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Physical parameters of wild boar meat quality: a review

Fizikalni pokazatelji kakvoće mesa divlje svinje: pregled

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ABSTRACT

For centuries, game meat has been an important source of proteins, vitamins and minerals in the human diet. Interest for game meat during last few decades is increasing, mainly due to lower ecological footprint and a preferred chemical composition in comparison to the meat of domestic animals. In recent years, Europe has been facing an overpopulation of wild boars, which affects the availability of game meat to a wider niche of consumers. Therefore, wild game meat is a great alternative to others red meats and it has a great advantage on the world meat market. Regarding physical parameters of wild boar meat wide range of values can be found depending on analysed muscle type, sex, age, season and/or hunting technique. In general, same as meat of other large game species, wild boar meat is darker (lower L*), more red (higher a*) and colour parameter values can highly vary depending on previously mentioned factors. pH value usually ranges between 5.5 to 5.8, but also variations are often as wild boars have different *post-mortem* pH decline than domestic pigs. Expected cooking loss of wild boar meat is about 30% and higher, while meat tenderness measured as Warner-Bratzler shear force is usually higher than 40 N.

Keywords: wild boar, meat, pH, colour, water holding capacity, tenderness

SAŽETAK

Stoljećima je meso divljači važan izvor bjelančevina, vitamina i minerala u ljudskoj prehrani. Zanimanje za mesom divljači posljednjih je desetljeća u porastu, uglavnom zbog niskog ekološkog otiska i preferiranog kemijskog sastava u usporedbi s mesom domaćih životinja. Posljednjih godina Europa se suočava s porastom populacije divljih svinja, što utječe na dostupnost ovog mesa većem broju potrošača. Stoga je meso divljači izvrsna alternativa crvenom mesu domaćih životinja i ima veliku prednost na svjetskom tržištu mesa. Fizikalni parametri kakvoće mesa divlje svinje mogu poprimiti vrlo različite vrijednosti ovisno o anatomskoj poziciji mišića, spolu, dobi i/ili tehnici lova. Općenito, meso divlje svinje kao i meso drugih vrsta krupne divljači je tamnije (niže vrijednosti parametra boje L*) i crvenije (više vrijednosti parametra boje a*) te vrijednosti parametara boje mogu jako varirati ovisno o prije spomenutim čimbenicima. Obično pH vrijednost mesa divlje svinje je u raspon između 5,5 i 5,8, međutim moguća su veća odstupanja budući da post-mortalni pad pH u divlje svinje nije jednak onome u domaćih svinja. Očekivani kalo kuhanja iznosi oko 30% i više, dok otpor presijecanju kao mjera mekoće mesa obično iznosi više od 40 N.

Ključne riječi: divlja svinja, meso, pH, boja, sposobnost vezivanja vode, mekoća

INTRODUCTION

Wild boar (*Sus scrofa*) is a widespread species distributed throughout Europe, the Mediterranean and Asia, to Japan and Southeast Asia (Kamieniarz et al., 2020). It is a highly adaptable species, inhabiting habitats from atypical suburban and urban areas to natural areas such as agricultural land, grasslands, scrub and forests (Barrios-Garcia and Ballari, 2012). Wild boar is prized as a source of meat, bristles and trophies, and Europe has a long-standing tradition of hunting this game (Andrzejewski and Jezierski, 1978; Quirós-Fernández et al., 2017). The number of wild ungulates is expected to rise in Europe in the coming decade (Milner et al., 2006), which in turn will increase the availability of the meat of these species. Only adaptive, evidence-based wildlife management strategies focusing on the local circumstances can ensure successfully control of the wild boar population. Monitoring populations and understanding its growth are essential if countries are to effectively control the wild boar population (Vicente et al., 2019; Vajas et al., 2019).

Wild boars are traditionally hunted for trophies, with meat as a by-product. Recently, large game meat has attracted significant attention given the new awareness of the relationship between diet and health (Sinclair, 2007). Also, hunters as primary producers by selling game meat in rural areas can obtain additional income and wild ungulates become important part of local agriculture economy (Gaviglio et al., 2017; Gaviglio et al., 2018). However, as possible problems in free-ranged game meat supply chain can be high variations in different quality (nutritional, sensory) and sanitary (microbial contamination, meat hygiene) parameters as well as ensuring traceability (Hoffman and Wiklund, 2006; Gill, 2007; Atanassova et al., 2008; Winkelmayer and Paulsen, 2008; Liepina et al., 2010; Paulsen et al., 2011; Avagnina et al., 2012; Soriano et al., 2016; Viganò et al., 2019). Carcasses managed according to "best practices" (dead on the spot and bled out immediately) show less variation in meat quality, otherwise *post-mortem* changes can lead to undesired meat quality (Viganò et al., 2019).

