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Effect of age on composition and quality of *Longissimus thoracis* muscle of the moose (*Alces alces* L.) harvested in Estonia

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Abstract. The aim of this study was to determine the biochemical composition and technological parameters of muscle (*Longissimus thoracis*) from adult and calf moose (*Alces alces* L.) hunter-harvested in the forest of southern Estonia. The experiment was based on 13 hunted moose, of which seven were adults (two males and five females) and six calves (two males and four females). The highest intramuscular fat (IMF) level was found in adult female moose muscles (1.50%), and the lowest in adult male moose muscle (0.46%). Adult moose muscles had higher IMF level (1.14%) than calves (0.98%) (P = 0.451). The protein content found in the muscle samples of adult moose was 0.64% higher than that in calves (21.80%) (P = 0.045). The moisture content of muscle from adult moose was lower (75.30%) and varied more than that of calves (76.07%) (P = 0.051). The initial (5.00–5.59) and ultimate (5.40–5.64) pH in muscle samples were within the normal range, both in adults and calves, except in one of the hunted female calf that had high pH values (pH_{45min} = 6.60 and pH_{72hr} = 6.90), obviously because of stress. The WHC of moose muscles was considerably high (60.50–75.20%), and cooking loss for thermally processed moose muscle ranged between 19.10% and 33.39%. Muscle sample from adult moose had the highest cooking loss (29.69%) while that from the calves was the lowest (26.42%) (P = 0.191). More force (32.54 N) was needed to share muscle samples from adult moose compared to cutting the samples from calves (23.92 N) (P = 0.374). Based on the results of the experiments it can be concluded that the meat from younger moose had better technological quality and tenderness.

Key words: moose*, Longissimus thoracsis*, meat quality, age, meat composition.

INTRODUCTION

Markets for venison and other cervid meats have traditionally been strong and stable in Europe. Germany alone consumes hundreds of thousands of tons of meat from different cervids (Thorleifson & Church, 2004). Over the past years, the high-quality meat obtained from wild cloven-hoofed animals (elk, deer, and moose) has become increasingly popular. The amounts of meat from hunted moose has increased almost six times during the last two decades (Veeroja & Männil, 2014), which allows meat

processors to diversify their production. There are five large scale meat processors in Estonia, which market moose meat mostly in the processed form. Bedilo et al. (2010) consider, that moose meat and meat products increase exotic, and, at the same time, low-calorie meat assortment.

According to the Estonian Environment Agency (Keskkonnateabe Keskus, 2013) there were 13,540 hunters in Estonia in 2011, whereas there is access to 38,880 km^2 hunting grounds (86% of the country's total land area). The estimated moose population was 11,650 in spring, 2014, which means that the average population density is less than five animals per 1,000 ha of habitat (Veeroja & Männil, 2014). Although the number of animals has increased over the last two decades, a 12% decline was observed in 2014 compared to year 2013. A total of 6,532 moose were harvested during the hunting season of 2013, which was the highest volume ever (Statistikaamet, 2010; Veeroja & Männil, 2014).

Meat quality can be defined in a number of ways, whereas technological, nutritional, hygienic and sensory aspects are taken into consideration (Konarzewski, 2004). The nutritional value and overall quality of meat depend on the animal species, age of the animal and animal feeding (Semple, 2011). Moose meat is fibrous, there are no fat layers in the cross-sectional surface of muscle, which refer to marbling, such as in beef. The connective tissue is underdeveloped being uniform in colour, tender and palatable (Bedilo et al., 2010).

Only a small number of studies on moose meat quality are available (Ponamareva, 1997; Taylor et al., 2002; Bedilo et al., 2010; Strazdiņa et al., 2011). The latest study on moose meat quality in Estonia dates back to the 1970s (Evendi & Tüür, 1976).

The aim of the present study was to determine the biochemical composition and technological parameters of muscle (*Longissimus thoracis*) from both adult and calf moose (*Alces alces* L.) hunter-harvested in the forests of southern Estonia.

