PERIÓDICO TCHÊ QUÍMICA
ARTIGO ORIGINAL

COMPOSIÇÃO DE AMINOÁCIDOS DE FARINHA POLI-CEREAL NÃO CONVENCIONAL PARA MASSA

THE AMINO ACID COMPOSITION OF UNCONVENTIONAL POLY-CEREAL FLOUR FOR PASTA

АМИНОКИСЛОТНЫЙ СОСТАВ НЕТРАДИЦИОННОГО ПОЛИЗЛАКОВОГО СЫРЬЯ ДЛЯ ИЗГОТОВЛЕНИЯ МАКАРОННЫХ ИЗДЕЛИЙ

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RESUMO

Os produtores de massas conhecem três formulações de massa para fabricar produtos de massa com o valor nutricional e biológico aumentado a partir de matérias-primas não convencionais de poli-cereais. Essas formulações para massas compõem misturas de farinha de cereais/legumes com adição de glúten de trigo seco. A mistura de farinha foi formulada através do método de *design* que permite regular o conteúdo de nutrientes no produto para atender aos requisitos de nutrição racional e adequada e proporcionar um efeito terapêutico e preventivo. Este artigo explora a cinética de secagem de massas a partir de matérias-primas não convencionais e relata a qualidade e as propriedades do consumidor para massas. Os resultados mostram que, com o aumento da porcentagem de glúten de trigo seco na mistura de farinha de cereais, a porcentagem de aminoácidos essenciais e não essenciais na mistura também aumenta. A Formulação No. 1 fornece uma mistura com a porcentagem máxima de aminoácidos nela. O referido máximo é significativamente superior à concentração total de aminoácidos (% em peso) em uma mistura feita de acordo com as formulações 2 e 3. O aumento do glúten de trigo seco de 15% para 35% leva a um aumento acentuado na concentração de aminoácidos essenciais (triptofano e lisina). Não foi detectado um aumento significativo em outros aminoácidos essenciais (valina, isoleucina, leucina, metionina, treonina, fenilalanina).

Palavras-chave: *glúten de trigo seco; aminoácidos essenciais; tecnologia de processamento de alimentos; produtos de massa; matérias-primas poli-cereais*.

ABSTRACT

Pasta producers know three pasta formulations for making pasta products with the increased nutritional and biological value from unconventional poly-cereal raw materials. These pasta formulations composite flour mixtures of cereal/legumes with added dry wheat gluten. The flour mix was formulated through the design method that allows regulating the content of nutrients in the product to meet the requirements of rational and adequate nutrition and provide a therapeutic and preventive effect. This article explores the drying kinetics of pasta from unconventional raw materials and reports on the quality and consumer properties of pasta. Results show that with the percentage of dry wheat gluten increasing in the poly-cereal flour mix, the percentage of both essential and non-essential amino acids in the mix also increases. Formulation No. 1 provides a mix with the maximum percentage of amino acids in it. The said maximum is significantly higher than the total concentration of amino acids (% by weight) in a mix made according to formulations No. 2 and No. 3. The increase in dry wheat gluten from 15% to 35% leads to a sharp increase in the concentration of essential amino acids (tryptophan and lysine). A significant increase in other essential amino acids (valine, isoleucine, leucine, methionine, threonine, phenylalanine) was not detected.

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Keywords: *dry wheat gluten; essential amino acids; food processing technology; pasta products; poly-cereal raw materials*.

АННОТАЦИЯ

Производителям макаронных изделий известны три рецептуры для производства макаронных изделий с повышенной пищевой и биологической ценностью из нетрадиционного цельносмолотого сырья. Эти пастообразные составы представляют собой смеси цельносмолотого зерна злаковых и крупяных культур с добавлением сухой пшеничной клейковины (СПК). В основу составления состава мучных смесей положена методология конструирования, позволяющая регулировать содержание нутриентов в продукте, удовлетворяющих требованиям рационального и адекватного питания, обеспечивая лечебно-профилактическую направленность. Изучена кинетика процесса сушки макаронных изделий из нетрадиционного сырья; дана качественная характеристика макаронных изделий и определены их потребительские свойства. Установлено, что увеличение процентного содержания СПК в мучной полизлаковой смеси в целом увеличивает процентное содержание как незаменимых, так и заменимых аминокислот. При этом рецептура № 1 отличается максимальными значениями процентного содержания группы аминокислот, что значительно выше значений общей массовой доли содержания аминокислотного состава, чем в рецептурах № 2 и № 3. Показано, что увеличение процентного содержания СПК с 15 до 35 % приводит к резкому увеличению массовой доли содержания таких незаменимых аминокислот как триптофан и лизин. Значительного увеличения содержания других незаменимых аминокислот (валин, изолейцин, лейцин, метионин, треонин, фенилаланин) не обнаружено.

Ключевые слова: *сухая пшеничная клейковина; незаменимые аминокислоты; технология пищевой промышленности; макаронные изделия; ползерновое сырье*.

1. INTRODUCTION

The current state of the art of the pasta industry allows producing a wide range of pasta products. Pasta goes in various shapes and sizes and is made according to various formulations. Classic pasta is made from durum wheat flour, sometimes with various vegetative additives (Bigliardi and Galati, 2013; Capozzi *et al*., 2012; Iztaev *et al*., 2018; Ospanov *et al*., 2014).

On the pasta market, domestic producers run their business next to the representatives from countries outside and inside the former Soviet Union. Pasta products stand out not only with high consumer properties and with high-quality packaging materials but also with the price policy. Prices for pasta are fixed specifically for particular segments of the population (Koryachkina, 2006).

There are various ways to improve pasta production. For example, pasta products can be enriched with dietary fiber, minerals, organic acids, vitamins, and antioxidants by adding vegetative raw materials (legumes, vegetables or berries) (Gull *et al*., 2018; Padalino *et al*., 2017; Zheng *et al*., 2016). For the same enrichment purpose, producers may use other types of additives. To enrich pasta with biologically active substances, they use a lactic acid starter or milk whey. To enrich pasta with minerals, producers use eggshell waste. The yeast is used to increase the protein content. Tomato-based products, if added, increase the mineral content of a product. There was a pasta-enriching method designed to solve the problem of iodine deficiency in the country. This method implies the fortification of pasta products with seaweed (Ivanišová *et al*., 2018; Ostrikov *et al*., 2018; Spinelli *et al*., 2019).

