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The effect of sex, storage time and muscle type on the quality French Lop rabbit meat

Agnieszka Ludwiczak, Marek Stanisz, Marta Bykowska, Joanna Składanowska, Łukasz Sikora, Piotr Ślósarz

Poznań University of Life Sciences,
Department of Animal Breeding and Product Quality Assessment,
Złotniki, Słoneczna 1, 62-002 Suchy Las, Poland; e-mail: agnieszka.ludwiczak@up.poznan.pl

The aim of the study was to analyse the effect of sex, storage time and muscle type (*m. longissimus dorsi* and *m. biceps femoris*) on quality traits of the meat of French Lop rabbits. The muscles were obtained from 12 males and 12 females slaughtered at the age of 90 days. The characteristics analysed included pH, colour parameters, water holding capacity and proximate composition. No effect of sex or muscle type was found (P>0.05) on the pH of the meat in any of the periods analysed. The storage time differentiated (P≤0.01) between pH_{45min} and pH_{24h} and between pH_{45min} and pH_{7days}. None of the colour parameters was influenced by sex (P>0.05), but they were significantly affected by storage time (P≤0.01). Redness and yellowness were also influenced by the type of muscle (P≤0.01). The rabbit meat stored for 7 days was characterised by higher drip loss than the meat stored for 24 hours (1.31-1.49% vs. 3.34-3.57%, P≤0.05). The *m. biceps femoris* of both sexes had a greater capacity to hold water as measured by the pressure method than *m. longissimus dorsi* (P≤0.01). There was no effect of sex or muscle type (P>0.05) on the level of cooking loss. Sex and muscle type also had no influence (P>0.05) on the proximate composition of French Lop meat.

KEY WORDS: French Lop /sex /time of measurement / meat quality

According to the Central Statistical Office (GUS) [16], in 2010 more than 95% of Polish agricultural holdings kept less than 20 rabbits, suggesting that rabbit farming in Poland has an amateur character. The data for Poland for 2010 also indicate that 116,000 agricultural holdings kept a total of 631,500 female rabbits [2]. Rabbit meat production in Poland in 2013 was 2,800 tonnes, accounting for only 0.07% of total meat production (3,810,370 tonnes) [13]. According to FAOSTAT, rabbit meat production in Poland in 2013 was much lower than in many other European countries, including Spain (63,289 tonnes), France (52,131 tonnes), Italy (262,500 tonnes) and Hungary (6,647 tonnes) [20]. According to Maj et al. [28, 32], rabbits are characterized by early maturation, high fertility, quick growth, and high adaptability to environmental changes, and their meat is of high quality and provides many health benefits. Kowalska et al. [20, 24] showed that rabbit meat has

a high percentage of protein, a low percentage of fat, and relatively low content of cholesterol compared to meat from other animals. Barabasz and Bieniek [2] reported that the human body is able to absorb even 90% of protein from rabbit meat. However, the quality of rabbit meat is affected by many factors, including breed [6, 8, 31], sex [29, 31], feeding system [20, 33], housing system [11, 34], and type of slaughter [1, 36, 37]. The most popular rabbit breeds raised for meat in Poland are New Zealand White and Red, Californian, Blanc de Termonde and Popielno White. The French Lop rabbit is an example of a large rabbit breed that is not suitable for factory farming. It is characterized by relatively late maturation, a low growth rate, and lower meat yield as compared to medium-sized rabbit breeds raised for meat production [14]. There is no literature on the quality of meat from French Lop rabbits. The aim of the study was to determine the effect of sex, storage time, and type of muscle (*m. longissimus dorsi* and *m. biceps femoris*) on quality traits of meat from French Lop rabbits.

Material and methods

The study was conducted on the *musculus longissimus dorsi* and *musculus biceps femoris* of 24 French Lop rabbits (12 males and 12 females) slaughtered at 90 days. The animals were kept in cages (4 per cage, males and females separately). During the period from the weaning to slaughter the rabbits were fed with a mix of pellets (commercial compound feed) and barley in a 2:1 proportion. The commercial compound feed contained 16.00% crude protein, 14.00% fibre, 3.20% crude oils and fats, and 10.40 MJ/kg digestible energy. The animals were weighed prior to slaughter. The average body weight was 2.86 (±0.11) kg for males and 3.18 (±0.11) kg for females.

