THE EFFECT OF BREED AND SEX ON THE ACIDITY AND COLOUR OF RABBIT MEAT

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Abstract

The objective of this study was to investigate the effect of breed and sex on the acidity and colour parameters of rabbit meat. The experiment material consisted of rabbit meat sourced from the following breeds: Flemish Grey Giant (n=30), Popielno White (n=64), Termonde White (n=39) and California Black (n=26). The animals were slaughtered at 84 days of age. The meat was examined for acidity (pH) and colour parameters such as L - lightness, a* - red component, b* - yellow component and C*- colour saturation at 45 minutes and 24 hours after slaughter. Both measurements were made on the surface of the m. longissimus lumborum and m. biceps femoris. Statistical analysis showed that breed significantly influenced meat colour and pH. After the maturation period, meat sourced from all the breeds under study was characterised by equal values for colour components. The highest pH was found in Flemish Grey Giant meat with a value above 6.0, which may indicate reduced shelf life. Sex has a significant effect on rabbit meat colour at 24 hours post-slaughter. The meat of females was found to be darker and show a higher value for the yellow colour component.*

Keywords: rabbit, acidity, colour, meat quality, sex, breed

Introduction

In recent years, selection has been used to improve the slaughter characteristics of rabbits, resulting in the rise of fast-growing breeds with meat-rich carcasses but poor in quality parameters most conspicuous to consumers (Pałka et al., 2017).

Acidity (pH) is an essential parameter in quality assessment. The pH value is close to neutral immediately after slaughter, decreasing over time as a result of post-slaughter glycogenolysis, and stabilising around 24 hours after slaughter. The final pH value of meat determines its shelf life and suitability for processing. Rabbit meat examined immediately after slaughter usually ranges in acidity from 6.1 and 6.8, a sign of good quality and the animal's moderate susceptibility to stress factors. When the pH measured 30-45 minutes post-slaughter falls below 6.0, meat has an exudative texture, possibly due to a defect in mature meat known as PSE (*pale*, *soft*, *exudative*), and will have sub-standard culinary properties. When measured after that period, a pH of 7.0 or more may signal the presence of a defect known as DFD (*dark*, *firm*, dry), in which the meat has inferior culinary properties while also having an undesirable dark colour. Full muscle tissue acidification in slaughtered rabbits

occurs up to 24 hours post-slaughter. When this time has lapsed and the carcass has been cooled to 4°C, the pH of good quality rabbit meat should fall between 5.4 and 5.8. These values are slightly higher than for meat from other farm-bred animals, which may suggest a reduced shelf life (Kozioł et al., 2015).

Meat colour is among the most conspicuous parameters to consumers (Łapa et al., 2008) and is assessed first. It is the result of qualitative transformations in the structure of meat due mainly to changes in myoglobin and haemoglobin. Currently, the most common objective method of meat colour assessment has been established by CIE (*Comission Internationale de l'Eclairage*) whose system defines the L*, a* and b* parameters, i.e. lightness and chromaticity coordinates that specify the proportions of red - a* and yellow - b*. For the L* parameter, a value of 0 indicates total blackness and a value of 100 pure white. Higher values of the a* coordinate will refer to colours tending towards red, while lower ones refer to colours tending towards green. Positive values of the b* coordinate, on the other hand, indicate yellow and negative values indicate blue. Also, these parameter values determine the saturation degree of a colour (C*) and its shade (H*). Meat colour depends on the amount of pigment, post-slaughter pH, drop in pH during meat maturation and the physical properties of muscles. Research has shown a negative correlation between meat acidity (pH) and the L* parameter determining colour lightness. An increase in meat acidity makes meat darker. Meat acidity is positively correlated with the yellow colour component (b*). In contrast, changes in pH values do not cause changes in the red colour component (a*) (Mancini and Hunt, 2005; Strzyżewski et al., 2008). As rabbits age, the lightness and colour fastness of their meat improves. Furthermore, the meat of intensive-fed rabbits is darker than that from conventionally reared animals (Barabasz and Bieniek, 2003).

Meat pH and colour values are influenced by genetic factors, i.e. breed and sex, as well as environmental factors such as nutrition, housing conditions or the level of stress experienced by the animals prior to slaughter (Goat et al., 2015). Therefore, the objective of this study was to determine how the breed and sex of rabbits affect meat quality indicators such as acidity and colour.