Additionally, to the nutritional improvement of pasta-like products, studies are focused on the improvement of pasta pressing and cooking techniques. Because various additives significantly change the structural and mechanical properties of the dough, the cooking properties of pasta will be different in different pasta products made from the different dough (Cubadda *et al*., 2007; Doxastakis *et al*., 2007; Lucisano *et al*., 2012). This is why new formulations should embrace the full cycle of pasta production, from the preparation of raw materials and flour mix formulation to the production and assessment of consumer properties of a cooked product (Ospanov *et al*., 2017; Ospanov *et al*., 2017).

When the product range increased due to the introduction of unconventional raw materials into production, the wholemeal pasta became of greater interest (Chillo *et al*., 2008). Now, pasta is produced with the inclusion of wheat bran (Brennan *et al*., 2008). This direction should be promoted in Kazakhstan without restrictions because of the high grain potential of this country. In 2017–18, for example, the grain harvest in Kazakhstan amounted to 19.3 million tons.

Thus, the pasta industry should be on the way towards the expansion of the product range with products from new types of raw materials, such as the unconventional poly-cereal raw materials. Pasta pressing, dough forming, pasta drying, and pasta cooking technologies should also be improved. The purpose of this research is to study the amino acid composition of a poly-cereal flour mixture for pasta dough, as well as to investigate the drying kinetics of pasta from unconventional raw materials.

2. MATERIALS AND METHODS

Analytical studies were conducted in the research laboratory of the 'Technology of Processing Industries' research center, attached to the Kazakh National Agrarian University, and in the research laboratory of the AgriTech Hub, which cooperates with the University.

The rheological properties of poly-cereal dough were studies using modern devices, such as the AlveoConsistograph (CHOPIN Technologies, France) and the farinograph (Brabender, Russia). Pasta from unconventional poly-cereal raw materials was made using the laboratory press machine (Germany).

Dry wheat gluten (hereinafter referred to as DWG) was added to the pasta formulation to improve the technological properties of the dough (Ospanov *et al.*, 2018a, 2018b). The amino acid composition was measured separately in various single-ingredient flour samples and in the poly-cereal flour mixtures afterward. The first stage of experimental studies was aimed at determining the limiting essential and non-essential amino acids both in the wholemeal flour (ground from cereal/legumes) and in the flour with added DWG. The next step was to determine the proportion of essential amino acids (EAA) in the reference of "ideal" protein (amino acid score). After determining the amount of non-essential amino acids both in the wholemeal flour and in DWG, their composition was compared between the two given raw materials.

A review of protocols for testing cereal crop varieties was made to form a database of nutritional information for pasta from poly-cereal raw materials. For the same purpose, the granted quality assurance certificates were analyzed. The resulting database allowed rationalizing the unconventional pasta formulations. The quality of raw materials and pasta was assessed in accordance with regulatory documents. The nutritional value of poly-cereal flour was determined using originally designed software (Ospanov *et al.*, 2013).

3. RESULTS AND DISCUSSION:

Figure 1 shows the total concentrations of essential amino acids in cereals/legumes and in DWG by weight. While in cereal flour (corn, barley, oats, buckwheat, millet), the total concentration of essential amino acids are low, in flour ground from legumes, it is almost twofold higher. The total concentration of essential amino acids in DWG reaches a high of 12.653% by weight.

The comparative diagram showcases an amino acid profile of the wholemeal flour against the amino acid profile of flour with added DWG (Figure 2). The comparative analysis includes essential amino acids, such as valine, isoleucine, leucine, lysine, methionine, threonine, tryptophan, and phenylalanine. In flour ground from cereals, the level of essential amino acids is insignificant. In flour ground from legumes, the level of essential amino acids is significantly higher by contrast: valine, isoleucine, leucine, lysine, threonine, and phenylalanine hit the maximum. However, tryptophan and methionine were not significant. The flour with added DWG was high in lysine and valine.

Figure 3 shows that the concentration of non-essential amino acids is almost twofold higher than the concentration of essential amino acids. As in the previous experiment, flour ground from legumes is higher in non-essential amino acids than flour ground from cereals. The flour with added DWG is also high in non-essential amino acids.

The comparative diagram showcases an amino acid profile of the wholemeal flour against the amino acid profile of flour with added DWG (Figure 4). The comparative analysis includes non-essential amino acids.

Figure 4 shows that flour samples ground from corn, barley, and oat contain the highest concentrations of glutamic acid and proline. Other non-essential amino acids turned to be insignificant. The flour samples ground from buckwheat and millet contain the highest concentration of non-essential amino acids. However, these samples of flour are lower in glutamic acid and proline but higher in other non-essential amino acids (alanine, arginine, aspartate, glycine, and serine). Flour ground from legumes contains concentrations that are significantly different from previous values. The analysis suggests that all non-essential amino acids, except histidine, hit the maximum. In this case, glutamic and aspartic acids stand out against other non-essential amino acids. The flour with added DWG higher concentrations of glycine, glutamic acid, proline, and serine.

The next step was to evaluate the amino acid profile of three different formulations with DWG added in different amounts. These formulations were labeled as Formulation No. 1, Formulation No. 2, and Formulation No. 3 with regard to the percentage of added DWG (15%, 25%, and 35%, respectively).

First, this evaluation touched upon the essential amino acids (Figures 5-7), then upon the non-essential amino acids (Figures 8-10). Figures 5-7 show that with an increase in DWG from 15% to 35%, the total concentration of essential amino acids becomes higher in all three flour mixtures.

In Formulation No. 1, comprising 15% of DWG, the total concentration of essential acids amounts to 6.124% by weight. With an increase to 25% of DWG, the total concentration of essential amino acids becomes higher, up to 7.39% by weight. With a further increase, up to 35%, the total concentration of essential amino acids becomes even higher, reaching 8.653% by weight (Figure 5).

Formulations No. 2 and No. 3 showed a pattern similar to one displayed by Formulation No. 1 (Figures 6 and 7). These figures show that an increase in DWG leads to an increase in the total concentration of essential amino acids. Figures 8-10 show that with an increase in DWG from 15% to 35%, the total concentration of non-essential amino acids becomes higher in all three flour mixtures.

This research shows that with an increasing percentage of DWG in the poly-cereal flour, both essential and non-essential amino acids become higher in concentration. Upon that, Formulation No. 1 stands out with the maximum concentrations of amino acids. At this point, we can state with certainty that Formulation No. 1 has the best amino acid composition.

The amino acid score was calculated for each of these three formulations. To accomplish this objective, the level of each essential amino acid was determined in the reference of “ideal” protein (Figures 11-13).

Figure 11 shows the laboratory concentrations of essential amino acids in the Formulation No. 1 with added DWG (15%, 25%, and 35%). From Figure 11, it follows that with an increase in DWG, Formulation No. 1 contained a higher total concentration of tryptophan, threonine, and lysine. On the background of a significant increase in these amino acids, the increase in valine concentration was less impressive. The level of other amino acids did not change.

