Original scientific paper
Originalan naučni rad
UDK: 633.13(497.2)
DOI: 10.7251/AGREN1301105G

University of Banjaluka, Faculty of Agriculture
Agro-knowledge Journal

The Content of Non-essential Amino Acids in the Grains of Winter and Spring Varieties of Oats (*Avena sativa* L.) under the Conditions of Central Southern Bulgaria

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Abstract

The purpose of this survey is to study the content of non-essential amino acids in four winter (Dunav 1, Ruse 8, Resor 1, Line M-K) and five spring (Obraztsov chiflik 4, Mina, HiFi, Novosadski golozarnest and Prista 2) cultivars of oats grown in Central Southern Bulgaria within the period from 2007 to 2009. The tested cultivars have different contents of non-essential amino acids. Dunav 1 has the highest quantity of glicine (5.12 g/100 g protein) of all the winter cultivars, Ruse 8 has the highest quantity of alanine (5.69 g/100 g protein) and Resor 1 – the highest quantity of arginine (6.14 g/100 g protein). Generally speaking, the spring cultivars have a larger quantity of glutamic acid (from 25.86 to 26.07 g/100 g protein) and proline (from 6.15 to 8.21 g/100 g protein) but a smaller quantity of glycine (from 4.68 to 4.99 g/100 g protein) compared to the winter cultivars. The naked cultivar Mina has the highest quantity of cystine (2.14 g/100 g protein), cultivar Prista 2 has the highest quantity of proline (8.21 g/100 g protein) and glutamic acid (26.07 g/100g protein) and HiFi ranks first in terms of aspartic acid (9.05 g/100 g protein), serine (5.02 g/100 g protein) and tyrosine (2.09 g/100 g protein). In the study we have also established certain relations between non-essential amino acids.

Key words: oats, non-essential amino acids, protein, alanine, arginine, aspartic acid, cystine, glutamic acid, glycine, proline, serine, tyrosine

Introduction

Non-essential amino acids seem to be less interesting for researchers compared to essential amino acids due to the fact that they can be synthesised in the body from other acids or can be replaced. However, they must be contained in the food we consume daily since their insufficiency leads to disorders in metabolism and

development of the body in general. As a valuable source of amino acids, oats are increasingly being included in the daily diet of people in different ways. The study of the complete acid content of perspective types of oats will provide the consumers with accurate information about the protein content of this important grain crop.

According to Cluskey et al. (1979) and Pomeranz (1973), oats contain good quality proteins and have the highest lysine content among common cereals. This explains the development of protein concentrates and isolates as brands from mechanically peeled oats as early as 1970 (Cluskey et al. 1973, 1976, 1978; Wu & Stringfellow, 1973; Youngs, 1974). Despite this, the protein content and nutritional value of these products are still being determined.

The amino acid composition of oat groats has been reported by several researchers. Robbins et al. (1971) determined 17 amino acids in 289 samples of oat groats proteins covering a wide range of genetic materials. Other authors have also established differences in the quantity of proteins and their amino acid properties as well (Reeves, 1974; Hischke et al., 1968; Robbins at al., 1971; Baker, 2007; Biel at al. 2009).

In one of our previous surveys, we reported the content of essential amino acids in the tested 4 winter and 5 spring cultivars of oats (Zorovski & Georgieva, 2011). This article presents the results obtained after a three-year survey of the content of non-essential amino acids in the same cultivars of oats in Central Southern Bulgaria.

Materials and methods

Four cultivars of winter oats (Dunav 1, Ruse 8, Resor 1, Line M-K) and five cultivars of spring oats (Obraztsov chiflik 4, Mina (hulless oat), HiFi, Novosadski golozarnest oat and Prista 2) were studied during 2006-2009 in an experimental field of the Plant Production Department at the Agricultural University of Plovdiv, Bulgaria. HiFi cultivar is American (McMullen at al., 2005); Novosadski golozarnest oat is a Serbian cultivar; and the other 6 cultivars together with line are from Bulgarian selection. The field test was repeated four times as the winter cultivars were sown in mid-October (with 500 germinating seeds per sq.m.), and the spring cultivars - in mid-March (600 germinating seeds per sq.m.). The fertilisers used were $N_6P_8K_8$.

The laboratory analyses for the contents of 7 non-essential amino acids tested have been carried out in accredited laboratories through automatic amino analysers – T 339 M under the Moore and Stein Method.

Statistical analysis, simple correlation coefficient among parameters and Duncan test were calculated with the SPSS V.9.0 programme for Microsoft Windows (SAS Procedures Guide, 1999).

Results and discussion

The proteins contained in food are decomposed to amino acids and our blood transports them to all tissues and organs where they perform their specific functions.

