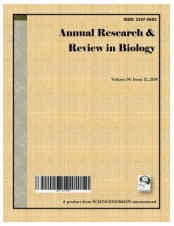

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Study of Water Binding Capacity, pH, Chemical Composition and Microstructure of Livestock Meat and Poultry

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Authors' contributions

This work was carried out in collaboration between all authors. Authors EO and MR designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors ZY, OZ and AS managed the analyses of the study. Authors NS, YR and OG managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

This paper shows the results of analysis of chemical composition, water binding capacity, pH and microstructure of maral meat, goat meat, lamb, and turkey meat. From the analysis, the high content of protein and ash is observed in turkey meat, fat prevails in lamb, and less amount in maral meat and goat meat. pH value lies between 5.7 (turkey white meat) and 6.4 (goat meat). Low value of water binding capacity is detected in turkey meat (58.2% in red meat, 59.2% in white meat) and high value – in maral meat 79.57%. The morphology and microstructure of meat have some

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differences in position and diameter of muscle fibers. Micrographic investigation shows that the largest diameter of muscle fibers was observed in turkey white meat (46.58 μm) and the smallest – in muscle tissue of lamb (29.92 μm). Obtained results will be useful for further processing and developing meat products.

Keywords: Lamb; maral; goat; turkey; protein; fiber; muscle; tissue.

1. INTRODUCTION

Meat and meat products are an essential part of human nutrition. Meat and meat products market is in abundance of various types of livestock meat (beef, pork, horsemeat, lamb, and goat meat), poultry (chicken, turkey, and duck meat) and game meat (deer meat, boar meat, rabbit meat, etc.). Different natural landscape, environmental conditions, and animal welfare have different impacts on the nutritive and biological value of meat [1]. Nutritive value and quality of meat depends on the animal type and has significant differences determined by species, surrounded and living environment of an animal, and other factors [2]. In East-Kazakhstan, big and small farms along the beef, sheep, and goat cattle are specializing in red deer breeding for obtaining the antlers and antler-based products. However, red deer meat has a good flavor and high nutritive value. It is rich in vitamins (A, B, C, E), minerals (iron, potassium, calcium, magnesium, copper, zinc, and selenium) [3] and is recommended as part of the healthy diet. The protein content ranges from 18.31-20.04%, which equals to beef and pork; the amount of fat is less in beef, lamb, and pork. Red deer meat (*Cervus elaphus*) or maral meat has a low level of cholesterol. It also contains bioactive substances, ferments, and hormones, which are considered beneficial. The caloric value of maral meat is 944 to 1154 kilocalories per 100 grams [4]. Maral meat is richer in calcium, fluorine, iron, copper, zinc, and chromium compared to beef [5]. The meat represents 55-60% of the weight of the animal [6,7].

Small ruminants (sheep and goats) breeding is really important for Agriculture of Republic of Kazakhstan. The nutritive and tasteful value of lamb is especially high. Protein, essential amino acids, and mineral content in lamb are highly competitive with beef [8]. Lamb fat contains less cholesterol. The calorie value of lamb is higher (2256 kCal/kg) than that of beef (1838 kCal/kg) [9]. By the high content of fluorine (twice higher than in beef), consumption of lamb promotes the hardness of enamel, and prevents carbohydrate metabolism disorder in diabetes. One of the main advantages of lamb is its hypoallergenicity [10]. Goat meat's nutritive value is comparable with lamb, but less fatty, and has a pleasant flavor, more tender, and moist. Goat meat contains all essential amino acids, but limited in valine. Proximate composition depending on the goat species varies between: moisture – 73.4-74.5%; fat – 3.36-4.04%; protein – 20.18-22.07; ash – 1.18-1.20%. Goat meat is high in unsaturated fatty acid. The total sum of polyunsaturated fatty acid is 3.7-3.84% [11]. The goat meat is considered as a dietary and baby food.

Turkey is one of the largest poultry birds, and breeding of turkeys is important for increasing the production of high-quality poultry meat. Turkey meat is an excellent source of protein of an animal origin, and also contains phosphorus, vitamins of the B, PP group, and minerals [12]. The nutrition and biological value of turkey meat are defined by the content of essential amino acids, their ratio, and also good digestibility [13]. Turkey meat favorably differs in its high nutritive taste and culinary qualities. It contains a large amount of protein (28% against 14–18% in other poultry meat) and a moderate amount of fat (2–5%), rich in vitamin of group B and has the lowest level of cholesterol in comparison with other types of meat [14].