Figure 12 shows the laboratory concentrations of essential amino acids in the Formulation No. 2 with added DWG (15%, 25%, and 35%). The presented values show a slight increase in the concentration of essential amino acids in the Formulation No. 2. However, this increase was driven mainly by two amino acids – tryptophan and lysine. Changes that occurred in the concentration of essential amino acids in the Formulation No. 3 after the introduction of DWG are presented in Figure 13.

Figure 13 shows that with a DWG fraction increasing from 15% to 35%, tryptophan and lysine concentrations in Formulation No. 3 show a sharp increase. Such an impressive change was not observed in the concentrations of other essential amino acids (valine, isoleucine, leucine, methionine, threonine, and phenylalanine).

The concentrations of non-essential amino acids were also analyzed (Figures 14-16).

Figure 14 shows those changes that occurred in the concentrations of non-essential amino acids in the poly-cereal flour made according to Formulation No. 1 with added DWG (15%, 25%, and 35%). The diagram in Figure 14 shows that glutamic acid, proline, and serine tend to hit the maximum of the possible concentration in all formulations. A slight increase was observed in the level of glycine and histidine. The concentration of tyrosine, cysteine, alanine, arginine, and aspartate did not change significantly.

Figure 15 shows those changes that occurred in the concentrations of non-essential amino acids in the poly-cereal flour made according to Formulation No. 2 with added DWG (15%, 25%, and 35%). According to the diagram, significant changes occurred in the concentration of serine, proline, and glutamic acid. The remaining amino acids showed less significant changes in the concentration.

Figure 16 shows the three-dimensional model of changes that occurred in the concentration of non-essential amino acids in the poly-cereal flour made according to Formulation No. 3 with added DWG (15%, 25%, and 35%). The 3D model shows that with an increase in DWG from 15% to 35%, the concentration of glutamic acid, serine, and proline became higher. The concentrations of the remaining non-essential amino acids remained almost within the same limits. The total concentration of non-essential amino acids did not show any significant change.

This research shows that DWG, added to the Formulations (No. 1, No.2 and No.3) at the level from 15% to 35%, leads to an increase in the concentration of specific amino acids. The most significant concentration increment was displayed by tryptophan, threonine, and lysine (essential amino acids), as well as by glutamic acid, serine, and proline (non-essential amino acids).

In this study, the resulting product, with reduced gluten content, is of acceptable quality. In conventional paste production, which involves durum wheat, gluten network formation is crucial to texture, but reaching quality in the gluten-free paste is a challenge (Mariotti *et al.,* 2011). In poly-cereal, mostly water-soluble, paste, weaker interactions between wheat proteins, mainly glutenins and gliadins, and proteins of other cereals can cause increased loss of weight during cooking (Phongthai *et al.*, 2017; Rizzello et al., 2017). Paste formulations in this study (Figure 13) contain essential amino acids in the amount higher than recommended by WHO/FAO/UNU for adults (WHO/FAO/UNU, 2007). Thus, products prepared in accordance with these formulations demonstrate sufficient consumer qualities, and there is no need to add additional protein-rich components to the flour, which is what other authors do.

Laleg *et al.* (2016) investigated the composition of amino acids in bean flour paste, and this allowed achieving compliance with the requirements of WHO/FAO/UNU (2007). However, the well-known anti-nutritional properties of legumes (Gupta, 1987; Nosworthy *et al.*, 2016) do not make this approach optimal. An alternative attempt to enrich paste with essential amino acids at the expense of animal proteins (Desai *et al.*, 2018) does not seem successful either due to obvious problems – short shelf life. Moreover, adding animal raw materials to the paste will make it unsuitable for vegan diets that are associated with many health benefits, including significantly lower risks of developing heart disease, high blood pressure, stroke, and diabetes.

4. CONCLUSIONS:

To sum up, poly-cereal pasta formulations are a promising innovation that can carve out a niche in the market due to obvious competitive advantages.

This research studied the amino acid composition of single-ingredient flour samples and a poly-cereal flour mixture for pasta dough. The analysis of diagrams suggests that the amino acid profile includes the following essential amino acids: valine, isoleucine, leucine, lysine, methionine, threonine, tryptophan, and phenylalanine. In flour ground from cereals, the total concentration of essential amino acids is insignificant. In flour ground from legumes, the level of essential amino acids is significantly higher by contrast: valine, isoleucine, leucine, lysine, threonine, and phenylalanine hit the maximum. However, tryptophan and methionine were not significant. The flour with added DWG was high in lysine and valine.

This research shows that with an increasing percentage of DWG in the poly-cereal flour, both essential and non-essential amino acids become higher in concentration. Upon that, the Formulation No. 1 stands out with the maximum concentrations of amino acids, which is significantly higher than in Formulations No.2 and No. 3.

Research results showed that the increase in dry wheat gluten from 15% to 35% leads to a sharp increase in the concentration of tryptophan and lysine. The concentration of other essential amino acids (valine, isoleucine, leucine, methionine, threonine, phenylalanine) did not change significantly.

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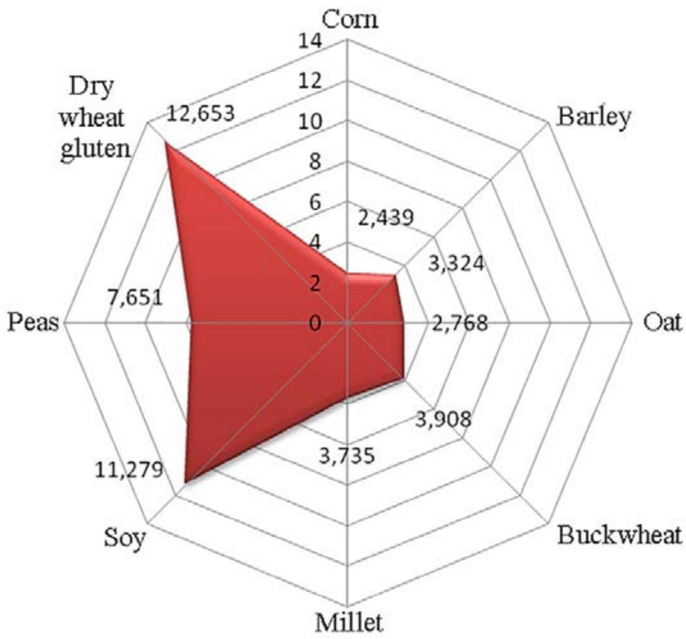

Figure 1. *Total Concentration of Essential Amino Acids in Cereals/Legumes and in DWG, % by Weight.*

