

ANALYSIS OF THE RELATIONSHIP BETWEEN SLAUGHTER WEIGHT, POST-SLAUGHTER TRAITS AND MEAT QUALITY TRAITS OF CALIFORNIAN RABBITS

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Funding source: The study was carried out with financial support from the Ministry of Science and Higher Education (funds for statutory activity, SUB.215-D201).

Abstract

The purpose of this study was to determine the relationship between slaughter weight, post-slaughter traits and meat quality traits of Californian rabbits. The experimental material consisted of 46 rabbits (26 males and 20 females) of the Californian Black breed. The slaughter weight was determined before slaughter. The rabbits were slaughtered at 84 days of age, with a body weight of approximately 2.4 kg. The post-slaughter characteristics of the rabbits included: hot and cold carcass weight, weight of the fore, middle and hind parts. In addition, the pH and colour of the meat 45 minutes and 24 hours after slaughter, the shear force and profile texture analysis, as well as the cooking loss of the meat were determined. A number of statistically significant correlations between meat quality traits of Californian rabbits were found on the basis of our study. The phenotypic correlation values we estimated for the basic post-mortem traits are highly positively correlated with each other. As a result, we were able to estimate, with a high level of accuracy, the weight of individual carcass cuts based on slaughter weight, which is valuable information in terms of practical application. In addition, the numerous correlations between post-slaughter traits and meat quality traits show how important it is to analyse the relationships between various traits that seemingly have nothing in common, such as the yellowness component (b^*_{45}) and the slaughter, hot and cold carcass and individual carcass weight, or the colour lightness L^*_{24} and springiness. The results obtained from the presented studies confirm our opinion that there is a need to analyse production traits not so much within species, but within individual rabbit breeds.

Keywords: *Californian rabbit, phenotypic correlation, slaughter weight, slaughter traits, meat quality*

Introduction

The Californian rabbit is the result of breeding work by J. West. It is a medium-sized breed developed from Russian (Himalayan), New Zealand White and Chinchilla rabbits. The well-muscled hindquarters are cylindrical and supported by strong, medium-long legs, while the head is short and broad. The ears are well haired, erect, rounded at the tips and reach 10.5–11.5 cm in length. The eyes are red, and the claws are black or brown. The coat is dense and elastic, with clearly marked pigmentation of the mask, ears, feet and tail. The breed occurs in three colour varieties: black, blue and Havana. Californian Black rabbits have a pure white coat, whereas the mask, ears, feet and tail are black; Havana animals have chocolate-coloured markings. In the blue variety, these markings are dark blue (Klewin et al., 2020).

The breed matures rapidly, between 4 and 6 months of age. Gestation lasts approximately 32 days, and an average litter contains 7 kits (Pałka et al., 2017). The milk yield coefficient of females of this breed is 3.63 (Pałka et al., 2017). Californian rabbits are a popular broiler breed worldwide and in Poland (Składanowska-Baryza, 2017). According to data from the National Animal Breeding Centre (KCHZ), in 2023 ten herds of this breed were under performance evaluation: nine herds of the black variety and one of the Havana variety. The blue variety is not recognised by KCHZ. KCHZ data also indicate an average of 10.4 does per herd and 5.49 kits born per litter (KCHZ, 2024). The breed has a dressing percentage of approximately 48% (Chwastowska-Siwiecka et al., 2011), and its meat contains as much as 23.16% protein and 0.84% fat (Daszkiewicz and Gugolek, 2020). Californian rabbits are frequently crossed with other breeds, for example New Zealand White rabbits (Maj et al., 2009; Abdel-Hamid, 2018; Rotimi, 2021).

The Polish and international literature contains many studies on reproduction (Ferraz and Eler, 2000; Strychalski et al., 2014a), growth (Maj et al., 2009; El-Bayomi et al., 2012; Strychalski et al., 2014b), post-slaughter traits (Maj et al., 2009; Chwastowska et al., 2011) and meat quality (Kozioł et al., 2017; Trung et al., 2017; Daszkiewicz and Gugolek, 2020) in Californian rabbits. However, studies on relationships between post-slaughter traits and meat quality in this breed are lacking. Therefore, the aim of the present study was to determine the relationships among slaughter weight, post-slaughter traits and meat quality traits of Californian rabbits.

