

EVALUATION OF TENDERNESS AND JUICINESS OF DOMESTIC YAK MEAT AND ITS HYBRID IN COMPARISON WITH DOMESTIC CATTLE MEAT

Blanka Zábrowská, Eva Vepřková, Adéla Faltusová

Agrovýzkum Rapotín s.r.o., Výzkumníků 267, 788 13, Rapotín, Czech Republic

Abstract

Production of alternative types of meat such as domestic yak meat, offers not only economic opportunities but also nutritional benefits and still represents a gap in the market due to supply and demand constraints. The aim of this study is to compare the tenderness and juiciness of domestic yak meat with meat of crossbreed domestic yak with domestic cattle and meat of domestic cattle itself during maturation. Samples of ribeye from domestic yak, domestic yak hybrid and domestic cattle were taken. Individual meat samples were vacuumed and matured at 4 °C. During maturation, the pH (Testo602-pH2-CONRAD probe), weight loss, tenderness and juiciness of grilled meat samples were evaluated once a week using a TA.XT texturometer plus Stable Micor Systems TM (Warner-Bratzler knife, 50 mm compression probe). Sensory analyzes of meat samples were also performed once a week, focusing on their color, fatness, aroma, consistency, juiciness and taste. Domestic yak is a neglected cattle with considerable and as yet untapped potential, especially for meat production, which represents a unique, nutritionally valuable opportunity to diversify the diet.

Keywords: domestic yak, domestic cattle, ribeye, texturometer, tenderness, juiciness, sensoric analysis

1. INTRODUCTION

1.1. Domestic yak

Domestic yak (*Bos mutus f. grunniensis*) is a domesticated form of wild yak, belonging to the order Artiodactyla, family Bovidae, subfamily Bovinae, genus *Bos* and species *Bos mutus* (Crha 1999; Leslie and Schaller, 2009). The process of domestication could have started 10,000 years ago with Quiang nomadic people. The establishment of the primary yak industry and culture in China began at least 4,500 years ago (Han, 2014). Adult males reach withers height 1.1 - 1.4 m and adult females 1.1 - 1.2 m. Body length in both sexes is 2.5 - 3.3 m. The weight of adult males is between 250 - 575 kg and 200 - 360 kg of adult females (Crha, 1999; Wiener et al., 2003). The length of pregnancy of female yaks is 257 - 270 days, almost all calving occurs between March and August. The birth weight of the yak ranges from 10 to 16 kg, which is about 3 - 7 % of the adult weight (Wiener et al., 2003; Leslie and Schaller, 2009).

The growth and development of yaks is strongly influenced by the seasons and the feed availability. The seasonality of grass growth is reflected in changes in the yak's body weight and condition throughout the year. Especially in the first 2 years of life, body weight decreases in the cold period and then in the grass growth season there is a large increase in body weight, the so-called compensatory growth (Xu et al., 2017; Juárez et al., 2019). During the period of compensatory growth, the average daily values of male and female weight increase in the pastures range between 0.2 and 0.5 kg/day (Wiener et al., 2003; Xu et al., 2017).

Compared to other species of the family Bovidae, domestic yak is very well adapted to life in the demanding conditions of alpine areas such as low temperature, high rainfall, difficult terrain and high altitude (Wiener et al., 2003; Juárez et al., 2019). Yaks live at altitudes between 2000 m.a.s.l. at 5000 m.a.s.l. (Nguyen et al., 2005). Yaks managed to adapt to chronic hypoxia, even though they belong to the same genus as domestic cattle. Unlike yaks, domestic cattle are known for their poor tolerability at high altitudes, when they suffer from severe pulmonary hypertension (Will et al., 1975; Durmowicz et al., 1993; Qiu et al., 2012). The average annual temperature in yak breeding areas is - 8 °C, while it is able to withstand temperatures of - 40 °C in the winter months. Average annual rainfall is 350 - 500 mm and grass in these areas grows only a third of the year (Bailey et al., 2002; Leslie and Schaller, 2009).

The total yak population is estimated at more than 14.2 million. The largest part of the population is located in China, where an estimated 13.3 million animals are kept. Another more than 0.8 million yaks can be found in Mongolia (Lhagvasuren and Munkhtsog, 2002) and small populations can be found in countries bordering China. In these countries, they provide the population with basic resources, especially transport, meat, milk, fur and skin (Wiener et al., 2003). Animal by-products such as blood, organs and bones are also used, although to a lesser extent (Jiang, 2002). Meat is often obtained from animals at the end of their productive lives, which causes its non-standardity and often lower quality, but it is an important resource for producers, providing both food and additional income. In some parts of China, yak populations appear to be growing and hybridization with domestic cattle is becoming more popular as improvement of animal meat yield, increase of milk production and improvement of carcass characteristics (Wiener et al., 2003; Juárez et al., 2019).

On a minority scale, yaks can be also found in North America (Wiener, 2002) and Europe (Wiener et al., 2003). For economic purposes, yaks are bred in Europe, especially in German-speaking countries. Yaks are bred mainly in mountain areas, where the possibility of settling and adapting their population is considered. The efficiency of yak production is currently being determined. German and Italian breeders focus mainly on the use of yak products - meat and milk and then cheese production, while breeders in Switzerland focus more on agritourism in alpine treks (Wiener et al., 2003; Nguyen et al., 2005; Juárez et al., 2019).

The breeding of domestic yak in the Czech Republic is still in its infancy, but the production of yak meat already serves to enrich the domestic market. In the Czech Republic, there are more than 10 private breeders, 27 male yaks, 24 yak heifers and 23 yak cows are registered, but higher numbers of yaks can be expected, but there is a problem with determining the exact number of individuals. Currently, yak meat in the Czech Republic is produced by several farms and other farms are planning to produce yak meat in the near future, as yak meat is becoming increasingly popular due to its high nutritional value (Škaryd, 2022; Czech-Moravian Association of Breeders, 2022).

1.2. Slaughter

In China and Mongolia, yak meat is often obtained from older breeding males and dairy females at the end of their production period. Therefore, there is a great variability of the age and weight of yaks at slaughter. Most yak males, that are not used for breeding, are castrated (Wiener et al., 2003). Meat-producing species are usually slaughtered in the autumn, at the end of the grass growing season, when they are in a 'fat' state (Wiener et al. 2003; Juárez et al., 2019).

Live body weight at slaughter varies between breeds, localities and sex (Wiener et al., 2003). In terms of sex, the live body weight of yak bulls is between 205 and 576 kg, yak cows is between 153 and 362 kg and yak steers is between 116 to 496 kg. The characteristics of carcasses vary with the influence of diversity of production systems, slaughter age of animals, sex, genetics and size of animals (Juárez et al., 2019).

Due to the large range of sizes and weights of slaughtered animals, there is a wide range of reported rib sizes ranging from 31.7 - 87.3 cm² (Wiener et al., 2003). Crossing domestic yak with wild yak increases the overall weight of the animals, increases meat yield and also increases the ribeye (Jialin et al., 1998). According to the classification of carcasses, the weights of the individual parts of the yaks and their hybrids are: neck and back meat 8 - 11 kg, ribs 3 - 5 kg, breast 5 - 6 kg, hips 2 - 3 kg, slices 7 - 8 kg, loins 7 - 9 kg, stern 5 - 7 kg and leg 6 - 9 kg - chuck/dorsal meat 8 - 11 kg, rib 3 - 5 kg, brisket 5 - 6 kg, plates 2 - 3 kg, shank 7 - 8 kg, loin 7 - 9 kg, rump 5 - 7 kg, and round 6 - 9 kg (Jialin et al., 1998; Juárez et al., 2019).