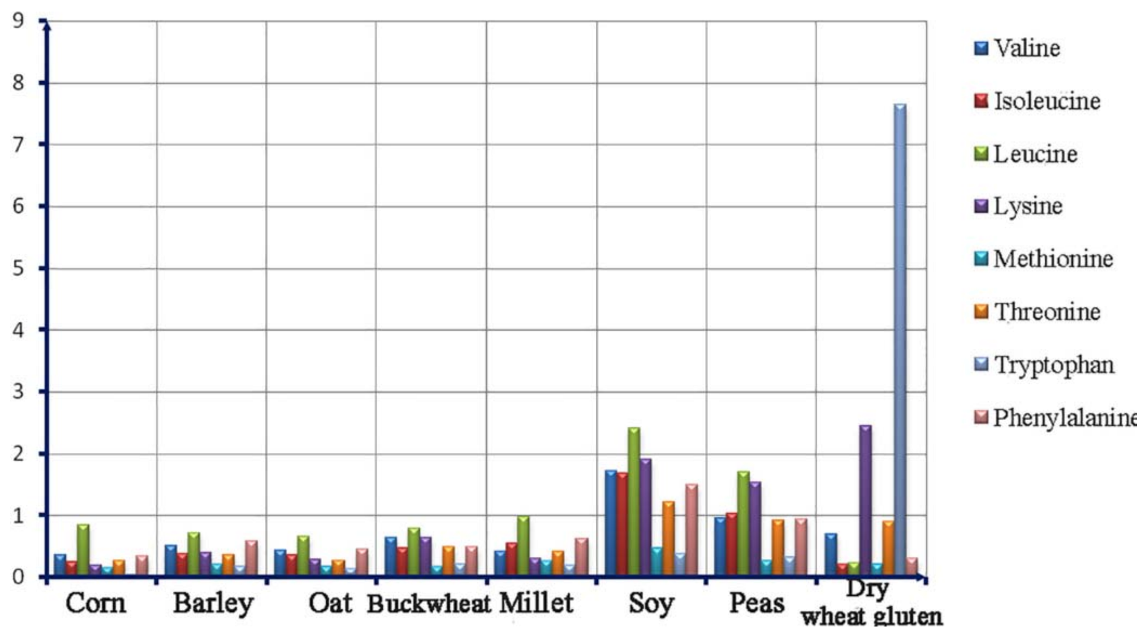

Figure 2. *Essential Amino Acid Profile: Wholemeal Flour (Ground from Cereals/Legumes) vs. Flour with added DWG, % by Weight.*

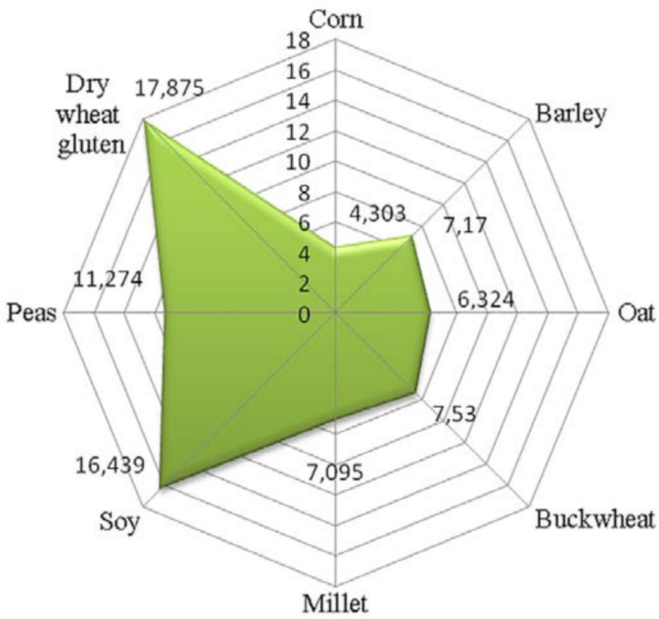

Figure 3. *Total Concentration of Non-Essential Amino Acids in Cereals/Legumes and in DWG, % by Weight.*

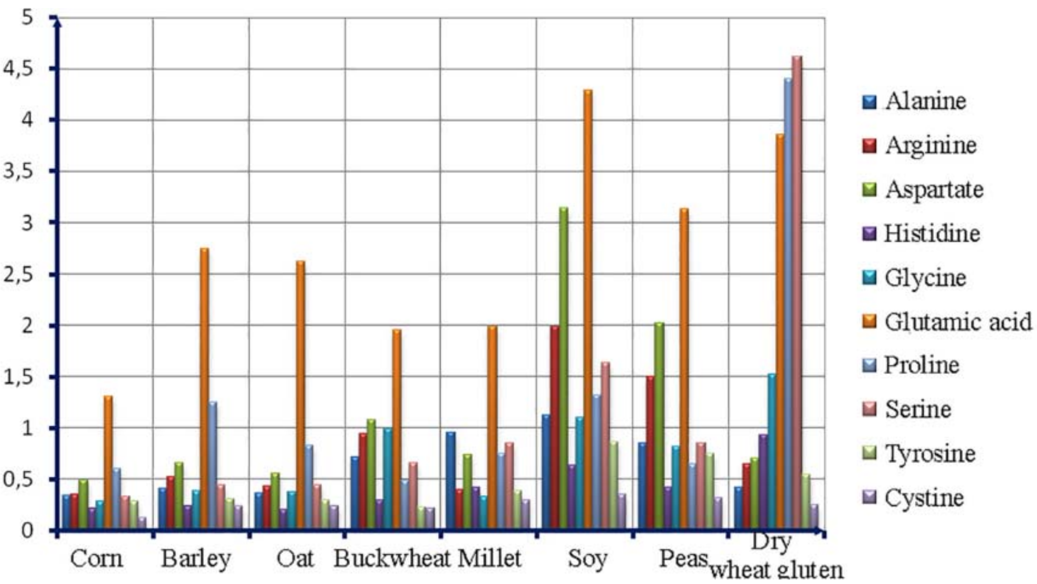

Figure 4. *Essential Amino Acid Profile: Wholemeal Flour (Ground from Cereals/Legumes) vs. Flour with added DWG, % by Weight.*