MATERIALS AND METHODS

Animals

Thirteen moose were harvested with a hunting rifle during the hunts from 27 October till 8 December 2013 in southern Estonia, whereas the average air temperature was from -3 to +10°C. Dissection and skinning started 15 minutes to five hours after harvesting, whereas delays were due to the different locations of the harvest. Skinning and dissection of a carcass took 45–80 minutes (Table 1), whereas the duration depended on the size of the animal, e.g. skinning and dissection of calves took less time. The age of the animals was estimated by the wear of mandibular premolars and molars, whereas the work was performed by an expert. The age of adult moose varied between 30 and 90 months. The calves were born in spring, i.e. they were about six months old. Hot carcass weight was determined, and carcass yield calculated according to the method used in meat processing plants. In adult moose, the hot carcass weight was, on average, 107.82 kg and red meat yield 79.43 kg higher than those in the calves, whereas both characteristics showed more variability in the adult animal group (Table 1).

Samples from *Longissimus thoracis* between the 11^{th} and 12^{th} ribs were obtained from six calves and seven adult moose (Fig. 1). The calf group comprised four and the adult group five female animals, whereas both groups included two male animals. Muscle samples (500 g) were taken from the carcasses within 90 minutes after skinning

in abattoir, and transferred directly to the chilling box. All muscle samples were packed into plastic bags and stored at +5°C until the analysis.

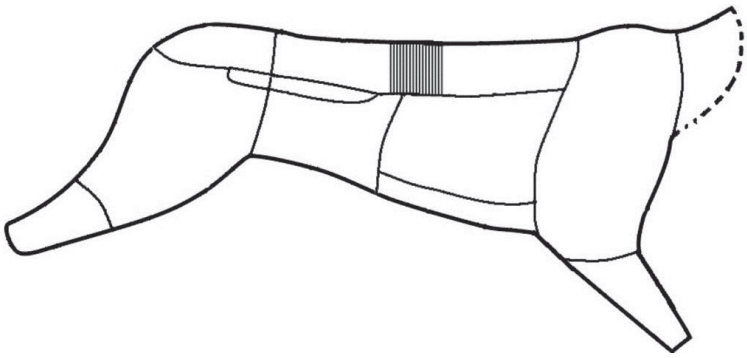

Figure 1. Location of *Longissimus thoracis* samples (500 g) obtained in carcasses between the 11th and 12th ribs.

Table 1. Descriptive statistics of the adult and calf groups of animals

Traits	Mean	Std. Dev.	Min	Max
Adult group (n = 7)				
Age, months	54	22.8	30	90
Hot carcass weight, kg	192.30	20.88	164.40	225.00
Carcass yield, %	72.79	0.39	72.00	73.00
Pre-processing time, min	65	8.66	60	80
Red meat yield, kg	139.93	14.61	120.00	162.00
Calf group (n = 6)				
Age, months	6	–	6	6
Carcass weight, kg	84.48	8.40	76.70	98.60
Carcass yield, %	71.50	1.76	69.00	73.00
Pre-processing time, min	45.83	2.04	45.00	50.00
Red meat yield, kg	60.50	6.75	54.00	72.00

Biochemical analysis

The analyses were carried out using acknowledged methods in the meat laboratory of the Department of Food Science and Food Technology at the Estonian University of Life Sciences. The chemical composition of *Longissimus thoracis* was determined three days after harvesting, whereas fat, protein, ash and moisture content were recorded. Muscle samples were homogenized in a micro grinder for 20 seconds per a preparation, and placed into plastic containers, which were covered with a lid.

