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# Development of Minced Meatball Composition for the Population from Unfavorable Ecological Regions

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### Authors' contributions

This work was carried out in collaboration between all authors. Authors EO, FS and MR designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript.

Authors SK, OZ and AM managed the analyses of the study. Authors YR and DT managed the literature searches. Authors ZG and NM involved in constant monitoring of the experiment and data analysis. All authors read and approved the final manuscript.

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## ABSTRACT

In this paper, a new technology for meatball production is presented. The ingredients in the formulation used are low value parts of poultry meat (neck and back part), rice, sea cabbage (*Laminaria*) and carrot. Three variants of meatball were prepared with different weight ratios of *Laminaria*: variant 1 – 15%, variant 2 – 10% and variant 3 – 5%. The comparative quality and

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organoleptic indicators of meatballs are studied. As a result, when compared with the control meatballs, the developed meatballs have soft consistency, a pleasant flavor, better sensory characteristics and balanced composition. The highest level of protein was obtained in variant 2 (19.7%) while the lowest one was determined in the control sample (10.1%). Variant 2 meatball also showed an increased level of mineral elements – 3.11%, compared with variant 1 (2.6%) and variant 3 (1.6%). The moisture content of the developed meatballs varied from 67.1% to 69.3% and these values are much higher than in the control sample (61.64%). Also, the developed meatballs show a higher content of fat compared with the control sample. Different proportions of *Laminaria* in meatball formulations caused significant changes in content of I, Mg, K and Na. The concentrations of these elements were reduced when the *Laminaria* weight ratio in meatballs was lowered. Using *Laminaria* demonstrated a positive effect to the food quality of meatball.

**Keywords:** Meat patties; poultry; *Laminaria digitata* (Huds.); carrot; quality; iodine.

## 1. INTRODUCTION

Meat and meat products belong to the most common food product and have a high importance in the human diet. Meat contains a considerable amount of essential amino acids [1,2]. However, environment contamination is negatively affecting the sensory and biochemical characteristics of meat and meat products. All this can lead to reducing the biological and nutritional value of food often resulting in human diseases. The after-effect of the Semipalatinsk nuclear test site (SNTS) activity had a negative role on the environment, including food safety [3,4,5] The contamination of water and food products derived from farmed animals can represent a major source of radiation exposure to humans.

Nowadays, an iodine deficiency problem is a major health concern in the population of Kazakhstan. As known, the biological role of iodine is connected with thyroid hormone formation – triiodothyronine and thyroxine. The human body contains 20-50 mg of iodine and about 30% of it accounts for thyroid [6]. One of the principal ways of iodine deficiency correction is the use of iodine mineral drugs. But the medical experience upholds the low efficiency of such mineral drugs. Iodine uptake by the human body of the nonorganic form has a low effect compared with the organic form which fully complies with human requirements. The dietary reference intake of iodine with food for adults is 0.15 mg/day.

Considering the high effectiveness of sea cabbage (*Laminaria digitata* (Huds.)), and its use in medicine for different pathologies, it is thought that sea cabbage can become widely used in the meat industry. *Laminaria* is a marine algae (aquatic organisms), a natural perfectly balanced product, containing 40 macro- and

microelements, connected with organic substances. *Laminaria* contains iodine (to 3%), bromine, manganese, cobalt, zinc, magnesium, iron, potassium, sodium, sulfur, phosphorous, nitrogen and other minerals; vitamins: A, B1, B2, B12, C, D, E, panthothenic and folic acid; *Laminaria* polysaccharides (21%); alginic acid and its salts (to 25%); L-fructose (4%); protein substances (to 9%). Sea cabbage intake promotes the removal of toxic substances, heavy metals; regulates blood clotting ability, reduces cholesterol level in the blood and the risk of atherosclerosis developing and other heart diseases; improves gastro-intestinal tract actions, averts rectal cancer, and fortifies the immune system [7].

The environmental conditions and the increase of the incidence of disease of people of all ages calls for developing new functional foods with beneficial nutritive and physiologic properties [8]. At the present time, the urgent goal for food experts is to ensure food safety and develop new types of food products with health-promoting properties. The main principles of nutrition are:

- Diversity of food products for providing all the essential nutrient materials in the human diet;
- Balance of energy value of food products to the actual energy losses of human;
- Usage of food products with easy digestibility [9].