Material and methods

The experimental material comprised 46 Californian Black rabbits, including 26 males and 20 females. The animals originated from 8 litters and were the offspring of 5 females and 3 males. During the first 35 days after birth, the kits were kept with their dams in wooden cages measuring 80 × 70 × 60 cm (length × width × height) in a room equipped with a water system (nipple drinkers), lighting (14 h of light per day) and forced ventilation. The animals were weaned at 35 days of age and subsequently reared in metal cages (2 animals per cage). Each cage measured 60 × 40 × 35 cm (length × width × height).

The rabbits were fed *ad libitum* a commercial complete pelleted diet containing 10.2 MJ metabolisable energy, 16.5% crude protein and 14% crude fibre. The diet was balanced to meet the animals' nutrient requirements specified in feeding standards (Zalecenia żywieniowe..., 2011). The live trait examined was body weight before slaughter. All animals were weighed 10 minutes before slaughter. Rabbits were slaughtered at 84 days of age, at a body weight of approximately 2.4 kg, after 24 h fasting with continuous access to drinking water. The animals were stunned, exsanguinated and skinned; the carcasses were then eviscerated and chilled for 24 h at 4°C. Subsequently, carcasses were divided into three cuts: fore part,

middle part and hind part. Post-slaughter traits included hot and cold carcass weight and the weights of the fore, middle and hind parts.

Meat colour in the CIE $L^*a^*b^*$ colour space (L^* – lightness, a^* – redness, b^* – yellowness) was measured using D65 illumination, a 0° measurement angle, a 2° observer angle and white calibration (Gozdecka, 2006). Colour was measured 45 minutes and 24 hours after slaughter on the surface of the longissimus lumborum muscle at the level of the first lumbar vertebra, always on the right side of the carcass. All measurements were made using a Minolta CR-410 reflectance colorimeter. Three point measurements were taken and averaged. Post-mortem muscle pH was measured with a Consort C561 microprocessor pH meter equipped with a reinforced SP24B glass penetration electrode at 45 minutes (pH45) and 24 hours (pH24) post mortem, to an accuracy of 0.01. Measurements were made on the right side of the carcass in the same muscle and at the same site as colour measurements.

After 24 h chilling, samples of the right middle part (m. longissimus lumborum) were collected from each carcass. Samples were individually vacuum-packed in plastic bags intended for food packaging and freezing, frozen for 72 h at -18°C , thawed at room temperature and then cooked in a water bath at 80°C for 40 minutes (Migdał et al., 2013). Shear force was measured using a TA.XT plus texture analyser (Stable Micro Systems) fitted with a Warner-Bratzler blade with a triangular notch. Samples with a cross-section of 10×10 mm were sheared at a blade speed of 2 mm/s perpendicular to the muscle fibres until complete cutting. Texture profile analysis (TPA) was performed using the same instrument fitted with a 50-mm-diameter cylindrical probe. Hardness, springiness, cohesiveness and chewiness were measured in cube-shaped samples with 10-mm sides. A double-compression test to 75% was performed according to Migdał et al. (2013), at a probe speed of 5 mm/s and a 5-s interval between compressions, along the muscle fibres. All meat texture and shear-force parameters were calculated automatically using Exponent for Windows version 5.1.2.0 (Stable Micro Systems). Cooking loss was determined in m. longissimus lumborum samples. Samples weighing approximately 50 g were weighed, placed in zip-lock plastic bags and pasteurised in a water bath at 75°C for 50 minutes. They were then cooled at room temperature, dried and weighed to 0.01 g. Cooking loss was calculated as: $\text{CL} = [(\text{sample weight before cooking} - \text{sample weight after cooking}) \times 100] / \text{sample weight before cooking}$.

All statistical calculations were performed using SAS statistical software (2014). Pearson correlation coefficients were calculated using PROC CORR, while traits were characterised using PROC MEANS.

Results

Table 1 presents the characteristics of all analysed traits. The mean slaughter weight of Californian Black rabbits was almost 2400 g. Mean hot carcass weight was nearly 1300 g, whereas after 24 h chilling the mean weight was 50 g lower. The fore part weighed on average more than 530 g, the middle part more than 250 g, and the hind part more than 430 g.