The moisture content of muscle was determined according to the Estonian Centre for Standardisation (EVS) standard EVS-ISO 1442:1999 (EVS, 1997). The protein content was measured according to ISO 937:1978, the method of EVS (EVS, 1978) by using a Kjeltec device. The fat level of muscles was determined by using the Soxtec apparatus according to EVS–ISO 1444:1996 method (EVS, 1996). Ash content of the samples was determined by incineration in electric muffle furnace according to EVS–ISO 936:1998 methodology (EVS, 1998).

Technological characteristics

The following characteristics were determined in moose muscle: pH, WHC (WHC), electroconductivity, colour, cooking loss and shear force.

The initial pH-value (pH_{45min}) of *Longissimus thoracis* was measured by using pH-meter Testo 205 (Testo AG, 2006) 45 minutes after the muscle samples were taken. The ultimate pH (pH_{72hr}) was measured using pH-STAR CPU **(**Ingenieurbüro R. Matthäus, 2011[a]) within 72 hours after skinning and dissection of the carcasses

The WHC of muscle was determined using the Grau & Hamm (1952; 1957) method, modified by Volovinskaja & Kel'man (1962).

To determine the electrical conductivity of muscle tissue the LF-STAR CPU apparatus was used (Ingenieurbüro R. Matthäus. 2011[c]). The equipment has two parallel steel electrodes, which were pressed into the tissue, and the electrical current between the electrodes was recorded. The result shows the degree of damages in cell structure, which is directly related to the WHC of muscle.

The colour of muscle tissue was determined using optometer Opto-STAR, which uses a light source to radiate muscle surface (Ingenieurbüro R. Matthäus, 2011[b]), that enables researchers to determine quality defects according to the intensity of emanated light from the muscle surface.

Cooking loss is the loss of liquid and soluble substances from meat during thermal treatment. Each muscle sample (100 g) was cut from *Longissimus thoracis* and sealed into a plastic bag with a thermometer. The bag was placed into hot water (95°C) and heated until the internal temperature of the sample increased up to 72°C. The sample was cooled down and weighed. Cooking loss was calculated according to the initial weight.

The shear force of moose muscles was determined by using texture-analyser TMS-Pro, which was equipped with force element TMS-PRO LOAD CELL 1 kN and cutting blade TMS-PRO Light weight blade set (Food Technology Corporation, 2011). The specifications of the TMS-Pro equipment were as follows: 60 degree V-shaped 1.016 mm cutting-blade; cutting speed of the blade 500 mm min^{-1}, and the maximum force applied ≤1000 N. Preparation of the samples and determination of shear force were performed according to Warner-Bratzler methodology (Savell et al., 2013). Muscles were aged 72 hours before testing in a freezer at 5°C. Samples were sheared perpendicularly to muscle fibres, whereas abnormal records (connective tissue detected) were excluded from the final analysis.

Statistical analysis

Data management and statistical analysis were performed by using a spreadsheet program MS Excel 2010. To determine the statistical difference between age groups the student's *t*-test was used. Data visualization was aided by Daniel's XL Toolbox addin for MS Excel, version 6.53, by Daniel Kraus, Würzburg, Germany.

RESULTS AND DISCUSSION

Biochemical analysis

Strazdiņa et al. (2011) analysed game (deer, roe deer, moose and wild boar) muscle samples and determined that intramuscular fat (IMF) content varied from 1.31% to 2.82%, being the lowest in moose muscles and the highest in wild boar muscles.

According to Anderson et al. (1989) from USDA, the fat content of raw moose meat was 0.74%. Bedilo et al. (2010) found that moose meat was low in fat: 0.68% in *Longissimus thoracis* and 1.45% on average in the red meat, whereas the study showed that fat content depends on the type of muscle used for analyses. On the contrary, Reede (personal communication, 15 December 2013) noted, that they found high IMF level (3.85%) in *Longissimus thoracis* from moose. Ponamareva (1997) studied trimmed moose meat used in making sausage, and found that this kind of meat also had a higher fat level (1.95%).