The physicochemical analysis of the rabbit meat included pH, colour and water holding capacity.

For calibration of the pH equipment, buffers of pH 7.0 and 4.0 were used. Acidity was measured in the two muscles by inserting a combination glass calomel electrode (ERH--11X1) attached to a portable pH meter (Handylab 2, SCHOTT) into the muscle. The first measurement was taken directly after the carcasses were placed in the chilling room, that is 45 minutes (pH_{45min}) post-slaughter. The following measurements were taken 24 hours (pH_{24h}) and 7 days (pH_{7days}) after slaughter.

Triplicate colour measurements of the muscles were taken on cross-sections 3 cm thick after a blooming period of 45 minutes. Measurements were taken 24 hours and 7 days after slaughter and expressed according to the CIE Lab system as L* (lightness), a* (redness), and b* (yellowness) (CIE, 1978). The colour space parameters were measured by the reflectance method using a Minolta Colorimeter CR-200b (illuminant C, 10° observer, 30 mm aperture size). Muscles for pH and colour analysis were stored at +2 °C between measurements.

The water holding capacity of the meat was determined for the fresh samples (24 hours post-slaughter) using different methods:

– Drip loss (%) was measured according to Honikel [19]. Transverse slices of the two muscles analysed, 2.5 cm thick (about 50 g), were weighed, hung on hooks, and placed

in a container to reduce evaporation (+2 °C). After 24 hours and 7 days the samples were weighed again to calculate the change in the weight of the sample.

– Free water (%) was measured using a pressure method according to Grau and Hamm [18] in a modification of the method described by Pohja and Niinivaara [41]. Samples of ground meat weighing 0.3 g were placed on filter paper between two glass tiles. A force of 2 kg was applied to each sample for 5 minutes, and then samples were weighed immediately to calculate the change in the weight of the sample (loose water %).

– Water holding capacity (WHC, cm^2) was determined according to Grau and Hamm [18]. Small samples of ground meat (0.3 g) were placed on filter paper between two glass tiles. A force of 2 kg was applied to each sample for 5 min and the meat surface to purge surface ratio was calculated (cm^2).

– Cooking loss (%) was measured according to Honikel [19]. Transverse slices of the two muscles analysed, 2.5 cm thick (about 50 g), were placed in thin polyethylene bags with the sides of the bag adhering firmly to the meat sample. The bags with the meat were placed in a water bath at 75 °C for 30 min and then cooled to room temperature and weighed to calculate the change in the weight of the sample.

The chemical composition of the meat was analysed to determine moisture content. The samples were dried at 105 °C to a constant weight [39]. Extracted fat was determined according to Soxhlet [40] and crude protein according to Kjeldahl [38].

The effect of sex, muscle type and time of storage on pH (pH_{45min}, pH_{24h} and pH_{7days}) and muscle colour L* (L^*_{45min}, L^*_{24h} and L^*_{7days}), a* (a^*_{45min}, a^*_{24h} and a^*_{7days}) and b* (b^*_{45min}, b^*_{24h} and b^*_{7days}) was estimated by means of three-way ANOVA, SAS ver. 9.1 software package [44].

$$Y_{ijkl} = \mu + p_i + t_j + r_k + e_{ijkl}$$

where:

Y_{ijkl} – phenotypic value of the trait;

μ – overall mean of analysed trait;

p_i – effect of i^{th} sex (i = 1 – males, 2 – females);

t_j – effect of j^{th} type of muscle (j = 1 – *musculus longissimus dorsi*, 2 – *musculus biceps femoris*);

r_k – effect of k^{th} time of storage (k = 1-45 minutes, 2-24 hours, 3-7 days);

e_{ijkl} – random error.

