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Journal:	<i>Canadian Journal of Animal Science</i>
Manuscript ID	CJAS-2018-0090.R2
Manuscript Type:	Article
Date Submitted by the Author:	28-Sep-2018
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Keywords:	age, high ultimate pH, meat quality, wild boar

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The effect of age and ultimate pH value on selected quality traits of meat from wild boar.

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Abstract

The meat from hunted wild boar juveniles (N=18) and yearlings (N=17), was analysed to assess the influence of age, and to assess the ultimate pH value on selected quality traits. The analysed meat of 55.56 % of the juveniles and 64.71 % of the yearlings was characterised with normal pH. The pH had been measured 24 h and 48 h post-mortem. More cases of high ultimate pH ($pH_u > 5.8$) and high maximal pH (about 6.2) have been noted in the meat of younger animals compared to older ones. We found no effect of pH_u on the colour coordinates of analysed wild boar meat. A slight effect of age was observed for the L^* coordinate. The post-mortem time was the most important factor influencing meat colour (L^* , b^* and hue-angle). A high pH_u was related to lower drip loss ($P=0.001$), lower percentage of free water ($P=0.036$), lower cooking loss ($P=0.001$), and lower plasticity ($P=0.042$). The meat from juveniles showed higher plasticity than meat from yearlings. Summing up, both the pH_u level and the age of wild boars may affect some qualitative patterns of meat, changing the technological usability of this raw animal product.

Key words: age; high ultimate pH; meat quality; wild boar

Introduction

Today's consumers are interested in 'healthy food' also referred to as 'bio', 'eco', 'organic', 'free-range' or 'pasture reared'. The most popular healthy products come from animals reared on pasture (having a lot of exercise and feeding on pasture/forage). It is important to also take into account wild animal meat. To distinguish commercial animal species from wild animals, the term 'game' is used. Game meat is characterised by a dark colour, intensive flavor, and unique texture. These traits make game completely different from meat of commercially

farmed animals, especially animals raised under intensive farming (Bodnár E.S. and Bodnár K., 2014; Hoffmann and Wiklund, 2006; Neethling et al., 2016; Sales and Kotrba, 2013; Soriano et al., 2006; Volpelli et al., 2002). Harvesting game animals is based on different hunting methods. Those methods, together with post-mortem management of game carcasses, determine the quality of the meat. The existing research indicates that post-mortem management of game is a significant factor to take into consideration, when making the final analysis of the quality of meat. The hunting method as well as the in-field evisceration of animals, in conditions that are far from what we call 'hygienic' (Cifuni et al., 2014; Mirceta et al., 2017; Neethling et al., 2016; Soriano et al., 2006). Among livestock animals, the domestic pigs are the closest genetic group to wild boars. The quality of pork, especially the influence of the pH value on meat quality traits, has been widely studied (Fauciano et al., 2010; Kauffman et al., 1993; Maganhini et al., 2007; Warner et al., 1993; Warner et al., 1997). There is a large population of wild boars in Poland. This is due to increased areas of crop fields treated by these animals as a major food source (Fruziński and Łabucki, 2002; Popczyk, 2016). Hunting prevents overpopulation of the wild boar and limits crop field damage (Cifuni et al., 2014). There are few scientific studies dealing with the influence of ultimate pH on the quality traits of meat from wild boar. For this reason, the aim of the presented research was to analyse the frequency of high ultimate pH in the wild boar, as well as the effect of age and ultimate pH value on some qualitative patterns of meat from this species.

2. Material and Methods

Animals and muscle samples

The animals analysed in the present study were shot in western Poland, in January. According to The Hunting Regulations of the Polish Ministry of the Environment (Journal of Acts of 2017, item 1991) the hunting season for wild boars is year-round. The age of the animals was estimated post-mortem through the assessment of tooth wear and replacement. Two groups were created: juveniles (< 1 year, N=18) and yearlings (1–2 years, N=17). The carcasses were weighed together with the head and skin, to obtain the dressed field weight. The carcasses were then transported to the meat processing plant and placed in the chilling room (0–2°C). The muscles for the analysis (left and right *m. semimembranosus*) were cut from the carcasses 24 hours post-mortem, and transported to the laboratory for analysis. For the time of analysis (24 h and 48 h time periods), the muscle samples were stored under chilled conditions (+ 2°C).