1.3. Yak meat

In recent years, due to the rapid development of globalization, consumer philosophy has changed and also the demand, supply and uptake of unconventional and exotic meat has increased significantly (Xiong et al., 2021). In recent years, yak meat has gained favor thanks to its good quality, especially its low fat content and high protein content. According to Choudhary et al. (2020), yak meat has a higher protein and dry matter content than cattle and has more favorable amino acid and fatty acid profile

(lower palmitic acid content, higher stearic acid and oleic acid content) and lower calorie, fat, saturated fat, cholesterol and triglyceride content. In the field of food safety, yak meat also has a good reputation (Wan et al., 2011). The meat of traditionally reared yaks is relatively similar to the meat of grazed cattle fed with grass, or it can be compared to game meat. However, when animals are reared using conventional intensive care systems and fed concentrated feeds, the meat approaches to be similar with the meat of intensively reared beef cattle (Wiener et al., 2003; Juárez et al., 2019). Crossing domestic yak and domestic cattle is used to increase production and improve the characteristics of carcasses without significantly increasing the fat content of the meat.

1.4. Nutritional composition

The nutritional composition of yak meat strongly depends on a number of factors such as the animal's genetics, age, sex, maturity, husbandry and diet, and grass growth season (Juárez et al., 2019; Xiong et al., 2021). The nutritional value of yak meat also depends on the altitude of the habitat (Bazhenova et al., 2018). The average composition suggests that yak meat could have the potential to be considered low-fat and low-sodium (based on the amount of fat and energy from the SFA. Male yak meat is healthier in terms of nutritional value, while female yak meat has better properties in terms of visual impact and mouthfeel (Xiong et al., 2021).

The fat content of yak meat is influenced by several factors, notably the breed, age and sex of the animal and its genetics, but also by the method of breeding and the availability of feed (Wiener et al., 2003; Juárez et al., 2019). The type and amount of fat are among the key factors influencing the quality of carcasses and meat. The composition of fats and fatty acids is closely related to the quality of meat, which includes its sensory properties, i.e. appearance, texture - tenderness, cohesiveness and juiciness, aroma and taste (Xiong et al., 2021). Breeding and nutrition in animals are crucial for the optimal amount of intramuscular fat (Xiong et al., 2021). The content of intramuscular fat in the ribeye is higher in female yak meat (2.51 %), compared to 1.83 % in male yak meat (Xiong et al., 2021), as confirmed by Zi et al. (2004), the meat of female yaks (10.86 %) and steers (7.26 %) has a higher fat content than bulls (2.97 %).

According to a study by Zi et al. (2004), ribeye of female yak contained higher amount of dry matter (31.93 %) in comparison with yak bulls (26.54 %) and yak steers (29.71 %). In terms of protein content, ribeye contained 22.58 % protein in male yaks, in female yaks the protein content was found to be 19.98 % and in steers 21.55 %. The content of connective tissue, which affects the meat consistency, was 12.1 % higher in yak meat than in beef. (Bazhenova et al., 2018). The meat of yak bulls, females and steers contains very similar amount of ash (1.00 % bulls, 1.00 % females, 0.93 % steers). The amino acid composition of yak meat is similar to beef, except for a lower methionine content (Zi et al. 2004).

Fatty acid content, ie. Σ SFA, Σ UFA, Σ PUFA and Σ MUFA in the ribeye are higher in female yak meat ($p \leq 0.01$). The content of Σ SFAs in females was 1002.82 mg/100g, in males 658.71 mg/100g, the content of Σ MUFAs in females was measured 536.21 mg/100g, in males 423.15 mg/100g, the content of Σ PUFAs in females 379.29 mg/100g, in males 328.71 mg/100g and the content of Σ UFAs was measured in females 915.50 mg/100g, compared to males, which was 751.86 mg/100g. The fatty acid spectrum of yak meat is dominated by C18:0, cis-C18:1, cis-C18:2, C16:0, C20:4n6, C24:0, C24:1 and cis-C20:5n3 fatty acids (Xiong et al., 2021). The fatty acid composition of ribeye of male yak is healthier for consumers, while ribeye of female yak has higher tenderness and marbling, making it more sensory acceptable and more attractive to consumers (Xiong et al., 2021).

1.5. Sensory properties

Sensory properties are an important factor influencing the consumption of yak meat, which are very important for consumers. The sensory properties of meat include appearance - color and marbling, texture (tenderness, cohesion and juiciness), aroma and taste. Taste is a key sensory attribute that distinguishes yak meat from conventional beef and is important for its acceptance by consumers. Texture is also an important feature of meat quality, sometimes even more important than aroma and color (Popoola et al., 2020).

Yak meat has a scarlet red to dark red color (Zi et al. 2004, Bazhenova et al., 2018), and tends to be

darker than beef. Myoglobin levels increase with age, so in some cases the very dark color of the meat may be due to older age at slaughter. Color differences may also be due to extensive breeding method compared to cattle, with selection for meat production increasing the proportion of light fibers and decreasing the proportion of red fibers, which is associated with a lower concentration of myoglobin pigment. Differences in the amount of antioxidants in meat may also be responsible for the premature browning of yak meat. Different production also contributes to meat color differences (Juárez et al., 2019; Bazhenova et al., 2018). Yak meat usually has a low to medium degree of marbling and an amount of intramuscular fat (Zi et al. 2004). According to Xionga et al. (2021) the degree of marbling is higher in female yaks ($p \leq 0.05$) compared to bulls and steers.

Yak meat is usually not categorized according to the age of the animal, which leads to the fact that it is commonly perceived as relatively tough with a rough structure, due to the frequent older age at slaughter (Wan et al., 2011; Juárez et al., 2019). As with beef, the tenderness of meat is negatively influenced by high age at slaughter (Juárez et al., 2019). The meat of young yak is very fine in terms of tenderness (Juárez et al., 2019; Choudhary et al., 2020). The shear force is lower ($p \leq 0.01$) for female yak meat compared to male yak meat, i.e. that the meat of the yak females is more fragile (Xiong et al., 2021). As with beef, it is important to maintain the optimal maturation time to increase the tenderness of yak meat (Wan et al., 2011). Wan et al., (2011) observed at Gannan Black yak that 7 days of maturation appears to be sufficient for the production of fragile meat. According to Wan et al. (2011) a period of meat maturation has a greater influence on the shear force, respectively, the tenderness of the meat than the age of yak at slaughter and tends to alleviate the effect of older age at slaughter on the shear force, respectively, the tenderness of the yak meat. The optimal time of meat maturation can be a valuable tool for the production of fragile yak meat, which will be more attractive to consumers and can lead to an increase in its market value.

Aroma and taste play an essential role in the sensory properties of food. The aroma and the taste of yak meat are defined as natural and without pollution of the odor or feed flavors. Yak meat is very specifically aromatic with unique volatile taste (Bazhenova et al., 2018; Huang et al., 2022). The main taste compounds in yak meat are 2,3-pentanedione and 3-hydroxy-2-butanone and the formation of aromatic compounds is involved in 3-dehydromangiferic acid. Yak meat proteins easily oxidize during maturation, transport and storage, which can affect the aroma and taste of yak meat. The degree of yak meat oxidation increases with an extending oxidation period, which increases the content of volatile aromatic compounds such as heptanal, octanal, nonanal, 2,3-glutaraldehyde and 3-hydroxy-2-butanone. The volatile aromatic compounds positively correlate with an oil, linoleic and stearic acid, which are important aromatic precursors. Octanal and nonanal may be related to the acidification of yak meat at a later stage of oxidation (Huang et al., 2022).

