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Abstract

The term venison in literature can be used in different meanings. Originally, ´venison´ referred to meat of any large game species suitable for human consumption. However, it should be noted that game meat comes not only from wild ungulates and other species, but also from farmed game animals. Nowadays term ´venison´ is used to define meat of antler ungulates, i.e. free-living or farmed cervids. Although production and consumption of venison are generally still modest, the both trends are constantly increasing. The most numerous cervids used for venison production in different systems worldwide are red deer (*Cervus elaphus*), fallow deer (*Dama dama*), elk (*Cervus canadensis*), axis deer (*Axis axis*) and reindeer (*Rangifer tarandus*). During last decade numerous studies have been published presenting different aspects of venison quality and factors affecting it. Thus, the aim of this paper was to give review of the quality and nutritional properties of venison.

Keywords: game meat, red deer, fallow deer, protein, fatty acids

Introduction

Due to world population growth, demand for animal protein increases steadily. For example, during last six decades global meat consumption has increased from 23 kg per capita annualy in 1961 to 43 kg in 2022 (OECD/FAO, 2022). In response to increased meat demand, alternative meat sources are imerging. Alternative animal species include horses, pigeons, ratites (mainly ostrich) and wild or farmed game species (Polawska et al., 2013). The term venison refers to meat derived from cervids (wild or farmed) and rates of global trade of venison are increasing (Kudračova et al., 2018). During last fifthy years trade has doubled and is currently around two million tonnes (Costa et al., 2016).

Meat is an important source of protein in the human diet, but during several last decades red meat has been considered as possible health risk. Health concerns were rising from food safety crises and livestock diseasses (such as ´mad cow´ disease) as well as recommendations to limit red meat intake due to its high fat and cholesterol content (Binnie et al., 2014). Venison is imerging as solution and non-traditional alternative to red meat from domestic ruminants. Alternative meat sources are preferred by so-called ″modern attentive consumers″ i.e. 41-50 year old consumers belonging to a middle cultural and professional status (Polawska et al., 2013). In general, meat from antlered ungulates is known to be lean and low in fat. Due to grass-based diet and limited contact with pharmaceuticals used in domestic animal disease treatments, venison is considered organic and safe for consumption (Barton et al., 2014; Wiklund et al., 2014). Consumer nowadays are highly interested in animal welfare, additives used in meat production and environmental pollution (Volpelli et al., 2003). Regading these aspects, vension harvested from free-living animals meets all the requirements. In case of deer farming there are some activities that are and can be questionable. These include castration of stags, intensive feeding and, as a next step human involvement in reproduction in form of artificial insemination, embryo transfer, vaccination etc. The use of hormones to increase the growth rate of deer has been rejected by all deer industries around the world. All of the above, if accepted as management practices in deer farming could contribute to damaging consumers´ perception of venison and its image as an organic and safe product (Hoffman and Wiklund, 2006).

Venison production and consumption

Venison is produced from cervids, farmed or harvested during hunting. Depending on the region of the world, the ratio between the number of wild and farmed deer differs. New Zeland and Australia are well knownfor their established deer farming systems . Althoughg deer for centuries were kept for antler velvet in Asia (mainly China), modern deer farming began at early 1970s in New Zealand, where deer farming was first legalized (Janiszewski et al., 2008; Kudračova et al., 2018). The estimated number of deers farmed globaly and the number of deer farms are presented in Table 1.

Table 1. Number of cervid animals and farms worldwide

Country	Number of animals on farms	Number of farms	Wild deer population	Number of wild cervids harvested annually
New Zealand[1]	1.700.000	3.000	250.000[d]	70.000[d]
Australia[2]	200.000	1.400	2.000.000	120.000[c]
Canada[3]	162.000	2.200	400.000	12.000[b]
Europe[4]	280.000	10.000	2.000.000	450.000[a]
USA[5]	250.000	10.000	25.000.000	6.300.000[e]

[1]Hoffman and Wiklund (2006); [2]https://www.deerfarming.com.au/wp-content/uploads/2016/11/DFH03-Introduction.pdf; [3] Hoffman and Wiklund (2006); [4] https://www.fedfa.com/fedfa-members/
[5]https://deerfarmer.com/resources/elk-farming-north-america-history;[a] https://www.tandfonline.com/doi/abs/10.2478/v10043-010-0038-z; [b]red deer and moose; https://www2.gnb.ca/content/dam/gnb/Departments/nr-rn/pdf/en/Wildlife/2020-big-game-report.pdf; [c] https://www.austdeer.com.au/@news/2022/10/19/1385200/2021-deer-harvest-report; [d] https://www.tandfonline.com/doi/pdf/10.1080/03014223.1993.10420359; [e] https://deerassociation.com/the-biggest-buck-harvest-in-21-years/

