Cutlet formulas with spelt and thistle seeds flour balanced by amino acid composition

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Abstract. Expansion of the range of chopped semi-finished products of high nutritional value is possible with a combination of meat and vegetable raw materials. The greatest interest is studying of possibility of use of alternative kinds of local plant raw materials, as a source of indispensable amino acids and fibre in technology of meat products of the higher biological value. Flour from spelt and thistle seeds is such an alternative plant raw material. The aim of the research was to develop cutlet formulas balanced in biological value using spelt flour and thistle seed flour. Based on the definition of water absorption and water retention capacity, the level of hydration of plant components was established, which amounted to 1:3. According to the results of organoleptic evaluation, the limit level of hydration of hydrated spelt and thistle seed flour in the formulas of meatballs was determined, which amounted to 15% and 5%, respectively. The method of computer design using the utility coefficient of amino acid composition as a target function determined the optimal amount of added plant component, which provides the highest biological value. For optimized formulas it was established to increase the utilitarian coefficient of amino acid composition to 0.82 and 0.83, to decrease the amount of unutilized amino acids to 63.00 mg and 59.79 mg, respectively, when using 15% spelt flour and 3% thistle seed flour. This indicates the high biological value of optimized cutlet formulas.

1. Introduction
Meat products are at the heart of the human diet. The changes that have taken place in the context of sanctions on imports of meat and meat products create a risk of under-consumption of this group of products by the population of the Russian Federation, which is a threat to food security. According to the adopted Food Security Doctrine (January 2020), one of the priorities is to provide the population with quality and safe food products. The achievement of the set goal should be ensured through the development of food production technologies, increasing the production of new enriched food products of high quality level [1].

Today, the production of meat and meat products is steadily growing, with the largest increase in volume observed in the sector of semi-finished meat products (according to 2018) [2]. A feature of the semi-finished meat market is a wide range of products, which includes both expensive natural products and products of lower price category. The greatest demand among mass consumption products is for chopped semi-finished products, in the production of which the raw materials of plant origin are widely used. Thanks to the peculiarities of the composition and properties of plant raw materials, its involvement in the production of chopped semi-finished products can improve the...
quality of finished products, enrich them with amino acids, biologically active components uncharacteristic for meat raw materials and reduce the use of food additives [3, 4, 5]. As a source of plant protein the products of pulses, grains, oilseeds, tubers and their processing products including local plant raw materials are used [6, 7].

Traditional components of meat products are soya, peas, lentils, beans, chickpea, lupine and others with protein content ranging from 23.0% to 39.0% [8]. The main leguminous crops in Russia are peas and beans [9]. Increasingly, chickpea is involved in the production of meat products, which outperforms other legumes in terms of nutritional value and taste, with a pleasant nutty aftertaste. Isolated proteins of chickpea have high functional properties [3].

It is possible to solve the problem of food protein deficiency by involving cereals in the production. Among all known cereal crops the most studied are wheat, corn, barley, rice and oats. These crops contain much less protein than legumes, but they are a source of dietary fibre and thus contribute to the resistance of the human body to harmful environmental impacts.

In order to increase food and biological value and price availability of semi-finished products, it is important to involve alternative types of plant raw materials in the production. These include flour from spelt and thistle seeds.

Spelt wheat flour is a product of processing spelt wheat or spelt wheat seeds (Triticum). The flour has a coarse grinding structure, beige color, pleasant smell. Spelt wheat flour has a higher content of balanced amino acid protein (14.0-15.0%) than traditional kinds of flour. In terms of mono- and polyunsaturated fatty acids and dietary fibre content it is superior to wheat and rice. Spelt flour is a hypoallergenic product that can be used by patients with celiac disease, and the presence of soluble mucopolysaccharides is considered a factor in improving human immunity [10].