Based on meat and vegetable raw materials, meat product production leads to the mutual enrichment of composition, increasing biological value, improving the organoleptic indicators of finished products and lowering of prime cost [10,11].

Chopped meat semi-finished products are the portion food, made from minced meat with additives [12]. The most preferred semi-finished

meat products are patties, stakes, noisettes and meatballs, schnitzels due to low price and simplicity of preparation. But the most important characteristic is the taste and quality of semi-finished meat products [13]. The production of chopped meat semi-finished products shall meet the requirements of specification #32951-2014 "Semi-prepared meat and meat-contained product." of the Republic of Kazakhstan. This specification establishes the type of meat (beef, horse meat, pork, poultry) and vegetable ingredients, including rice, wheat, onion, garlic, cabbage, hydrobionts etc. during the production of meat products.

Poultry meat is an essential component of the human diet. It is a lean and dietary meat, with a healthy source of easy digestible proteins, vitamins and fatty acids. Chicken meat contains more protein than any other meat, herein the fat content does not exceed 10%. As for comparison, the protein content in the chicken meat is 22.5%, however in turkey meat 21%, duck meat 17% and in goose meat 15%. There is much less protein in red meat: in beef – 18.4%, pork – 13.8%, lamb – 14.5%. A noteworthy detail is that the protein of chicken meat contains 92% of essential amino acids (as in protein of pork, lamb and beef which are 88%, 73% and 72% respectively). Chicken meat also contains a minimal amount of cholesterol. In addition, chicken meat is rich in vitamin B (B2, B6, B9 and B12), iron, zinc, phosphorous, selenium, calcium, magnesium and copper [14,15].

Carrot delivers some nutrients, which are totally absent in the animal products, such as food fibers, ether oil, tannin and flavoring agents, organic acids, phytoncids, vitamin C, beta-carotene and calciferol. The organic acids contained in the carrot promote the specific environment of microflora; slow down the putrefaction process in the gastrointestinal tract. Food fibers are helping to accelerate and remove toxins from the body. Vitamin C increases the body's resistance to various infections; regulates the cholesterol exchange and endocrine and nervous system functions [16].

The purpose of this study is to develop the formulation of meat and vegetable semi-finished products for the nutrition of people from an unfavourable radiology environment and product-line expansion of purpose-designed dietary semi-finished food products with high nutritive and biological value and better sensory properties.

## 2. MATERIALS AND METHODS

Meatballs were prepared in the Laboratory of meat and meat products of the Shakarim State University of Semey (Kazakhstan). Four formulations of meatballs were produced differing in their recipe composition (Table 1). The control recipe composition of the meatballs was beef, rice, bulb onion and spices. In other formulations, beef was replaced by poultry meat and *Laminaria*. The low value parts of poultry meat (neck and back part) deboned, grinded on the chopper with a 2-3 mm plate and transferred for mincing. Rice is cleaned, boiled for 15 minutes at 100°C and cooled by adding cold water. The carrot, bulb onion are cleaned, grinded to 3-4 mm and blanched at 90-95°C for 5-7 min. Sea cabbage (*Laminaria*) is grinded on the colloid grinding machine to powder. According to the technology, all the components poultry meat, sea cabbage (*Laminaria*), carrot, rice, bulb onion, eggs or egg mélange, salt, black pepper are mixed and cut on a meat cutting and mixing machine for 6-8 min until smooth. Meatballs are formed in the shape of balls (40 g) and baked for 20 minutes at 160-180°C. The ready meatballs are cooled and vacuum packed in a multilayer film bag. Optionally, after forming the meatballs, they can be cooled and frozen at 0 – (-6)°C. Storage time is 2 days in closed packing.

By the experimental results, we produced three variants of formulation of meat balls (Table 1).

### 2.1 Chemical Composition Determination

The determination of the chemical composition of meatballs was based on the determination of the following constituents: moisture, fat, ash and protein. To determine water content, a 2-3 g aliquot of each sample of meatball was weighted to the nearest 0,001 g using a Mettler Toledo electronic balance, (Mettler Toledo, Switzerland), and placed into a metallic cup (IngoLab, Russia). It was then dried for 1 hour, in a drying oven SNOL 67/350 (Umega, Latvia), at a temperature of 150°C. The moisture content was calculated using Equation 1, according to the standard GOST 9793-74 (2010) and GOST R 51479-99 (2010).

$$x_1 = (m_1 - m_2) \cdot 100 / (m_1 - m), \quad (1)$$

Where

$x_1$  – moisture content, %;

$m_1$  – weight of sample with cup before drying, g;

$m_2$  – weight of sample with cup after drying, g;

$m$  – weight of cup, g.