Meat pH and colour

The pH and colour measures were taken 24 h and 48 h post-mortem on the slices of *m. semimembranosus* used for the assessment of drip loss. The pH of the wild boar meat was measured using a temperature compensated, combination glass calomel electrode (ERH-11X1, SCHOTT, Germany) connected to a portable pH-meter (Handylab 2, SCHOTT). For calibration of the pH equipment, buffers of pH 4.0 and 7.0 at room temperature were used.

Freshly cut samples obtained 24 h post-mortem were allowed to bloom for 45 min at +4°C before measurement. The colour measures were made with the Minolta colourimeter CR-200b (illuminant D65, 2° observer with a 8-mm-diameter aperture size; Konica Minolta, The Netherlands). The tristimulus CIE system was used for the measurement of lightness (L^*), redness (a^*), and yellowness (b^*) (CIE 1976). The chroma (C^*) and hue-angle (H°) was calculated according to the following formulae:

$$C^* = (a^{*2} + b^{*2})^{1/2}$$

$$H^\circ = \tan^{-1}(b^*/a^*)$$

The capacity to hold residual water, water fractions, and plasticity

The drip loss, cooking loss, total water, free water, percentage of free water in total water, and plasticity were measured 24 h post-mortem.

- The drip loss (%) was measured according to Honikel (1998). The muscle slices (2.5-cm-thick and 40-50 g) were cut perpendicular to the direction of the muscle fibers, weighed, hung on hooks, and placed in a container to reduce evaporation (+2°C). After 24h, the samples were reweighed to calculate the change in their weight.

- The cooking loss (%) was measured according to Honikel (1998). The muscle slices (2.5-cm-thick and 40-50g) were cut perpendicular to the direction of muscle fibers and placed in thin plastic bags. The bags with meat were placed in a water bath set at 90°C until reaching the core temperature of 70°C (measured with thermocouples). Then, the bags with meat were cooled to room temperature and reweighed after removing excess moisture with a paper towel. Changes in the sample weight were calculated (%).

- The free water (%) was measured using a filter-paper press method, according to Grau and Hamm (1953) as modified by Pohja and Niinivaara (1957). Samples (0.300g) of ground meat (one slice of the muscle was ground for the press method and chemical analysis) were placed

on a filter paper between two glass tiles. A force of 2 kg was applied on each sample for 5 minutes. Then, samples were removed from the filter paper and immediately reweighed, to calculate the change in their weight.

- Meat plasticity (cm²) measurement was conducted according to Pohja and Niinivaara (1957),

at the same time as the free water measurement was being conducted. The meat plasticity was expressed as the area of the compressed meat sample used for the measurement of free water.

Proximal chemical composition

The analyses of the chemical composition (AOAC, 2007) of wild boar meat were made 48 h post-mortem and included: the determination of dry matter content (the samples were dried at 105°C to a constant weight),

the determination of the total protein content with the Kjeldahl procedure (K-424 Buchi digestion unit; Büchi Labortechnik AG, Switzerland), and the determination of extracted fat content using Soxhlet extraction with diethyl ether (MLL 147, AJL Electronics, Poland).

Statistical analysis

The effect of age on the carcass weight was calculated according to the model:

$$Y_{ij} = \mu + \alpha_i + e_{ij}$$

where:

μ - the overall mean of the analysed trait,

α_i - the effect of the i^{th} age ($i=1, 2$),

e_{ij} - random error.

