. The same conclusions confirmed this research analyzing conventional and organic pea flours. The differences of various amino acids between conventional and organic pea flours were insignificant ($p>0.05$); however, the content of amino acids in organic pea flour was higher with the exception of proline, methionine, leucine, tyrosine, histidine and tryptophan. The first limited amino acid was methionine in conventional and organic pea flours. Similar results can be found in literature suggesting that all essential amino acids except methionine and tryptophan are present in excessive amounts in legume (Iqbal *et al.*, 2006; Zia-Ul-Haq *et al.*, 2013).

The content of aspartic acid, threonine, serine, glycine, alanine, valine, histidine, lysine and arginine was high in buckwheat flours comparing with wheat flour (Table 2). There were significant ($p<0.05$) differences in the individual amino acid contents, particularly for serine, glutamic acid, proline, alanine, isoleucine, leucine, phenylalanine and arginine across buckwheat flours. The differences in amino acid contents in various buckwheat flours may be due to the cultivars variability and growing conditions. Aspartic acid, glutamic acid and arginine were abundant in the buckwheat flours. Similar results were reported in Wei *et al.* (2003) for buckwheat kernels.

The sum of all amino acids was significantly ($p< 0.05$) different in the examined flour samples. The highest amount of total amino acids was found in pea flours, respectively in conventional (18.82 g 100 g^{-1}) and in organic (19.30 g 100 g^{-1}) flours. The total amino acids content in pea flours was close to the data given by Gómez, Doyagüe, & de la Hera (2012) about protein content in pea flour (22.23 g 100 g^{-1}). The total amino acids content of buckwheat flours ranged from 9.62 g 100 g^{-1} for OSBF to 11.09 g 100 g^{-1} for CSBF. The results are in a fair agreement with those reported by Qin *et al.* (2010) where the flour of common buckwheat cultivars contained 8.06-12.44% protein.

Table 2

Amino acids content of pea and buckwheat flours, g 100 g^{-1}

Amino acids	WF	CPF	OPF	OBF	OSBF	CSBF
Essential amino acids						
Histidine	0.38	0.83	0.78	0.64	0.62	0.52
Isoleucine	0.14	0.41	0.43	0.14	0.17	0.30
Leucine	0.61	1.53	1.51	0.66	0.86	0.64
Lysine	0.33	1.48	1.58	0.68	0.56	0.65
Methionine	0.12	0.16	0.15	0.16	0.12	0.19
Phenylalanine	0.50	1.01	1.14	0.52	0.35	0.70
Threonine	0.19	0.73	0.75	0.34	0.43	0.43
Tryptophan	0.19	0.23	0.17	0.16	0.11	0.20
Valine	0.23	0.42	0.53	0.42	0.33	0.33
Unessential amino acids						
Alanine	0.19	0.81	0.82	0.66	0.52	0.34
Arginine	0.14	1.67	1.67	0.72	0.38	1.03
Aspartic acid	0.61	2.60	2.83	1.31	1.24	1.27
Glutamic acid	3.28	2.99	3.09	2.43	2.30	2.02
Glycine	0.30	0.90	0.92	0.68	0.56	0.70
Prolamin	1,22	1.25	1.04	0.20	0.16	0.56
Serine	0.38	0.99	1.09	0.53	0.58	0.69
Tyrosine	0.37	0.81	0.80	0.36	0.33	0.52
Total	**9.18**	**18.82**	**19.30**	**10.61**	**9.62**	**11.09**

Literature (Biel & Maciorowski, 2013) reports that low lysine/arginine and methionine/arginine ratios may suggest that buckwheat products have blood cholesterol-lowering properties. Evaluating the results of this research it could be concluded that lysine/arginine ratio was low for CSBF and OBF and methionine/ arginine ratio was low for all buckwheat flour samples.

Both the quantity and quality of protein are very important in nutrition. The amino acid composition determines the nutritional value of protein and, more specifically, the amount of essential amino acids.