After moisture determination, each dried sample was moved to a glass cup. Then to fifteen milliliter of ethylic ether (Chemically pure 100%, Skat, Kazakhstan) was poured into the glass cup and the contents were mixed for 3-4 min. During the extracting process, the ethylic ether, containing the fat residues, was poured out and replaced with fresh ethylic ether. After 4-5 repetitions, the residual ethylic ether was evaporated at room temperature. The metallic cup containing the fat depleted sample was dried at 105°C for 10 min. According to the standard GOST 23042-86 (2010) the fat content was calculated according to Equation 2.

$$x_2 = (m_1 - m_2) \cdot 100 / m_0 \quad (2)$$

Where

$x_2$  – fat content, %;

$m_1$  – weight of cup and dry sample before extraction, g;

$m_2$  – weight of cup and sample after extraction, g;

$m_0$  – weight of cup, g.

In order to obtain the ash content, the sample from which the fat was extracted was placed into a weighted and preheated (to 150°C) crucible (50 cm<sup>3</sup>, Mankor, Ukraine). Then, 1 ml of magnesium acetate (Purity 98%, Labofarma, Kazakhstan) was added to the crucible and burned on an electric hot plate. After that, it was placed into a muffle furnace set at a temperature of 500°C – 600°C (SNOL 7.2/1100, Umega, Lithuania) for

30 min. The ash content was calculated following Equation 3:

$$x_3 = (m_1 - m_2) \cdot 100 / m_0, \quad (3)$$

Where

$x_3$  – ash content, %

$m_1$  – weight of ash, g;

$m_2$  – weight of magnesium oxide, obtained after the mineralization of magnesium acetate, g;

$m_0$  – weight of sample, g.

The protein content was assayed according to the standard GOST 25011-81 (2010) and calculated using Equation 4.

$$x = 100 - (x_1 + x_2 + x_3), \quad (4)$$

Where

$x$  – protein content, %

$x_1$  – moisture content, %;

$x_2$  – fat content, %;

$x_3$  – ash content, %.

## 2.2 pH Measurement

Active acidity (pH) was determined using the potentiometer method. A pH-tester 340 (Infrapak-Analit, Russia) was used to obtain the information. This was done simply by dipping the two electrodes into the solution and taking a reading. The solution was prepared as follows: the meat samples was minced and mixed with (distilled-deionized water in the ratio 1 part of meat: 10 parts of water. The pH reading was obtained after 30 minutes of infusion at 20°C.

**Table 1. Formulation of meatballs**

Ingredient	kg/100 kg			
	Control	I variant	II variant	III variant
Beef	55	-	-	-
Low value parts of poultry meat (neck and back part)	-	40	45	50
Rice	15	15	15	15
Sea cabbage ( <i>Laminaria</i> )	-	15	10	5
Carrot	15	15	15	15
Bulb onion	10	10	10	10
Egg	5	5	5	5
<b>Total:</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>
<b>Spices , g/100 kg</b>				
Salt	1000	1000	1000	1000
Black pepper	50	50	50	50

### 2.3 Water-binding Capacity (WBC)

The method used to determine the water binding capacity of the samples is based on exudation of moisture to a filter paper by the application of pressure. The moisture absorbed by the filter paper is evaluated based on the spot area on the filter paper. Specifically, for each sample, 0.3 g of minced meat was placed on a 15-20 mm diameter disk plate on a Mettler Toledo electronic balance, (Mettler Toledo, Switzerland). The meat was then transferred onto an ash-free filter (Munktell Filter AB, Sweden) and placed on a glass or plexiglass plate. The sample was covered with the same filter before a 1 kg load was carefully placed on top of the meat. The weight was left for 10 min. Once removed, the top filter was pulled off and bound water was calculated, as described below (see Equation 5 and 6). The filter was scanned using an Xpress M2070 scanner (SAMSUNG, Japan) after the contour of the wet spot was traced on the filter. The area was calculated using the «Compas-3D V-10» software.

$$X_1 = (A - 8,4B) \cdot 100 / m_0, \quad (5)$$

$$X_2 = (A - 8,4B) \cdot 100 / A; \quad (6)$$

Where

$X_1$  – bound water content, expressed as % of meatball;

$X_2$  – bound water content, expressed as % to total water;

$B$  – wet spot area,  $\text{cm}^2$ ;

$m_0$  – sample weight, mg;

$A$  – total content of moisture in the sample, mg.