2. MATERIAL AND METHODS

2.1. Material

2.1.1. Characteristics of animal

The domestic yak steer (Photo No. 1), the crossbreed of domestic yak with domestic cattle steer (yattle, Photo No. 2,) and five Galloway bulls (Photo No. 3) were used for the experiment. The domestic yak and the yattle were bred all year round by the grazing system. Galloway bulls were bred intensively in a stable system. Animal identification, pedigree, date of birth, date of slaughter and slaughter weight of domestic yak, yattle and Galloway bulls are specified in Table No. 1. Animals were slaughtered at the slaughterhouse in Kamenec near Polička in the Czech Republic. Meat cooling and sampling also took place in this company. Ribeye samples were taken for chemical, physical and sensory analyzes.

Table 1. Animal identification, pedigree, date of birth, date of slaughter and slaughter weight of domestic yak, yattle and Galloway bulls

Animal identification	Pedigree	Date of birth	Date of slaughter	Slaughter weight (kg)
CZ732624081	Domestic yak	01.01.2018	25.03.2022	365
CZ754064081	Yak/cattle Q50 Y25 C25	15.08.2018	25.03.2022	587
CZ000780685 071	W100	08.10.2019	09.03.2022	596
CZ000791806 071	W100	01.10.2019	09.03.2022	613
CZ000714696 071	W100	28.06.2019	09.03.2022	641
CZ000804160 071	W100	08.10.2019	09.03.2022	602
CZ000780666 071	W100	28.06.2019	09.03.2022	654

Note: W - Galloway, Q - Blonde d'Aquitaine, Y - Limousine, C – Simmental-fleckvieh

2.1.2. Machines

pH - Testo602-pH2-CONRAD prob

Tenderness - TA.XT texturometer plus Stable Micor Systems TM - Warner-Bratzler knife (Photo No. 4)

Juiciness - TA.XT texturometer plus Stable Micor Systems TM - 50 mm compression prob

Photo 1. Domestic yak



Photo 2. Yattle



Photo 3. Galloway



Photo 4. TA.XT texturometer



2.2. Methodology

Maturation took place in a refrigerator at a constant temperature of 4 °C, each slice of meat was 2 cm high and was vacuum-packed separately. Maturation intervals were set at 7, 14, 21 and 28 days after slaughter. Before grilling, the pH was measured, the measurement took place in the cutting area of the muscle with the Testo602-pH2CONRAD probe. The samples were grilled without added fat on a double-sided grill while the grill plates were heated to 180 °C. The grilling time of the sample was 5 minutes. Weight loss by heat treatment during grilling was determined by weighing the samples before and after grilling and subsequent dripping for 5 minutes. Percentage weight loss was calculated = ((weight of meat per raw - weight after grilling and subsequent dripping) / weight of meat per raw) x 100. After dripping, the slice was cut into about 5 strips 1.5 cm thick. Shear force in kg required to cut the meat strip to determine tenderness and was measured using ten sections of a V-shaped Warner-Bratzler knife on a TA.XT.plus Stable Micro System texturometer. The probe speed when cutting the sample was 3.33 mm.sec-s. The compression force in kg required to determine juiciness was measured using a 50 mm compression probe on a TA.XT texturometer plus Stable Micor Systems TM, the depth of compression of the probe was 13 mm, the length of compression lasted 10 s. The raw part of every sample was frozen and stored. The determination of individual indicators - dry matter, proteins and fat was performed according to ČSN 57 0185. For each sample, 2 determinations were performed for each indicator. An average value was calculated from these two determinations. Sensory analyzes were also carried out with the help of 10 specialists. The appearance of the raw meat was evaluated - color and fatness. For grilled meat (a strip of meat 2 cm wide, 2 cm high and grilled for 5 minutes at 180 °C), the aroma, tenderness / texture - by touch and bite, juiciness and taste were evaluated.

For statistical data processing was used STATISTICA data analysis software, version 10 (Staf-Soft, Inc.).

3. RESULTS AND DISCUSSION

The basic composition, i.e. the content of dry matter, protein and fat content in the samples of ribeye of domestic yak, yattle and 5 Galloway bulls during the four weeks of maturation are shown in Table No. 2.

Table 2. Dry matter content (%), protein content (%) and fat content (%) in the ribeye of domestic yak, yattle and Galloway bulls during meat maturation.

Animal	Dry matter (%)	Proteins (%)	Fat (%)
1 st week of meat maturation			
Domestic yak	33.98	21.49	6.35
Yattle	29.56	21.15	4.76
Galloway bulls	26.18	22.16	2.27
2 nd week of meat maturation			
Domestic yak	34.04	21.56	6.28
Yattle	29.62	21.05	4.89
Galloway bulls	26.27	22.23	2.22
3 rd week of meat maturation			
Domestic yak	34.21	21.43	6.41
Yattle	29.72	21.18	4.95
Galloway bulls	26.36	22.31	2.41
4 th week of meat maturation			
Domestic yak	34.23	21.33	6.37
Yattle	29.75	21.29	4.79
Galloway bulls	26.31	22.30	2.36

The measured values of 5 Galloway bulls agreed with the average contents of dry matter (25.75 %, 25.70 %, 25.73 % and 25.94 %, min. 23.29 %, max. 29.08 %), protein (22.73 %, 22.18 %, 22, 48 % and 22.38 %, min. 20.88 %, max. 25.02 %) and fat (1.66 %, 1.72 %, 1.96 % and 2.28 %, min. 0.14 %, max. 6.10 %) of ribeye of Galloway crossbreeds during the four weeks of maturation (Dufek et al., 2018) and with values of Filipčík et al. (2015) who analyzed ribeye of 72 Galloway bulls (dry matter 25.59 %, proteins 21.41 %, fat 1.83 %). The content of dry matter, protein and fat in domestic yak meat, with the exception of dry matter, for which slightly lower values were measured, agreed with the results of Zi et al. (2004), who analyzed the ribeye of 20 bulls (2.5 to 6.5 years), 7 females (4.5 years) and 11 steers (4.5 - 5.5 years) of domestic yak. Zi et. al., 2004 measured values in the range of 24.99 - 31.93 % dry matter, 19.98 - 22.58 % proteins, 2.52 - 10.86 % fat. They found that meat of yak steers contained a higher percentage of fat than meat of yak bulls. The dry matter, protein and fat content of a yattle coincided with the results of a study by Cao et al. (2018), who measured 31.68 % dry matter, 22.31 % proteins and 5.02 % fat in female yattles. No statistically significant difference ($p \geq 0.05$) was found in dry matter, protein and fat content during meat maturation in all animals. These findings are confirmed by Dufek et al. (2018), who evaluated changes in these parameters during the 4 weeks of meat maturation in Galloway crossbreed bulls. There was a statistically highly significant difference in dry matter, protein and fat content between domestic yak, yattle and Galloway bulls ($p \leq 0.01$).

The value of pH, temperature of samples before grilling (°C), weight of individual samples (g) and weight loss by grilling (g, %) during meat maturation of ribeye of domestic yak, yattle and Galloway bulls are summarized in Table No. 3.