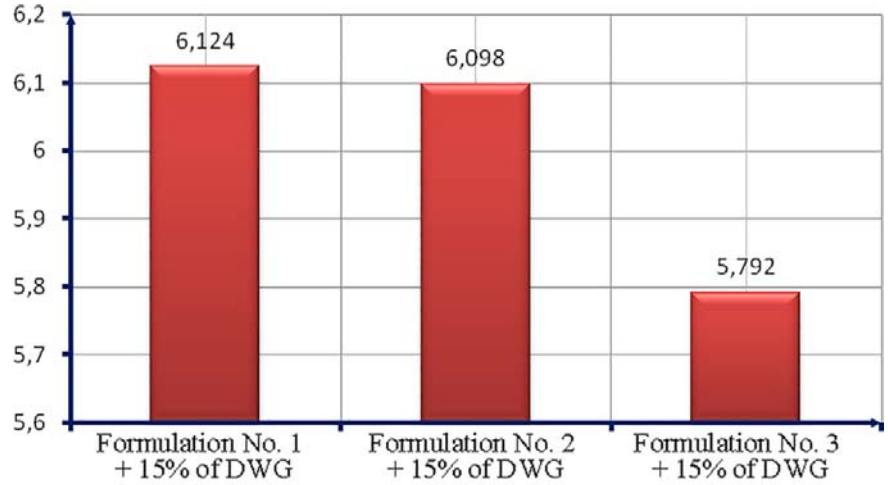

Figure 5. *Total Concentration of Essential Amino Acids in Formulations (No. 1, No. 2 and No. 3) with added DWG (15%).*

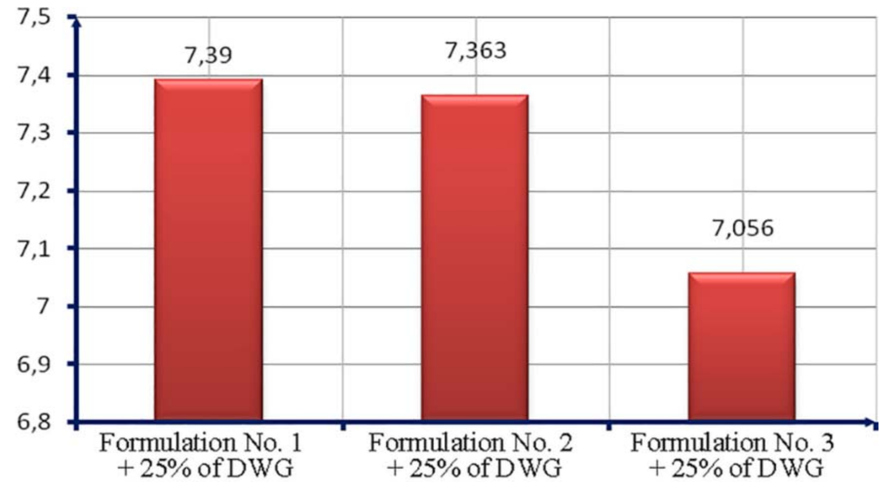

Figure 6. *Total Concentration of Essential Amino Acids in Formulations (No. 1, No. 2 and No. 3) with added DWG (25%).*

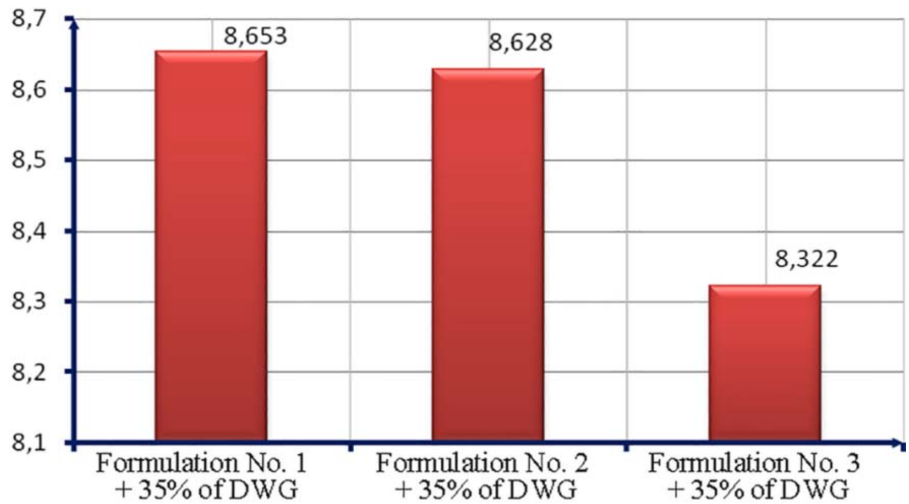

Figure 7. *Total Concentration of Essential Amino Acids in Formulations (No. 1, No. 2 and No. 3) with added DWG (35%).*

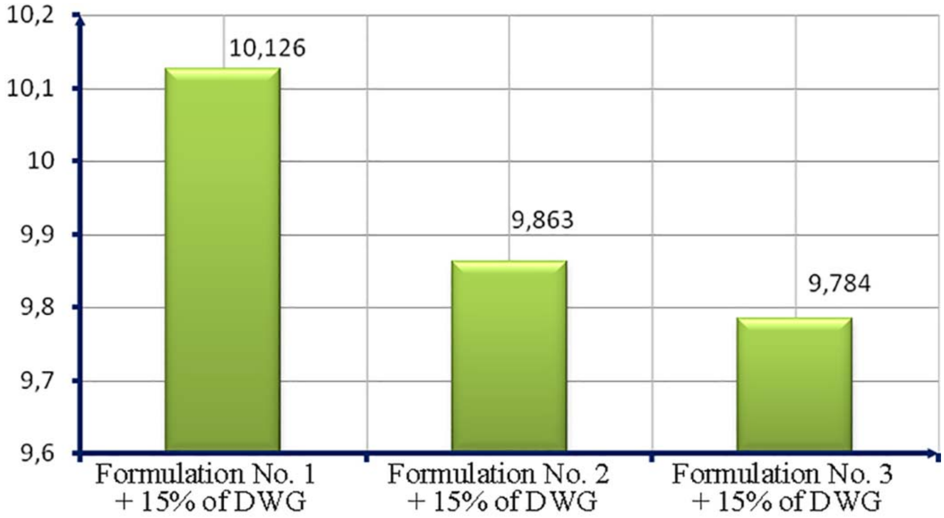

Figure 8. *Total Concentration of Non-Essential Amino Acids in Formulations (No. 1, No. 2 and No. 3) with added DWG (15%).*