### 2.4 Determination of the Mineral Elements

1 - 2 g of the sample was placed in high-pressure Teflon containers. The samples were combusted at the temperature of 400°C for 4 h and then to 600°C for 2 h in a muffle furnace. For the digestion, a representative 1 g (dry weight) sample is digested with additions of 3  $\text{cm}^3$   $\text{HNO}_3$  and 2  $\text{cm}^3$  of HF in a microwave for 20 min in a Milestone microwave system. After microwave digestion the samples were diluted with 1%  $\text{HNO}_3$  in a 10  $\text{cm}^3$  vessel.

The content of elements in muscle samples was determined with the inductively coupled plasma–

mass spectrometric method (ICP-MS, Varian-820 MS, Varian Company, Australia). The method was validated with certified reference materials. Calibration standards Var-TS-MS, IV-ICPMS-71A (Inorganic Ventures Company, USA) were used for calibrating the mass-spectrometer. The sensitivity of the mass-spectrometer was tuned up using a diluted calibration solution Var-TS-MS with concentration of Ba, Be, Ce, Co, B, Pb, Mg, Tl, Th of 10  $\mu\text{g/L}$ . Three calibration solutions were used for the detector calibration. They were IV-ICPMS-71A of Cd, Pb, Cu, Zn elements diluted to 10, 50 and 100  $\mu\text{g/L}$ . Discrepancies between the certified values and concentrations quantified were below 10%. The operating parameters of the inductively coupled plasma mass spectrometer Varian ICP 820 –MS were as follows: plasma flow 17.5 L/min; auxiliary flow 1.7 L/min; sheath gas 0.2 L/min; nebulizer flow 1.0 L/min; sampling depth 6.5 mm; RF power 1.4 kW; pump rate 5.0 rpm; stabilization delay 10.0 s.

### 2.5 Sensory Evaluation

A sensory evaluation was done by a panel of twelve (12) skilled persons (aged 23-58). In case of defects in flavor and aroma (inadequate pronounced flavor, weedy flavor, slightly acid flavor), consistency and structure, color and packaging, the score mark has been reduced for each defect according to the special sensory evaluation scale. The evaluation scale ranged from 1 to 5 points, where 1 – Unliked extremely; 5 – Liked extremely. Data on sensory analysis of meatballs was presented in Supplementary.

### 2.6 Statistical Analysis

Statistical analysis was performed using Statistica 12.0 (STATISTICA, 2014; StatSoft Inc., Tulsa, OK, USA). The differences between samples were evaluated using the ANOVA method. The differences were considered to be statistically significant at  $p \leq 0.05$ .

## 3. RESULTS AND DISCUSSION

For poultry meat, we used the neck and back part of the carcass. Poultry meat is a dietary meat and contains all water and fat soluble vitamins, mineral elements, including phosphorous, iron, manganese and zinc. Mineral elements in the poultry meat are more fully digested in the human body [17].

In the first stage, we determined the chemical composition, pH and water binding capacity (WBC) of poultry meat (Table 2).

**Table 2. Physical-chemical characteristics of poultry meat (n\*=10)**

Index	Poultry meat
Moisture, %	72,05
Fat, %	6,4
Protein, %	20,8
Ash, %	0,75
pH	6,2
WBC, %	69,8

\*n – number of samples

Comparative quality and organoleptic indicators of meatballs is presented in Tables 3 and 4.

According to Table 4, the protein content in the developed meatballs was higher than in the control. The highest level was obtained in variant

2 (19.7%) while the lowest one was determined in the control sample (10.1%). Variant 2 of meatball also showed an increased level of mineral elements – 3.11%, compared with variant 1 (2.6%) and variant 3 (1.6%). The moisture content of the developed meatballs varied from 67.1% to 69.3% and these values are much higher than in the control sample (61.64%). Also, the developed meatballs show a higher content of fat compared with the control sample.

With the introduction of sea cabbage into the minced meat, an improvement of functional and technological properties has been observed. This is due to the presence of mannitol, which can form a gel after the heat treatment. In addition, the sodium, magnesium, phosphorous and iron cations are incorporated with the minced meat.