The animals were divided into two groups according to the pH_u level of meat, with the threshold being $\text{pH}_u=5.8$. The effect of the age, pH_u level, and time post-mortem, on the pH and muscle colour (L^* , a^* , b^* , C^* , H^0) was calculated with the model:

$$Y_{ijkl} = \mu + \alpha_i + \pi_{j(i)} + \gamma_k + \beta_l + \text{bw}_{ijk} + e_{ijkl}$$

where:

μ - the overall mean of the analysed trait,

α_i - the fixed effect of the i^{th} age ($i=1, 2$),

$\pi_{j(i)}$ – the random effect due to the j^{th} animal in the i^{th} age ($j=1, 2, \dots, 35$),

γ_k - the fixed effects of k^{th} pH_u level ($k=1, 2$),

β_l - the effect of l^{th} time post-mortem ($l=1, 2$) as the repeated measures in j^{th} animal,

b - the partial regression coefficient,

w_{ijk} - the carcass weight of ijk^{th} animal,

e_{ijkl} - random error.

The effect of age and pH_u level on the: drip loss, cooking loss, total water, free water, percentage of free water in total water, plasticity, dry matter, crude protein, extractable fat, and total water to protein ratio (W/CP), was calculated with the model:

$$Y_{ikl} = \mu + \alpha_i + \gamma_k + bw_{ikl} + e_{ikl}$$

where:

μ - the overall mean of the analysed trait,

α_i - the fixed effect of the i^{th} age ($i=1, 2$),

γ_k - the fixed effects of k^{th} pH_u level ($k=1, 2$),

b - the partial regression coefficient,

w_{ikl} - the carcass weight of ikl^{th} animal,

e_{ikl} - random error.

There was no interaction between the analysed effects, therefore they were not included in the model. All the statistical analyses were made with SAS ver. 9.4 software package (SAS, 2012). Tukey–Kramer adjustment was implemented for multiple comparisons of Least Squares (LS) mean differences.

3. Results and Discussion

Carcass weight

The weight of wild animals is mainly affected by their age and the season (Żochowska-Kujawska et al., 2010). The mean dressed field weight of juveniles in the presented study, was about 22 kg, while for the yearlings it was more than 50 kg (Table 1). In their study, Cifuni et al. (2014) give a dressed field weight of male boars aged 18.67–20.50 months, as ranging

from 34.25 to 39.83 kg, while Górecka et al. (2012) reported an approximate live weight of 30–35 kg for animals that were 8–10 months old.

The pH value and colour coordinates

The course and rapidity of biochemical processes in the post-mortem muscle are associated with a variety of environmental and genetic factors. In the case of livestock species, we are able to control the environment as well as select animals so as not to produce an abnormal meat quality. In game meat, the course of anaerobic glycolysis is related to the hunting method (the level of glycogen reserves associated with physical effort and stress) and the management of the harvested animals (the accuracy of exsanguination and the hygienic conditions during in-field carcass dressing). The aforementioned factors offer limited possibilities for controlling the quality of game meat (Neethling et al., 2016; Micerta et al., 2017). The optimal range of pH decides about the qualitative patterns of meat, with the ultimate pH (pH_u) being the best predictor of meat quality attributes (Boler et al., 2010). The literature on pork quality gives different pH_u thresholds indicating the DFD lower quality meat: $\text{pH}_u \geq 6.0$ (Faucitano et al., 2010), $\text{pH}_u \geq 5.9$ (Maganhini et al., 2007) or $\text{pH}_u \geq 5.7$ (Kauffman et al., 1993; Warner et al., 1993), with the last of given thresholds demonstrating that even slightly increased pH (sometimes referred as intermediate DFD) is detrimental for meat shelf life. In our study, the animals were divided into two groups, according to the pH_u threshold value of 5.8. Among the analysed animals, 55.56 % of juveniles and 64.71 % of yearlings were characterised with normal pH values measured 24 h and 48 h post-mortem. More cases of high ultimate pH ($\text{pH}_u > 5.8$) and high maximal pH (about 6.2) have been noted in the meat of younger animals compared to older ones (Table 2). The pH_u of game meat may indicate ante-mortem stress of animals connected with the harvesting method. The ante-mortem stress is known to negatively affect meat quality, as it leads to the development of dark, firm, dry (DFD) meat. The main indicators of this abnormal condition in meat are: high pH ($\text{pH} > 6.0$), dark colour, and high water bounding capacity (Daszkiewicz et al., 2012; Hoffman et al., 2005; Honikel, 2004). Available data indicate that the rate of the pH decrease differs between domestic pigs and wild boars. Boars show a higher initial pH compared to domestic pigs (Kasprzyk et al., 2010), and a slower pH decline post-mortem (Marchiori and Felício, 2003). The aforementioned differences may be related to the different share of slow oxidative and fast glycolytic muscle fibres in wild boars and domestic pigs (Bowker et al., 2000). According to Pedrazzoli et al. (2017), the pH of the wild boar meat, ranges from 5.46 to 5.72, with no age effect (12–24 months of age vs. older than 2 years; $P=0.08$). In the study