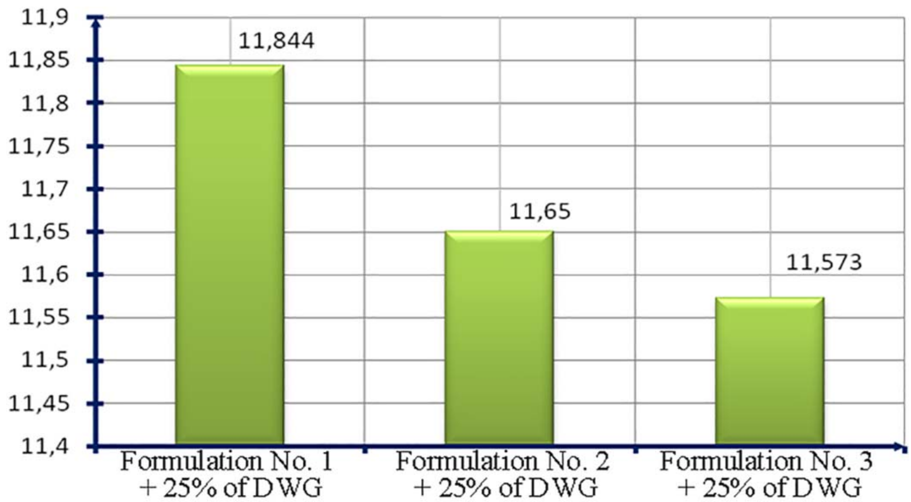

Figure 9. *Total Concentration of Non-Essential Amino Acids in Formulations (No. 1, No. 2 and No. 3) with added DWG (25%).*

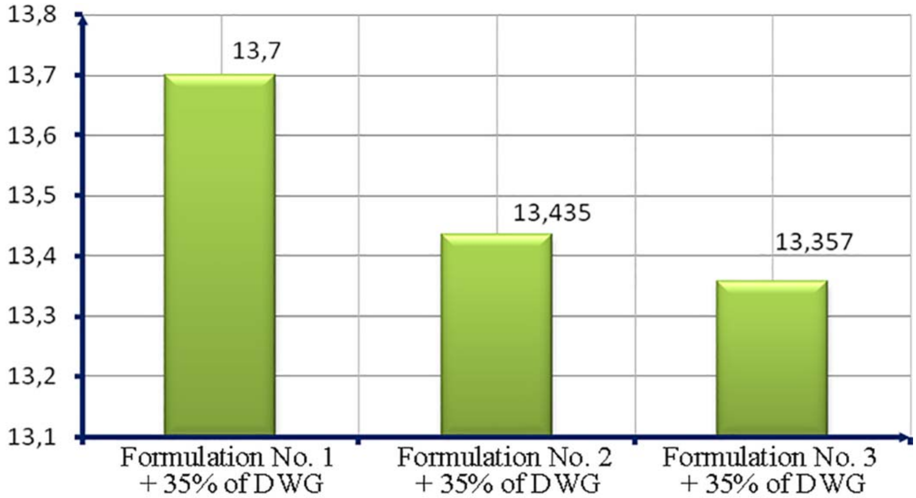

Figure 10. *Total Concentration of Non-Essential Amino Acids in Formulations (No. 1, No. 2 and No. 3) with added DWG (35%).*

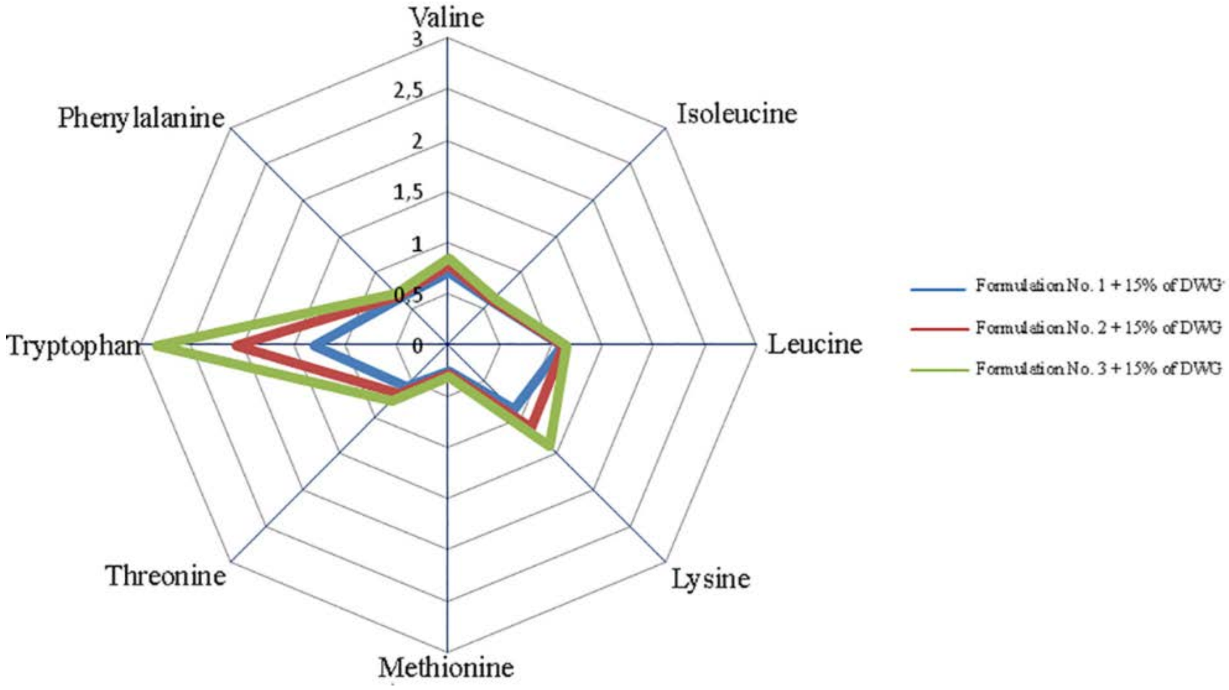

Figure 11. *The Concentrations of Essential Amino Acids in Formulation No. 1 with added DWG (15 %, 25 %, and 35 %).*