Red deer (*Cervus elaphus*) and fallow deer (*Dama dama*) are the most abundant cervid species in Europe, New Zealand and Australia. In the Nordic countries, Russia and Alaska, reindeer (*Rangifer tarandus*) are reared in semi-domesticated systems. Wapiti (*Cervus canadensis*), fallow deer, sixa deer (*Cervus nippon*) and axis deer (*Axis axis*) are present on farms in North America and in the USA, deer farming in one of the fastest growing industries in rural areas (Hoffman and Wiklund, 2006; Danszkiewicz et al., 2015; Kudračova et al., 2018).

Worldwide, deer are kept in different farming conditions, some of which are very similar to those in nature, while others are very similar to intensive livestock production systems (Volpelli et al., 2002). But farming has contributed to making venison more accesible to consumers and to a renewed interest in deer meat. However, in Europe,the majority of venison meat (two-thirds) is harvested during hunting (Kudračova et al., 2018). Likewise, venison consumption in EU varies from 0.08 kg/capita/year (Poland, Portugal), 5.7 kg/capita/year in France up to 8.4. kg/capita/year in Andalusian hunter families (Milczarek et al., 2021).

Venison quality and nutritional properties

Meat quality includes physical, chemical and organoleptic meat attributes that have affect consumer purchasing decision and satisfaction (Purslow, 2017). These attributes are influenced by animal species/breed, sex, muscle type, nutrition, pre-slaughter handling and post-mortem changes in the meat such as pH, temperature and ageing) (Kudračova et al., 2018). Besides all the factors previously mentioned, the quality of venison is also influenced by the production system (wild vs farmed), season, environment and climate. Thus, venison quality can be very variable (Milczarek et al., 2021).

Among the physical parameters of meat quality, the ultimate pH value (pH_u; 24h after slaughter) is one of the most important. This value is associated with meat colour, tenderness and water-holding capacity. After slaughter deer meat has pH_{45} from 6.5 to 7.2 and within 24-48 h *post mortem* this value is in range of 6.0-5.4. The rate of post-mortem pH decline in deer meat is highly variable and depended on complex interactions between previously mentioned factors (Volpelli et al., 2003). Namely, in farm animals, a characteristic relationship has been found between *ante-mortem* handling and *post-mortem* pH_u due to glycogen depletion (more stress pre-mortem, less pH_u decline). However, this is not case for wild or farmed deer and it is suggested that more complex interactions occur than are known for domestic farm animals (Pollard et al., 2002). Farm-raised deer were reported to have a higher percentage of meat with pH_u >6.0 (57%), while meat samples from wild harvested deer were all in the pH_u <6.0 category (Danszkiewicz et al., 2015).

The colour of venison is intense red and as such is typical feature of deer meat. This is one of potential confunding physical characteristcs of venison quality, as consumers associate dark red colour with meat originating from older animals and dark, firm and dry defect of meat (Kudračova et al., 2018). Values of lightness (L^*) and chromaticity (a^*, b^*) in venison strongly depend on the production system. Indeed, wild, grass-fed deer have darker meat than farmed ones finished on concentrate. As wild animals are more physically active, higher content of muscle myoglobin is responsible for the darker colour than farm-raised deer (Danszkiewicz et al., 2015). Also, low colour stability is characteristic of deer meat. . This is thought to be due to high content of oxidants, like iron and copper, in venison (Ramanzin et al., 2010). It is recommended to modify feeding regime in farming systems and implement a pasture-based finishing diet instead of concentrate feeding or supplement deer diet with vitamin E (Hoffman and Wiklund, 2006). Reported values of red deer meat colour parameters ranged between 29.88-39.7 for lightness (L^*) , 9.35-15.6 for redness (a^*) and 4.10-12.2 for yellowness (b^*), regardless of farming system, sex, age or anatomic position of muscle (Volpelli et al., 2003; Purchas et al., 2010; Bureš et al., 2014; Serrano et al., 2018). For fallow deer, the following values of colour parameters are reported: 29.88-40.01 for lightness, 11.9-16.37 for redness and 6.2-11.13 for yellowness, regardless of farming system, sex, age or anatomic position of muscle (Danszkewicz et al., 2015; Piaskowska et al., 2015; Stanisz et al., 2015).