The fat content in the meat from the other species of the *Cervidae* family has been reported to be as follows: 1.60% (Strazdiņa et al., 2011) and 1.45% (Anderson et al., 1989) in wild deer (*Cervus elaphus*), and 1.59% (Strazdiņa et al., 2011) in roe deer (*Capreolus capreolus*). Daszkiewicz et al. (2012) found a significant difference between female and male roe deer IMF percentages 1.46% and 0.83%, respectively. This indicates that meat from the other species of the *Cervidae* family also has a low IMF level. Still, in case grounded meat was used for analysis, the fat content of the meat from elk (*Cervus canadensis*) (4.5% in bulls, 7.8% in cows) was relatively high (Field et al., 2003).

In the present study the recorded fat content in moose muscles was low, ranging from 0.46–1.50%, whereas it was higher in cows and lower in bulls. Zhitenko (1984) has reported higher fat level in moose muscle (1.1−2.5%). The fat content in the muscles of adult animals was slightly (0.16%) higher than that in calves, but the difference between the age groups was not statistically significant ($P = 0.451$) (Fig. 2).

The protein content (18.5–19.0%) in the meat from wild, free-range moose does not differ significantly from that of beef (19.0–20.0%) (Rogozhin, 2009). Strazdiņa et al. (2011) showed that the protein content of the muscle from the different species of the *Cervidae* family were in deer – 22.36%, roe deer – 22.82% and moose – 22.72%. Bedilo et al. (2010) found, that the protein content of *Longissimus thoracis* of moose was 19.78%, whereas it was 4.48% higher in red meat. However, Zhitenko (1984) estimated 20.6–21.6% protein content in moose meat. The protein content of trimmed meat (21.28%) does not differ significantly from the above values (Ponamareva 1997). The highest protein level (24.94%) in the longest spinal muscles from moose was found by T. Reede (personal communication, 15. December 2013). Field et al. (2003) analysed the meat from another representative of the family *Cervidae* - the elk (*Cervus canadensis*), and determined 23.0% protein content in the meat from bulls, and 21.8% in that from cows.

Protein content in the moose muscle samples was between 21.10% and 23.30%, whereas it was 22.44 ± 0.21%, as an average, in the muscle from adult animals, i.e. significantly higher ($P = 0.045$) compared to the calf group (21.80 ± 0.18%) (Fig. 3).

Previous studies have shown that protein content does not differ much between meat cuts from different parts of moose. Hoffman & Wiklund (2006) have stated that game meat and venison fulfil the expectations and dietary requirements of the modern consumer due to low fat and high protein level.

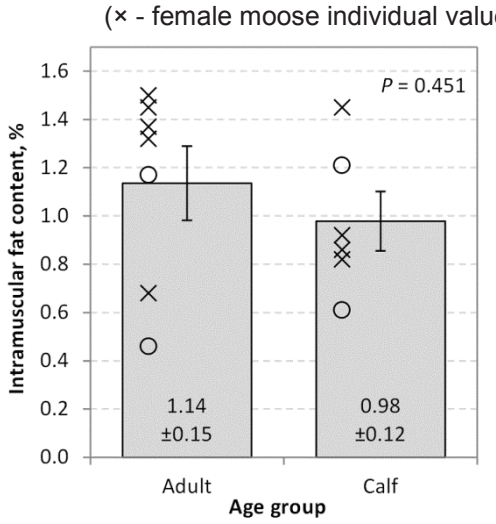

Figure 2. Average intramuscular fat content (± standard error) of moose muscles by age group.