The effect of sex and muscle type on the chemical composition of the muscles (water, crude protein and intramuscular fat), water to crude protein ratio, free water, WHC and cooking loss was estimated by two-way ANOVA, SAS ver. 9.1 software package [44].

$$Y_{ijk} = \mu + p_i + t_j + e_{ijk}$$

where:

Y_{ijk} – phenotypic value of the trait;

μ – overall mean of analysed trait;

p_i – effect of i^{th} sex (i = 1 – males, 2 – females);

t_j – effect of j^{th} type of muscle (j = 1 – *musculus longissimus dorsi*, 2 – *musculus biceps femoris*);

e_{ijk} – random error.

The effect of sex and storage time on the drip loss (24 hours and 7 days) was estimated by two-way ANOVA, SAS ver. 9.1 software package [44].

$Y_{ikl} = \mu + p_i + r_k + e_{ikl}$

where:

Y_{ikl} – phenotypic value of the trait;

μ – overall mean of analysed trait;

p_i – effect of i^{th} sex (i = 1 – males, 2 – females);

r_k – effect of k^{th} time of storage (k = 1-24 hours, 2-7 days);

e_{ikl} – random error.

The significance of differences between pairs of means was verified by the LSD (Least Significant Difference) test, SAS [44].

Results and discussion

The pH of meat is one of the most important factors determining its quality. According to Maj et al. [30], the pH of high quality rabbit meat measured 45 minutes post-slaughter ranges from 6.1 to 6.8, while the pH after 24 hours (the ultimate pH) should be within a range of 5.4-5.8. In the present study the pH of the rabbit meat changed with the storage time (P≤0.01) (Table 1). The pH_{45min} was between 6.38 and 6.46. Similar pH values 45 minutes post-slaughter were obtained by Bieniek et al. [6] for Burgundy Fawn (6.45) and New Zealand White (6.85) rabbits, and by Dal Bosco et al. [10] for hybrid rabbits (6.41--6.85). A lower pH_{45min} was reported by Łabecka [26] for New Zealand White (6.35), Vienna Blue (6.05) and Danish White (6.16). Maj et al. [30] reported higher pH_{45min} (6.74-6.87) for the Castorex breed. The pH_{24h} value in our study ranged from 5.83 to 5.91, and was lower than the pH_{45min} by 0.54 units (P≤0.01). A similar pH_{24h} was observed by Bianchi et al. [5] for hybrid rabbits and by Maj et al. [30] for the Castorex breed (5.87-5.92 and 5.82-5.89, respectively). Bieniek et al. [6] found a lower meat pH_{24h} in the New Zealand White (5.55) and Burgundy Fawn (5.45) breeds, while Bianchi et al. [4] and Dal Bosco et al. [10] noted a higher pH_{24h} for hybrid rabbits (6.12-6.24 and 5.99-6.35, respectively). In a study by Dal Bosco et al. [10], the drop in pH between the period immediately after slaughter and the 24th hour post-slaughter was lower than in the present study, at 0.46 units for *m. longissimus*, and 0.43 units for *m. biceps femoris.* A greater decrease between pH_{45min} and pH_{24h} was reported by Bieniek et al. [6] (1.27 pH units for New Zealand White, 1.00 for Burgundy White and 1.15 for crossbreeds), by Chwastowska-Siwiecka et al. [9] (0.82 units for Californian rabbits and 1.16 for New Zealand White) and by Kowalska [21] (0.87 units for New Zealand White). In our research the pH after 7 days of storage ranged from 5.84 to 5.94, and was 0.53 units lower than pH_{45min}. Nakyinsige et al. [36] reported a smaller pH drop between pH_{24h} and pH_{7days}, at a level of 0.15 units (no stunning) or 0.17 units (gas stunning). To conclude, in this study a significant decrease in pH was found between pH_{45min} and pH_{24h} and between pH_{45min} and pH_{7days} (P≤0.01), while there were no differences between pH_{24h} and pH_{7days} (P>0.05). These results can be explained by the completion of the glycolysis process by the 24th hour post-slaughter, resulting in the pH stabilization. The results of the study indicate that there was no influence of sex on the quality of rabbit meat