Different type of livestock and game meat has its own unique proximate composition and physicochemical properties, which should be considered during the further deep processing. Therefore, the purpose of this paper is to study the water binding capacity, pH, chemical composition and microstructure of meat of different animal.

2. MATERIALS AND METHODS

Samples of maral meat, lamb, goat meat and turkey meat were purchased in local trade markets of Semey city. Totally 50 kg of all types of meat were collected. The meat samples were packed to polyethylene bag and transported to the laboratory and stored at (-18) – (-20) °C before analysis.

2.1 Chemical Composition

The determination of the chemical composition of meat was based on the determination of the following constituents: moisture, fat, ash and protein. The methods were performed as described by Amirkhanov et al. [14].

2.2 Water-binding Capacity

The method used to determine the water-binding capacity (WBC) 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 of and bound water was calculated, as described below (see Equation 1 and 2). 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 [15].

$$X_1=(A-8,4B)\cdot 100/m_0, \quad (1)$$

$$X_2=(A-8,4B)\cdot 100/A; \quad (2)$$

Where

X_1 – bound water content, expressed as % of meat;

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

B – wet spot area, cm^2;

m_0 – sample weight, mg;

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

2.3 Microstructure

Microstructure of meat samples was observed on low vacuum scanning electron microscope «JSM-6390LV JEOL» (Japan). Samples were prepared according to Rao, M. V. et al. [16].

2.4 Active Acidity (pH)

Active acidity (pH) was determined using a potentiometer method. A pH-tester 340 (Infraspak-Analit, Russia) was used to obtain the information. Before the analysis the pH-tester was calibrated using special standard solution mixed with distilled water with pH 4.0 and 6.68. This was done simply by dipping the two electrodes into a solution and taking a reading. Then, the sample 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.

2.5 Statistical Analysis

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

3. RESULTS AND DISCUSSION

The results of the proximate analyses of maral meat, lamb, goat meat and turkey meat (red and white meat) are presented in Table 1. The highest protein content determined in turkey meat (25.84% in white and 24.95% in red meat), while in maral and goat meat 24.76% and 22.07%, respectively. Differential characteristic of poultry meat is a high ratio of protein (more complete protein, and less hardly digestible, non-complete proteins, like collagen and elastin), which determine its high nutritive value. The percentage ratio of non-complete protein to complete in turkey meat is about 7%, while in beef – 15-20% [16]. Lowest fat content is determined in maral meat 0.68% and goat meat 1.13%, while the highest – in lamb 12.79%. Maral meat is very lean because the lipids are mainly deposited in the subcutaneous fat layer of the animal while, in the livestock animals, fat deposits are not only in the subcutaneous fat layer, but also in the muscular fraction [17]. Similarly, Uzakov [18] reported that the amount of fat in lamb was 11.5%. A significantly lower content of fat in lamb was presented by Babiker [19] and Aboneyev, etc. [20] 3.5% and 4.3%, respectively. Gerber [21] reported a proximate composition of lamb loin with a higher moisture (73.0%), protein (21.8%), and ash (1.4), and lower fat (3.3%) content in comparison with the

current study. Pulatov [22] showed that lamb loin (uncooked) contains 17.32% of protein, 7.77% of fat, and 1.01% of ash. In turkey meat, the fat content varies from 2.06% (white meat) to 5.02% (red meat). Lamb fat has a high concentration of vitamin E, but low stearin. Among all the types of meat, lamb has an optimum balance between polyunsaturated fatty acids ω6/ω3, which is equal to 2.5:1 and positively affect human health (lower blood pressure, protect against irregular heartbeats, and lower your risk for heart diseases) [23]. The highest ash content is determined in turkey meat (2.37% in red and 1.65% in white meat), in goat meat – 1.45% and in maral meat and lamb is less than 1%. This fact is due to the high concentration of minerals (especially iron, sodium, phosphorous, potassium, iodine, manganese, selenium, and copper) in turkey meat. The iron concentration in turkey meat is considerably larger than in beef and chicken [24]. According to research [25], the average chemical composition of lean goat meat of the race Serbian white goat contains about 75.42% water, 3.55% fat, 19.95% protein, and 1.06% mineral matter. Jussupbekova [26] investigated the maral meat and showed a lower protein content (19.4%), higher fat (1.4%) and similar ash (0.7%) contents, compared to the results of the current study.

Active acidity pH has a significant effect on water binding capacity (WBC), color, tenderness, microbiology characteristics [27], and rheological properties [28]. The pH value lies between 5.7 (turkey white meat) and 6.4 (goat meat). Low WBC is determined in turkey meat (58.2% in red meat and 59.2% in white meat). The WBC value of lamb and goat meat is within 70%. WBC of maral meat is the highest 79.57% (Fig. 1).

