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ANALYSIS OF SUBSTANCES MIGRATION WITHIN THE TROPHIC CHAIN "SOIL — PLANT — RAW MEAT MATERIALS"

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Abstract
The trophic chain, which manifests the correlation at nutritional level between various macro- and microorganisms, is an important factor of the ecosystem; it can show the migration of various substances within the chain "soil — water — plant — animals". The trophic chain in Borgoy depression area was studied due to the profound correlation between the compositional characteristics of the soil and pronounced organoleptic features of meat of the sheep that feed on grass in this area. For the experiments, control and experimental samples of soil, water, plants and mutton meat were examined. The samples taken near the saline lake within the Borgoy depression on the west of Beloozersk village served as an experimental sample. The samples taken 30 km from the salt lake near Petropavlovsk village in the Republic of Buryatia served as control sample. Experiments have shown that the soil of the Borgoy depression is a saline soil, with a depth of the salt horizon of 0–30 cm, and the salt belongs to chloride-sulfate-soda type of salinity. It is noted that the saline soil is characterized by a much higher content of carbonates, chlorides and cations of sodium, potassium and magnesium. Correlation was found between the isotopic composition in soil, vegetation and the raw meat materials. More profound certain organoleptic features of Borgoy mutton were noted. It's highly probable that this fact is associated with the peculiarities of the mineral, chemical, and amino acid compositions of meat of the livestock that lives in the pastures of the Borgoy depression, characterized by saline soils. Despite the increased content of heavy metals such as lead and copper in the soil, data on sheep muscle tissue showed that all values of toxic elements content are within the permissible concentration range. The transfer of heavy metals from the soil to the aboveground part of plants is hindered by the underground root part, which serves as barrier.

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Introduction

The trophic chain, as the nutritional relation between various macro- and microorganisms, contributes to the transformation of energy and matter. All plants, animals and microscopic organisms are closely related according to the principle food-to-food consumer [1]. A number of scientists study the trophic chain as an important factor in the ecosystem to confirm the fact of transfer of various substances within the chain: soil-water-plant-animals. Works [2–3] show that the trophic chain characterizes the process of transit of the substances in a certain ecosystem, while accumulation is observed of the substances valuable for the heterotrophs and the contaminants too.

The issues of the substances transition in the process of trophic communication and its significance have been the subject of research for many domestic and foreign scientists. Thus, the influence of trophic transfer and transformation of CeO_2 nanoparticles was studied by spraying the soil where lettuce was growing for 30 days with radioactive CeO_2 nanoparticles, followed by giving the lettuce leaves to the land snails to eat. The second half of the lettuce was treated by foliar application of the radioactive nanoparticles directly onto the leaves. Experimental data have proven that with direct trophic influence, the rate of transition of the test substance into the tissues and feces of snails is higher [4].

The work [5] presents the results of a study of the accumulation of heavy metals in the trophic chain "soil — vegetable feed — cattle — human". The content of heavy metals in all objects of study was studied, and the coefficient of biological absorption of metals was calculated. The research results showed: at all levels of the trophic chain, the greatest accumulation was observed for zinc and copper; along with an increase in the trophic chain level, the transition coefficients of such toxic metals as lead and cadmium increased too.

The authors of [6] studied the transit of heavy metals and phyto-hormones in the trophic chain "soil — plant — bee — honey". It was revealed that honey builds up heavy metals that accumulate in the soil in accordance with the laws of the trophic chain.

The processes of transit of heavy metals in the soil — potato — Colorado beetle ecosystem were studied. The influence of the content of heavy metals in the soil on their content in potato leaves and the body of the Colorado potato beetle has been confirmed [7].

Bioaccumulation of organochlorine pesticides in marine organisms (oysters, crabs, etc.) due to trophic connections with surface sediments has been proven. The authors proposed to use the obtained results to create the criteria for monitoring water quality [8].

The authors [9] studied the specific features of the Caspian sea trophic chain: plankton — mollusks — fish. Research allows identifying the reason for the quality deterioration of fish food base.

The issues of the influence of microelements in the trophic chain "soil — plant — animal" under certain environmental conditions are considered. The critical levels of microelements and the ways of their detoxification are shown [10].