Material and methods

The study material consisted of rabbit carcasses from the following breeds Flemish Grey Giant (n = 30, ♀ = 12, ♂ = 18), Popielno White (n = 64, ♀ = 33, ♂ = 31), Termonde White (n = 39, ♀ = 22, ♂ = 17) and California Black (n = 26, ♀ = 8, ♂ = 18). The rabbits were housed with their mothers until weaning under standardised conditions: standing wooden cages in a hall with access to water (drinking troughs), lighting (14L:10D) and forced ventilation. The young were weaned at 35 days of age and kept in battery cages. The rabbits were on an *ad libitum* diet, fed with a full-ration commercial pelleted feed with 10.2 MJ metabolisable energy, 16.5% total protein and 14% crude fibre. Slaughter and post-slaughter processing took place at 12 weeks of age according to the methodology described by Barabasz and Bieniek (2003). Prior to slaughter, the rabbits were starved for 24 hours with constant access to drinking water. After slaughter, the carcasses were chilled at 4°C for 24 hours.

Meat colour in the CIE colour space L*a*b* (L* - lightness, a* - red component, b* - yellow component), illuminant D65, measurement angle 0°, observer angle 2° and calibration against white (Gozdecka, 2006) was measured at 45 minutes and 24 hours after slaughter on the surface of the following muscles: *m. longissimus lumborum* (at the level of the first lumbar vertebra) and *m. biceps femoris*, midway along the length of the muscle, always on the right side of the carcass. Measurements were taken with a Minolta CR-410 reflectance colourimeter (three-spot measurements from which the average was drawn). In addition, the coordinates a* and b were used to calculate the colour saturation index C*

($C^* = \sqrt{a^{*2} + b^{*2}}$).

Post-slaughter acidification of muscular tissue was measured using a Consort C561 microprocessor-based pH meter equipped with a SP24B reinforced glass driven electrode at 45 minutes after slaughter (pH_{45}) and then at 24 hours after slaughter (pH_{24}), to the second decimal place. Measurements were taken on the right side of the carcass of the same muscles and at the same locations as for meat colour.

Results were processed using the SAS statistical package (SAS Institute Inc., 2014). A two-factor analysis of variance with interaction was performed for the model in which breed and sex were fixed effects. In addition, the significance of differences between the means was tested using the Tukey-Kramer test.

Results

The experiment showed the effect of sex on the colour of rabbit meat. The *longissimus lumborum* and *biceps femoris* muscles of males were darker at 24 hours post-slaughter than the same muscles in females (Tables 1 and 2). In addition, the muscles of males were characterised by lower values of the b_{24} and H_{24} parameters for both muscles and of the C_{24} parameter for the *biceps femoris* muscle than in females. In contrast, sex was found to have no effect on meat pH in either the leg or lumbar area, indicating that the meat of males and females had equal shelf life.

Table 1. Effect of breed and sex on pH and colour of *m. longissimus lumborum* measured 45 minutes and 24 hours post-mortem

Cecha Trait	Rasa Breed				Płeć Sex		Interakcja Interaction
	TER	POP	KAL	BOS	♂	♀	rasa× płeć breed× sex
n	39	64	26	30	84	75	
pH_{45}	6.51^{a} (0.09)	6.98^{b} (0.07)	6.51^{a} (0.08)	6.91^{b} (0.08)	6.72 (0.05)	6.73 (0.05)	*
pH_{24}	5.95^{a} (0.04)	5.79^{b} (0.03)	5.88^{ab} (0.03)	6.16^{c} (0.04)	5.99 (0.02)	5.90 (0.02)	ns
L^*_{45}	57.59^{a} (1.16)	59.18^{a} (0.97)	60.29^{ab} (0.99)	64.29^{b} (1.10)	60.20 (0.66)	60.47 (0.67)	ns
a^*_{45}	0.01^{a} (0.73)	3.68^{b} (0.61)	3.51^{b} (0.63)	1.60^{ab} (0.69)	2.10 (0.42)	2.30 (0.42)	ns
b^*_{45}	-4.92^{a} (0.86)	1.95^{b} (0.72)	0.00^{bc} (0.73)	-0.88^{c} (0.81)	-1.02 (0.49)	-0.90 (0.50)	ns
C^*_{45}	4.37 (0.73)	5.07 (0.62)	5.27 (0.63)	3.31 (0.70)	4.54 (0.42)	4.47 (0.46)	ns
L^*_{24}	57.04^{a} (0.81)	58.01^{a} (0.68)	57.74^{a} (0.69)	61.07^{b} (0.77)	59.81^{a} (0.46)	57.12^{b} (0.47)	*
a^*_{24}	5.92^{ac} (0.54)	4.09^{bc} (0.46)	6.25^{a} (0.46)	6.73^{a} (0.51)	5.75 (0.31)	5.74 (0.31)	*
b^*_{24}	3.42^{ac} (0.54)	1.80^{bc} (0.39)	3.20^{a} (0.40)	3.92^{a} (0.44)	2.61^{a} (0.27)	3.56^{b} (0.27)	*
C^*_{24}	7.32^{a} (0.62)	4.61^{b} (0.53)	7.12^{a} (0.53)	7.96^{a} (0.59)	6.67 (0.36)	6.84 (0.36)	*