Preferences of modern consumers are changing, some being more interested in production technologies of meat (organic vs conventional), others in environment impact (use of chemical fertilisers and tillage intensity) (Kasprzyk et al., 2019; Latvala et al., 2012; de Boer et al., 2014). Game meat is widely considered as organic, mainly due to different nutrition and living conditions of wild boar regarding domestic pigs (Kasprzyk, 2012). Wild animals live freely with unlimited access to natural pastures, choosing their own food.

A recent statistical study in Europe indicated that consumers are showing increased interest in game meat despite relatively high price (Hoffman and Wiklund, 2006; Daszkiewicz, 2007; Quaresma et al., 2011). A healthy diet with a low calorie and low cholesterol content, is becoming increasingly important in the lifestyle of the modern consumer. Beside these health-related positive effects, game meat attracts new consumers also by specific flavour, taste and aroma components (Hoffman and Wiklund, 2006; Sales and Kotrba, 2013). The meat quality of wild ungulates varies considerably, depending on diet, sex, age and fat levels of the animal, in addition to hunting season and hunting methods (Russo, 2005; Ramanzin et al., 2010; Stanisz et al., 2019; Viganò et al., 2019). In the wild, seasonal food availability, environmental conditions, and sexual behaviour all affect the quality of the animal's meat. Fatty meat is uncommon after the mating season (Kasprzyk, 2012), and both age and weight affect muscle shape and texture (Żochowska et al., 2005).

A range of hunting techniques are used in harvesting game animals, and these procedures and the *post-mortem* handling of carcasses will define the quality of the meat (Stanisz et al., 2018). According to the literature, *post-mortem* management of game should be taken into consideration in determining the meat's final quality. Carcasses are often processed once *rigor mortis* has set in, affecting meat characteristics (Pérez Serrano et al., 2020). In general, a low stress death by stalking should result in better quality meat and meat-processing companies will pay better prices for meat from stalked animals than for stress-hunted meat (Güldenpfennig et al., 2021). The way that animals are hunted and eviscerated in the field differs from the typical sanitary conditions in effect in slaughterhouses (Soriano et al., 2006; Cifuni et al., 2014; Neethling et al., 2016; Mirceta et al., 2017).

Therefore, the aim of this paper was to present a review on the physical parameters of wild boar meat.

pH and colour of wild boar meat

Dynamic of biochemical processes in meat *post-mortem* in influence by diverse factors that can be divided to environmental and genetic. Different hunting methods are associated with causing stress and intensive ante-mortem physical activity leading to possible negative impact on meat quality due to glycogen consumption (Stanisz et al., 2018). Fabijanić et al. (2021) reported about 10 times higher values of blood serum cortisol in wild boar hunted during driven hunts compared to individual hunt from high seats (312.57 vs 33.70 nmol/L). However, given the field conditions, the possibilities for quality control of game meat are limited (Neethling et al., 2016; Mirceta et al., 2017). Stress is detrimental and also has a negative impact on meat quality (Edwards, 2019). Farm animals can be stressed following inadequate or improper handling on farms, inadequate transport conditions, poorly maintained trucks and roads, while conditions that agitate animals can lead to bruising, lesions, and thermal stress (Dos Santos et al., 2019). Wild animals are exposed to short-term stresses, such as predation or weather conditions, which can alter the chemical properties of meat, resulting in lesser nutritional quality and reducing its functionality (Edwards, 2019). These changes can lead to pale, soft, exudative or dark, firm, dry meat, depending on the stressors. Pale, soft, exudative (PSE) meat is pale in colour with a poor water holding capacity, meaning that it has a high drip loss, becomes tough and flavourless after cooking, and is not suitable for processing into products (such as ham). Dark, firm, dry (DFD) meat is characterised by its darker colouration and more rapid spoilage, giving it a lower appeal for consumers. Both PSE and DFD are caused by an inappropriate pH in *post-mortem* muscle. pH is the best indicator of meat quality, and optimally should be about 5.8 (Boler et al., 2010), though literature reports as to optimal values varies. According to Edwards (2019), the ideal muscle pH in domestic pigs should be at 5.6–5.7 within 3-5 hours of slaughter to avoid PSE or DFD, while other reports indicate that DFD meat of lower quality can occur at slightly higher pH values: pH ≥ 6.0 (Faucitano et al., 2010), pH ≥ 5.9 (Maganhini et al., 2007), or pH ≥ 5.7 (Kauffman et al., 1993; Warner et al., 1993). The meat categorisation of Viganò et al. (2019) defines high-quality meat with a pH<5.8, intermediate DFD occurs between a pH of 5.8 and 6.2, and DFD meat at pH ≥ 6.2. pH value of meat will also affect its shelf life.