An analysis of the level of toxicants contamination of certain links within the trophic chain "soil — feed — animal's body — livestock products" was implemented. A method has been proposed for calculating the coefficients of substances transfer along the food chain to the animal's organs to control the quality of livestock products [11].

Analysis of the composition of natural stable isotopes of carbon, nitrogen and sulfur is one of the potential tools for verifying geographic origin [12–14]. Plants and non-migratory animals that feed on them potentially have region-specific isotopic compositions determined by climatic and environmental conditions.

Researchers have found that the consumer characteristics of raw meat in the form of tissues and organs of the farm livestock depend not only on the type of the animal, its gender, breed, variety, but also on the growing and feeding conditions [15–18].

It has been shown that mutton that lives in the area of the Borgoy depression of Dzhida district of the Republic of Buryatia has more profound organoleptic characteristics: richer taste of meat and richer broth, sweetish taste, and so on [19], however, there are studies on the trophic chain "soil — plant — Borgoy mutton"

Thus, an analysis of the literature showed that the quality of raw meat can be affected by the composition of soil, plant materials, and feed for the free-range livestock. In connection with the above, the purpose of the study was to analyze the migration of substances, isotopes of carbon, nitrogen and some trace elements within the trophic chain "soil — water — plant — raw meat" to assess the quality of mutton from the sheep that live in the Borgoy depression.

Material and methods

To conduct the experiments, the control and experimental samples of soil, water, plants and mutton were analysed. As control samples the samples of soil, water and plants were taken 30 km from a saline lake, near Petropavlovka village in the Republic of Buryatia. The experimental samples were the samples of soil, water, and plants taken near a saline lake within the Borgoy depression on the west of Beloozersk village (Figure 1). Characteristics of control and experimental samples of soil, water, plants and mutton meat are given in the Table 1.

The sampling area is a hilly terrain of the Borgoy steppe spanning along the river Dzhida, here there are three fairly large lakes: Nizhneye Beloe, Verkhneye Beloe and Kamenny Klyuch, plus several small lakes, including those of a temporary, seasonal nature — they are presented in the form of flooded meadows.

Table 1. List and characteristics of the researched objects

Objects of research	Characteristics	
	Control sample	Tested sample
Sampling location	Republic of Buryatia, Dzhida district, 30 km from the saline lake — near Petropavlovka village	Republic of Buryatia, Dzhida district, near saline lakes within the Borgoy depression on the west of Belozersk village
Sampling date	September-October 2022	September-October 2022
Soil samples within the depth of 0–10 cm	Within the sampling location, the soils are chestnut powdery-carbonate	Within the sampling location, the soils are saline
Samples of plants that sheep living in the sampling areas feed on	Vegetation of the sedge and common sedge pastures	Vegetation of the sedge and common sedge pastures
Water samples	From a stream near the soil sampling location	From a well within the Borgoy depression
Mutton samples	Mutton of the sheep living near the soil and vegetation sampling site	Mutton of the sheep living within the Borgoy depression

Figure 1. Sampling location

The landscape of the area is characterized by medium-hilly, gentle relief, has the general outline of a flat plain, slightly inclined (3–5°) towards the river Dhzida. The terrain is a bit undulating, with poorly developed microrelief. The terraces of the river Dzhida, Verkhnee lake and Nizhneye Beloe lake are expressed.

The specific feature of the Borgoy steppe and, to a greater extent, whole area around Beloozersk village, which received its name from the Beloe (White) Lake located next to it, is a white coating on the soil surface along the shores of lakes — this is the evaporation of saline mineral salts from the lake and sedimentation of salty fogs in windy weather.

Table 1 presents the characteristics of the researched objects.

In the soil and water samples, water extract analysis was run to determine the type of soil salinity and water quality; isotopic and mineral composition was studied in the samples of soil, plants and raw meat. Soil and water parameters were determined and analyzed in five repetitions in the laboratory of the Institute of General and Experimental Biology of the Siberian Branch of the Russian Academy of Sciences.

To study the meat properties, the samples of muscle tissue of the semitendinosus muscle were taken from Buryat type sheep of Transbaikal breed (n = 3) at the age of 5–6 months of spring-summer free-range pasture feeding. The animals were slaughtered in the slaughterhouse of the consumer cooperative "Khamtaa" (Dzhida district, the Republic of Buryatia). To conduct research, the hip cuts were selected from the pairs of the control carcasses and experimental carcasses, cooled at a temperature of 2–4 °C, packaged in polymer film and delivered to the research site in Ulan-Ude within 24 hours.