Table 3. pH value, temperature (°C), weight before and after grilling (g), weight loss by grilling (g, %) during the maturation of ribeye of domestic yak, yattle and Galloway bulls.

Animal	pH	Temperature (°C)	Weight before grilling (g)	Weight after grilling (g)	Weight loss by grilling (g)	Weight loss by grilling (%)
1 st week of meat maturation						
Domes-tic yak	6.2	12.2	170	142	28	16.47
Yattle	5.5	12.7	250	198	52	20.80
Gallo-way bulls	5.6	12.7	297	202	96	31.90
2 nd week of meat maturation						
Domes-tic yak	5.6	12.6	172	135	37	21.51
Yattle	5.5	11.3	212	158	54	25.47
Gallo-way bulls	5.5	11.8	283	196	87	31.29
3 rd week of meat maturation						
Domes-tic yak	6	13.0	275	201	74	26.91
Yattle	5.3	12.5	286	212	74	25.87
Gallo-way bulls	5.3	11.9	220	139	81	37.27
4 th week of meat maturation						
Domes-tic yak	6.2	12.9	152	106	46	30.26
Yattle	5.5	12.6	205	135	70	34.15
Gallo-way bulls	5.7	13.2	271	180	91	38.64

Standard development of pH changes during meat maturation was found for the pH values of domestic yak, yattle and Galloway bulls. Post-mortem pH values are consistent with results of Dufek et. al. (2018), who measured the average pH of Galloway crossbreed bulls in the first week after slaughter (5.66), with the results of Zi et al. (2004) who measured the pH of ribeye 24 h post mortem in domestic yaks in the range of 5.84 - 6.11 and with Cao et al. (2018), who measured the pH of yattles first week after slaughter (5.48). As for weight loss by grilling, similar results were achieved by Dufek et al. (2018), who evaluated

weight loss by grilling during four weeks of meat maturation in Galloway crossbreed bulls. During meat maturation, average weight losses by grilling were 30.3 % three days after slaughter, 32.24 % after two weeks of meat maturation, 33.36 % after three weeks of maturation and 30.36 % after four weeks of maturation (max. 43.55 %). It was found that during meat maturation there is a statistically highly significant ($p \leq 0.01$) increase in weight loss by grilling in domestic yak, yattle and Galloway bulls, which is confirmed by the results of Dufek et al. (2018), who also found a statistically significant increase in the weight loss of Galloway crossbreeds bulls meat during maturation ($p \leq 0.01$). There was a statistically significant difference ($p \leq 0.05$) in the weight loss by grilling between the domestic yak together with the yattle against Galloway bulls ($p \leq 0.05$).

Values of shear force (kg) expressing tenderness of meat (Picture No. 1) and values of compression force (kg) and pressing loss expressing juiciness of meat (Picture No. 1) during ribeye maturation of domestic yak, yattle and Galloway bulls are summarized in Table No. 4.

Table 4. The tenderness - shear force (kg) and juiciness - compression force (kg) and pressing loss (%) during the maturation of ribeye of domestic yak, yattle and Galloway bulls

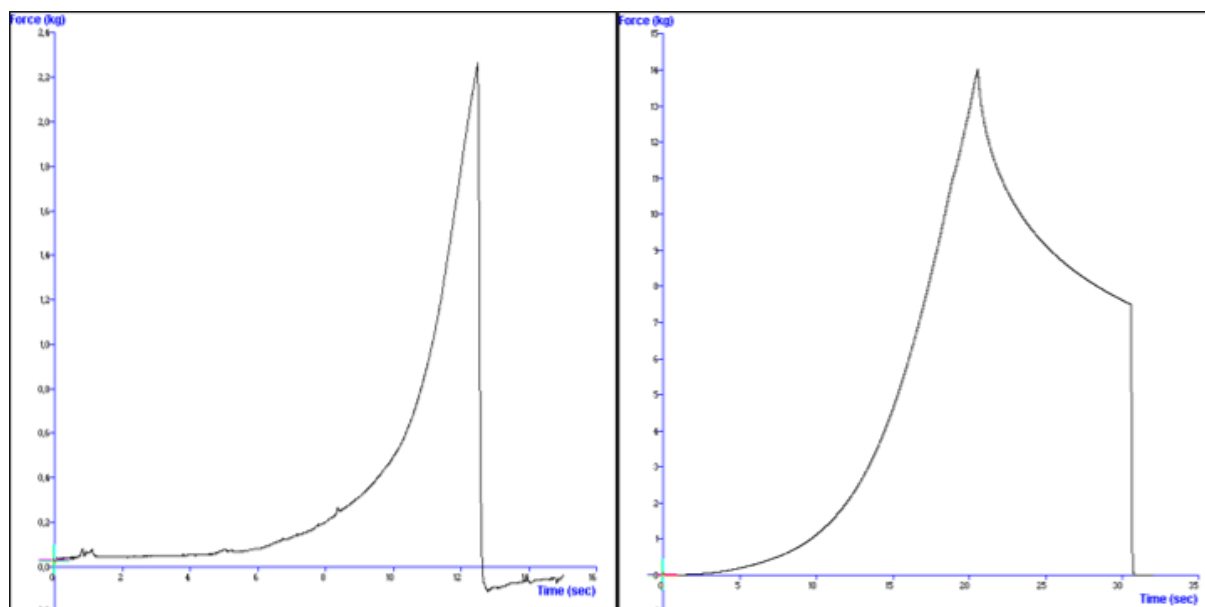
Animal	Tenderness			Juiciness			
	Shear force (kg)	S.D.	Coefficient of variation	Compression force (kg)	S.D.	Coefficient of variation	Pressing loss (%)
1 st week of meat maturation							
Domestic yak	4.547	1.042	22.913	16.953	7.870	48.127	8.930
Yattle	4.161	0.983	23.637	18.945	5.736	30.275	13.617
Galloways	5.594	2.330	39.626	23.609	9.497	43.949	5.693
2 nd week of meat maturation							
Domestic yak	3.728	0.988	20.456	17.218	3.604	13.241	7.404
Yattle	3.190	0.723	35.564	10.853	8.899	51.994	5.136
Galloways	4.474	1.837	53.547	22.842	7.663	34.866	5.489
3 rd week of meat maturation							
Domestic yak	2.133	0.654	26.868	11.114	3.901	35.096	6.290
Yattle	2.034	0.640	31.466	10.526	7.507	23.812	6.624
Galloways	2.317	0.731	33.033	22.716	5.829	24.745	4.537
4 th week of meat maturation							
Domestic yak	2.037	0.387	15.267	4.504	1.211	26.885	6.613
Yattle	1.983	0.561	22.612	9.261	6.275	18.866	6.772
Galloways	2.168	0.784	41.806	21.807	6.542	34.882	4.484

The average value of shear force expressing the ribeye tenderness of 5 Galloway bulls is 3.64 kg. Rather, this value coincided with the average value for beef measured by Dikeman et al. (2005), which is

4.61 kg (min. 3.75 kg) than with Cain et al. (2003) who reported an average value 7.74 kg or with Dufek et al. (2018), who measured an average shear force value 7.35 kg, which confirms the above-average tenderness of the meat of these Galloway bulls. The shear force of the ribeye of domestic yak was 3.11 kg, which is substantially lower than the average shear force value 9.29 kg, which was measured by Xiong et al. (2021) in the ribeye of 6 male yaks from China, which indicates a substantially higher tenderness of the meat of this animal. The shear force of ribeye of yattle 2.84 kg is also lower than the results of the study by Cao et al. (2018), who measured sheer force value 5.84 kg in yattle female, which proves its high tenderness. Increasing tenderness, resp. shear force decrease in the ribeye of domestic yak, yattle and Galloway bulls during meat maturation was statistically highly significant ($p \leq 0.01$), which is confirmed by the work of Dufek et al. (2018), who reached the same conclusions in Galloway crossbreed bulls, and Wana et al. (2011), who detected changes in tenderness of 181 domestic yaks (2 - 4 years) during three weeks of maturation. Between the tenderness of meat, resp. the shear force of domestic yak, yattle and Galloway bulls did not show a statistically significant difference ($p \geq 0.05$), but the results show that highest tenderness was measured in meat of yattle followed by domestic yak.