Thistle seed flour is a product of processing oil thistle culture (lat. Sílybummariánun). The flour has a light brown or grey colour, fine texture and pleasant original taste. In terms of protein content (22.0-24.0%), thistle flour is comparable to bean products and exceeds spelt [11]. The uniqueness of thistle seed flour is that along with fat-soluble vitamins, polyunsaturated fatty acids, it is a source of selenium and selimarin flavolignan. Selimarin has a pronounced antioxidant effect, protects the liver from the effects of harmful compounds, that is, shows the properties of hepatoprotector [12].

All this makes it possible to talk about the prospects of using spelt and thistle seed flour as an alternative plant raw material in the technology of chopped semi-finished products.

2. The purpose of the study
Research is aimed at working out of cutlet formulas with flour from spelt and thistle seeds, balanced on indicators of biological value.

3. The object of the study
The objects of study were:
- the spelt flour;
- the flour from thistle seeds;
- cutlets with spelt flour and flour from thistle seeds.

The main components of the formula: whole meal spelt flour (OOO "Garnets", Vladimir, Russia) and thistle seed flour (OOO "Specialist", Biysk, Russia), purchased from the trading network of the city of Kemerovo (Russia); sausage beef, fat pork in chilled condition, with maturation period in autolysis not less than 48 hours at +2° C (Local producer "Peasant farm of Volkov A.P.", Kemerovo, Russia)

4. Materials and methods
**Determination of Water Absorption Capacity (WAC)** - the method is based on determining the amount of water absorbed by the material against gravity [13].

**Determination of water retention capacity (WRC)** - the method is based on determining the amount of moisture absorbed and retained by the material when centrifuged [13].
**Determination of organoleptic indicators** on a five-point scale based on GOST 9959 - 2015 "Meat products. General requirements for organoleptic evaluation". Final estimates are obtained as arithmetic mean values of estimates assigned by individual tasters, which reduces the subjectivity of opinion.

**Optimization of the cutlet formulas** - by computer-aided design method, using the "Solution Finder" tool of Microsoft Excel software. Utility coefficient and indicator of comparable amino acid composition redundancy are accepted as the target function. Varying factors are the level of introduction of spelt flour (thistle) into the cutlet recipe.

**Mass fraction of protein** – by Kjeldahl method according to GOST 25011-2017.

**Determination of biological value indicators:**
- amino acid score by formula:
  \[
  C_j = \frac{A_j}{A_{j\text{min}}} \cdot 100, \tag{1}
  \]
  where \(C_j\) is the j-th of indispensable amino acids (IAA) relative to the model, %; \(A_j\) is the mass fraction of the j-th of IAA in the product, mg/1g protein; \(A_{j\text{min}}\) is the mass fraction of the j-th of IAA in the protein model, mg/1g protein (FAO/WHO scale, 2011) [14].
- utilitarian coefficient of amino acid composition by formula:
  \[
  U = \frac{\sum_{j=1}^{q} A_{j\text{min}} \cdot A_j}{\sum_{j=1}^{q} A_j}, \tag{2}
  \]
  where \(A_{j\text{min}}\) is the minimum IAA score of the protein under study, fractions [14].
- indicator of comparable redundancy of IAA, \(\sigma\), mg, by formula [14]:
  \[
  \sigma_c = \frac{\sum_{j=1}^{q} (A_j - A_{j\text{min}} \cdot A_{j\text{min}})}{C_{j\text{min}}}, \tag{3}
  \]
- amino acid composition imbalance coefficient (AAIC) by formula [14]:
  \[
  AAIC = \frac{\sum_{j=1}^{q} (C_j - C_{j\text{min}})}{9}, \tag{4}
  \]
- indispensable amino acids index (IAAI, or Auxerre index) by formula [14]:
  \[
  IAAI = \sqrt[9]{\prod_{j=1}^{q} \frac{A_j}{A_{j\text{min}}}}, \tag{5}
  \]
- protein efficiency ratio (PER) by equations of Alsmeyer [15]:
  \[
  \text{PER I} = -0.684 + 0.456(\text{Leu}) - 0.047(\text{Pro}) \tag{6}
  \]
  \[
  \text{PER II} = 0.468 + 0.454(\text{Leu}) - 0.105(\text{Tyr}). \tag{7}
  \]