To study the isotopic composition, semitendinosus muscles were selected from hip cuts, packed in a polymer film, frozen at a temperature of minus 14–16 °C, packed in a thermal bag to slow down the thawing process, and delivered by aircraft to the Center for shared use of isotope mass spectrometry based in the Institute's laboratory of ecology and evolution problems named after. A. M. Severtsov RAS (Moscow). The studies were done within three days after the delivery of the samples.

In the laboratory of VSGUTU, the organoleptic characteristics of meat and mutton broth were studied, in the laboratory of the Center for Hygiene and Epidemiology of the Republic of Buryatia, the content of some microelements, including toxic ones, was determined.

The organoleptic characteristics of mutton and mutton broth were evaluated after the thermal processing. Mutton was cooked as follows: meat lump of 1 kg was placed in a container with cold water in a ratio of 1:3 and boiled until the temperature in the center of the lump reached 75 °C for about 60 minutes, 30 minutes before the end of cooking table salt was added (at rate of 1% by weight of mutton lump). After cooking, the meat was cooled down, sliced and sent for tasting. The meat was rated on a nine-point scale according to the following parameters: appearance, smell, taste, texture, juiciness. To evaluate the mutton broth, it was poured into transparent glasses and its appearance, color, smell, taste, flavor richness was assessed.

The content of toxic microelements was defined with the help of atomic-adsorption method of Spectr AA240 (Agilent, USA) spectrophotometer in the vegetative feeds according to the state standard GOST 30692–2000[1], in the soil — according to the FR.1.31.2013.14150 "M–MVI–80–2008[2], in the water — according to the GOST R57165–2016[3], in the ram meat materials — according to the GOST 30178–96[4]. Content of mercury and arsenic by atomic adsorption spectrometry using the universal spectrometric complex USK "Gamma-plus" (ZAO "NTC Expertcenter", Moscow, Russia). In the raw meat the arsenic content was determined according to the GOST R51766-2001[5], of the mercury — by GOST 26927–86[6], in the vegetation — by GOST 34427–2018[7], in water — by GOST 31950–2012[8], in soil — by PND F 16.1.2.23–2000[9].

The water extract of the soil was analyzed in accordance with the Guidelines for Chemical Analysis of Soils. The dry residue was tested after evaporating an aliquot and its drying in an oven at a temperature of 105 °C. The calcined residue was found by calcining the dry residue in a SNOL muffle furnace (SnolTerm, Russia) at a temperature of 550 °C.

Alkalinity was determined by titration with 0.02H H_2SO_4 solution with phenolphthalein added. Chlorine was titrated with $AgNO_3$ (0.02H solution) in the presence of 10% K_2CrO_4. Ca+ and Mg+ were determined by the trilonometric method, SO_4^{2-} — with the addition of glue, ending on a PE-5300VI spectrophotometer (EKROSHIM, Russia). The K+ and Na+ contents were determined using a PFA-378 flame photometer (Yunico-Sys, Russia).

[1] GOST 30692–2000 "Fodders, mixed fodders and animal raw foodstuff. Atomic absorption method for determination of copper, lead, zinc and cadmium" Retrieved from https://docs.cntd.ru/document/1200013014 Accessed September 05, 2023

[2] FR.1.31.2013.14150 "M–MVI-80–2008 Methods for measuring the mass fraction of elements in soil samples, soils and bottom sediments by atomic emission and atomic absorption spectrometry (Replaced with FR.1.31.2004.01278 according to the letter, OOO Monitoring, Ref. No. 267 of". Retrieved from https://www.russiangost.com/p-275510-fr131201314150.aspx Accessed September 05, 2023

[3] GOST R57165–2016 "Water. Determination of elements by inductively coupled plasma atomic emission spectrometry" Retrieved from https://docs.cntd.ru/document/1200140392 Accessed September 05, 2023

[4] ГОСТ 30178–96 "Raw material and food-stuffs. Atomic absorption method for determination of toxic elements" Retrieved from https://docs.cntd.ru/document/1200021152 Accessed September 05, 2023