Analyses showed that meat obtained from farmed-raised deer usually has lower drip loss, higher thawing loss and lower cooking loss than meat harvested from wild ones. However, there are major variations in results depending on sex, muscle type and production system (Kudračova et al., 2018). Reported values of drip loss for red deer and fallow deer meat range between 1.09-3.29%, cooking loss between 25.63-33.45%, thawing loss between 9.2-14.67% and shear force between 19.17-53.7 N (Purchas et al., 2010; Bureš et al., 2015; Piaskowska et al., 2015; Stanisz et al., 2015; Ludwiczak et al., 2017). Regarding tenderness rating according shear force values of beef (Silva et al. 2015), venison tenderness ranges from tender to tough. Effect of different *post-mortem* methods to improve venison tenderness has been studied (Hutchinson et al., 2014). It was found that venison from pelvic-suspended deer carcasses was significantly more tender than venison from carcasses hung by Achilles tendon. There are limited data regarding different ageing treatments on venison quality. It was reported that prolonged storage (21 days, 4°C) results in increased cooking loss and reduced shear force of venison (Kim et al., 2017).

Regarding chemical composition, deer meat is preferable in human diet and has beneficial nutritional properties. Generally, venison has less calories (cca. 100 kcal/100 g meat) than meat of domestic animals (114-231 kcal/100 g meat) due to low content of fat. Average content of fat in venison is less than 3% (Hoffman and Wiklund, 2006). Venison can be considered as a rich source of protein (20-25%), with glutamine, aspartic acid, lysine, leucine and alanine being the most abundant aminoacids. Reported ash content in venison is 1-2% (Strazdina et al., 2013; Daszkiewicz et al., 2015; Serrano et al., 2019). Venison, like the meat of other game species, is often associated with higher shear force values and is less tender. This can be attributed to collagen content and its lower solubility. Increased collagen content in meat may also imply lower nutritional value, as collagen lacks some aminoacids, i.e. tryptophan (essential) and tyrosine (non-essential) (Volpelli et al., 2003; Purslow, 2005).

Fat content in meat increases with the age of deer. Concentrate-fed and farm-raised deer usually have higher fat content than those pasture-fed or in the wild (Vollpeli et al., 2003). The venison intramuscular fat content ranges between 0.35-10.9 g/100 g lean meat and it is usually several time lower than in domestic ruminants (Bureš et al., 2014; Kudračova et al., 2018). Compared to beef, venison has higher protein content and about four times lower fat content (Bureš et al., 2015). From a nutritional perspective, t the fatty acid composition of meat has important role in human diet. The most abundant fatty acids in venison are C16:0, then C18:1n-9, C18:2n-6 and C18:0, while in beef they are C18:1n-9, C16:0 and C18:0 (Bureš et al., 2015). Considering individual fatty acids, venison has considerably higher content of essential C18:2n-6 and C18:3n-3 than beef, especially venison produced in grass-based systems and in wilderness (Purchas et al., 2010; Bureš et al., 2015). It was found that venison in general has lower content of conjugated linoleic acid (CLA) than conventionally produced beef. This is considered to be due to lower intramuscular fat content (IMF) of venison meat which mainly consists of triglycerides, target lipids for CLA deposition (Bureš et al., 2015; Kudračova et al., 2018). Considering sums of total (FA), saturated (SFA), mono- (MUFA) and poly- (PUFA) unsaturated fatty acids, it was found that venison has lower content of SFA and MUFA than beef (Bureš et al., 2015). Venison can have up to three times higher content of PUFA (mainly C20:4n-6, C20:5n-3 and C22:n-6) than beef (Polowska et al., 2013; Bureš et al., 2015). Despite similar content of precursors (C18:2n-6 and C18:3n-3) in synthesis, PUFA content varies in meat of red and fallow deer. These differences in content of individual PUFA are probably result of differences in activity of desaturases and elongation enzymes during conversion processes (Cherfaoui et al., 2012).