Table 1 – Tabela 1

Muscle pH of French Lop Rabbits

Kwasowość (pH) mięśni królików rasy baran francuski

Time of measurement Czas pomiaru		Males – Samce		Females – Samice		Effect – Wpływ	
		m. longissimus dorsi LSM ±SE	*m. biceps femoris* LSM ±SE	*m. longissimus dorsi* LSM ±SE	*m. biceps femoris* LSM ±SE	sex płeć	type of muscle rodzaj mięśnia
45 minutes 45 minut	I	6.38 ±0.07	6.46 ±0.07	6.39 ±0.07	6.45 ±0.07	ns	ns
24 hours 24 godziny	II	5.87 ±0.07	5.91 ±0.07	5.83 ±0.07	5.88 ±0.07	ns	ns
7 days 7 dni	III	5.85 ±0.07	5.94 ±0.07	5.84 ±0.07	5.90 ±0.07	ns	ns
				Effect of time of measurement Wpływ czasu pomiaru			
		I – II**	I – II**	I – II**	I – II**		
		I – III**	I – III**	I – III**	I – III**		
		II – III^{ns}	II – III^{ns}	II – III^{ns}	II – III^{ns}		

**P≤0.01, ns – not significant – różnice nieistotne statystycznie

(P>0.05), similarly to the conclusions reported by Maj et al. [29] on the pH_{45min} and pH_{24h} of the meat of rabbits aged 12-32 weeks. On the other hand, Yalçin et al. [46] reported a significant effect of sex (P≤0.05) on the pH of the *m. longissimus* of New Zealand White rabbits, but no differences between males and females in the case of the *m. biceps femoris* pH (P>0.05). The acidity of the French Lop meat did not differ between muscles (P>0.05), which is consistent with research on meat from other rabbit breeds conducted by Barròn et al. [3], Preziuso et al. [42] and Daszkiewicz et al. [12]. Maj et al. [29] also reported a very similar pH range for the *m. longissimus dorsi* and *m. biceps femoris* measured both 45 minutes (6.73-6.82 and 5.55-5.93) and 24 hours (6.61-6.83 and 5.83-6.03) post-slaughter for rabbits of different ages. Yalçin et al. [46] showed a significantly higher pH_{24h} for the *m. biceps femoris* in comparison with the *m. longissimus* (by 0.44 units) and linked it to differences in the structure of the two muscles and in the course of post-mortem biochemical changes.

An appropriate and acceptable colour of meat has a significant influence on the consumer's willingness to purchase the product. The impact of storage time was very clear for all the analysed colour parameters. A decrease in meat lightness between 45 minutes and 24 hours post-slaughter (about 1.41 units for *b. femoris* and 1.59 units for *longissimus dorsi*, P≤0.01) was observed only for females (Table 2). A decrease in L* between 45 minutes and 7 days post-slaughter was reported for both muscles (by 2.31 units for *m. longissimus dorsi* and from 0.99 to 1.91 for *m. biceps femoris*) and was not affected by sex. The greatest differences (P≤0.01) in the gradual decrease in L* were noted between 45 minutes and 7 days post-slaughter. In the case of the chromatic colour components, a* and b*, the greatest changes were observed for *m. longissimus dorsi.* An increase in redness was observed between 24 hours and 7 days post-slaughter (by 1.99 for males and 2.97 for females; P≤0.01). For *m. biceps femoris*, the reverse trend with respect to *m. longissimus dorsi* was noted for a*, which decreased by 0.90-0.95 (P≤0.01) between 24 hours and 7 days of storage. The final difference between a^*_{45min} and a^*_{7days} was within a range of 0.74-1.89 (P≤0.01). The significant changes in a* can be explained by the different microstructure of the muscles [27]. The direction of the changes in yellowness depended on the type of muscle, and as in the case of a*, it decreased with storage time in *m. biceps femoris* and increased in *m. longissimus dorsi.* The change in b* was greatest between 24 hours and 7 days of storage and between 45 minutes and 7 days of storage.