[5] GOST R51766–2001 "Raw material and food-stuffs. Atomic absorption method for determination of arsenic" Retrieved from https://docs.cntd.ru/document/1200025461 Accessed September 05, 2023

[6] GOST 26927–86 "Raw material and food-stuffs. Methods for determination of mercury" Retrieved from https://docs.cntd.ru/document/1200021114 Accessed September 05, 2023

[7] GOST 34427–2018 "Foodstuff and animal fodder. Determination of mercury by Zeeman atomic absorption spectrometry" Retrieved from https://docs.cntd.ru/document/1200159810 Accessed September 05, 2023

[8] GOST 31950–2012 "Water. Method for determination of total mercury by flameless atomic absorption spectrometry" Retrieved from https://docs.cntd.ru/document/1200096958 Accessed September 05, 2023

[9] PND F 16.1.2.23–2000 "Measurement method for measuring the mass fraction of total mercury in soil, soil and bottom sediment samples on a RA-915 mercury analyzer with RP-91C attachment" Retrieved from https://www.russiangost.com/p-162459-pnd-f-161223–2000.aspx Accessed September 05, 2023

The content of stable isotopes was determined using Finnigan Delta V Plus mass spectrometer (Thermo Electron Corporation, USA). Isotopic ratios were calculated in ppm using the folowing formula (1):

$$\delta\, n X_{sample} = [(R_{sample}/R_{standard}) - 1] \times 1000, ‰ \quad (1)$$

where X is the element (nitrogen or carbon), n is the number of the heavy isotope, R is the molar ratio of the heavy and light isotopes of the element.

The results of the measurement were brought to international standards. For nitrogen — N2 of atmospheric air, for carbon the "Viennese" equivalent of PeeDee belemnite (PDB); the analytical error in determining the isotopic composition did not exceed 0.3‰.

The obtained experimental data were statistically processed by finding the arithmetic mean, standard error and confidence interval. The significance of the differences was considered as significant at $p < 0.05$.

Results and discussion

In result of the experimental studies presented in the Table 2, it was found that the studied soils were of saline type, with a salt horizon depth of 0–30 cm, of chloride-sulfate-soda type of salinity, and a chestnut powdery-carbonate soil. It was noted that the saline soil is characterized by a much higher content of carbonates and bicarbonates (28.8 and 612.44 mg/l) than the chestnut soil (4.8 and 219.6 mg/l), as well as the higher amount of anions and cations (447.42 and 155.2 versus 127.5 and 64.4 mg/l accordingly). The composition of saline soil anions is dominated by chlorides (104.9 mg/l), the composition of cations is sodium (69.4 mg/l), calcium (54.0 mg/l) and magnesium (30.0 mg/l). In chestnut soil their content is almost 2 times less (25.2, 22.0 and 15.6 mg/l, respectively). The data obtained from the water analysis (Table 2) showed that the water from the well features high alkalinity (carbonates and bicarbonates — 28.8 and 612.44 mg/l) and a high content of sodium, calcium and magnesium chlorides, which is apparently related to the soil salinity. The water from the stream is much softer and has much lower content of anions and cations.

The work [20] also indicates that in Borgoy depression the salinity of the soil is soda-based, and the chemistry of the salinity is predominantly sulfate-sodium. The authors note that the soils have a slightly-alkaline and alkaline reaction of the environment; the composition of the CEC (cation exchange capacity) is dominated by exchangeable Na. There is a high content of exchangeable magnesium throughout the profile of chemical elements, which can be attributed to the specific regional features. A highly saline type with a high predominance of sodium and magnesium is demonstrated by the ratio of Ca: Mg: Na cations equal to 1:4:5. In the saline soil the maximum of salts is clearly reached in the upper horizons; the total salt content along the profile reaches 0.89–2.75%. The salinity of the soils of the Borgoy depression was also pointed out by the authors of the scientific work [21], who studied the genesis, geography and classification of steppe and forest-steppe soils in the basin of the Baikal Lake.

The content of toxic microelements is very important for characterizing the quality of raw meat, which microelements can also migrate through the trophic chain. In this regard, the content of heavy metals in the studied objects of Borgoysky Nature Reserve region was tested (Table 3).