Beside content of individual fatty acids and they sums, the nutritional aspect of fat and fatty acids in meat is estimated through specific ratios, i.e. n-6/n-3 and PUFA/SFA. Recommended value for n-6/n-3 ratio is less than 4.0 and in wild harvested or grass-fed venison this ratio ranges from 2.1-3.3, while for meat from concentrate-finished systems it ranges between 4.5-9.6 (Volpelli et al. 2003, Bureš et al., 2015). Recommended value of PUFA/SFA ratio is above 0.4 and in venison ranges between 0.18-0.84, depending on production system. Higher PUFA/SFA ratio was reported in venison (0.68-0.84) than in beef (0.18-0.22) (Bureš et al., 2015; Kudračova et al., 2018).

Fatty acids affect meat firmness and flavour while during heat treatment lipid oxidation, Maillard reactions and similar processes produce volatile and odours components. Contribution of MUFA and PUFA to meat flavour is crucial (Wood et al., 2004). Higher PUFA content in grass-based diet results in development of game aroma, while concentrate-besed diet results in lower PUFA content and less ´gamey´ flavour (Wiklund et al., 2003; Bureš et al., 2015). However, higher PUFA content is also associated with lower oxidation stability of meat and meat products (Polowska et al., 2013). Regarding game aroma and flavour, consumer preferences can be positive and negative (Wiklund et al., 2003).

Beside production system of venison, fatty acid content differs according to sex. Namely, higher PUFA content and PUFA/SFA ratio were found in meat of male than female deer. Age should be also considered when analysing fatty acid composition since it was found that venison from older animals has higher MUFA and lower PUFA content. This is result of higher IMF content in older animals and changes in lipid fraction ratios with age (Purchas et al., 2010; Piaskowska et al., 2015).

In terms of mineral content, venison has higher levels of iron, potassium, phosphorous, zinc, copper and calcium than meat of domestic ruminants or other wild species (Vengušt and Vengušt, 2004; Grace et al., 2008). Mineral composition of venison is result of different plants grazed and browsed in natural habitat and mineral composition of soil where plants grow (Kudračova et al., 2018). Besides minerals, muscle and organs (mainly liver and kidney) of deer can be source of toxic elements, such as cadmium, lead or mercury. These elements are components of some plants (holm oak) and mushrooms eaten by deer and slightly higher concentrations can be found in tissues of older animals. However, available results regarding this matter show that heavy metals in venison are below limiting values in most cases (Kudračova et al., 2018).

Conclusions

Trends production and consumption of venison meat are positive and meat of different deer species can be considered as good alternative to red meat of domestic animal species. From a nutritional point of view, venison is a very valuable source of macro- (high protein content, low fat content, favourable fatty composition) and micro- (iron, zinc, copper) nutrients. Venison is dark red in colour and physical parameters such as thawing loss, cooking loss and tenderness can differ depending on the sex, age and production system (free-living or farmed). Future research is are needed to cover all aspects of venison quality, especially sensory characteristics and the effects of different production systems.

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Kakvoća i nutritivna svojstva mesa jelenske divljači

Sažetak

Pojam ´meso divljači´ **u** literaturi se koristi u različitim značenjima. Izvorno se 'meso divljači' odnosilo na meso bilo koje vrste krupne divljači koje je dobiveno lovom divljih **životinja** i bilo je prikladno za ljudsku prehranu. No, treba napomenuti da se meso divljači ne proizvodi samo od divljih, slobodnoživućih papkara i drugih vrsta, već i od farmski uzgojene divljači. Meso jelenske divljači je meso različitih vrsta jelena, slobodnoživućih ili farmski uzgojenih. Iako su proizvodnja i potrošnja mesa jelenske divljači općenito još uvijek skromni, oba trenda su u stalnom porastu. Najbrojnije vrste jelena u svijetu koje se koriste za proizvodnju mesa u različitim sustavima su jelen obični (*Cervus elaphus*), jelen lopatar (*Dama dama*), kanadski jelen (*Cervus canadensis*), jelen aksis (Axis axis) i sob (*Rangifer tarandus*). Tijekom posljednjeg desetljeća objavljena su brojna istraživanja koja prikazuju različite aspekte kvalitete mesa divljači i **čimbenike** koji je određuju. Stoga je cilj ovog rada bio dati prikaz kakvoće i nutritivnih svojstava mesa jelenske divljači.

Keywords: meso, jelen obični, jelen lopatar, fizikalna svojstva, kemijski sastav, nutritivna vrijednost