Note: L*45 and L*24 - lightness 45 minutes and 24 h post-mortem, a*45 and a*24 - red colour coordinate 45 minutes and 24 h post-mortem, b*45 and b*24 - yellow colour coordinate 45 minutes and 24 h post-mortem, C*45 and C*24 - saturation 45 minutes and 24 h post-mortem, ns - not-significant. Mean values with different letters are significantly different at $p \leq 0.05$.

Table 2. Effect of breed and sex on pH and colour of *m. biceps femoris* measured 45 minutes and 24 hours post-mortem

Cecha Trait	Rasa Breed				Płeć Sex		Interakcja Interaction
	TER	POP	KAL	BOS	♂	♀	rasa × płeć breed × sex
n	39	64	26	30	84	75	
pH_{45}	6,38^{a} (0,08)	6,87^{b} (0,07)	6,62^{a} (0,07)	6,54^{a} (0,08)	6,54 (0,05)	6,66 (0,05)	ns
pH_{24}	6,03^{ab} (0,03)	5,94^{a} (0,02)	5,95^{a} (0,03)	6,08^{b} (0,03)	5,99 (0,01)	6,01 (0,01)	ns
L^*_{45}	51,76^{a} (0,82)	52,98^{ab} (0,70)	54,60^{b} (0,71)	54,68^{b} (0,79)	53,62 (0,47)	53,83 (0,48)	ns
a^*_{45}	3,53^{a} (0,23)	1,84^{b} (0,20)	2,70^{a} (0,20)	3,23^{a} (0,23)	2,74 (0,14)	2,91 (0,14)	ns
b^*_{45}	0,05 (0,41)	-1,01 (0,34)	-0,89 (0,35)	-0,02 (0,40)	-0,48 (0,24)	-0,46 (0,24)	ns
C^*_{45}	3,85^{a} (0,26)	2,53^{b} (0,22)	3,13^{ab} (0,22)	3,57^{a} (0,25)	3,27 (0,15)	3,27 (0,15)	ns
L^*_{24}	56,53^{a} (0,49)	57,79^{a} (0,42)	57,82^{a} (0,42)	59,63^{b} (0,47)	58,60^{a} (0,28)	57,29^{b} (0,29)	*
a^*_{24}	4,35^{a} (0,31)	2,92^{b} (0,26)	4,31^{a} (0,27)	3,67^{ab} (0,30)	3,65 (0,28)	3,97 (0,18)	ns
b^*_{24}	2,77 (0,33)	2,94 (0,27)	3,28 (0,28)	3,84 (0,31)	2,80^{a} (0,19)	3,61^{b} (0,19)	ns
C^*_{24}	5,38^{ab} (0,37)	4,20^{a} (0,31)	5,52^{b} (0,32)	5,36^{ab} (0,35)	4,78^{a} (0,21)	5,45^{b} (0,22)	ns

Note: L*45 and L*24 – lightness 45 minutes and 24 h post-mortem, a*45 and a*24 – red colour coordinate 45 minutes and 24 h post-mortem, b*45 and b*24 – yellow colour coordinate 45 minutes and 24 h post-mortem, C*45 and C*24 – saturation 45 minutes and 24 h post-mortem, ns – not-significant. Mean values with different letters are significantly different at $p \leq 0.05$.

The study found an effect of breed on the pH of rabbit meat. Forty-five minutes after slaughter, the pH value of the *longissimus dorsi* muscle in Flemish Grey Giant and Popielno White rabbits was significantly higher than in Termonde White and California Black rabbits. For the *biceps femoris* muscle, the pH value was shown to be highest 45 minutes after slaughter in Popielno White rabbits, while not statistically different in the other breeds. In each of the studied breeds, it ranged between 6.2 and 7.0, which did not indicate the presence of quality defects. The pH measured 24 hours after slaughter showed greater variation, particularly in the *longissimus lumborum* muscle. The acidity found in that muscle 24 hours after slaughter was highest in Popielno White rabbits, lower in Termonde White and California Black rabbits, and lowest in Flemish Giants. For the *biceps femoris* muscle, the pH values were no longer so different, but statistically lower acidity was found in the meat of Flemish Giants compared to California and Popielno rabbits. As the meat of Flemish Giants was characterised by pH values higher than 6.0, this may indicate its reduced shelf life and quality.