Table 1. Proximate composition of meat, %

Type of meat	Moisture	Protein	Fat	Ash	Energy value
Maral meat (n=10)	74.15±1.21^{a}	24.76±0.25^{d}	0.41±0.01^{d}	0.68±0.01^{a}	102.73
Lamb (n=10)	67.20±0.98^{b}	19.12±0.25^{c}	12.79±0.21^{c}	0.89±0.01^{a}	191.59
Goat meat (n=10)	75.34±1.35^{c}	22.07±0.36^{b}	1.13±0.01^{b}	1.45±0.02^{b}	98.48
Turkey meat (red) (n=10)	67.66±1.06^{b}	24.95±0.38^{d}	5.02±0.08^{a}	2.37±0.03^{c}	144.97
Turkey meat (white) (n=10)	70.45±1.23^{d}	25.84±0.47^{a}	2.06±0.02^{f}	1.65±0.02^{b}	121.94

^{a,b,c} Mean values in the same column with different letters differ significantly (P<0.05). Results are mean± SD. n – number of samples

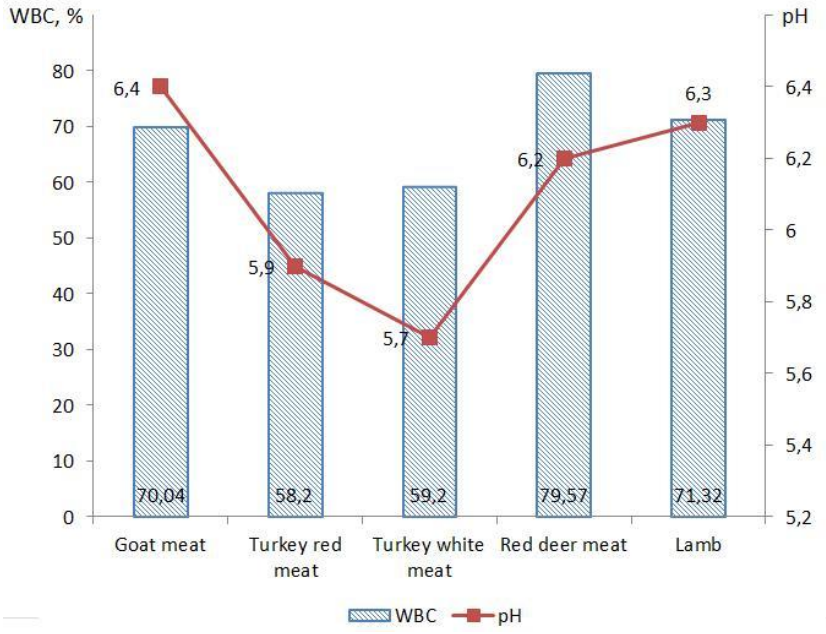
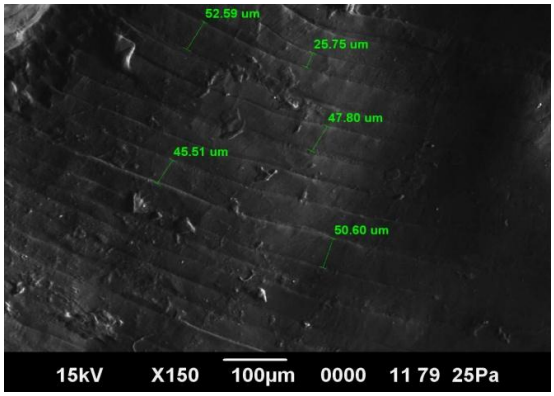


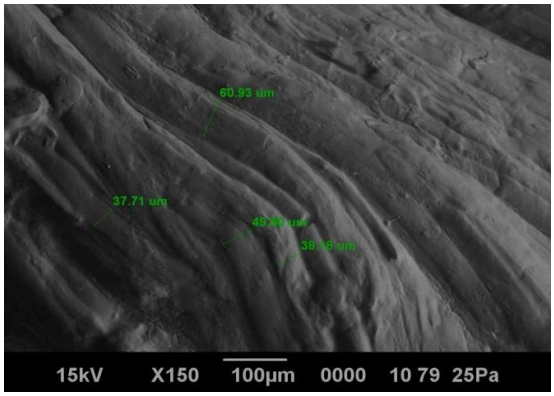
Fig. 1. WBC and pH of meat of different animal

Meat muscle is made up of bundles of muscle fibers. Fibers are the long, narrow, multinucleated cells, which line the overall muscle and 34 cm in length and 10-100 μm in diameter. Muscle fiber diameter depends on muscle type, breed, and sex of animal [29,30]. Given microstructure images of meat show the size of muscle fibers. Thus, in maral meat, the muscle fibers are positioned transversal, without breaks and deformations. The length of fibers varied from 25.7 μm to 52.59 μm with average size 44.44 μm (Fig. 2).