Stanisz et al. (2018) monitored pH values of meat of wild boar juveniles (<1 year) and yearlings (1–2 years). They showed that 55.56% of juveniles' meat and 64.71% of yearlings' meat had an optimal pH value (pH=5.8) measured at 24 and 48 h *post-mortem*. However, 44.44% of juveniles and 35.29% of yearlings had a pH > 5.8, indicating that meat quality was generally higher in yearlings.

When an animal feels threatened, stress hormones (cortisol and adrenaline) are released into the bloodstream to activate energy for use in the 'fight or flight' response. This energy comes from glycogen that is stored in the muscles and liver, as a rapidly available energy source for emergency use. To access this energy, the glycogen is first converted into glucose and then into lactic acid, as the primary factor determining the pH of muscle tissue (Edwards, 2019). Animals exposed to a severe, short-term stressor will experience an increase in metabolism and body temperature. The cells continue to metabolise glycogen but the muscles can no longer remove the lactic acid build-up, leading to a drop in pH. High temperature and low pH damage muscle proteins, causing them to lose their water holding capacity. If an animal is shot (and dies instantly), lactic acid remains trapped in the muscles, resulting in PSE meat. In comparison, animals that experience a long-term stressor use up their glycogen reserves and have very little left at the time of death, meaning that less glycogen is converted into lactic acid in the muscles *post-mortem*. This raises the pH of meat, resulting in DFD meat (Edwards, 2019). Ante-mortem stress caused by harvesting method can results in changes of game meat pH and impaired meat quality (like DFD meat) (Stanisz et al., 2018). DFD meat is characterised by high pH value (pH > 6.0), low values of L colour parameter, and dry appearance due to increased water binding capacity (Honikel, 2004; Hoffman et al., 2005; Daszkiewicz et al., 2012). It was found that wild boars in regard to domestic pigs have different *post-mortem* pH decline. Namely, in wild boar were found higher initial values and slower decline of during early *post-mortem* changes in meat (Kasprzyk et al., 2019; Marchiori and Felcio, 2003). Main reason for this can be attributed to type of muscle fibres (fast glycolytic vs slow oxidative) between these two species (Bowker et al., 2000). Reported pH values of wild boar meat range from 5.46 to 5.72 regardless to age (Pedrazzoli et al., 2017). Regarding different parts of meat, Borilova et al. (2016) reported a pH of 5.78 in raw wild boar hind leg and for the shoulder 5.70, while for thawed shoulder meat was reported higher pH value (5.93; Florek et al., 2017). On the other hand, Marchiori and Felício (2003) reported a pH value of 5.57 and 5.60 in wild boar at 24 h after slaughter, and 5.46 and 5.47 at 48 h after slaughter in *m. longissimus* and *m. semimembranosus*, respectively. Fabijanić et al. (2020) reported higher pH in meat of male wild boar than in female (6.22 vs 5.73).