The amino acids composition of the pea and buckwheat flours showed significant ($p<0.05$) differences in the content of essential and unessential amino acids (Fig.1). The level of essential amino acids content was lower than the level of unessential amino acids in the tested samples. Similar conclusions were reported by Radu (2012) about pea and buckwheat flours. The highest total essential and unessential

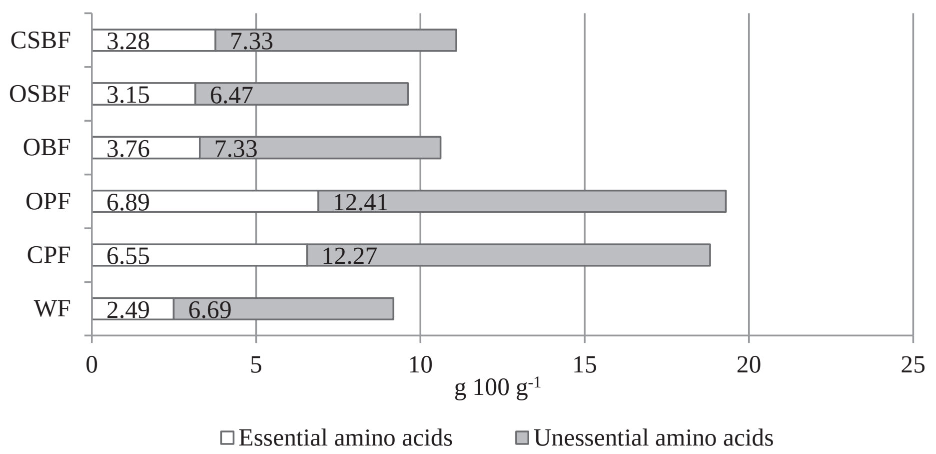

Figure 1. Comparison of essential and unessential amino acids content in pea and buckwheat flours.

Table 3

Essential amino acidsand lysine content of pea and buckwheat flours

Flours	Essential amino acids content, g 100g^{-1}	Proportion of essential amino acids to total amino acids, %	Lysine content, g 100g^{-1}	Lysine content of essential amino acids content, %
WF	2.49	27.12	0.33	13.25
CPF	6.55	34.80	1.48	22.60
OPF	6.89	35.77	1.58	22.93
OBF	3.28	30.91	0.68	20.73
OSBF	3.15	32.74	0.56	17.78
CSBF	3.76	33.90	0.65	17.30

amino acids was found in organic pea flour, although the differences of essential and unessential amino acids were insignificant ($p>0.05$) between organic and conventional pea flours. Buckwheat flour samples had higher essential and unessential amino acids content comparing with wheat flour, however, the differences were insignificant ($p>0.05$).

Many studies (Boye, Zare, & Pletch, 2010; Davidsson *et al*., 2001; Qin *et al*., 2010; Cai, Corke, & Lee, 2004) have shown that pea and buckwheat flours are a good source of protein and are rich in essential amino acid – lysine. Biel *et al.* (2009) reported that, as it concernsthe nutritional value, the amino acid composition of buckwheat is the most favourable among cereals due to the content of lysine, which can be found in limited amounts inmost cereals.

Significant ($p<0.05$) variation existed in the content of essential amino acids across flour samples (Table 3), whereas the results concerning the proportion of essential amino acids to total amino acids showed insignificant ($p>0.05$) differences for pea flours (34.80 – 35.77%) and for buckwheat flours (29.96 – 33.90%). It could be concluded that the amount of essential amino acids made one third of the total amino acid content in the tested pea and buckwheat flours (Table 3).The highest content of lysine was found in pea flours (1.48 g 100 g^{-1}in conventional and 1.58 g 100 g^{-1} in organic flours respectively), and it formed about 23% of the essential amino acids content. Results are comparable to those presented in the research papers by Zia-Ul-Haq *et al.* (2013) and Lisiewska *et al.* (2008).The content of lysine in OBF was more than double comparing with wheat flour and formed 20.73 % of the essential amino acids content. Similar results are confirmed by the data presented by Wei, Zhang, & Li (1995) and Bonafaccia, Marocchini, & Kreft (2003). The results of our research that pea and buckwheat flours are rich in lysine comparing with wheat flour confirmed the conclusions made in the literature.