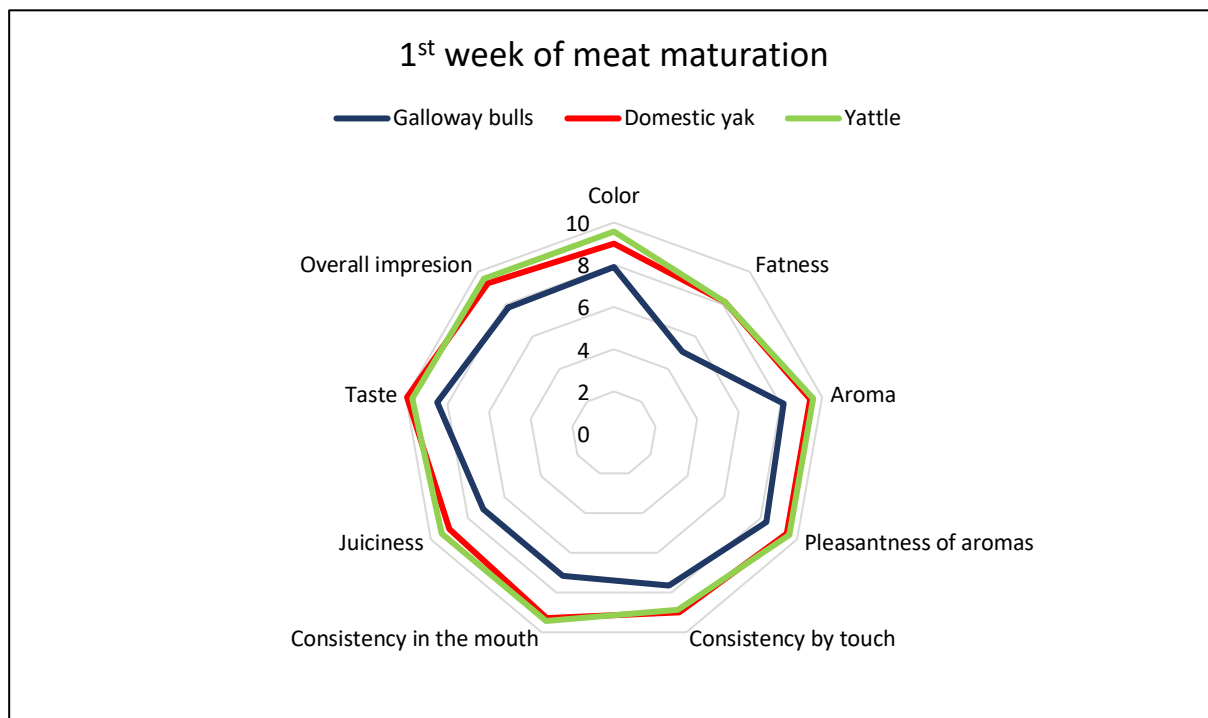
During meat maturation, compression force decreased statistically highly significantly ($p \leq 0.01$) in the analysis of the pressing loss of the ribeye of the domestic yak and the yattle which indicates an increasing tenderness of the meat. This could not be proved in Galloway bulls ($p \geq 0.05$). During meat maturation, the loss by pressing decreased statistically highly significantly ($p \leq 0.01$) and the overall juiciness of the meat gradually decreased during the maturation, which also corresponds to the increasing weight losses by grilling. The same conclusions were reached by Wan et al. (2011), who conducted a study of pressing losses on ribeye during the three weeks of meat maturation of 181 domestic yaks with a statistically highly significant difference ($p \leq 0.01$). A statistically highly significant difference ($p \leq 0.01$) was demonstrated in the compression force analysis of ribeye of the domestic yak together with the yattle against Galloway bulls, which proves the higher tenderness of the yak and yattle meat. A statistically highly significant difference ($p \leq 0.01$) was found between domestic yak and Galloway bulls, which indicates a higher juiciness of domestic yak meat.

Picture 1. Texturometry a compressimetry of domestic yak

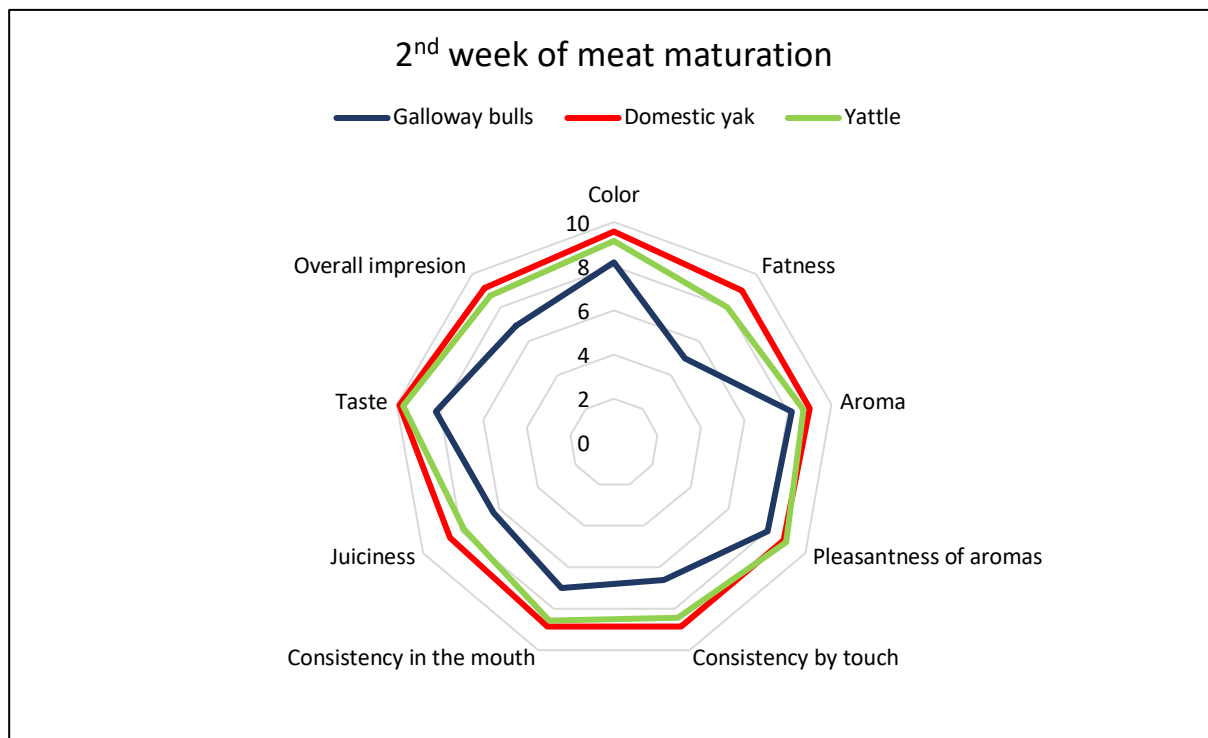


The results of sensory analysis, i.e. evaluation of appearance - color and fatness of raw meat and evaluation of aroma, consistency, juiciness and taste of ribeye of domestic yak, yattle and Galloway bulls during four weeks of meat maturation are summarized in Graphs No. 1 - 4.