Table 5 shows the concentration of mineral elements in the meatball.

**Table 3. Organoleptic parameters of meatballs**

Indicator name	Characteristics and regulatory standard for meatballs
Appearance	Unflawed surface without broken ends
Flavor	Appropriate to common meatballs in view of ingredients used in the formulation
Color	Appropriate to the color of used ingredients: poultry meat, <i>Laminaria</i> , carrot, rice and spices
Shape	Spherical
Protein, % atleast	10,0
Fat, % at most	16,0
Sodiumchloride, % at most	0,9
Weight of one meat ball, g	40
Energy content, kcal	220

**Table 4. Chemical composition and organoleptic parameters of meatballs**

	Meatball (control) (n*=10)	Meatball with sea cabbage		
		1 variant (n=10)	2 variant (n=10)	3 variant (n=10)
Protein, %	17.2±0.46 <sup>a</sup>	18.72±0.45 <sup>b</sup>	19.2±0.73 <sup>c</sup>	19.7±0.56 <sup>c</sup>
Moisture, %	67.52±2.28 <sup>b</sup>	69.63±1.99 <sup>a</sup>	68.24±2.60 <sup>a</sup>	67.47±2.74 <sup>b</sup>
Fat, %	15.1±0.64 <sup>a</sup>	9.05±0.35 <sup>c</sup>	10.16±0.41 <sup>c</sup>	11.53±0.52 <sup>b</sup>
Mineral elements	0.18±0.01 <sup>a</sup>	2.6±0.10 <sup>c</sup>	2.4±0.08 <sup>c</sup>	1.3±0.04 <sup>b</sup>
<b>Organoleptic estimation by five-point grading scale</b>				
Appearance	4.8	4.2	4.3	4.4
Color	5.0	4.3	4.8	4.8
Flavour	4.2	4.0	4.9	5.0
Taste	4.0	5.0	5.0	5.0
Consistency	4.4	4.7	5.0	4.7
Juiciness	4.3	4.8	5.0	4.9
Overall assessment	4.45	4.50	4.83	4.80

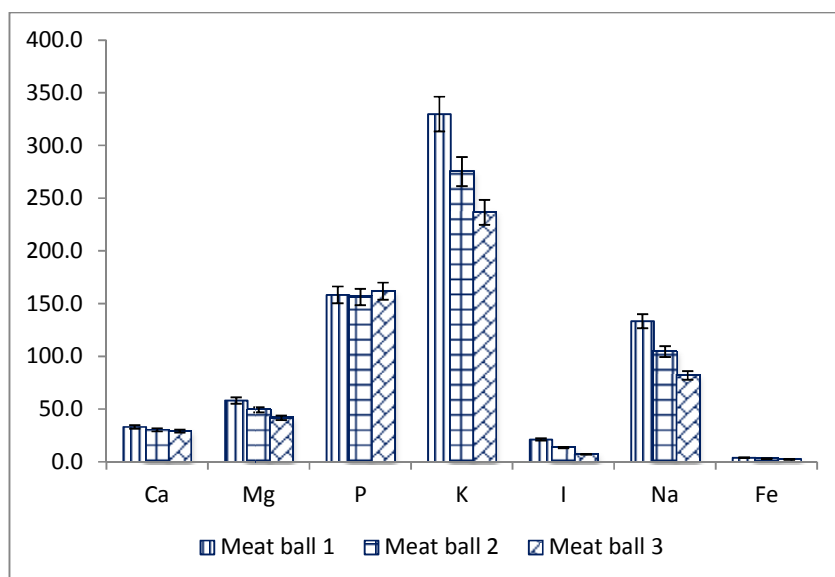
<sup>a,b,c</sup>Mean values in the same row with different letters differ significantly ( $P<0.05$ ). Results are mean±SD.