The data presented in the Table 3 showed that the soil has high lead content of 40 mg/kg, which exceeds the maximum permissible standards by 1.25 times. High content of copper was noted (30 mg/kg). The increased content of iron was noted in the water (0.76 mg/dm^3), which is 1.5 times higher than the maximum permissible concentration according to the standard SanPin 1.2.3685–21[10].

Analysis of the content of heavy metals in pasture vegetation, presented in Table 3, showed that in the above-ground parts of plants their content is significantly lower than the level of maximum permissible concentrations.

The presented data on vegetation are consistent with the results of scientists represented in the works [22–25]. The increased content of microelements, including lead (57.3–92.8 mg/kg), was noted in the upper humus horizon of the saline soils of the West Trans-Baykal area in the work [23], which is associated with a relatively large amount of carbonates thus serving as a reservoir (barrier) for all elements. Chestnut soils of the steppe ecosystems of West Trans-Baykal area in the work are characterized by the increased content of lead (2.9 times), which is determined by the soil-forming rocks [24].

The heavy metals are prevented from their transportation from the soil to the above-ground part of plants by the humus substances of the soil and the underground root part, which plays a barrier role. In this regard, the vegetation that serves as food for grazing sheep is safe from an environmental point of view. No connection was found between the increased lead content in the soil and vegetation [22]. The lead content in herbaceous vegetation on the chestnut soils of West Trans-Baykal area in the work does not exceed the permissible standards.

Data on the muscle tissue of the sheep showed that all parameters of the toxic elements content are within the permissible concentrations, which confirms the food safety and quality of Borgoy mutton.

Next, the isotopic composition of the trophic chain "soil — plants — raw meat materials" was analyzed; the isotopic signature of the animals reflects the integral information about its trophic relations, starting with the plants that form the soil environment of the pastures [26].

Figure 2 presents the results of a study of the isotopic composition in the trophic chain "soil-plant-raw meat materials".

Analysis of the isotope composition of soils showed that in the saline soil there is a highly profound fractionation of the heavy carbon isotope, C13, and the chestnut soil is richer with the light isotope. Discrimination δ13C (Δ‰), that is, the difference in the content of the heavy isotope 13C in them is large and equal to 11.68‰ ($p < 0.05$). This is apparently caused by high content of carbonates, sodium chlorides, calcium and magnesium in the saline soil and the lower content of carbon and nitrogen (1.4 and 0.2%). The same phenomena can be seen with the fractionation of the heavy isotope 15N. The difference in the δ15N content is lesser and amounts to 1.51‰.

The obtained data are consistent with the scientific literature data. Thus, in articles [26,27] it is noted that the isotopic composition of soils depends on its composition: saline soils, as a rule, are characterized by high content of carbon isotope in contrast to the other types of soils. Data on the isotopic composition of carbon are consistent with the data of articles [28,29], which show the "isotopic signature" of grass vegetation from the pastures in the muscle tissue of raw livestock meat with a δ13C value not exceeding the level of –24.0‰.

The research results presented in the Figure 2 showed that the isotopic composition of carbon in soils differs from the isotopic composition of carbon in the plant material by 1.19‰ in the chestnut soils and by 13.47‰ in the saline soil; the weighting takes place in the process of destruction of vegetation residues by microorganisms.

The analysis of the literature data revealed that the obtained data are consistent with the literature data, so in the article [22] the following fact is presented: usually the value of soil carbonates δ13C is 14–16‰ more than that value of organic matter.

The vegetation on the saline soil is represented by hard sedge; in the vegetation mass on the chestnut soils this herb occupies a dominant position; the codominant is the false wheatgrass. This is probably why the vegetation on the studied soils has the similar carbon isotope indices, but the plant residues on the saline soil are lighter ($\Delta = 0.6$‰). The degree of fractionation of the 15N isotope during their life activity is higher — δ15N is 6.4‰. Low discrimination of δ13C (1.19‰) and δ15N (2.01) proves the high rates of vegetation mineralization on the chestnut soils.