Meat pH decreases after slaughter as lactic acid accumulates in the muscles. Meat examined 45 minutes post mortem had a near-neutral reaction (pH above 6.6), whereas after 24 hours it was acidic (pH decreased to approximately 6.0). Meat colour is related to pH. A rapid pH decline may cause pale colour and reduce water-holding capacity. Lightness (L^*) measured 45 minutes after slaughter averaged above 60. Redness (a^*) and yellowness (b^*) measured at the same time averaged approximately 3.2 and -1.1 , respectively. Lightness (L^*) measured 24 hours after slaughter averaged above 57, while redness and yellowness measured after 24 hours increased to above 6.7 and 4.3, respectively. Cooking loss is associated with meat pH and water-holding capacity and indicates losses of muscle juice during thermal processing. Mean cooking loss exceeded 29%. Table 1 also presents texture profile analysis.

Shear force exceeded 2.2 kg. Mean hardness was approximately 11.1 kg, mean springiness approximately 0.5, mean cohesiveness 0.4, and mean chewiness approximately 2.4 kg.

Table 1. Characterisation of slaughter weight, post-slaughter and meat quality traits (n=46)

Traits	Mean	sd	Min.	Max.
Slaughter weight (g)	2398,00	288,37	1950,00	3305,00
Hot carcass weight (g)	1276,00	174,95	961,00	1754,00
Cold carcass weight (g)	1226,00	172,02	928,00	1704,00
Fore part weight (g)	532,37	82,12	411,00	760,00
Middle part weight (g)	258,74	43,74	179,00	415,00
Hind part weight (g)	434,70	54,07	338,00	585,00
pH45	6,63	0,53	5,50	7,45
pH24	5,96	0,18	5,64	6,45
L*45	60,14	5,13	47,76	69,65
a*45	3,21	3,45	-1,29	17,09
b*45	-1,08	3,71	-7,60	6,81
L*24	57,15	3,01	50,24	65,07
a*24	6,76	2,55	2,58	16,64
b*24	4,31	1,79	1,76	8,85
Shear force (kg)	2,24	0,80	0,54	3,93
Hardness (kg)	11,06	2,09	6,70	16,85
Springiness	0,48	0,05	0,40	0,66
Cohesiveness	0,44	0,03	0,36	0,50
Chewiness (kg)	2,43	0,74	1,18	4,92
Cooking loss (%)	29,29	3,81	23,30	45,15

Notes: pH45 – acidity 45 minutes after slaughter, pH24 – acidity 24 hours after slaughter, L*45 – lightness 45 minutes after slaughter, a*45 – redness 45 minutes after slaughter, b*45 – yellowness 45 minutes after slaughter, L*24 – lightness 24 hours after slaughter, a*24 – redness 24 hours after slaughter, b*24 – yellowness 24 hours after slaughter.

Table 2 presents phenotypic correlation coefficients among slaughter weight, post-slaughter traits and meat quality traits of Californian Black rabbits. Slaughter weight, hot carcass weight, cold carcass weight, fore part weight, middle part weight and hind part weight were all highly positively correlated in pairs ($P < 0.05$). In addition, each of these six traits was moderately positively correlated ($P < 0.05$) with yellowness (b^*) measured 45 minutes after slaughter. A moderate positive correlation ($P < 0.05$) was found between meat pH measured 45 minutes post mortem and lightness measured at the same time. pH measured 45 minutes after slaughter was moderately and significantly negatively correlated ($P < 0.05$) with hardness and chewiness. Lightness (L^*) measured 45 minutes post mortem was moderately negatively correlated ($P > 0.05$) with redness (a^*) measured at the same time. A moderate negative but significant Pearson correlation was found between redness (a^*) and yellowness (b^*) measured 45 minutes post mortem.

Lightness (L^*) measured 24 hours after slaughter was moderately negatively correlated ($P < 0.05$) with redness (a^*) measured at the same time. Lightness (L^*) at 24 hours was also moderately positively and significantly correlated ($P < 0.05$) with meat springiness. A moderate positive phenotypic correlation ($P < 0.05$) was found between redness (a^*) and yellowness (b^*) measured 24 hours after slaughter. Among texture parameters, moderate positive and significant correlations were found between shear force and each of the following traits: hardness, cohesiveness, chewiness and cooking loss. Positive high or moderate correlations ($P < 0.05$) were found between hardness and springiness, cohesiveness and chewiness.