of Borilova et al. (2016), they reported a pH of 5.78 in fresh (24 h post-mortem) wild boar leg, and 5.70 for the shoulder. An analysis made by Marchiori and Felício (2003) noted that the pH value of wild boar *m. longissimus* and *m. semimembranosus* 24 h after slaughter, measured 5.57 and 5.60, and 48 h after slaughter; 5.46 and 5.47. It should also be noted that Florek et al. (2017) reported a pH of 5.93 for frozen and thawed wild boar meat from the shoulder.

The colour of meat is associated with the pH value, but also with the amount and chemical forms of myoglobin (Karamucki et al., 2006; Swatlan, 2004). A dark and purplish red color is typical for game meat. This colour is mostly due to the amount of exercise and to a high proportion of red fibers in the muscles (Bodnar ES and Bodnar K, 2015; Daszkiewicz et al., 2012; Hoffman et al., 2008). However a dark color may also indicate a high ultimate pH, stipulating a DFD abnormal meat quality. The colour measures of wild boar meat analysed in our study are presented in Table 3. A slight effect of age was observed for the L^* coordinate. The most important factor influencing the meat colour (L^* , b^* and hue-angle) was the time post-mortem. The *m. semimembranosus* of yearlings was darker compared to that of the juveniles ($P \leq 0.05$). The meat of older boars was also redder compared to the younger ones, but this was not confirmed statistically ($P > 0.05$). No negative effect of high pH_u on meat lightness was observed (no difference in L^* between normal and high pH_u groups; $P > 0.05$). It was found by Pedrazzoli et al. (2016), that meat from 12-24 month old animals was less red (a^* ; $P < 0.001$) and less yellow (b^* , $P < 0.05$) compared to the meat of older animals. The meat redness in the present paper ranged from 11.01 to 12.09 and was much lower compared to a^* measures reported by Pedrazzoli et al. (2016). In comparison to the measures presented in this paper, Cifuni et al. (2014) reported lower L^* measures ($L^* = 34.89$) for wild boars harvested with selective hunting, and higher L^* ($L^* = 45.37$) for the animals obtained when a dog-driven hunt was used. The measures of wild boar meat colour made by Marchiori and Felício (2003) indicate higher L^* and b^* than the results in our study. According to Marchiori and Felício (2003), the *m. longissimus*, 24 h post-mortem, is characterised by $L^* = 51.30$, $a^* = 7.94$ and $b^* = 13.24$, while the *m. semimembranosus*, 24 h post-mortem, is characterised by $L^* = 50.38$, $a^* = 9.50$ and $b^* = 12.99$. The authors reported that the course of post-mortem colour-changes depends on the muscle type. The colour parameters for the shoulder of the wild boar, after frozen storage and thawing, were reported by Florek et al. (2017) to be: $L^* = 33.25$, $a^* = 25.13$, $b^* = 1.97$. The

shoulder meat in the aforementioned study was much darker and redder compared to our research material.