Muscle myoglobin content and its different forms are main factors affecting meat colour (Swatlan, 2004; Karamucki et al., 2006). Due to more physical activity and increased number of red muscle fibres, game meat is characterised by darker colour (Hoffman et al., 2008; Daszkiewicz et al., 2012; Bodnár and Bodnár, 2014). Marchiori and Felício (2003) showed that the course of *post-mortem* colour changes depends on muscle type, where at 24 h *post-mortem* the *m. longissimus* showed values of L*=51.30, a*=7.94, and b*=13.24, as opposed to the *m. semimembranosus* with values of L*=50.38, a*=9.50, and b*=12.99. Also, age needs to be considered when analysing meat colour and lower values of lightness (L*) and yellowness (b*) colour parameters were found in older animals (yearlings and adult vs piglets). At same time, this darker meat colour was not correlated with high pH (Stanisz et al., 2018). Pedrazzoli et al. (2017) reported that the meat from 12 to 24-month-old animals had lower values of a* (16.13) and b* (4.39) colour parameters than meat of animals older than two years (20.01, 6.56). The values of a* colour parameter of wild boar meat in Stanisz et al. (2018) ranged from 11.01 to 12.09. Effect of hunting method on wild boar meat colour was reported by Cifuni et al. (2014). Namely, meat of wild boars harvested in selective hunting had lower L* (L*=34.89) and b* (10.02) values than meat obtained during dog-driven hunt (L*=45.37, b*=14.74). Tomljanović et al. (2022) analysed effect of hunting method (selective vs driven) and time of death (A≤1 min, B≥1 min) on wild boar meat and reported significantly higher L values (39.98) in females of group A compared to group B (32.08) during selective hunt. Regarding driven hunt, same authors reported significantly lower pH (5.61) in meat of females of group A compared to group B (5.86). As hunting method did not affect myoglobin content, authors higher L* and b* meat values from dog-driven hunt explained as result of protein denaturation. The colour parameters for wild boar shoulder, after freezing and thawing, were L*=33.25, a*= 25.13, and b* =1.97 (Florek et al., 2017). Analysing effect of sex on wild boar meat colour, Fabijanić et al. (2020) reported minor differences between male (L=38.32, a=21.16±0.37, b=9.39±0.31) and female animals (L=37.78±0.49, a=21.69±0.37, b=9.38±0.27).

Water holding capacity

Water is dominant component of muscle tissue (up to 70%) and as such has determinantal effect of meat quality parameters, like colour, appearance, tenderness (Coombs, 2017). Muscle water is used for transporting metabolites into and through the muscle fibres (Kolczak et al., 2007). Swelling of myofibrils in muscle *post-mortem* caused by electrostatic or osmotic forces determines meat water holding capacity (WHC) (Puolanne and Halonen, 2010). Water is contained in different muscle structures (within or between the myofibrils, between the myofibrils and the sarcolemma, between the muscle cells, or between muscle bundles) (Huff-Lonergan and Lonergan, 2005). Capillary forces within myofibrils result the highest water holding capacity of this muscle structures (Huff-Lonergan and Lonergan, 2005; Hughes et al., 2014). There are three types of water found in muscles (Kolczak et al., 2007): free (16–18%), immobilised (74–75%) and bound (7–8%) water.

Ability of fresh meat to preserve moisture during different manipulation processes (like transport, storage, cutting, heating, grinding, pressing, and cooking is defined as water holding capacity (Pearce et al., 2011). The weight of meat cut and external pressure determine rate and content of water drip in fresh meat is determined by the (Hughes et al., 2014). Water holding capacity can be presented as one of the following parameters: dripping, purging, weeping, exudation or loss during cooking (Warner et al., 1993). Both consumers and meat industry are interested in meat water holding capacity. Namely, better appearance of fresh meat and better sensory quality of final meat products are obtained when values of WHC are low (Offer et al., 1989). For producers, this also means higher profit due to better final product quality (Hughes et al., 2014).

WHC is affected by many factors, from stress to slaughter, and steps involved in meat processing and production (Coombs, 2017). *Post-mortem* changes in muscle metabolism, temperature and ultimate pH are associated with loss of muscle water and WHC rate (Traore et al., 2012). WHC is also largely influenced by storage conditions, and ideally, meat should be just above freezing, as freezing and thawing of fresh meat both affect the meat moisture drip loss (Coombs, 2017).

If meat samples need to be frozen before analyses, WHC can be determined as thawing loss. In that case, difference in weight (in %) between frozen and thawed meat sample at 4 °C is presented as water loss. Drip loss and thawing loss are usually measured in triplicate on fresh and frozen meat samples (Cifuni et al., 2014; Amici et al., 2015).

Ludwiczak et al. (2020) measured the drip loss (%) according to the method of Honikel (1998) and reported that drip loss, cooking loss and plasticity were higher in the meat of juveniles (<1 year) compared to yearlings (1–2 years) wild boar. Same author reported sex related differences, as the meat of males had a higher drip loss than female wild boar.