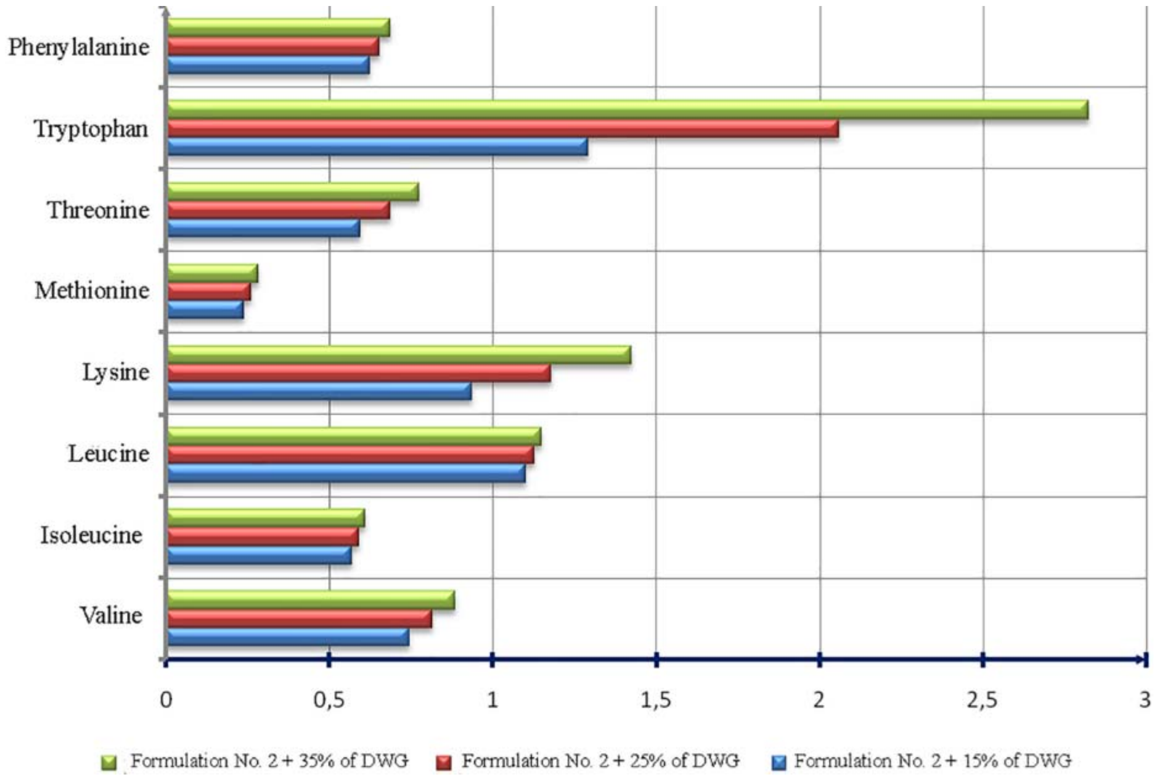

Figure 12. *The Concentrations of Essential Amino Acids in Formulation No. 2 with added DWG (15 %, 25 %, and 35 %).*

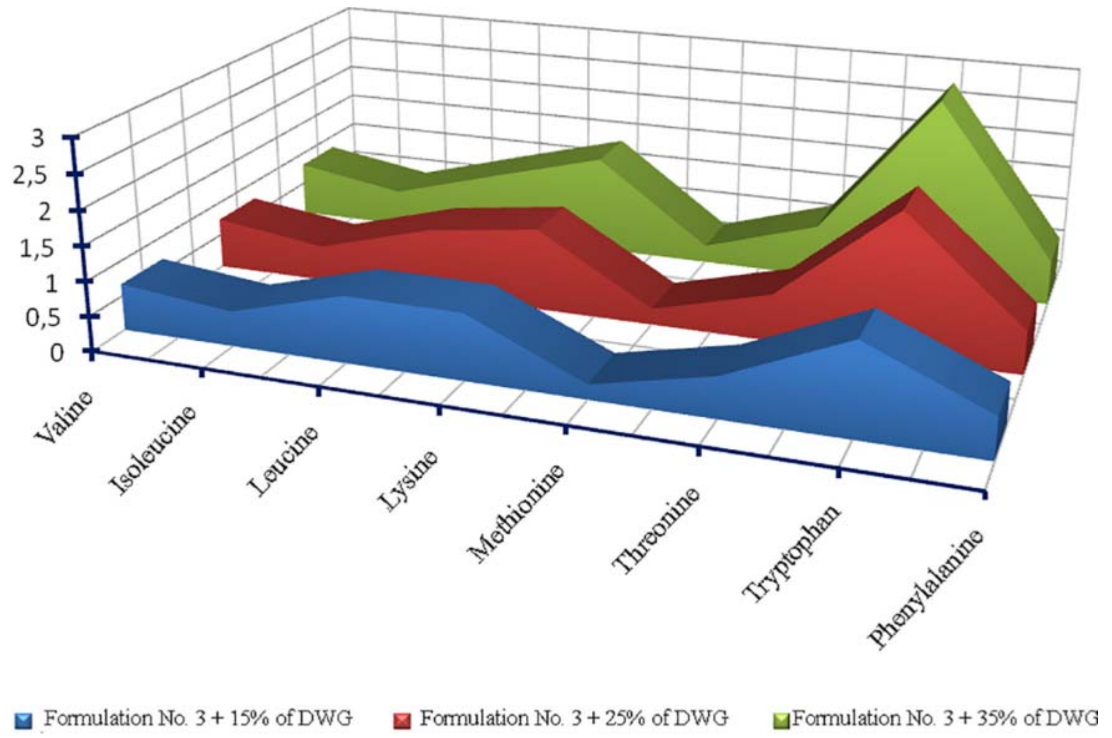

Figure 13. *The Concentrations of Essential Amino Acids in Formulation No. 3 with added DWG (15 %, 25 %, and 35 %).*