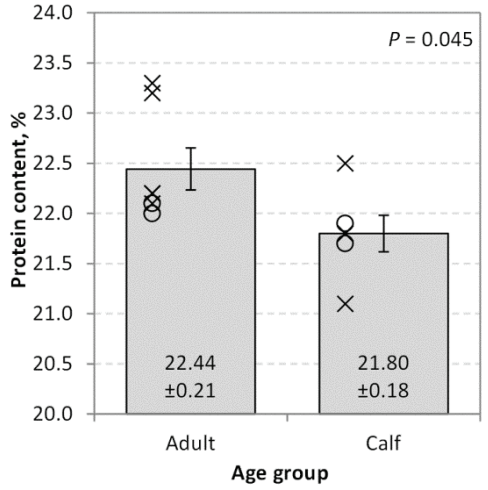

Figure 3. Average protein content (± standard error) of moose muscles by age group.

The highest moisture content of *Longissimus thoracis* from moose (78.44%) was reported by Bedilo et al. (2010). In the current study, the average moisture content found in the muscle samples from moose calves was 76.07 ± 0.21%, which was by 0.77% higher than that in adult animals (75.30 ± 0.27%). No significant difference was found between age groups, but just a tendency to it was observed ($P < 0.01$) (Fig. 4). The moisture content in the muscle from adult moose (74.00–76.20%) varied slightly more than that in calf group (75.50–76.80%). Similar variation (74.3–75.8%) was found by Zhitenko (1984). The lowest moisture level (69.62%) was detected by. Reede (personal communication, 15 December 2013), which may have been due to the use of frozen muscle samples. Analyses of moisture content in grounded moose meat showed higher results in the works of Anderson et al. (1989) and Bedilo et al. (2010) (75.55% and 73.24%, respectively). Also, the moisture content in trimmed meat (74.85 ± 0.83%) did not differ from that of untrimmed meat (Ponamareva, 1997). Similar values (73.80% in female and 75.32% in male animals) were found in the meat from roe deer by Daszkiewicz et al. (2012).

According to literature, the total mineral content in moose meat ranged within narrow limits, from 1.05% to 1.13% (Zhitenko, 1984; Anderson et al., 1989; Bedilo et al., 2010). Ponamareva (1997) showed that trimmed meat had slightly higher ash level (1.20 ± 0.11%). The current study showed that the ash content in moose muscles was 1.03–1.32%, whereas less variability was observed in calves. Still, the average values in the calf (1.14 ± 0.03%) and adult groups (1.13 ± 0.04%) differed by only 0.01% ($P = 0.816$) (Fig. 5).

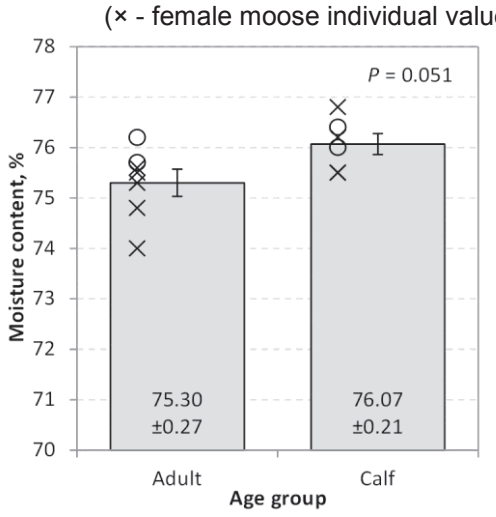

Figure 4. Average moisture content (± standard error) of moose muscles by age group.

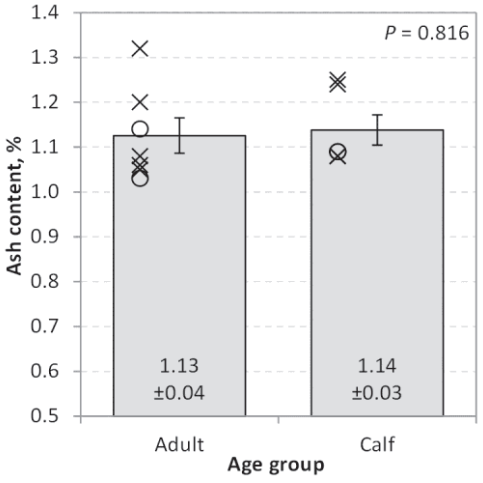

Figure 5. Average ash content (± standard error) of moose muscles by age group.