In the food chain "plant-to-animal", as a result of physiological processes, muscle tissue of the animal is enriched with the heavy carbon isotope, but depleted in the 15N isotope. In the analyzed samples, the weighting of carbon in the Borgoy mutton is 2.2, in the control sample — 2.03‰, and the δ13C discrimination between them is low and amounts to 0.43‰. Enrichment of δ15N occurs in control sample of meat ($\Delta = 0.34$‰), and lighting occurs in Borgoy mutton meat ($\Delta = 0.55$‰). The control sample of mutton, compared to Borgoy mutton, is more enriched in the heavy carbon isotope 13C ($\Delta = 0.43$‰) and the heavy nitrogen isotope ($\Delta = 0.09$‰). Thus, there is a correlation between the isotopic composition of soil, of vegetation and raw meat.

[10] Sanitary and epidemiological rules and regulations SanERR1.2.3685–21 "Hygienic standards and requirements for ensuring the safety and (or) harmlessness of environmental factors for humans" Retrieved from https://docs.cntd.ru/document/573500115 Accessed September 05, 2023

Table 2. Results of the soil and water samples analysis (n = 5)

No.	Water samples	Calcined residue, mg/l	Dry residue, mg/l	Alkalinity, mg/l		Cl^- mg/l	SO_4^{2-} mg/l	Σ of anions,%	Ca^+ mg/l	Mg^+ mg/l	Na^+ mg/l	K^+ mg/l	Σ of cations,%
				CO_2^{2-}	HCO_3^-								
							Water						
1	Experimental sample	598.1 ± 35	674.0 ± 45	28.8 ± 5.2	612.4 ± 65.4	104.9 ± 21.3	7.5 ± 1.2	447.4 ± 20.4	54.0 ± 9.5	30.0 ± 8.2	69.4 ± 11.3	1.8 ± 0.2	155.2 ± 56.2
2	Control sample	194.2 ± 28*	312.1 ± 32.2*	4.8 ± 1.6*	219.6 ± 58.2*	5.7 ± 2.2	7.5 ± 3.4	127.5 ± 36.9*	22.0 ± 6.5*	15.6 ± 6.3*	25.2 ± 12.0*	1.6 ± 0.09	64.4 ± 12.3*
							Soil						
	Soil samples	Calcined residue, mg/l	Dry residue, mg/l	Alkalinity, mg/l		Cl^- %	SO_4^{2-} %	Σ of anoins, %	Ca^+ %	Mg^+ %	Na^+ %	K^+ %	Σ of cations,%
				CO_2^{2-}	HCO_3^-								
3	Experimental sample	2.92 ± 0.2	3.32 ± 0.82	0.81 ± 0.02	1.46 ± 0.01	0.13 ± 0.03	0.019 ± 0.002	1.69 ± 0.04	0.01 ± 0.001	0.0048 ± 0.0003	0.12 ± 0.06	0.031 ± 0.004	0.162 ± 0.006
4	Control sample	0.32 ± 0.05*	0.48 ± 0.09*	0.01 ± 0.002*	0.09 ± 0.002*	0.05 ± 0.002*	0.003 ± 0.001*	0.11 ± 0.001*	0.012 ± 0.06	0.0036 ± 0.0012	0.031 ± 0.008*	0.003 ± 0.001*	0.05 ± 0.01*

Note: * The difference between the values of groups 1 and 2, 3 and 4 is significant, since $p < 0.05$.

Table 3. Content of the microelements in the analyzed samples obtained from the location of Borgoy depression

No.	Name of toxic elements	Soil		Water		Pasture vegetation (fodders)		Muscle tissue of sheep	
		Content, mg/kg	MAC/ SanPin 1.2.3685–21	Content, mg/dm³	MAC/ SanPin 1.2.3685–21	Content, mg/kg	MAC/ SanPin 1.2.3685–21	< 0,01	< 0,5
1	Lead	40.0 ± 1.2	32	< 0.003	0.01	< 0.1	5.0	< 0.01	< 0.05
2	Cadmium	0.54 ± 0.12	—	< 0.0001	0.001	< 0.1	0.3	< 0.01	< 0.1
3	Arsenic	2.7 ± 0.21	—	< 0.005	0.01	—	—	—	—
4	Copper	30.0 ± 1.5	—	< 0.001	1.0	—	—	—	—
5	Iron	—	—	0.46 ± 0.05	0.3	—	—	< 0.001	< 0.5
6	Mercury	< 0.005	2.1	< 0.0001	0.0005	0.0085	0.05		