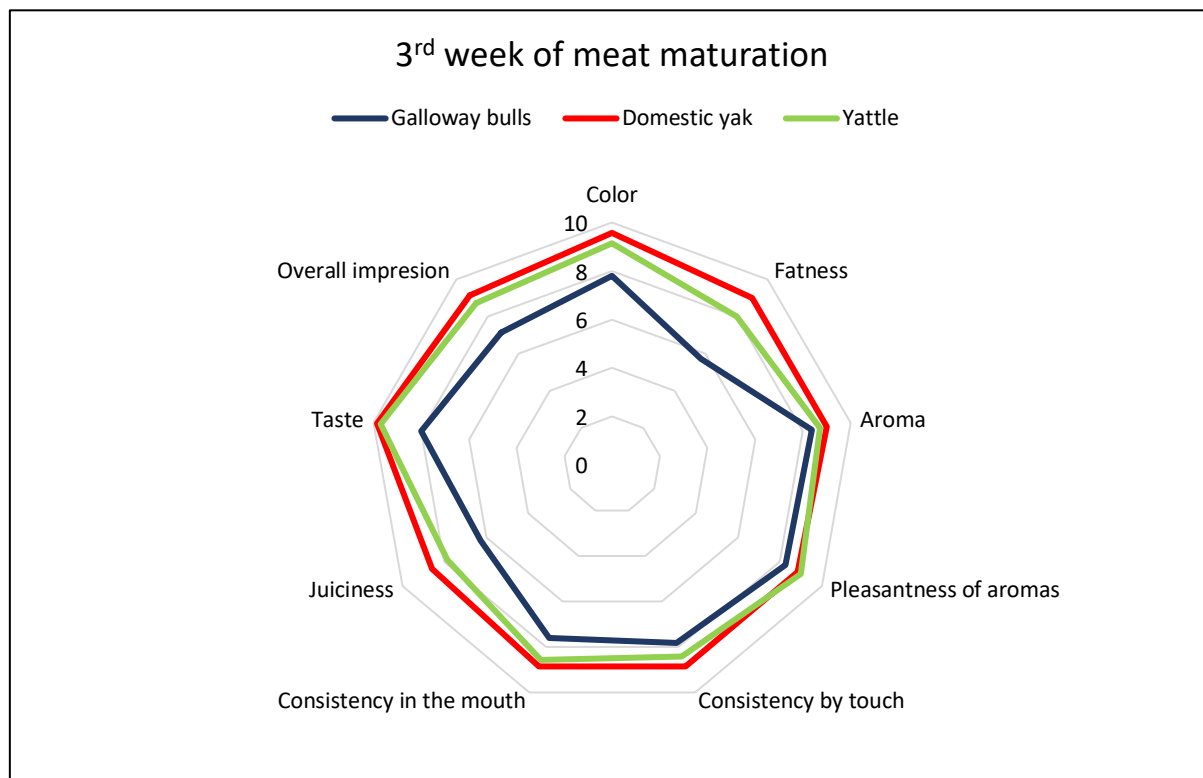
Graph 1. Sensoric analysis of ribeye domestic yak, yattle and Galloway bulls in first week of maturation



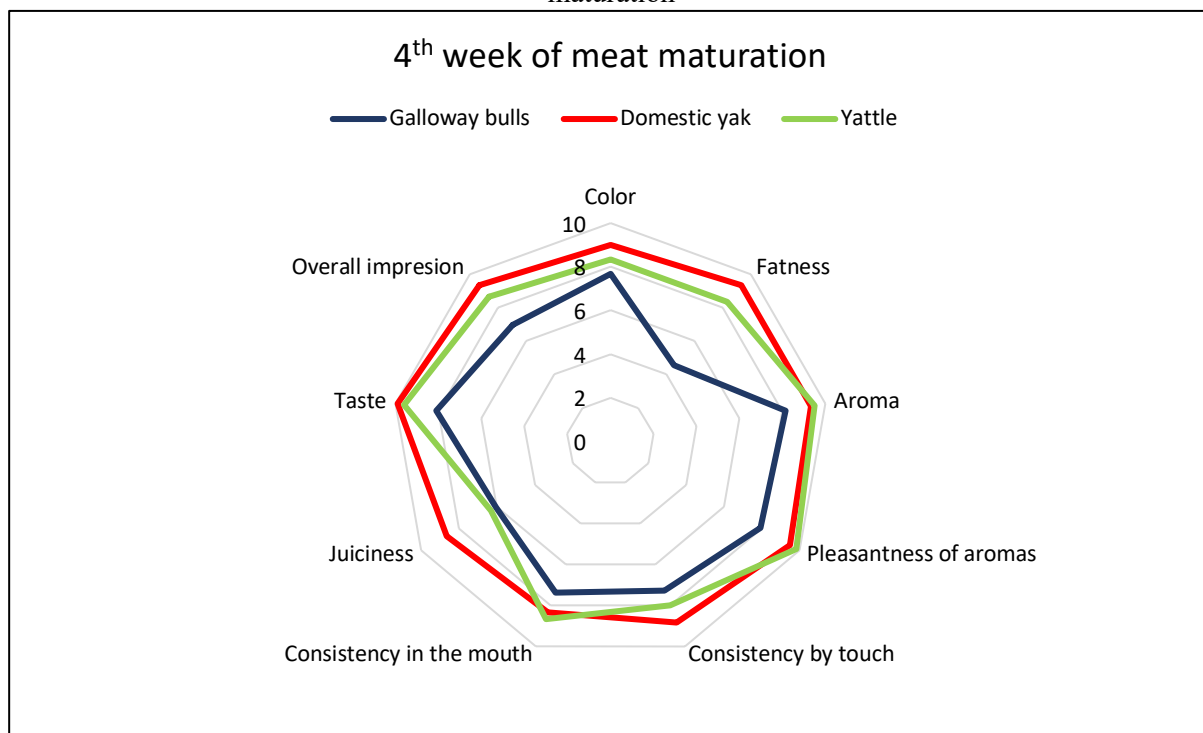
Graph 2. Sensoric analysis of ribeye domestic yak, yattle and Galloway bulls in second week of maturation



Graph 3. Sensoric analysis of ribeye domestic yak, yattle and Galloway bulls in third week of maturation