Cystine is an important structural element of many proteins and enzymes. It acts as an antioxidant. In the tested cultivars of oats during the period of the survey, the quantity of the cystine varied from 1.68% in 2007 to 2.25% in 2008 (Table 1).

A content of more than 2% was established in the proteins during that period in the following cultivars: Mina (2.14%), Dunav 1 (2.02%) and HiFi (2.00%) (Table 2). HiFi cultivar has other valuable nutritional components – a high content of β – glucane (Georgieva et al, 2010) and a high content of lysine (4.02 g/100 g protein) (Zorovski & Georgieva, 2011).

Alanine participates in the regulation of blood sugar and the provision of energy. The most favourable year for the synthesis of alanine was 2007 – on average 5.70% of the protein for all cultivars, followed by the years 2008 and 2009 with almost the same values (5.37 – 5.36%) (Table 1). Despite the fact that no statistical difference between the cultivars was established, the largest quantity of alanine was found in Ruse 8 – 5.69% and the smallest quantity was registered in the naked cultivars Mina and Novosadski golozarnest (Table 2).

Glutamic acid constitutes the highest percentage of raw proteins in the tested cultivars of oats (winter and spring). It is related to the functioning of the brain. It is also involved in the synthesis of other amino acids. In the studied cultivars, the glutamic acid constitutes from 23.65% (Mina) to 26.07 (Prista 2) of the raw proteins. A high level of glutamic acid can also be observed in Novosadski golozarnest and Obraztsov chiflik 4.

Aspartic acid ranks second in terms of quantity. It is involved in the development of the immune system and also in the transformation of carbohydrates into energy. All winter cultivars as well as the spring cultivars Mina and HiFi have been proven to have a higher quantity of aspartic acid compared to Obraztsov chiflik 4, Novosadski golozarnest and Prista 2. The HiFi cultivar has the highest percentage – 9.05% whereas among the winter cultivars – Ruse 8 (8.94%).

The amino acid tyrosine constitutes the lowest percentage of the raw protein in the tested cultivars. It is involved in the synthesis of most of the proteins in the body. In HiFi, we established the highest quantity of tyrosine – 2.10% of the raw protein and the lowest quantity was found in cultivar Mina. The most favourable year for the synthesis of tyrosine was 2009. No proven statistical difference between the cultivars has been registered.

The percentage of glycine (the smallest amino acid that plays a very important role in metabolism) and serine (contained in a number of enzymes) in the tested cultivars varied but no definite difference between the cultivars was established. The highest quantity of glycine was found in Dunav 1 (5.11%) and the lowest quantity of glycine was registered in Obraztsov chiflik 4 – 4.68%. The highest quantity of serine was established in HiFi (5.02%).

Arginine is a very important amino acid for newborn babies and small children. It is important for adults in stressful situations, in case of traumas and infections.

The highest quantity of arginine was found in Obraztsov chiflik 4 – 6.26% and the lowest quantity was registered in Novosadski golozarnest – 5.69%.

Tab. 1. Quantity of non-essential amino acids (g/100 g protein) divided by years for winter and spring oat cultivars (2007-2009).
Količina neesencijalnih amino kiselina (g/100 g proteina) po godinama za ozime i jare sorte zobi (2007-2009).

Cultivar *Sorta*	Non – essential amino acids *Neesencijalne amino kiseline*								
	Alanine	Arginine	Aspartic acid	Cystine	Glutamic acid	Glycine	Proline	Serine	Tyrosine
2007									
Dunav 1	5,53	5,94	8,93	1,69	25,88	5,21	5,91	4,74	1,99
Ruse 8	5,68	5,87	9,09	1,58	25,54	5,37	6,21	4,82	2,01
Resor 1	5,77	6,01	8,71	1,60	25,28	5,15	6,70	4,55	1,83
Line M-K	5,65	5,61	8,82	1,43	25,56	5,14	6,73	4,75	1,94
Obraztsov chiflik 4	6,18	5,75	8,46	1,33	25,71	4,27	8,84	4,93	2,00
Mina	5,21	5,97	9,02	1,91	27,14	5,19	6,10	4,76	1,96
HiFi	6,27	5,61	9,18	1,57	26,06	4,82	8,60	5,20	2,05
Novosadski golozarnest	5,19	5,66	8,57	2,02	25,47	4,83	8,82	4,76	1,95
Prista 2	5,86	5,47	8,35	1,88	25,85	4,62	8,75	4,69	1,94
2008									
Dunav 1	5,54	5,67	8,94	2,40	25,87	5,12	6,00	5,17	1,97
Ruse 8	5,55	5,50	9,02	2,30	25,57	5,19	6,18	5,21	2,02
Resor 1	5,35	6,22	8,57	2,18	24,97	5,11	6,98	4,93	2,06
Line M-K	5,35	6,41	8,91	2,30	25,77	5,15	6,01	5,13	1,81
Obraztsov chiflik 4	5,36	6,07	8,46	2,19	26,37	5,09	6,28	4,81	1,77
Mina	5,07	5,89	8,92	2,29	26,59	5,04	6,10	4,62	1,76
HiFi	5,16	6,13	8,89	2,29	25,35	5,06	6,67	4,87	2,12
Novosadski golozarnest	5,70	5,60	8,04	2,04	25,56	4,94	8,57	4,69	1,91
Prista 2	5,28	6,34	8,70	2,30	26,46	5,18	7,83	5,14	1,79