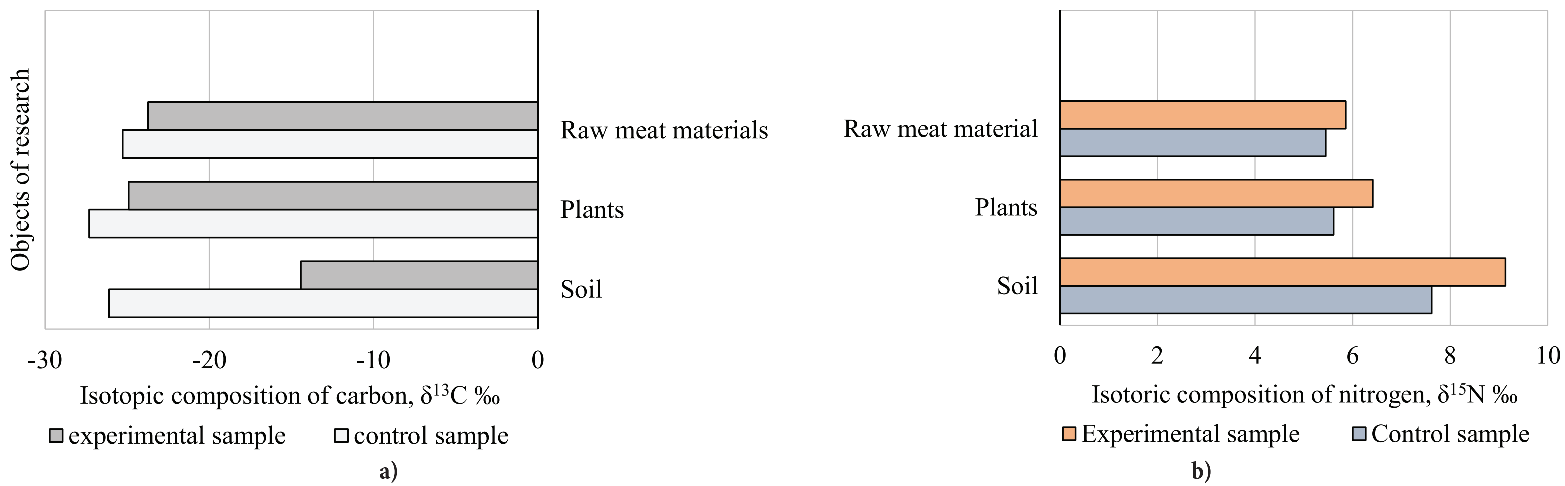

Figure 2. Results of isotopic analysis

The similar correlation between the trophic chain of "soil — plants — livestock meat" was established in regards to the carbon and nitrogen isotopes in [28,29]. The data obtained are consistent with the conclusions that the isotopic composition of soil organic matter is a cumulative characteristic that reflects the ratio of photosynthetic types of vegetation and depends on the type of vegetation, the level of its fractionation during soil processes, and climatic conditions [27].

To study the quality parameters of Borgoy mutton, the organoleptic values of the meat and broth of the control sample and experimental sample of mutton were studied, the data are presented below in the profile diagrams (Figure 3 and Figure 4).

The data of the profile diagram (Figure 3) presented for assessing the quality of the boiled mutton showed that the experimental sample and control sample did not differ in their appearance ($p > 0.05$). More pronounced rich aromatic taste, a sweetish taste and a more delicate texture were noted in Borgoy mutton, which is confirmed by plenty of points for taste — by 8.4%, for smell (aroma) — by 6.6% compared to the control ($p < 0.05$).

Figure 4 presents the profile diagram data for assessing the quality of the broth, which showed that the broth cooked from the meat of experimental sample is richer, more saturated, highly fragrant with an expressed meat taste in comparison with the control sample. Analysis of the obtained data showed that the broth cooked from the control sample and experimental sample did not have any special differences in appearance and color ($p > 0.05$). But when tasting the broth the higher average points were conferred upon the experimental sample: for taste it got 7.4% higher assessment, for smell — more by 7.2%, for richness — by 5.7% compared to the control sample ($p < 0.05$).

The obtained data confirm that Borgoy mutton has more pronounced organoleptic characteristics [19]. Probably, the migration of micro- and macroelements, which the soil of the Borgoy depression is rich in, through the chain "soil — water — plant — animal", contributes to the accumulation of micronutrients that form the peculiar organoleptic characteristics of Borgoy mutton.