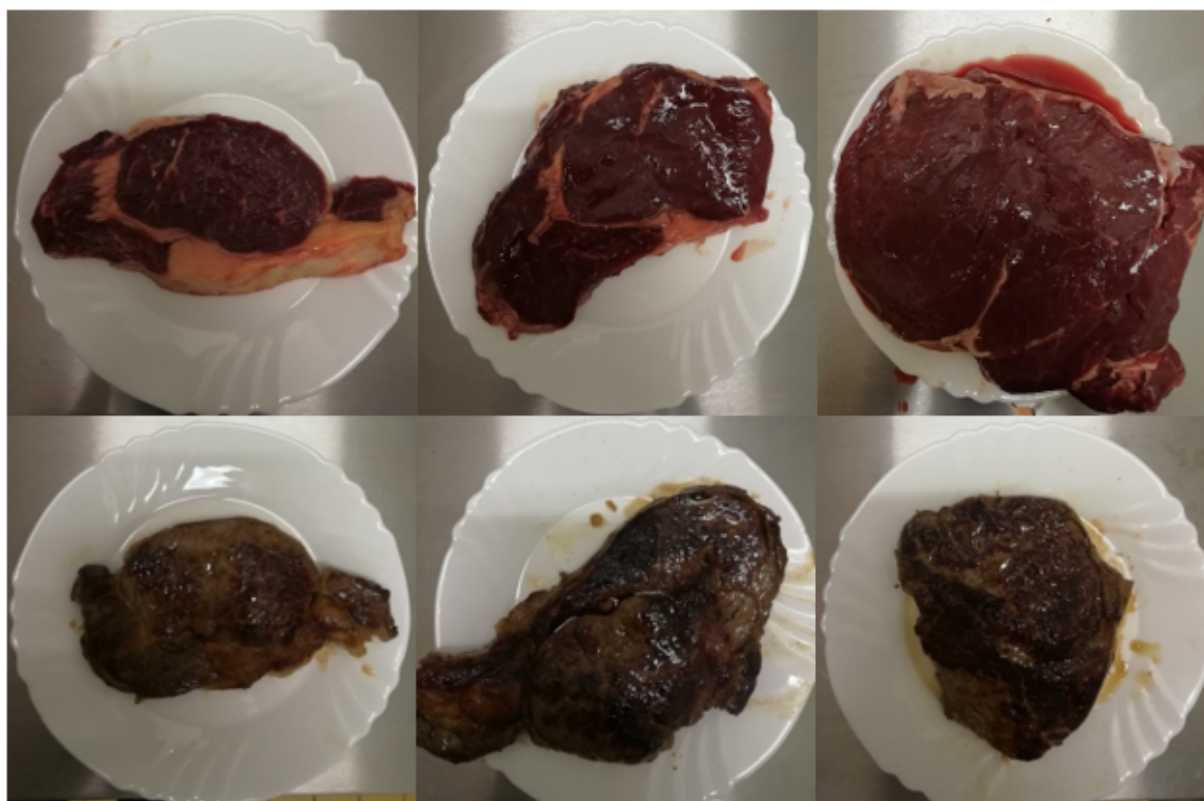


Graph 4. Sensoric analysis of ribeye domestic yak, yattle and Galloway bulls in fourth week of maturation



It is evident from graphs that ribeye of domestic yak and yattle were sensorically evaluated better in all parameters compared to Galloway bulls during entire meat maturation period. Color of domestic yak was evaluated as scarlet red and was the most prominent of all evaluated meats (Photo No. 5), followed by meat of yattle (Photo No. 5). Likewise, fatness was sensory evaluated most markedly in domestic yak and subsequently in yattle (Photo No. 5), but in general, intramuscular marbling was insignificant. The same conclusions were reached by Zi et al. (2004), who evaluated color of domestic yak meat as dark red to scarlet and intramuscular marbling weak. Aroma of yak meat was evaluated as pleasant and specific, for yattle meat it was evaluated as closer to domestic yak than to Galloways. Consistency was rated as very tender in all types of meat. Juiciness was rated as very high for all types of meat. Taste was evaluated as very good for Galloway bulls and as excellent and very above average for domestic yak and yattle. Sensory changes during meat maturation were evident in aroma of yak and yattle meat, which was rated the most distinctive and pleasant in fourth week of meat maturation, and in juiciness, which showed a decreasing tendency in yattle and Galloway bulls meat, which corresponds to the results of physical analyzes.

Photo 5. Raw and grilled meat of domestic yak, yattle and Galloway bull



4. CONCLUSIONS

During a study of meat maturation of ribeye of domestic yak, yattle and Galloway bulls, it was found that there was a statistically highly significant difference in dry matter, protein and fat content ($p \leq 0.01$). The highest values of dry matter and fat were shown by meat of domestic yak. It was found that during meat maturation there is a statistically highly significant ($p \leq 0.01$) increase in weight loss by grilling in all animal species and a statistically significant difference was found between domestic yak together with yattle against Galloway bulls ($p \leq 0.05$), which indicates a higher juiciness of domestic yak and yattle meat. Increasing tenderness during meat maturation, resp. decrease in shear force in the ribeye of all these animals was statistically highly significant ($p \leq 0.01$). During meat maturation, compression force decreased statistically highly significantly ($p \leq 0.01$) in analysis of compression loss in ribeye of

domestic yak and yattle and compression loss decreased in all animals ($p \leq 0.01$) and also overall juiciness of meat gradually decreased. A statistically highly significant difference ($p \leq 0.01$) was proved in compression force analysis of ribeye of domestic yak together with the yattle against Galloway bulls, which proves the higher tenderness of domestic yak and yattle meat. A statistically highly significant difference ($p \leq 0.01$) in pressing loss was found between domestic yak and Galloway bulls, which indicates a higher juiciness of domestic yak meat. From sensory analysis it is evident that ribeye of domestic yak and yattle were sensory evaluated better in all parameters in comparison with Galloway bulls during whole meat maturation period. Meat of domestic yak and yattle have potential to be included in diet of the Czech population, these meats have different sensoric characteristics compared to beef, but of the same quality, which Czech consumers could appreciate.

ACKNOWLEDGMENTS

The result was supported by the Ministry of Agriculture, institutional support MZE-RO1218.

REFERENCES

- Bailey, JF, Healy, B, Jianlin, H, Sherchand, L, Pradhan, SL, Tsendsuren, T, Foggin, JM, Gaillard, C, Steane, D, Zakharov, I, Bradley DG 2002 “Genetic variation of mitochondrial DNA within domestic yak populations” In book from Jianlin, H, Richard, C, Hanotte, O, Mcveigh, C, Rege JEO (eds) Yak production in central Asian highlands. 1st edition, International Livestock Research Institute, Nairobi, Kenya. pp. 572.
- Bazhenova, BA. Zabalueva, Y Y, Danilov, MB, Vtorushina, IA, Badmaeva, TM 2018 “Yak meat as a lucrative raw material for meat products”, *Food Processing, Techniques and Technology*, vol. 50, no. 3, pp.16-33.
- Caine, WR, Laalhus, J, Best, DR, Rdugan, ME, Jeremiah, LE 2003 “Relationship of texture profile analysis and Warner-Bratzler shear force with sensory characteristics of beef rib steaks”, *Meat Science*, vol. 64, no. 4, pp. 333-339.
- Cao, XK, Cheng, J, Huang, YZ, Wang, XG, Ma, YL, Peng, SJ, Chaogetu, B, Zhuoma, Z, Chen H 2019 “Growth performance and meat quality evaluations in three-way cross cattle developed for the tibetan plateau and their molecular understanding by integrative omics analysis”, *Journal of Agricultural and Food Chemistry*, vol. 67, no. 1, pp. 541–550.
- Crha, J 1999 Basics of zoology for VFU students. 1st reprint of texts from 1985. University of Veterinary and Pharmaceutical Sciences Brno, Faculty of Veterinary Hygiene and Ecology, Department of Biology and Zoology. VFU Brno.
- Czech-Moravian Association of Breeders 2022 “Statistics of the number of domestic yaks bred in the Czech Republic”, *Czech-Moravian Association of Breeders*, viewed 16 April 2022 <<https://www.cmsch.cz/evidence-a-oznacovani-zvirat/statistiky-ue/>>.
- Dikeman, ME, Pollak, EJ, Zhang, Z, Moser, DW, Gill, CA, Dressler, EA 2005 “Phenotypic ranges and relationships among carcass and meat palatability traits for fourteen cattle breeds, and heritabilities and expected progeny differences for Warner-Bratzler shear force in three beef cattle breeds”, *Journal of animal science*, vol. 83, no. 10, pp. 2461–2467.
- Dufek, A, Veselý, A, Vacátko, E, Látal, O 2018 “Meat quality in two slaughter-age groups of Wagyu-sired bulls from an extensive”, *Výzkum v chovu skotu*, vol. 60, no. 2, pp. 13-23.
- Durmowicz, AG, Hofmeister, S, Kadyraliev, TK, Aldashev, AA, Stenmark, KR 1993 “Functional and structural adaptation of the yak pulmonary circulation to residence at high altitude” *Journal of applied psychology*, vol. 74, no. 5, pp. 2276-2285.
- Filipčík, R, Voříšková, J, Dufek, A, Pavlík, A, Hošek M 2015 “Comparison of the carcass and beef quality of the czech fleckvieh bulls with genotype tt and ct for leptin and bulls of galloway and charolais