Technological characteristics

To determine the technological properties of muscle tissue parameters that characterize the toughness of meat, the following was studied: weight loss during heat treatment, ability to bind and retain moisture that ensures juiciness, and the pH value which is related to maturation of meat due to biochemical processes and accumulation of glycogen in muscle.

The initial average pH_{45min} values ranged from 5.06 to 6.60, whereas the highest values were determined in the muscles of female calves and in the adult moose group. The pH_{45min} value in the muscle of female animals was 5.59 which was higher than that in the muscle of males (Fig. 6a). Furthermore, the acidity of the muscles in cows dropped to the normal level (pH_{72hr} = 5.50), while that in the muscle of calves continued to increase up to pH_{72hr} 6.9 (Fig. 6b). This indicated that DFD-specific meat developed due to stress obtained during hunt. The average pH_{45min} differed by only 0.2 units (P = 0.549) between the groups, whereas it was lower in the muscles of adult moose (pH_{45min} = 5.18).

The ultimate acidity (pH_{72hr}) of moose muscles declined compared with the initial pH_{45min}, and was 5.53 ± 0.03 in the adult and 5.76 ± 0.23 in the calf group (Fig. 6b). As the difference between the initial pH_{45min} values between the groups was 0.23 units, and the difference in the ultimate pH_{72hr} falls in the same range (P = 0.362), it can be concluded, that the acidity of muscles was relatively evenly changed. Bedilo et al. (2010) found that the ultimate pH of moose muscles fell in a normal range (5.47–5.71), and the calculated average value was 5.59. Field et al. (2003) determined that muscle pH in elk (*Cervus canadensis*) was 5.5 in both bulls and cows

The highest initial and ultimate muscle pH was determined in calves, while calf muscle also had the highest WHC (75.2%), which indicates damage to muscle structure and emergence of excess water. (Fig. 7).

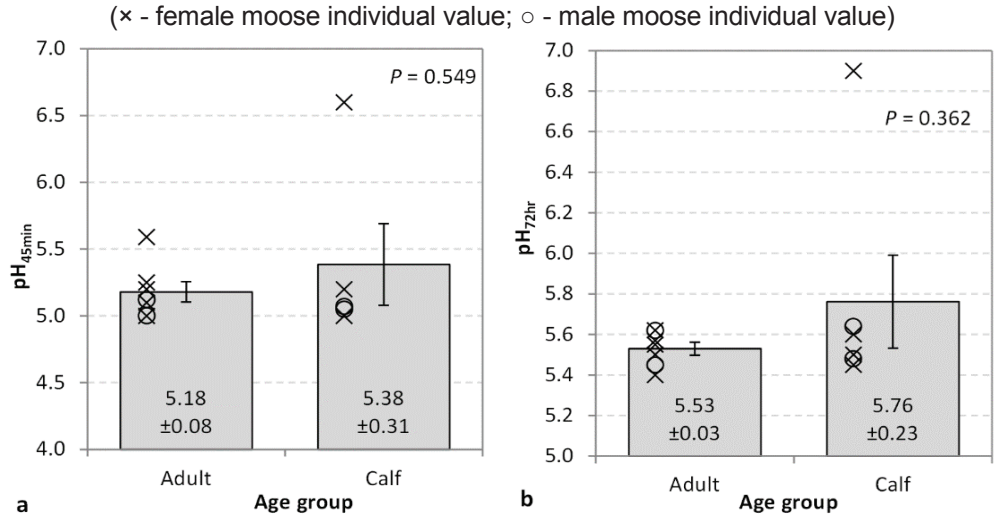

Figure 6. Average initial (pH_{45min}) (a) and ultimate (pH_{72hr}) (b) pH values (± standard error) of moose muscles by age group.