Tab. 1. Quantity of non-essential amino acids (g/100 g protein) divided by years for winter and spring oat cultivars (2007-2009). (continued)

Količina neesencijalnih amino kiselina (g/100 g proteina) po godinama za ozime i jare sorte zobi (2007-2009). (nastavak)

Cultivar *Sorta*	Non – essential amino acids *Neesencijalne amino kiseline*								
	Alanine	Arginine	Aspartic acid	Cystine	Glutamic acid	Glycine	Proline	Serine	Tyrosine
2009									
Dunav 1	5,31	5,99	8,93	1,98	25,64	4,99	6,25	5,08	2,11
Ruse 8	5,83	6,01	8,71	1,53	25,30	4,69	6,11	4,89	2,14
Resor 1	5,35	6,18	9,29	1,89	25,30	4,93	6,22	5,08	2,32
Line M-K	5,73	5,47	8,63	1,91	24,94	4,94	7,12	4,84	2,02
Obraztsov chiflik 4	5,00	5,97	8,06	2,14	25,77	4,67	8,37	4,68	2,17
Mina	5,02	6,03	9,01	2,21	27,23	4,73	6,25	4,97	1,89
HiFi	5,22	5,72	9,07	2,15	26,16	4,83	6,41	4,99	2,12
Novosadski golozarnest	5,27	5,83	8,32	1,88	27,01	5,05	6,77	4,58	1,87
Prista 2	5,53	5,76	8,07	1,19	25,91	4,58	8,06	4,04	2,22

*Results represent a mean value of 3 measurements (2007, 2008, 2009).

**Rezultati predstavljaju srednju vrijednost 3 mjerenja (2007, 2008, 2009).*

Tab. 2. Non-essential amino acids (g/100 g protein) for oat cultivars (2007-2009)
Neesencijalne amino kiseline (g/100 g proteina) sorte zobi (2007-2009)

Cultivar *Sorta*	Protein %	Alanine	Arginine	Aspartic acid	Cystine	Glutamic acid	Glycine	Proline	Serine	Tyrosine
Dunav 1	11,42	5,46a	5,87a	8,93a	2,02a	25,80a	5,11a	6,05c	4,99a	2,02a
Ruse 8	11,83	5,69a	5,79a	8,94a	1,80a	25,47a	5,08a	6,17c	4,97a	2,06a
Resor 1	10,96	5,49a	6,14a	8,86a	1,89a	25,18a	5,06a	6,63bc	4,85a	2,07a
Line M-K	11,54	5,58a	5,83a	8,79a	1,88a	25,42a	5,07a	6,62bc	4,91a	1,92a
Obraztsov chiflik 4	12,91	5,51a	6,26a	8,33b	1,89a	25,95a	4,68a	7,83ab	4,80a	1,98a
Mina	15,21	5,10a	5,96a	8,98a	2,14a	23,65a	4,99a	6,15c	4,78a	1,87a
HiFi	13,16	5,55a	5,82a	9,05a	2,00a	25,86a	4,90a	7,23abc	5,02a	2,09a
Novosadski golozarnest	16,94	5,39a	5,69a	8,31b	1,98a	26,01a	4,94a	8,05ab	4,68a	1,91a
Prista 2	13,26	5,56a	5,86a	8,37b	1,79a	26,07a	4,79a	8,2a	4,62a	1,98a

*Results represent a mean value of 3 measurements (2007, 2008, 2009) / **Rezultati predstavljaju srednju vrijednost 3 mjerenja (2007, 2008, 2009)*
** Duncan's test: different letters in the same column indicate that the values are significantly different (P<0.05) / ** *Duncan test: različita slova u istoj koloni ukazuju da su vrijednosti znatno različite (P<0.05)*

Tab. 3.Correlation between non – essential amino acids for oat cultivars (2007-2009)
Korelacija između neesencijalnih amino kiselina za sorte zobi (2007-2009)