**Statistical processing.** Experimental data are obtained on 5 series of measurements, tested for homogeneity, repeatability of measurements of each of the indicators within the series being three times. Data processing was carried out using standard methods of mathematical statistics.
Homogeneity of sample effects was checked by Student's t-criterion. The differences between the mean values were considered significant, with a confidence probability $p \leq 0.05$. The measurement results are presented as $\pm$SD average (standard deviation).

5. Discussion of the results

Introduction of vegetative components instead of meat raw materials in meat products should not lead to decrease in functional and technological characteristics of raw materials, change of consistence, yield reduction. Technological activity of raw materials should exclude whenever possible application of additional food additives that promotes increase in hygienic level of products.

When using a component, it is necessary to establish a hydration level in order to ensure the adequacy of the protein system and its high capacity to retain water. Therefore, for spelt and thistle flour, water-absorbing and water-retention capacities have been determined, which are formed by the combined action of the protein and carbohydrate components.

It was found that the WAC of spelt flour was 297.0% ($p<0.05$), the value of WRC was 2.5 times lower than the WAC and equal to 128% ($p<0.05$). Despite the fact, that spelt flour contains significant amount of carbohydrates (60.56-64.5%), most of them are represented by starch (60-63%), which in the water of room temperature has low capacity for water absorption and swelling. As the temperature rises, the water absorption capacity increases, starch granules are destroyed, amylose and amylopectin are solubilised and colloidal solution is formed [16].

Thistle seed flour had a WAC of 318.0% and WRC of 186.0% ($p<0.05$) respectively, which is 7.0% and 450.0% higher than the corresponding figures for spelt flour, respectively. This can be explained primarily by the higher protein content (23.6%). In interaction with water, proteins form colloidal solutions with the formation of hydrogen bonds between the molecules of protein and water, which give stability to hydrated systems that are not impaired by centrifugation. A significant contribution to the formation of WAC and WRC from thistle flour is made by fibre, which is able to absorb and retain water, whose content is 22.4%.

According to the results of determination of the WAC and WRC, the hydromodule of the investigated plant raw materials was installed - 1:3.

Permissible level of introduction of flour from spelt or from thistle seeds into cutlets was determined by organoleptic evaluation. The cutlets were made according to "Homemade" formula with replacement of sausage beef and fat pork in equal proportion to the examined flour types in the amount from 5 to 20 % with 5 % step (Table 1).

| Table1. Cutlet formulas under study |
|-----------------------------------|
| Name of raw materials            | Norm, g for 100 grams, for cutlets with plant content |
|                                  | 0% | 5% | 10% | 15% | 20% |
| Sausage beef                     | 28.0 | 25.5 | 23.0 | 20.5 | 18.0 |
| Fat pork                         | 30.0 | 27.5 | 25.0 | 22.5 | 20.0 |
| Hydrated spelt flour / thistle seed flour | - | 5.0 | 10.0 | 15.0 | 20.0 |
| Bread from wheat flour           | 13.0 | 13.0 | 13.0 | 13.0 | 13.0 |
| Bread crumbs                     | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| Fresh onions                     | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| Chicken egg                      | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| Chopped black pepper             | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| Cooked food salt                 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 |
| Drinking water                   | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 |
| TOTAL                            | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

Formed breaded cutlets were brought to culinary readiness by frying in fat. The results of organoleptic analysis are given in Table 2.

According to the results of the tasting analysis, the replacement of meat with hydrated spelt flour in the amount of 5% to 15% does not cause changes in organoleptic properties. Cutlets are very well kept...
in shape after heat treatment, have a pronounced meat flavor, uniform browning on the surface. Increasing the level of meat replacement up to 20% leads to deterioration of the appearance, consistency and taste of cutlets.