breeds”, *Acta Universitatis Agriculturae Et Silviculturae Mendelianae Brunensis*, vol. 63, no. 1, pp. 29-37.

Choudhary, R, Yadav, DS, Yadav, J, Jamra, MS, Singh, M 2020 “Importance of yak to himalayan culture: A review”, *Raksha technical review*, vol. 53, no. 1, pp. 37-38.

Han, J 2014 *Encyclopedia of Global Archaeology*, “Yak: Domestication”, Smith, C (ed.), Springer Science+Business Media. New York.

Huang, Q, Dong, K, Wang, Q, Huang, X, Wang, G, An, F, Luo, Z, Luo, P 2022 “Changes in volatile flavor of yak meat during oxidation based on multi-omics”, *Food Chemistry*, vol. 371, pp. 103-131.

Jialin, B, Mingqiang, W, Zhonglin, L, Chesworth, JM 1998 “Meat production from crossbred and domestic yaks in China”, *Animal Science*, vol. 66, no. 2, pp. 465–469.

Jiang, H 2002 “Processing and use of yak slaughter by-products” In Book from Jianlin, H, Richard, C, Hanotte, O, Mcveigh, C, Rege, JEO (eds) *Yak production in central Asian highlands*. 1st edition, International Livestock Research Institute, Nairobi, Kenya. pp.572.

Juárez, M, López-Campos, Ó, Prieto, N, Roberts, J, Galbraith, J, Failla, S, Aalhus, JL 2019 “Carcass characteristics and meat quality of bison, buffalo, and yak. More than beef, pork and chicken – the production”, *Processing, and Quality Traits of Other Sources of Meat for Human Diet*, pp. 95-117.

Leslie, JRDM, Schaller, GB 2009 “*Bos grunniens* and *Bos mutus* (Artiodactyla: Bovidae)”, *Mammalian species*, vol. 836, no. 1, pp. 12-25.

Lhagvasuren, B, Munkhtsog, B 2002 “The yak population in Mongolia and its relation with snow leopards as a prey species” In book from Jianlin, H, Richard, C, Hanotte, O, Mcveigh, C, Rege, JEO (eds). *Yak production in central Asian highlands*. 1st edition, International Livestock Research Institute, Nairobi, Kenya. pp. 572.

Nguyen, TT, Genini, S, Me’Ne’Trey, F, Malek, M, Vogeli, P, Goe, MR, Stranzinger, G 2005 “Application of bovine microsatellite markers for genetic diversity analysis of Swiss yak (*Capra falconeri*)”, *Animal Genetics*, vol. 36, no. 2, pp. 484–489.

Popoola, IO, Soladoye, PO, Gaudette, NJ, Wismer, WV 2020 “A review of sensory and consumer-related factors influencing the acceptance of red meats from alternative animal species”, *Food Reviews International*, Doi: 10.1080/87559129.2020.1860084.

Qiu, Q, Zhang, G, Wang, J, Ye, Z, Cao, Ch, Hu, Q, Kim, J, Larkin, DM, Auvil, L, Capitanu, B, Ma, J, Lewin, HA, Qian, X, Lang, Y, Zhou, R, Wang, L, Wang, K, Xia, J, Liao, S, Pan, S, Lu, X, Hou, H, Wang, Y, Zang, X, Yin, Y, Ma, H, Zhang, J, Wang, Z, Zhang, Y, Zhang, D, Yonezawa, T, Hasegawa, M, Zhong, Y, Liu, W, Zhang, Y, Huang, Z, Zhang, S, Long, R, Yang, H, Wang, J, Lenstra, AJ, Cooper, DN, Wu, Y, Wang, J, Shi, P, Wang, J, Liu, J 2012 “The yak genome and adaptation to life at high altitude”, *Nature Genetics*, vol. 44, pp. 946–949.

Škaryd, V 2022 “Statistics of registered domestic yaks in 2021”, *Ministry of Agriculture of the Czech Republic, Section of organic farming, commodities, research and education, Department of agricultural commodities, Department of animal commodities and central animal records*, viewed 25 April 2022 <<https://eagri.cz/public/web/mze/farmar/EZP/statistiky/>>.

Wan, HL, Zhang, LP, Brown, MA, Wu, XJ, Wang, JH, Wu, JP 2011 “Influence of aging days and age at harvest on the meat quality characteristics of Gannan black yak”, *Journal of Animal and Veterinary Advances*, vol. 10, no. 9, pp. 1089-1096.

Wiener, G, Jialnlin, H, Ruijun, L 2003 *The yak*. Second edition. Food and agriculture organization of the United Nations Regional Office for Asia and the Pacific. Bangkok, Thailand.

Wiener, G 2002 “Adaptation of yak to non-typical environments: A preliminary survey of yak in North America” In book from Jianlin, H, Richard, C, Hanotte, O, Mcveigh, C, Rege, JEO (eds) *Yak production in central Asian highlands*. 1st edition, International Livestock Research Institute, Nairobi, Kenya. pp.572.

Will, DH, Hicks, JL, Card, CS, Alexander, AF 1975 “Inherited susceptibility of cattle to high-altitude pulmonary hypertension”, *Journal of applied psychology*, vol. 38, pp. 491–494.

Xiong, L, Pei, J, Chu, M, Wu, X, Kalwar, Q, Yan, P, Guo, X 2021 “Fat deposition in the muscle of female and male yak and the correlation of yak meat quality with fat”, *Animals*, vol. 11, no. 7, pp. 2142–2165.

Xu, T, Xu, S, Hu, L, Zhao, N, Liu, Z, Ma, L, Liu, H, Zhao X 2017 “Effect of dietary types on feed intakes, growth performance and economic benefit in tibetan sheep and yaks on the Qinghai-Tibet plateau during cold season”, *PLoS ONE*, vol. 12, no. 1.

Zi, XD, Zhong, GH, Wen, YL, Zhong, JC, Liu, CL, Ni, YA, Yezi, YH, Ashi, MG 2004 “Growth performance, carcass composition and meat quality of Jiulong-yak (*Bos grunniens*)”, *Asian Australas Journal of Animal Science*, vol. 17, no. 3, pp. 410–414.