Tabela 2. Współczynniki korelacji między masą ubojową, cechami poubojowymi i cechami jakości mięsa (n=46)

Table 2. The correlation coefficients among slaughter weight, the post-slaughter and meat quality traits (n=46)

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Discussion

The body weight of rabbits in the present experiment was almost 2400 g, which agrees with earlier findings by Trung et al. (2017) for a Vietnamese population of Californian rabbits. Maj et al. (2009) reported hot and cold carcass weights of 1270.2 g and 1232 g, respectively, while fore part, middle part and hind part weights were 461.9 g, 263.2 g and 445.4 g, respectively. These results are very similar to those obtained in the present study. According to Barabasz and Bieniek (2003), rabbit meat pH measured immediately after slaughter most often ranges from 6.1 to 6.8, indicating good quality and moderate susceptibility of animals to stress. After 24 h chilling, the pH of good-quality rabbit meat should range from 5.4 to 5.8. These values are slightly higher than in meat from other livestock species, which may indicate lower shelf life. Meat from Californian rabbits in our experiment had a normal pH 45 minutes post mortem, but the pH after 24 hours was too high. Daszkiewicz and Gugolek (2020) reported an even higher pH value of 6.14 after 29 hours. Meat colour parameters reported by these authors also differed from those measured in the present study: they found higher L^* and b^* values and lower a^* values. These differences probably resulted from the later measurement time (approximately 29 hours) and the use of minced meat. Comparison of shear force and texture profile analysis among medium-sized breeds and Flemish Giant Grey rabbits indicates that meat from Californian Black rabbits does not differ significantly in these parameters from meat of New Zealand White, Popielno White, Termond White and Flemish Giant Grey rabbits (Kozioł et al., 2017). Rybarczyk and Łupkowska (2016) found cooking loss of almost 22% in the longissimus lumborum muscle of Californian rabbits.

In meat-animal breeding, positive and negative relationships among slaughter-performance and meat-quality parameters should be considered because they are highly relevant to selection. High correlations between slaughter traits and meat quality can be observed in meat rabbit breeding. Researchers have noted that selection over recent decades for improved growth rate and slaughter traits in meat rabbits has produced fast-growing animals with high carcass meat content, but unfortunately poorer meat quality (Maj et al., 2008). Long-term selection for improved growth rate has changed mean post-slaughter trait values and may also indirectly increase the frequency of undesirable changes in rabbit meat quality parameters (Maj et al., 2008).

Blasco and Piles (1990) reported low negative phenotypic correlations between pH measured 15 minutes and 24 hours post mortem: -0.27 for purebred New Zealand White rabbits and -0.18 for rabbits from a synthetic line based mainly on the Californian breed, slaughtered at 69–71 days of age. Sternstein et al. (2015) found a moderate positive phenotypic correlation between pH₄₅ and pH₂₄ measured in the biceps femoris of New Zealand White $\times$ Flemish Giant Grey crossbred rabbits (0.39). Hernandez et al. (1997) reported a moderate negative correlation between pH measured 24 hours after slaughter and meat lightness (-0.41) measured at the same time. Łapa et al. (2006) found a moderate negative phenotypic correlation (-0.44) between pH₄₅ and yellowness (b^*_{24}). Maj et al. (2008) reported a high negative phenotypic correlation between lightness (L^*_{24}) and redness (a^*_{24}), equal to -0.72 . Łapa et al. (2006) likewise reported a high negative phenotypic correlation between L^*_{24} and a^*_{24} (-0.77), as well as a moderate positive phenotypic correlation between a^*_{24} and b^*_{24} (0.43). In Maj et al. (2008), meat hardness was highly positively correlated with chewiness (0.66). For Castorex rabbit meat, Łapa et al. (2006) reported high positive correlations of chewiness with hardness (0.67), springiness (0.63) and cohesiveness (0.52). Hernandez et al. (2000) found a high positive correlation between meat hardness and chewiness (0.82) and a high positive correlation between chewiness and springiness (0.69).

The phenotypic correlation values estimated in our study for basic post-slaughter traits were highly positively correlated with one another. This makes it possible to estimate the

weight of individual carcass cuts with high accuracy on the basis of slaughter weight, which is valuable from a practical standpoint. In addition, the numerous correlations between post-slaughter traits and meat quality traits demonstrate the importance of analysing relationships among traits that may appear unrelated, such as yellowness (b^* 45) and slaughter weight, hot and cold carcass weight and the weights of individual cuts, or lightness L^* 24 and meat springiness. The results of the present study reinforce the need to analyse production traits not only at the species level but also within individual rabbit breeds.

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- Approved for publication: 12 November 2024