Legumes are a rich source of dietary fibre having a hypoglycaemic effect (Trinidad *et al*., 2010), ie., consumption of legumes showed an improvement in fasting blood glucose concentration in both diabetic and non-diabetes subjects (Sievenpiper *et al*., 2009). However, Stoughton-Ens *et al.* (2010) reported that there were very strong genotypic and environment (location and year) effects on the dietary fibre content in field pea. Similar conclusions about the growing conditions and milling methods' effects on the dietary

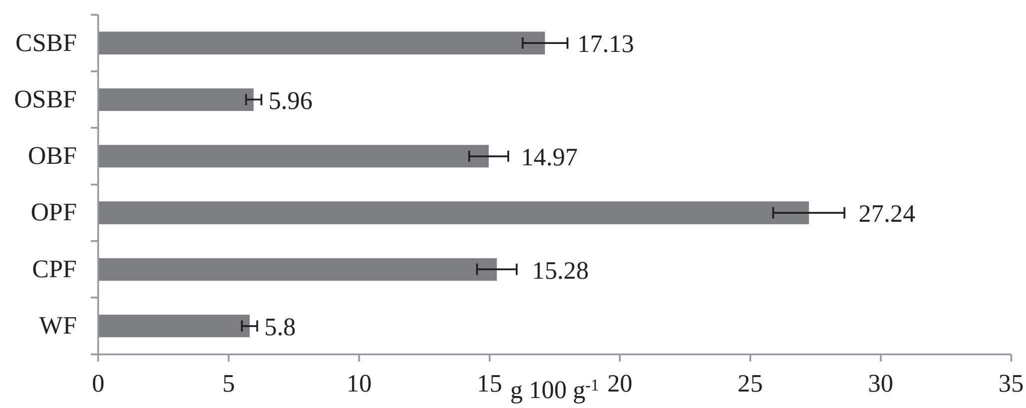

Figure 2. Total dietary fibre amount in pea and buckwheat flours.

fibre content in buckwheat were made by Bonafaccia, Marocchini, & Kreft (2003).

For pea flours the total dietary fibre amount varied between 15.28 g 100 g^{-1} for conventional and 27.24 g 100 g^{-1} for organic pea flour (Fig.2). The significant ($p<0.05$) difference of dietary fibre among pea flours could be associated with different stage of pea treatment for flour production. The appearance of conventional pea flour was daffodil without impurities whereas organic pea flour was light brown with black flecks. It indicated that organic pea flour could be potential high amount of dietary fibre. It was confirmed by obtained data. The research data differed from the results obtained by Stoughton-Ens *et al.* (2010) where the total dietary fibre content of the pea samples ranged from 10.7% to 14.8% of dry matter. It could be explained by the conclusion made by Aldwairji *et al.* (2014) that the fibre content is affected by both the processing method and the method of analysis. The total dietary fibre content of buckwheat flours ranged from 5.96 g 100 g^{-1} for OSBF to 17.13 g 100 g^{-1} for CSBF (Fig. 2).The significantly lower total dietary fibre content of OSBF comparing to OBF and CSBF could be associated with differences in the flour processing method and environment because the buckwheat flour samples were taken from various locations (Lithuania, Latvia) and producers. Comparing results with the data given by Bonafaccia, Marocchini, & Kreft (2003) where common buckwheat grain contained 22.17 g 100 g^{-1} of the total dietary fibre and buckwheat flour contained 5.87 g 100 $g^{-1,}$ it was possible to see similarities. Pea and buckwheat flours could be characterised as a good source of dietary fibre with significantly ($p<0.05$) higher content of the total dietary fibre comparing to wheat flour, except OSBF.

Conclusions

1. The highest amount of total amino acids was determined for pea flours (18.82 g 100 g^{-1} for conventional and 19.30 g 100 g^{-1} for organic flours respectively), whereas for buckwheat flours it ranged from 9.62 g 100 g^{-1} for OSBF to 11.09 g 100 g^{-1} for CSBF.
2. There were significant ($p<0.05$) differences in the individual amino acid contents, particularly as concerns serine, glutamic acid, proline, alanine, isoleucine, leucine, phenylalanine and arginine, across buckwheat flours.
3. The amount of essential amino acids made up one third of the total amino acid content in the tested pea and buckwheat flours which were rich in lysine (1.58 – 1.68 g 100 g^{-1} and 0.56 – 0.68 g 100 g^{-1} respectively) in comparison with wheat flour (0.33 g 100 g^{-1}).
4. Pea and buckwheat flours had a significantly ($p<0.05$) higher content of the total dietary fibre comparing to wheat flour, except OSBF.
5. Due to the biological value of buckwheat and pea flours, it is strongly recommendable to use these ingredients in the production of new functional products and to increase their consumption.

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