Colour is among the fundamental quality parameters of meat and one of the most conspicuous to consumers. It is the one most easily and quickly assessed by a potential purchaser. When selecting meat, the customer can instantly assess the colour and decide whether it is a high-quality raw material, which is why research into this parameter is so important for practical reasons.

The colour of the *longissimus dorsi* muscle at 45 minutes after slaughter varied across breeds. The lightest lumbar meat was found in Flemish Giant rabbits. The lowest value for the a* parameter was found in Termonde rabbit meat, and the highest in Popielno and California breeds. With regard to the b* parameter, Termonde rabbit meat had by far the lowest value, while that of the Popielno rabbits had the highest. This means that the reddest meat was found in Termonde and California rabbits. Despite the differences found in the basic colour parameters, colour saturation C^*_{45} did not differ significantly from breed to breed. After maturation for 24 hours in refrigerated conditions, the meat colour became similar across breeds. 24 hours after cooling, the meat was darker and the colour was more saturated. Significant differences occurred in the L^*_{24} parameter, where Flemish Giant meat was

characterised by a higher value, and for the other parameters between the California and the other breeds.

The colour of the *biceps femoris* muscle had lower values than that of the *longissimus lumborum* muscle both 45 minutes after slaughter and after 24 hours (Table 2). Differences in colour measurements at 45 minutes after slaughter were found between Termonde rabbits and the other breeds in the case of lightness L* (Termonde meat was the darkest) and between Popielno rabbits and the other breeds in the case of the red component a* and colour saturation C* (Popielno rabbit meat had the lowest value of the a* parameter, while also having the lowest colour saturation). 24 hours after slaughter, the meat from the hind leg, in contrast to the meat from the haunch, became lighter. The values of the other parameters also increased compared to the measurements made at 45 minutes. As in the case of the *m. longissimus lumborum*, the lightness of the *m. biceps femoris* in Flemish Giants was significantly higher than in the other breeds. On the other hand, the values of the red component a* and colour saturation C* in Popielno rabbits were significantly lower compared to the other breeds.

Discussion

The effect of breed and sex on the physical and chemical properties of meat has been demonstrated in a variety of species, including cattle (Xie et al., 2012; Litwińczuk et al., 2014), pigs (D'Alessandro et al., 2011; Pugliese and Sirtori, 2012), sheep (Teixeira et al., 2005; Yousefi et al., 2012) and poultry (Musa et al., 2006). This thesis is also supported by the present study. Both Polish and foreign researchers use various tools to assess the quality of raw materials obtained from livestock. One of the most widespread methods of meat quality assessment, popular because of its precision, ease and reliability, is the method in which the acidity and colour of meat are evaluated using specialised measuring equipment. The compactness of the equipment and its uncomplicated operation mean that the visual aspect, which is the most important from the consumer's point of view, can be objectively assessed as early as several minutes to several hours after slaughter. Meat pH and colour data can be collected without the need for costly laboratory analysis or carcass damage.

Frunza et al. (2019) attempted to determine the effect of cooling time on rabbit meat acidity. Flemish Giants were used in the experiment. The pH value of the *longissimus dorsi* muscle measured 24 hours after slaughter in female carcasses was 5.72 and in males 5.73. For the *biceps femoris* muscle, these values were 6.02 and 6.06, respectively. The values obtained in their experiment are higher, but comparable, for both *m. longissimus lumborum* and *m. biceps femoris.* Being a large, late-maturing breed, Flemish Giant meat may be characterised by shorter shelf life when the animal is slaughtered under standardised conditions designed for medium-sized breeds. Animals slaughtered at a later age could have technological meat characteristics similar to those of the other rabbit breeds studied. The cited study and our own research did not show that sex significantly influenced the pH of meat 24 hours after slaughter in the studied breed.

When investigating the effect of a nutritional supplement in the form of nettle (*Urtica dioica L.*) and fenugreek (*Trigonella foenum-graecum L.*), Pałka et al. (2021b) showed that the aforementioned herbs influence the colour of Termonde White rabbits. In control animals fed with commercial feed, the values of the L*, a* and b* parameters measured 45 minutes after slaughter on the *biceps femoris* muscle were 50.67; 2.61 and 2.50. On the other hand, for the same parameters measured after 24 hours, these values were 55.91; 3.17; 3.90, respectively. All the values measured for the *biceps femoris* muscle in our study are higher than in the cited paper, except for the b* parameter, which is lower. For the *m. longissimus lumborum*, the values of L*, a* and b* measured after 45 minutes were 60.56; 0.25 and -4.71,