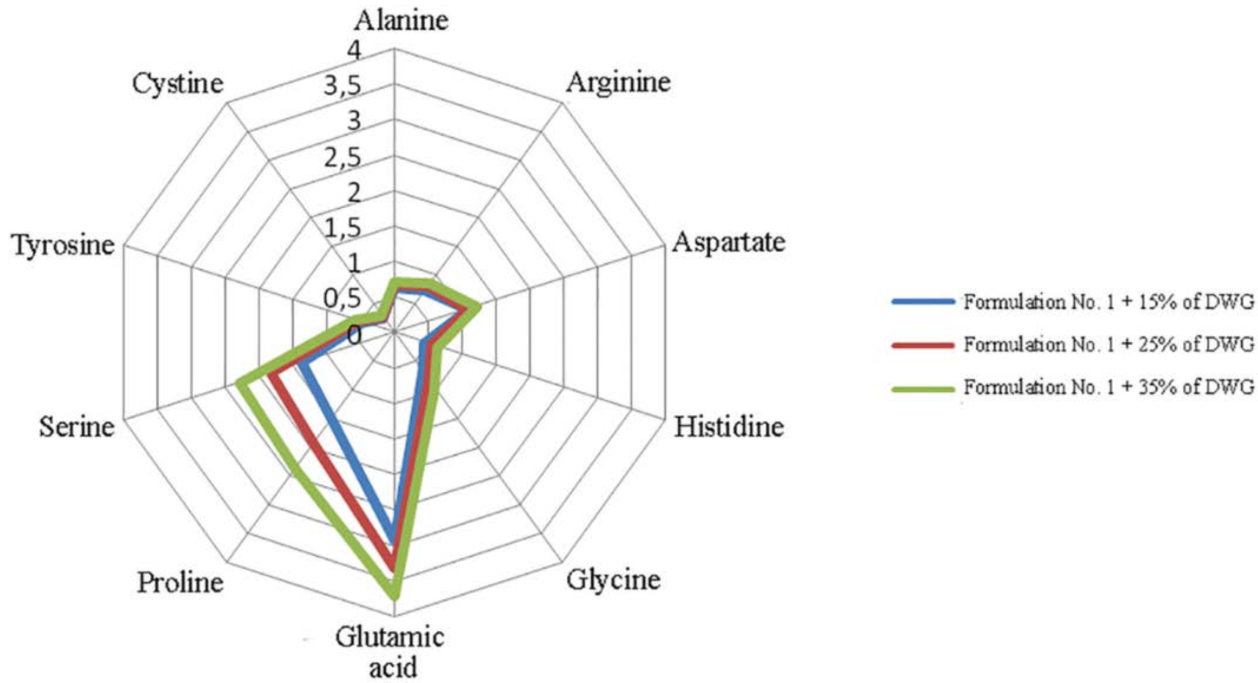

Figure 14. *The Concentrations of Non-Essential Amino Acids in the Formulation No. 1 with added DWG (15 %, 25 %, and 35 %).*

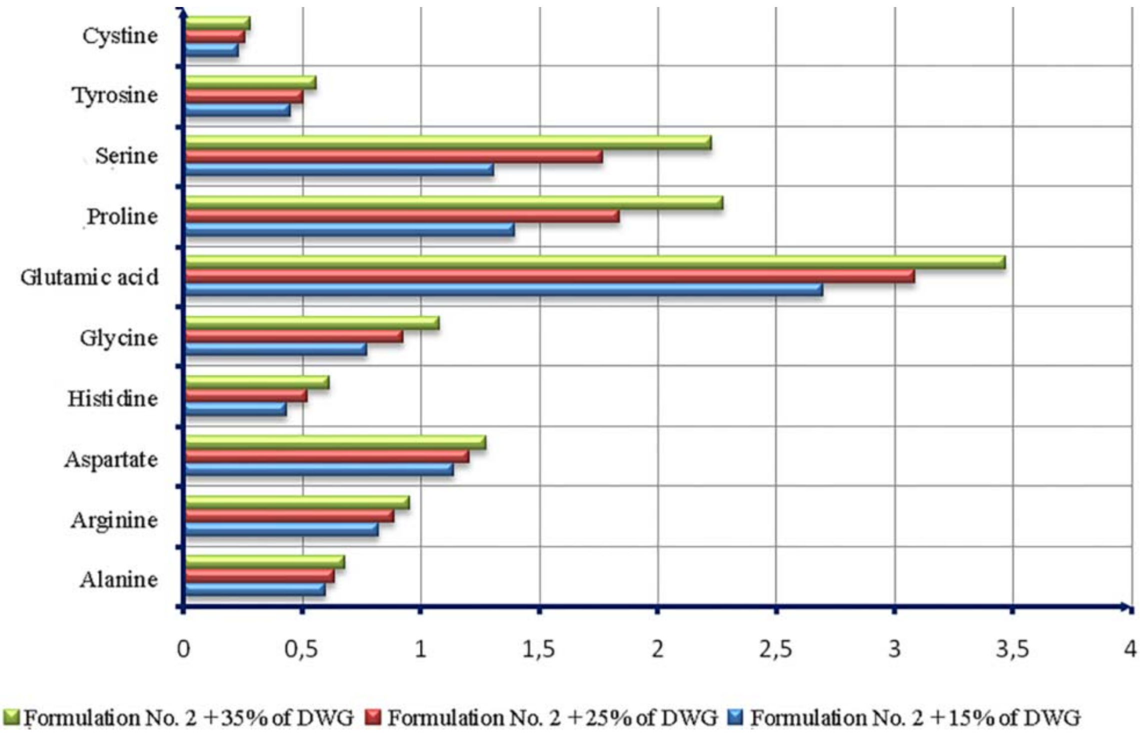

Figure 15. *The Concentrations of Non-Essential Amino Acids in the Formulation No. 2 with added DWG (15 %, 25 %, and 35 %).*

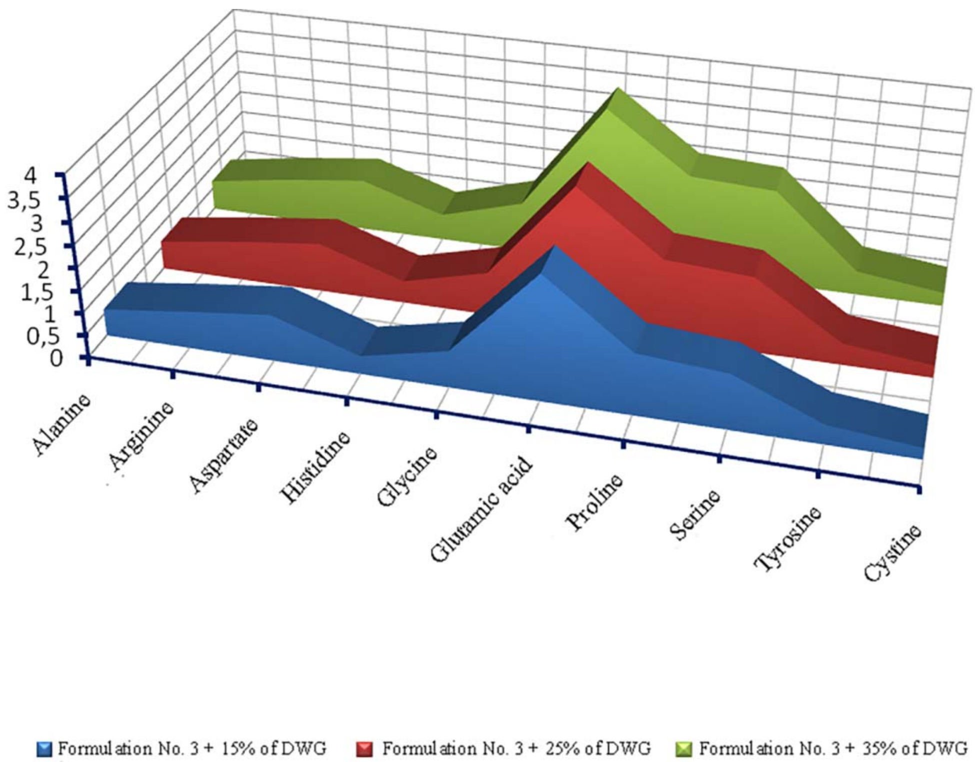

Figure 16. *The Concentrations of Non-Essential Amino Acids in the Formulation No. 3 with added DWG (15 %, 25 %, and 35 %).*