The WHC of moose muscles was considerably high (60.50–75.20%), therefore the meat can become dry and firm after ageing. Calf muscles contained 1.82% more water than those of adult animals (Fig. 7), and although this difference proved insignificant, a tendency existed ($P < 0.01$). Also, Bedilo et al. (2010) stated that the WHC of moose muscle is high (59.10–61.19%; 60.10% on average).

The highest cooking loss during thermal treatment (29.69 ± 1.18%, $P = 0.191$) was observed in the muscles of adult moose, while it was the lowest in calf muscle (26.42 ± 2.14%) The average cooking loss of thermally processed moose muscles ranged from 19.10% to 33.90%, whereas there was more variation in the calf group (19.10–33.20%) than in the adult group (26.10–39.90%) (Fig. 8).

On the contrary, Bedilo et al. (2010) showed much higher loss during thermal treatment (39.44%), which varied from 38.30% to 40.58%. This indicates that moose meat may become dry after processing, and therefore requires specific pre-treatment.

The electroconductivity of moose muscles was in a range 4.00–13.10 mS. The lowest average value in the calf group was observed in male calves (5.00 mS) and the highest in females (10.38 mS). The average value was quite similar in both groups, being only slightly higher in the adult group ($P = 0.885$) (Fig. 9).

Consistently uniform colour of meat attracts consumers. Bedilo et al. (2010) found that colour values of moose meat are uniform, which is in accordance with the present study, in which the colour values did not vary significantly, ranging from 85 to 90. The values indicated that moose meat is dark in colour. The average muscle colour was slightly darker (88.43) in adult moose compared to that of calves (87.6), whereas muscle colour of male animals tended to be lighter than that of females in both groups (Fig. 10).

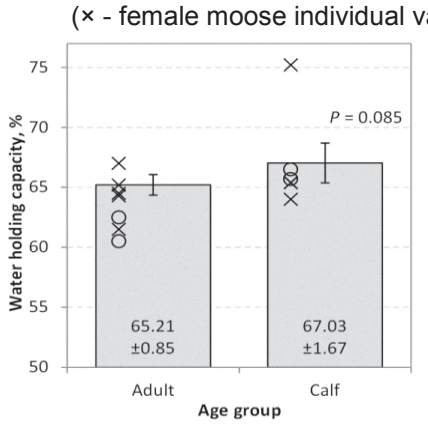

Figure 7. Average water holding capacity (± standard error) of moose muscles by age group.

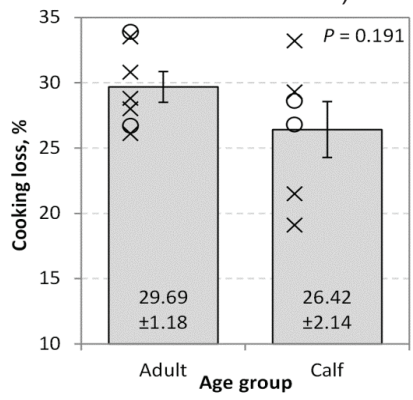

Figure 8. Average cooking loss (± standard error) of moose muscles by age group.

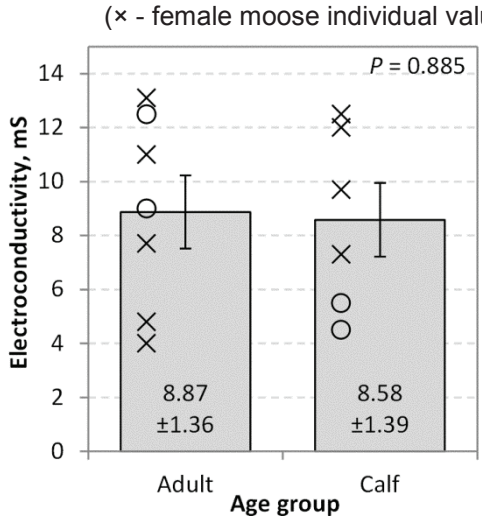

Figure 9. Average electroconductivity (± standard error) of moose muscles by group.