and after 24 hours 55.97; 4.88 and 1.98. In our own experiment, the haunch meat after 45 minutes was characterised by lower values of the individual colour parameters, while after 24 hours this relationship was reversed. The authors found no significant effect of sex on the colour of rabbit meat. Our own research indicates an effect of sex on the L^*_{24} and b^*_{24} parameters. However, it should be remembered that the study by Pałka et al. (2021b) used only Termonde White rabbits, while our own study used four different rabbit breeds, including one large breed. Also, the study by Pałka et al. (2022) focused on determining the quality of meat from Termonde White rabbits. In the experiment, pH was measured at 45 minutes and 24 hours after slaughter on the haunch and on the hind leg. The values measured on the haunch were comparable to the results presented by the authors of this paper, while there were discrepancies for the leg. The acidity measured at 45 minutes was lower than that obtained in our own study, while the result obtained in the measurement at 24 hours after slaughter was higher. Colour saturation for both tested muscles had similar values to our own experiment. For the other colour components, there were differences in the case of measurements taken 45 minutes after slaughter on the two muscles in question, but the values equalised and were comparable to the results of the authors of this paper after meat maturation time. Only the b^*_{24} parameter was significantly higher.

Kmiecik et al. (2017) investigated the effect of season and feeding method on meat quality traits in Popielno White rabbits. Animals from the group fed with full-ration pellets reached pH values of 6.72 and 5.97, as measured at 45 minutes and 24 hours in the leg muscle, and 6.73 and 5.90 as measured in the haunch muscle. In the case of the leg, the values obtained by the authors were similar to our own results, while the pH $value_{24}$ measured on the *longissimus dorsi* muscle was lower than in the present study, which may indicate a better quality of the meat. The haunch meat after the maturation time in the experiment of Kmiecik et al. (2017) was characterised by a significantly higher value of the yellow colour component. In both *m. longissimus lumborum* and *m. biceps femoris,* the L^*_{24} parameter reached a lower value than in the rabbits used in the experiment presented by the authors of this paper**.**

In the publication by Pałka et al. (2021a), the values of meat colour and pH parameters were determined for Popielno White rabbits. All measurements were made on the surface of the *longissimus lumborum* muscle. The values presented in that work do not differ significantly from the results obtained in our own experiment. A significant discrepancy can only be observed for the meat colour parameters a* and b*. In the present study, the results obtained are higher than those presented by Pałka et al., with the exception of pH_{24} , L^*_{45} , a^*_{24} and b^*_{24} as these parameters returned higher values.

Meat pH and colour values in California Black rabbits were determined by Chwastowska-Siwiecka et al. (2011). In the cited study, the authors compared the values of meat quality traits (*m. biceps femoris*) between two breeds (Californian and New Zealand White). Significant differences were observed between the tested rabbit groups only for the red colour component. The pH values measured at 45 minutes and 24 hours after slaughter were higher in the 2011 study. Rabbits in the cited experiment also had higher values for the L^*_{24} parameter and the yellow colour component. In contrast, a higher value of the a* parameter was recorded in our own study. The differences may be due to the fact that the measurement of meat colour and acidity was carried out on whole carcasses, whereas in the experiment in Chwastowska-Siwiecka et al. (2011), a detailed dissection was carried out and the muscle was separated before measuring meat colour.

The determination of the pH value of the *longissimus lumborum* muscle in California Black rabbits was also addressed by May et al. (2008). That study compared the meat quality of California Black and New Zealand White rabbits as well as their hybrids. For meat acidity values, there were no statistically significant differences between the groups, and the pH

value measured at 45 minutes and 24 hours after slaughter was 6.87 and 5.89 in the California rabbits. The value measured at 45 minutes differed from that obtained in our own experiment, but that obtained at 24 hours after slaughter was almost identical. High pH values 24 hours after slaughter may indicate a reduced quality of the meat.

Summary

The experiment demonstrated that breed and sex significantly influence the acidity and colour of the two most valuable rabbit carcass cuts, i.e. the haunch (*m. lomgissimus lumborum*) and the leg (*m. biceps femoris*). The meat with the lowest pH value, which may indicate its longest shelf life, is that of the Popielno White breed, while the one with the shortest shelf life is that from Flemish Grey Giant carcasses. Significant differences in colour components were observed for all the studied breeds when measured at 45 minutes after slaughter. However, it was noted that the colour equalised as the meat matured. Sex was not shown to have a significant effect on the acidity of rabbit meat. It does, however, have a significant effect on the lightness of the meat and the yellow colour component at 24 hours after slaughter. At the same time, meat from females is darker and more yellow than meat obtained from males.

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