Cifuni et al. (2014) reported a cooking loss of 32.85% and 29.91% for wild boar meat samples originating from dog-driven hunt and harvest culling. Stanisz et al. (2019) reported results of meat cooking loss from juvenil wild boar with normal and high pH (33.95 vs 30.71%) in regard to yearling wild boar (32.72 vs 29.72%). A high cooking loss for the shoulder (36.74%) and hind leg (37.08%) of wild boars was reported by Borilova et al. (2016). Marchiori and Felício (2003) analysed the capacity to hold residual water in the *m. longissimus* of wild boars and reported a free water amount of 20.15 cm^2 (Grau and Hamm press method), with a drip loss of 3.42 g 100 g^{-1} of meat sample. Fabijanić et al. (2020) reported significantly higher cooking loss in meat of male than in female wild boar (19.83 vs 17.15).

Meat tenderness

Consumers´ perception of sensory quality and general satisfaction with meat quality in influenced by meat tenderness (Koohmaraie and Geesink, 2006; Silva et al., 2015). Palatability is a complex human perception and it is result of interactions between sensory and physical processes during chewing (Caine et al., 2003). However, there is high variability of meat tenderness within carcass depending on anatomic location and collagen content in muscle. Thus, meat industry is faced with challenge to find and develop effective methods for improving tenderness (Van Wezemael et al., 2014).

Meat tenderness in general and differences in tenderness between different muscles within same carcass are influenced by breeding technology, animal age, nutrition, connective tissue content, sarcomere length and content of intramuscular fat (Belew et al., 2003; Coombs, 2017). Also, differences in tenderness between different muscles within same carcass are affected by these factors (Belew et al., 2003). Collagen crosslinking in older animals is associated with tougher meat (Purslow, 2005; Voges et al., 2007). It is known that tenderness increases with meat marbling, and there is also a known correlation between animal sex and tenderness and marbling (Emerson et al., 2013). The perimysium tissue arrangement (that defines muscle fascicle or meat grain size) is used as an indicator of tenderness (Purslow, 2005). As myofibres weaken, the meat becomes more tender. There is high correlation between pH and meat tenderness (as pH early *post-mortem* decreases, tenderness increases) (Veiseth-Kent et al., 2010). Ngapo et al. (2002) reported a weak correlation between collagen content and tenderness, and Lepetit (2008) found no correlation. Proteolysis caused by calpain enzymatic system also affects meat tenderness. Calpain activity within muscle myofibrils causes increased myofibril fragmentation during *post-mortem* changes, especially during aging (Taylor et al., 1995).

Texture analysis

Texture analysis experiments are performed by measuring the Warner-Bratzler (WB) shear force. Górecka et al. (2012) analysed the WB shear force of fresh wild boar meat compared to meat stored for different lengths of time (14 and 28 days) and at different temperatures (-3 ± 0,1 °C and -18 ± 1 °C). Authors reported higher (86.21 N/cm^2) WB shear force for fresh *longissimus lumborum* samples than for stored (14 days -70.39 N/cm^2, 28 days – 64,22 N/cm^2). By Cifuni et al. (2014) different hunting methods showed no significant effect on WB shear force of wild boar meat samples, for dog drive it was 43.57±3.69 N and for harvest culling 52.49±4.91 N. Pérez Serrano et al. (2020) analysed effect of hunting type and season on meat quality and reported that higher WB shear force of wild boar meat samples originating from stressful driven winter hunts (46.5 N) compared to stalking summer hunt (39.3 N). Pierzchała et al. (2008) reported similar values of meat colour parameters of autumn and spring hunted wild boars, but meat of spring hunted wild boars had higher values of shear force than those hunted in autumn.

CONCLUSIONS

Due to increasing size of wild boar population across Europe, wild boar meat is becoming easily available to wider niche of consumers. The dynamic of biochemical *post-mortem* processes in meat is influenced by a variety of factors, which can be classified as environmental and genetic. Some meat quality attributes (pH, colour, water holding capacity, tenderness) are affected by age, sex, season, region, nutrition, and stressful ante-mortem events like hunting technique. Although these factors effect physical parameters of wild boar meat on similar way as in domestic animals, there is higher variability in reported values. Possible effect of hunting technic as stress-related factor on physical parameters of wild boar meat needs to be researched in more details.

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