Table 2. Organoleptic evaluation of cutlets

| Indicator          | "Homemade" | "Homemade" with spelt flour in quantities | "Homemade" with thistle flour in quantities | ±SD |
|--------------------|------------|------------------------------------------|-------------------------------------------|-----|
| Appearance         | 5.0        | 5.0de 4.9de 4.8e 3.0bcd 5.0        | 4.8i 4.5di 3.2dfe                       | ±0.49|
| Colour             | 5.0        | 5.0de 4.7e 4.5de 3.5bcd 5.0        | 4.0dhe 3.5dfe 2.5dfe                       | ±0.35|
| Smell              | 5.0gh      | 5.0 4.8 4.8 4.5cd 5.0        | 4.5di 4.3ef 4.0g                       | ±0.43|
| Consistency        | 5.0gh      | 5.0 4.9e 4.8e 4.0bcd 5.0        | 4.7dhe 4.0fhe 4.0fhe                       | ±0.27|
| Taste              | 5.0gh      | 5.0 5.0e 4.7e 4.1bcd 5.0        | 3.5afe 3.0de 2.0e                       | ±0.32|

a,b - values in rows differ significantly (p<0.05)

For cutlets with a level of introduction of flour from thistle seeds more than 5% distortion of organoleptic characteristics was detected. There appeared unpleasant bitter aftertaste, grayish-green shade of minced meat and loose consistency. Degradation of organoleptic characteristics increases with increase of replacement level more than 10%.

According to the results of organoleptic analysis of cutlets the permissible level of meat replacement with spelt flour is established, equal to no more than 15%, for flour from thistle seeds - no more than 5%.

The task of computer design was to determine the optimal amount of flour to be added from the values within the specified range, which provides the highest biological value. The target function of optimization was the utilitarian coefficient (U \rightarrow 1) with minimum comparable redundancy of amino acid composition and protein content in the finished product not less than 9%. Variable criteria - level of introduction of flour from spelt - no more than 15%, flour from thistle - no more than 5% are determined. In calculations analytical data, characterizing quantity and quality of protein of investigated kinds of raw materials are used [11, 17, 18, 19, 20].

As a result of computer design, optimal formulas for cutlets were established, in which the share of spelt flour was 15% that of thistle seed flour - 3% (Table 3).

Table 3. Amino acid composition of cutlets

| Cutlet formulas       | Indispensable amino acids | Aa/Cb |
|-----------------------|---------------------------|-------|
|                       | Valine | Histidine | Isoleucine | Leucine | Lysine | Methionine+cystine | Threonine | Tryptophan | Phenylalanine | Total IA AAmg/1g protein |
| "Homemade"            |        |           |            |         |        |                  |           |             |                |                     | 457.9 |
| "Homemade" with 15% spelt flour. | 50.9 | 31.0 | 46.8 | 78.0 | 77.2 | 36.6 | 46.1 | 13.1 | 48.2 | 454.2 |
| "Homemade" with 3% thistle flour. | 51.6 | 30.3 | 46.5 | 78.4 | 72.7 | 36.7 | 44.8 | 12.9 | 80.4 | 454.2 |
| FAO/WHO (2011)         | 40.0 | 16.0 | 30.0 | 61.0 | 48.0 | 23.0 | 25.0 | 6.6 | 41.0 | 290.6 |

a - NAC content (A), mg/1 g protein;
b - amino acid score (C), %
In terms of total IAA content, optimized formulas for cutlets with spelt flour (454.2 mg/1g protein) and thistle seed flour (523.3 mg/1g protein) exceed those for "Homemade" cutlets (457.9 mg/1g protein). Amino acids for indispensable amino acids of all cutlet recipes indicate the absence of limiting amino acids.

Optimized formulas are characterized by a high content of sulfur-containing amino acids, which is positive in terms of absorption of minerals, especially zinc [21]. The leucine/isoleucine ratio in cutlet formulas with spelt and thistle flour is 1.68 and 1.76. The data obtained are comparable with the ratio established for casein protein, which is 1.5 [22].