The capacity to hold residual water, water fractions, and plasticity

The development of pH value in the early post-mortem period and the ultimate pH are the major factors affecting the capacity of meat to bind residual water (Puolanne and Halonen, 2010; Hamoen et al., 2013). This is confirmed by the results of our study (Table 4). The high pH_u was related to lower drip loss ($P=0.001$), lower percentage of free water ($P=0.036$), lower cooking loss ($P=0.001$), and plasticity ($P=0.042$). Moreover, an influence of age on meat plasticity was found ($P=0.029$), with the meat from juveniles showing higher plasticity than the meat of yearlings. In their study, Cifuni et al. (2014) presented a similar cooking loss measuring 32.85% and 29.91% (depending on the hunting method), as that presented in our study. A high cooking loss for the shoulder (36.74%) and the leg (37.08%) of wild boars, was reported by Borilova et al. (2016). Compared to our study, Dannenberger et al. (2013) obtained a lower total water content; averaging 74.3% in the *m. longissimus* of wild boars, with no difference between younger or older animals. An analysis of the capacity to hold residual water in the *longissimus* muscle of wild boars was done by Marchiori and Felicio (2003). They reported the amount of free water to be 20.15 cm² (according to the Grau & Hamm press method), and a drip loss of 3.42 g 100g⁻¹.

Proximal chemical composition

In the presented study, no effect of age, pH_u level or carcass weight was observed on the proximal chemical composition of wild boar meat (Table 5). Yearlings, however, revealed a higher but not significant, percentage of dry matter and fat in the *m. semimebranosus*. Similarly to our group of wild boars with high pH_u, Borilova et al. (2016) obtained a dry matter content in wild boar leg, averaging 24.37%. In their analysis, Dannenberger et al. (2013) noted the chemical composition of the *longissimus* muscle of wild boars younger than one year, and found that the protein and fat content averaged 22.5% and 2.1%, while the fat content in meat of older males reached even 4.4%. A very low fat content measuring 0.83% in the shoulder of wild boars, and a water to protein ratio of 3.86 was observed by Florek et al. (2017). According to the available literature, the greatest variety in the chemical composition of meat from wild boars refers to the percentage of fat, and is associated with the season and the available forage (Lachowicz et al., 2008; Żochowska-Kujawska et al., 2010).

Conclusions

Summing up, the age of wild boars may affect the qualitative patterns of meat, causing slight differences in the meat brightness. The water capacity, free water fractions, and plasticity measures were significantly affected by high pH_u , but there was no influence of pH level on the colour coordinates (especially L^*). For these reasons, we cannot make a deduction concerning the development of abnormal quality conditions. We can only conclude about different technological usability of meat from wild boars, depending on the pH_u of the meat and the age of animals.

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For Review Only

Table 1. The dressed field weight ^x of wild boars				
Age	N	LSM ± SE	Minimum	Maximum
Juveniles (kg)	18	22.6 ± 1.4 A	18.0	29.0
Yearlings (kg)	17	52.4 ± 1.5 B	39.0	62.0

^x Carcass together with the skin and the head

^{A-B} Means within the same column are significantly different at $P \leq 0.01$

For Review Only

Table 2. The percentage of wild boars with normal/high pH and the minimum/maximum pH values recorded considering the age, pH level and time post-mortem.

Age	pH	Number/Percentage	pH _u ≤ 5.8		pH _u > 5.8	
			Normal		High	
			24 h	48 h	24 h	48 h
Juveniles		N	10	10	8	8
		%	55.56	55.56	44.44	44.44
	Min.		5.59	5.54	-	-
	Max.		-	-	6.29	6.27
Yearlings		N	11	11	6	6
		%	64.71	64.71	35.29	35.29
	Min.		5.55	5.51	-	-
	Max.		-	-	6.21	6.17

Table 3 The pH and color measures of wild boar meat (LSM ± SE).