Conclusion

The trophic chain, which characterizes the correlation at the nutritional level between various macro- and microorganisms, is an important factor in the ecosystem and can show the migration of various substances within the chain "soil — water — plant — animals". The trophic chain in Borgoy depression area was studied due to the profound correlation between the compositional characteristics of the soil and pronounced organoleptic features of meat of the sheep that feed on grass in this area. To conduct the research the control and experimental samples of soil, water, plants and mutton were examined. The experiment was implemented on the samples taken near a salt marsh lake within Borgoy depression to the West of Beloozersk village. The control samples were the samples taken 30 km from a salt lake — near Petropavlovka village of the Republic of Buryatia. Experiments showed that the soil of Borgoy depression is a saline soil with a salt horizon depth of 0–30 cm, and of chloride-sulfate-soda type of salinity. It is noted that the saline soil features much higher content of carbonates, chlorides and cations of sodium, potassium and magnesium. Correlation was found between the isotopic composition in the soil, vegetation and the raw meat. Borgoy mutton has more profound organoleptic characteristics; this fact is probably associated with the peculiarities of the mineral, chemical, amino acid composition of the meat of the livestock that lives in the free-range pasture conditions of the Borgoy depression on the saline soils. Despite the increased content of heavy metals like lead and copper in the soil, analytic data on the muscle tissue of sheep showed that all values of the toxic elements content are within the acceptable concentrations. The transfer of heavy metals from the soil to the above-ground part of plants is prevented by the underground root part, which serves as barrier. The research showed that Borgoy mutton has high quality characteristics.

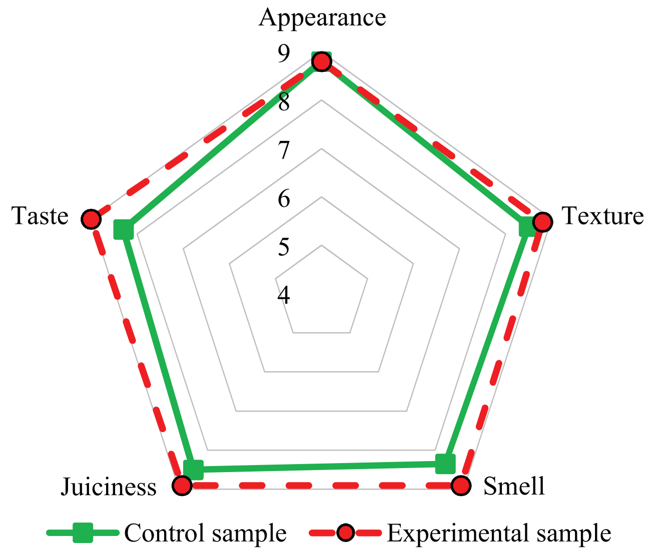

Figure 3. Profile diagram of the control and experimental samples of boiled mutton

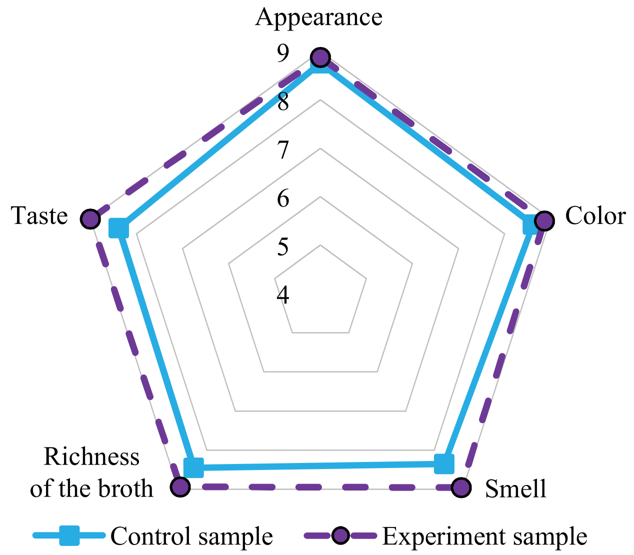

Figure 4. Profile diagram of broth cooked from the control and experimental samples of mutton

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