Non–essential amino acids	Alanine	Arginine	Cystine	Aspartic acid	Glutamic acid	Glycine	Proline	Serine	Tyrosine
Alanine	1,000	-0,530**	-0,642**	-0,038	+0,050	-0,274	+0,365	0,073	0,067
Arginine		1,000	+0,292	-0,081	-0,012	0,080	-0,144	+0,052	+0,082
Cystine			1,000	+0,167	+0,082	+0,365	-0,283	+0,473*	-0,304
Aspartic acid				1,000	-0,160	+0,433*	-0,617**	+0,673**	+0,080
Glutamic acids					1,000	0,199	+0,137	+0,050	-0,104
Glycine						1,000	-0,621**	+0,216	-0,354
Proline							1,000	-0,244	+0,071
Serine								1,000	-0,004
Tyrosine									1,000

*,** Correlation is significant at the 0,05 and 0,01 level respectively / *,** *Korelacija je značajna na nivou od 0,05 i 0,01*

There are certain differences regarding the proline content in these cultivars (Table 2). As an amino acid that is included in the composition of all protein structures in the body but mainly collagen and the connective tissue, it is essential for the joints and the tendon. Among the studied cultivars, the one that has the highest quantity of proline is Prista 2 98.21%) and the cultivar with the lowest quantity of proline is Dunav 1 – 6.05%.

In order to establish certain dependence between the non-essential amino acids, we conducted a correlation analysis (Table 3). We established a very strong positive correlation between aspartic acid and the glycine (r=+0.433*) and also between aspartic acid and serine (r=+0.673**). Another strong positive correlation was found between cystine and serine (r=+0.473*).

Negative dependence was established between alanine and arginine (r= -0.530**), between alanine and cystine (r=-0.642**), between aspartic acid and proline (r=-0.617**) and also between glycine and proline (r=-0.621**).

Conclusion

The tested cultivars have different combinations of non-essential amino acids. Dunav 1 has the highest quantity of glycine (5.11 g/100g protein), Ruse 8 has the highest quantity of alanine (5.69 g/100g protein), Resor 1 has the highest quantity of arginine (6.14 g/100g protein) among the winter cultivars.

Generally speaking, the spring cultivars have a larger quantity of glutamic acid (from 25.86 to 26.07 g/100 g) and proline (from 6.15 to 8.21 g/100 g protein) but a smaller quantity of glycine (from 4.68 to 4.99 g/100 g protein) compared to the winter cultivars. The naked cultivar Mina has the highest quantity of cystine (2.14 g/100 g), cultivar Prista 2 has the highest quantity of proline (8.21 g/100g protein) and glutamic acid (26.07g/100 g protein) and HiFi ranks first in terms of aspartic acid (9.05 g/100g protein), serine (5.02 g/100g protein) and tyrosine (2.09 g/100g protein).

We have also established strong positive correlation dependence between the aspartic acid and glycine (r=+0.433*), aspartic acid and serine (r=+0.673**) as well as between cystine and serine (r=+0.473*).

We have also established negative dependence between alanine and arginine (r=-0.530**), between alanine and cystine (r=-0.642**), between aspartic acid and proline (r=-0.617**) and also between glycine and proline (r=-0.621**).

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Sadržaj neesencijalnih amino kiselina u zrnu ozimih i jarih sorti zobi (*Avena sativa* L.) u uslovima centralne južne Bugarske

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Sažetak

Cilj ovog istraživanja bio je da se ispita sadržaj neesencijalnih amino kiselina u četiri ozime (Dunav 1, Ruse 8, Resor 1, Line M-K) i pet jarih (Obraztsov chiflik 4, Mina, HiFi, Novosadski golozarnest and Prista 2) sorti zobi u periodu od 2007. do 2009. godine koje se uzgajaju u centralno južnoj Bugarskoj. Ispitivane sorte imaju različit sadržaj neesencijalnih amino kiselina. Dunav 1 ima najveću količinu glicina (5,12 g/100 g proteina) od svih ozimih sort, Ruse 8 ima najveću količinu alanina (5,69 g/100 g proteina), a Resor 1 – najveću količinu arginina (6,14 g/100 g proteina). Opšte gledano jare sorte imaju veću količinu glutaminske kiseline (od 25,86 do 26,07 g/100 g proteina) i prolina (od 6,15 do 8,21 g/100 g proteina), ali manju količinu glicina (od 4,68 do 4,99 g/100 g proteina) u poređenju sa ozimim sortama. Gola sorta Mina ima najveću količinu cistina (2,14 g/100 g proteina), sorta Prista 2 ima najveću količinu prolina (8,21 g/100 g proteina) i glutaminske kiseline (26,07 g/100g proteina), a HiFi je prvi po količini aspartinske kiseline (9,05 g/100 g proteina), serinu (5,02 g/100 g proteina) i tirozinu (2,09 g/100 g proteina). U ovom istraživanju smo uspostavili određene veze između neesencijalnih amino kiselina.

Ključne riječi: zob, neesencijalne amino kiseline, protein, alanin, arginin, aspartinska kiselina, cistin, glutaminska kiselina, glicin, prolin, serin, tirozin

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