	Age								Effect (P-value)			
	Juveniles				Yearlings				Age	pHu level	Time post-mortem	Carcass weight
	Normal pH _u		High pH _u		Normal pH _u		High pH _u					
	24 h	48 h	24 h	48 h	24 h	48 h	24 h	48 h				
pH	5.75 ± 0.05 A	5.69 ± 0.05 A	6.18 ± 0.05 Ba	6.16 ± 0.05 B	5.67 ± 0.05 A	5.66 ± 0.08 A	6.06 ± 0.05 Bb	6.05 ± 0.05 Bb	0.268	<.0001	0.143	0.486
L*	41.8 ± 0.9 ab	42.7 ± 0.9 ac	42.3 ± 0.9 a	43.5 ± 0.9 a	38.7 ± 0.9 b	39.2 ± 0.9 b	39.9 ± 0.9 bc	40.3 ± 0.9 abc	0.023	0.979	0.001	0.339
a*	11.74 ± 0.69	11.01 ± 0.69	11.19 ± 0.69	11.68 ± 0.69	12.66 ± 0.66	11.99 ± 0.66	12.99 ± 0.70	11.74 ± 0.71	0.335	0.892	0.135	0.243
b*	7.06 ± 0.65 a	8.14 ± 0.65 a	6.68 ± 0.74 ab	8.11 ± 0.74 a	5.15 ± 0.69 b	6.61 ± 0.71 ab	6.11 ± 0.74 ab	7.27 ± 0.74 ab	0.181	0.536	<.0001	0.424
C*	13.61 ± 0.77	13.59 ± 0.77	12.93 ± 0.88	14.20 ± 0.88	13.66 ± 0.84	13.84 ± 0.85	14.45 ± 0.88	13.96 ± 0.88	0.763	0.685	0.473	0.534
H°	29.2 ± 2.1 ACa	34.9 ± 2.1 Ab	28.8 ± 2.3 ABa	33.4 ± 2.3 Ab	24.2 ± 2.2 B	30.5 ± 2.3 AC	26.3 ± 2.3 BC	32.9 ± 2.3 A	0.281	0.667	<.0001	0.543

^{A-C}, ^{a-c} Means within the same row are significantly different at P≤0.01, P≤0.05

Table 4. The capacity of wild boar meat to hold its residual water, water fractions and plasticity (LSM $\pm$ SE).

	Age				Effect (P-value)		
	Juveniles		Yearlings		Age	pH _u level	Carcass weight
	Normal pH _u	High pH _u	Normal pH _u	High pH _u			
Drip loss (%)	3.03 $\pm$ 0.27 A	2.54 $\pm$ 0.21 AB	2.66 $\pm$ 0.25 AB	2.07 $\pm$ 0.26 B	0.404	0.001	0.871
Total water (%)	76.71 $\pm$ 0.54	76.77 $\pm$ 0.60	75.60 $\pm$ 0.61	75.56 $\pm$ 0.59	0.252	0.975	0.951
Free water (%)	30.51 $\pm$ 0.61 a	29.11 $\pm$ 0.59 b	29.97 $\pm$ 0.68 a	28.18 $\pm$ 0.55 b	0.067	0.036	0.622
Free water share in total water (%)	39.80 $\pm$ 0.79 a	37.95 $\pm$ 0.71 b	39.62 $\pm$ 0.79 a	37.29 $\pm$ 0.71 b	0.868	0.034	0.623
Cooking loss (%)	33.95 $\pm$ 1.17 A	30.71 $\pm$ 1.33 B	32.72 $\pm$ 1.32 AB	29.72 $\pm$ 1.29 B	0.611	0.001	0.715
Plasticity (cm ²)	4.35 $\pm$ 0.32 a	4.16 $\pm$ 0.31 ad	3.66 $\pm$ 0.34 bcd	3.34 $\pm$ 0.32 c	0.029	0.042	0.331

^{A-B}, ^{a-d} Means within the same row are significantly different at $P \leq 0.01$, $P \leq 0.05$

Table 5. The proximal chemical composition of the wild boar meat (LSM ± SE).

	Age				Effect (P-value)		
	Juveniles		Yearlings		Age	pH _u level	Carcass weight
	Normal pH _u	High pH _u	Normal pH _u	High pH _u			
Dry matter (%)	23.29 ± 0.54	23.24 ± 0.62	24.41 ± 0.61	24.44 ± 0.60	0.252	0.974	0.951
Crude protein (%)	21.80 ± 0.52	21.79 ± 0.59	22.66 ± 0.59	22.67 ± 0.57	0.373	0.998	0.644
Extracted fat (%)	1.26 ± 0.15	1.27 ± 0.17	1.64 ± 0.17	1.68 ± 0.16	0.163	0.819	0.566
W/CP ^x	3.33 ± 0.08	3.43 ± 0.10	3.32 ± 0.10	3.37 ± 0.09	0.832	0.241	0.631

^x Total water to protein ratio