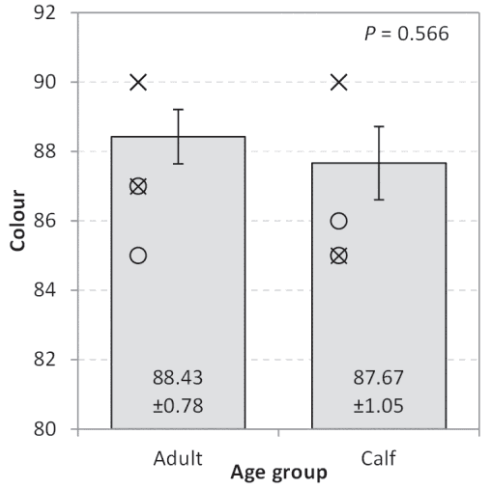

Figure 10. Average colour values (± standard error) of moose muscles by age group.

Generally, consumers prefer tender meat. Bedilo et al. (2010) concluded that elk meat was sufficiently tender (shear force 2.65 kg $cm^{2\ -1}$ (25.99 N)), i.e. similar to the Aberdeen Angus beef (27.81 N) (Tänavots et al., 2013). Taylor et al. (2002) indicated to the reported toughness of moose meat and concluded that this is probably due to the lack of I band breaks and normal to large fibre size.

The present study showed that more force had to be used to shear adult moose muscles (32.54 N), compared to cutting veal samples (23.92 N). Although the difference between age groups was statistically insignificant, it can be concluded that the meat from adult moose was slightly tougher (Fig. 11).

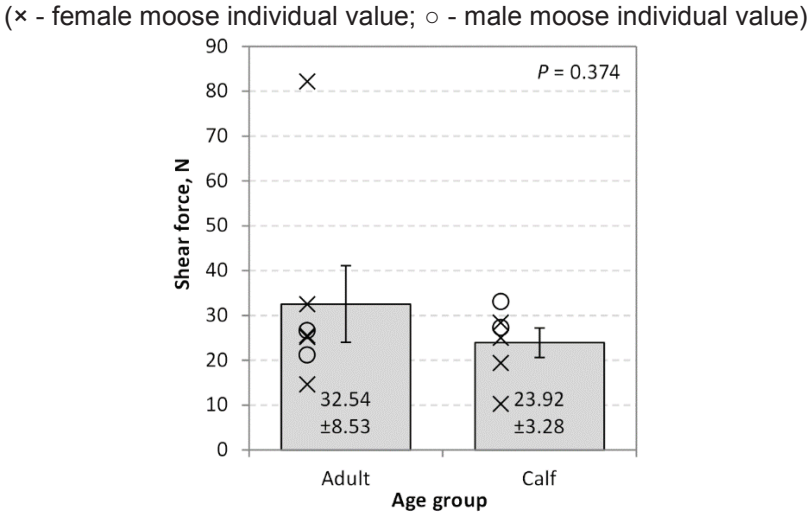

Figure 11. Average shear force (± standard error) of moose muscles by age group.

CONCLUSIONS

Fresh or processed moose meat is an alternative to traditional meats that enables the consumer to diversify the range of exotic and low-calorie meat products. Due to its low IMF and high protein content, moose meat corresponds to the modern dietary demands. The protein and moisture content of moose muscle was significantly influenced by age. On the other hand, pH, WHC, electroconductivity and boiling loss did not differ between age groups. Although the meat from adult animals was tougher, the dry matter, protein and IMF level was higher than that in calves. Still, it can be concluded, that the meat from younger moose was more tender and of better overall quality.

Since there is small numbers of published information on moose meat, it is necessary to continue research in this field. The number of game meat handlers and their increasing production volumes also demonstrates the need for further research, which shall involve after-processing and product development issues.

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