The importance of leucine/isoleucine balance in regulation of tryptophan and niacin metabolism as well as in prevention of pellagra development is demonstrated by Belavady & Udayasekhara Rao studies [16, 21]. The balance of the amino acid composition is also evidenced by the ratio of branched-chain amino acids (BCAA), which is leucine/isoleucine/valine as 1.95/1.0/1.13 for adults according to WHO/FAO/UNU (2007) [23], respectively. For optimized formulations with spelt flour, these ratios are 1.68/1.0/1.1, with thistle seed flour 1.76/1.0/1.34 and for the "Homemade" formulas - 1.66/1.0/1.08.

Optimized formulas are characterized by an increase in the utilitarian coefficient of amino acid composition (U) with a decrease in the number of amino acids not used by the body for plastic needs (Table 4). The utilization factor for cutlets with spelt flour and thistle flour was 0.82 and 0.81, respectively.

The comparable redundancy index (σ) of optimized cutlet formulas is lower than that of “Homemade” cutlets (69.48mg) and amounted to 63.00mg for cutlets with spelt flour and 59.79mg for cutlets with thistle seed flour. This means that the essential amino acids of the optimized cutlet formulas are used more by the body for metabolic processes.

In favor of a higher biological value of cutlets with plant components is evidenced by a decrease in the value of the indicator, characterizing the average value of the amino acid score surplus (AAIC), compared with the formulas of "Homemade" cutlets. This indicates a higher balance of indispensable amino acids with respect to the "ideal" protein in the developed products.

| Cutlet formulas            | U  | σ, mg | AAIC | IAAI (Auxerre index) | PERI | PER II | Mass fraction of protein, % |
|----------------------------|----|-------|------|----------------------|------|--------|-----------------------------|
| “Homemade”                 | 0.81 | 69.48 | 0.39 | 0.90                 | 3.23 | 3.25   | 10.3±0.08bc                |
| “Homemade” with 15% spelt flour | 0.82 | 63.00 | 0.36 | 0.89                 | 3.25 | 3.25   | 10.0±0.06ac                |
| “Homemade” with 3% thistle seed flour | 0.83 | 59.79 | 0.32 | 0.98                 | 3.77 | 3.69   | 10.5±0.04a                 |

**bc** values in rows differ significantly (p<0.05)

The value of IAAI (Auxerre index) allows to judge about the quality of protein. According to Penaflore scale [25] the value of IAAI for good quality protein is more than 0.90, for low quality protein - below 0.70. IAAI value of "Homemade" cutlets and new cutlet formulas corresponded to 0.90; 0.89 and 0.98, which meets the requirements of good quality protein.

The values of protein PER efficiency factor for optimized cutlet formulas were estimated in comparison with PER value for casein protein, which is 2.8 [16]. The PER value for all formulas is higher than 3.0, which indicates that the developed cutlet formulas are a good source of protein and generally have a high biological value [24].

In terms of protein content, the optimized formulas fully meet the requirements for protein content of at least 9%.
The use of spelt flour and thistle seed flour in the technology of chopped semi-finished products allows one to obtain products with high biological value. The introduction of plant components in the cutlet formulas contributes to a balanced amino acid composition, as evidenced by an increase in the coefficient of utilitarianism, with a decrease in the number of amino acids unused for the metabolic needs of the body. The optimized cutlet formulas are balanced not only in terms of the amino acid composition as a whole, but also in terms of the ratio of leucine/isoleucine and branched-chain amino acids (BCAA).

6. Conclusion
The assortment of chopped semi-finished products can be extended by using alternative plant raw materials of local origin, such as spelt and thistle seeds flours, as prescription components. Based on the organoleptic evaluation of cutlets and calculated biological value indicators, the optimal level of replacement of meat raw materials with spelt and thistle flours, equal to 15% and 3%, respectively, has been established.

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