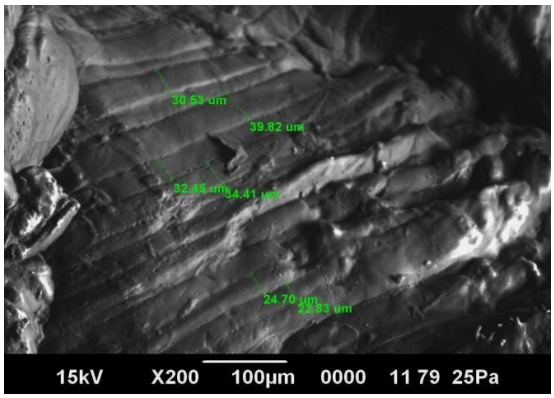
The microstructure of white turkey meat is characterized by muscle fiber bundles, with the diameter of fibers between 37.71 μm to 60.93 μm (Table 2). The average diameter is 46.58 μm. In red turkey meat, some deformation of muscle fibers is observed, and the diameter varied from 22.83 μm to 39.82 μm with average 30.79 μm.



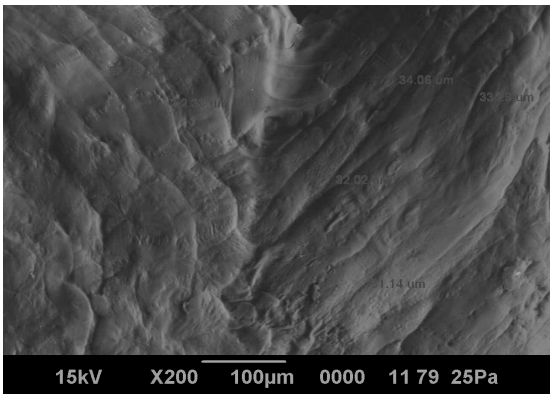
Maral meat (magnification X150)



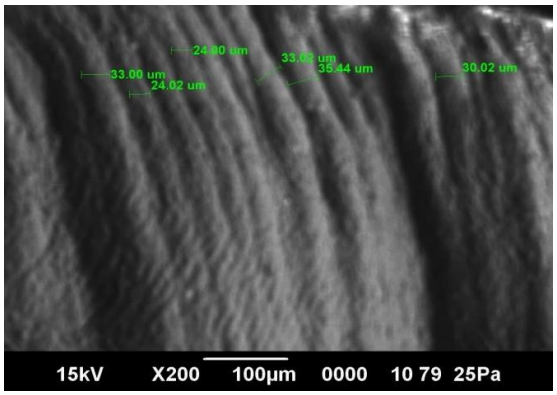
Turkey meat (white) (magnification X150)



Turkey meat (red) (magnification X200)



Goat meat (magnification X200)



Lamb (magnification X200)

Fig. 2. Scanning electron microscopy images of various type of meat

Table 2. Diameter of muscle fibers, μm

Type of meat	n	Average	min	max
Maral meat	30	44.44±5.60	25.70	52.59
Turkey meat (white)	30	46.58±7.75	37.71	60.93
Turkey meat (red)	30	30.79±3.94	22.83	39.82
Goat meat	30	32.57±1.18	31.14	34.06
Lamb	30	29.92±3.52	24.00	35.44

n – number of measurements

The obtained results indicate that the diameter of muscle fibers of different type of meat is varied. The largest fiber diameter was measured in the turkey meat (white meat), and the smallest – in lamb muscle fibers. The diameter of muscle fibers depends on the type of muscle, animal age, and the level of physical stress.

4. CONCLUSION

The obtained results revealed that the various types of meat have significant differences in proximate and physicochemical properties. Thus, the lower WBC is determined in turkey meat and higher in maral meat. Turkey meat has the lowest pH among the other types of meat. The more caloric meat is lamb, the less – goat meat. The morphology and microstructure of meat have some differences in position and diameter of muscle fibers. The smallest fibers were detected in lamb, turkey red meat, and goat meat, while the largest in maral and turkey white meat. Therefore, this kind of study will be useful for further processing and developing meat products.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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