\*n – number of samples

**Table 5. Mineral composition of meatballs, mg/100 g**

Sample	Ca	Mg	P	K	I	Na	Fe
Meatball 1	33,13±0.83 <sup>a</sup>	58,14±1.37 <sup>c</sup>	158,45±5.65 <sup>b</sup>	329,91±14.62 <sup>a</sup>	21,19±0.50 <sup>a</sup>	133,40±3.60 <sup>a</sup>	3,90±0.12 <sup>a</sup>
Meatball 2	30,35±1.16 <sup>b</sup>	49,40±2.29 <sup>a</sup>	156,40±6.00 <sup>b</sup>	275,40±9.03 <sup>b</sup>	13,61±0.60 <sup>b</sup>	104,55±3.84 <sup>b</sup>	2,99±0.12 <sup>a</sup>
Meatball 3	29,15±1.13 <sup>b</sup>	41,80±1.07 <sup>b</sup>	161,90±7.35 <sup>c</sup>	236,60±9.21 <sup>c</sup>	7,04±0.25 <sup>c</sup>	82,05±2.87 <sup>c</sup>	2,27±0.07 <sup>b</sup>

<sup>a,b,c</sup>Mean values in the same row with different letters differ significantly ( $P < 0.05$ ). Results are mean±SD

**Fig. 1. Mineral composition of meatballs**

Different formulation of meatballs changed its mineral composition. Significant difference in iodine concentration was observed in the meatballs. Thus, the highest concentration of iodine was in variant 1 – 21.19 mg/100 g, while the lowest in variant 3 of meatballs receipt – 7.04 mg/100 g. Such a difference can be explained by the weight ratio of *Laminaria* in the receipt of meatballs.

Also, different proportions of *Laminaria* in meatball formulations caused significant changes in content of Mg, K and Na. The concentrations of these elements were reduced with the lowering of *Laminaria* weight ratio in meatballs.

It is commonly known that mineral elements are taking part in the mass-exchange processes (proteins, lipids, carbohydrates, vitamins and etc.). For instance, phosphorous and calcium play an important role during the bone formation. Moreover, phosphorous is a constructive element of the tissues. Magnesium helps to stimulate intestinal motility and bile flow. Iron is required for the production of red blood cells (a process known as haematopoiesis), but it's also part of

haemoglobin (that is the pigment of the red blood cells) binding to the oxygen, and thus facilitating its transport from the lungs via the arteries to all cells throughout the body [18].

Magnesium is essential for the cell's life. It maintains normal muscular and nervous function, heart rate within physiological limits and favors the development of strong bones. It is also involved in energy metabolism (it participates in the transformation of blood sugar into energy) and in the synthesis of proteins.

Iodine enrichment of meat products promotes adequate daily income of iodine to the human body. Acceptable daily intake of iodine for infants (0-12-month age) is 50 mkg, for children (from 2 to 6 years old) – 90 mkg, for school-aged children (from 7 to 12 years old) – 120 mkg, adult man – 150 mkg and for pregnant and lactating women – 200 mkg [19].

The obtained results were compared with the findings of other works. Thus, Gorlov et al. [20] developed the smoked-scalded sausage enriched with iodine. During the sausage

preparation, grinded wheat was used as the iodine and vitamin source. The iodine concentration in ready sausage was 22.9 mkg/kg.

Another study, conducted by [21] studied the effect of iodine casein in sausages on physicochemical properties and iodine content. The iodine content was 47.18 mkg in 100 g of product.

Yevdokimova [22] developed meat patties comprising beef, pork, liver, "Tipro" protein supplement, water. For enrichment with iodine, the extract of rockweed was additionally added which increased the total iodine in meat patties to 42.0 mkg of 100 g product.

Waszkowiak and Szymandera-Buszka [23] fortified processed meat with iodine by adding 2% of iodine carrier comprising wheat dietary fibre, soy protein isolate and iodised table salt. According to the obtained results, 100 g of processed meat contains 43.0 mkg of iodine which meets approximately 30% of the recommended daily allowance.

Baglacheva et al. [24] developed the technology of iodised food collagen emulsion from fish skin of which 15-20% weight ratio to recipe of meat products can be added. The iodine content in ready meat products varied between 50-70 mkg (35-50% of recommended daily allowance). The source of iodine used was "JODIS-CONCENTRATE" artesian mineral water, saturated with multyatom ions of iodine.

#### 4. CONCLUSION

The problem of production of ecologically safe and high quality food products for the population from unfavorable ecological regions is one of the most pressing issues. Meat and meat products in Kazakhstan have a special place, as they have historically been one of the main national products. Meat products play an important role in the human diet, as they are a source of protein needed for vital functions. The developed meatballs enriched with iodine have a soft consistency, pleasant flavour, better sensory characteristics and balanced composition compared with the control sample. Using *Laminaria* demonstrated a positive effect on the overall mineral composition and were enriched with iodine which can be used as an effective method of iodine deficiency.

#### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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