The b* value of *m. longissimus dorsi* increased between 24 hours and 7 days by 1.81-3.56 units (P≤0.01). The total change in b* (between 45 minutes and 7 days of storage) was between 8.58 and 9.41 (P≤0.01). In the case of *m. biceps femoris* the total change in the b* value was 6.31-7.23 (P≤0.01). To conclude, the direction and rapidity of the colour changes depended on the colour parameter analysed. During the 7 days of storage the meat became lighter. The redness and yellowness increased in the case of *m. longissimus dorsi* and decreased in *m. biceps femoris.* Chwastowska-Siwiecka et al. [9] reported an increase in L* and a* by 2.21 and 0.38 and a decrease in b* by 0.45 for vacuum-packed rabbit leg stored for 10 days. Bieniek et al. [6] analysed the quality of the *m. longissimus* of three rabbit breeds 45 minutes and 24 hours post-slaughter. The colour brightness decreased 24 hours post-slaughter (by 2.67 for New Zealand White, by 1.11 for Burgundy White and by 2.14 for crossbreeds), while redness increased rapidly (by 4.49 for New Zealand White,

Table 2 – Tabela 2

Colour parameters of French Lop Rabbits

Barwa mięśni królików rasy baran francuski

Trait Cecha	Time of measurement Czas pomiaru		Males – Samce		Females – Samice		Effect (P-value) – Wpływ	
			m. longissimus dorsi LSM ±SE	*m. biceps femoris* LSM ±SE	*m. longissimus dorsi* LSM ±SE	*m. biceps femoris* LSM ±SE	sex płeć	type of muscle rodzaj mięśnia
L*	45 minutes 45 minut	I	53.78 ±0.81	52.78 ±0.81	54.56 ±0.81	53.46 ±0.81	ns	ns
	24 hours 24 godziny	II	52.97 ±0.81	51.75 ±0.81	52.57 ±0.81	52.05 ±0.81	ns	ns
	7 days 7 dni	III	50.66 ±0.81	50.76 ±0.81	50.06 ±0.81	50.86 ±0.81	ns	ns
a*	45 minutes 45 minut	I	0.21^{A} ±0.48	4.83^{B} ±0.48	0.82^{A} ±0.48	3.38^{B} ±0.48	ns	**
	24 hours 24 godziny	II	0.36^{A} ±0.48	3.89^{B} ±0.48	0.16^{A} ±0.48	3.54^{B} ±0.48	ns	**
	7 days 7 dni	III	2.35 ±0.48	2.94 ±0.48	3.13 ±0.48	2.64 ±0.48	ns	ns
b*	45 minutes 45 minut	I	6.41^{A} ±0.51	8.45^{B} ±0.51	7.32^{AC} ±0.51	7.61^{BC} ±0.51	ns	**
	24 hours 24 godziny	II	6.77^{A} ±0.51	8.24^{B} ±0.51	5.85^{C} ±0.51	8.13^{B} ±0.51	ns	**
	7 days 7 dni	III	8.58^{A} ±0.51	7.23^{B} ±0.51	9.41^{C} ±0.51	6.31^{B} ±0.51	ns	**
			Effect of time of measurement Wpływ czasu pomiaru					
L*			I – II^{ns} I – III** II – III*	I – II^{ns} I – III** II – III*	I – II** I – III** II – III*	I – II** I – III** II – III*		
a*			I – II^{ns} I – III** II – III**	I – II^{ns} I – III** II – III**	I – II^{ns} I – III** II – III**	I – II^{ns} I – III^{ns} II – III*		
b*			I – II^{ns} I – III** II – III**	I – II^{ns} I – III** II – III*	I – II** I – III** II – III**	I – II^{ns} I – III** II – III**		

a, b, c (A, B, C) – means within the same row with different lower-case (capital) letters are significantly different at P≤0.05 (P≤0.01)

a, b, c (A, B, C) – średnie oznaczone różnymi małymi (dużymi) literami w wierszach różnią się przy P≤0,05 (P≤0,01) *P≤0.05, **P≤0.01, ns – not significant – różnice nieistotne statystycznie

by 4.35 for Burgundy White and by 7.02 for crossbreeds). The yellowness value shifted from negative to positive, representing the greatest change. The direction of colour changes described in the research cited was similar to the results of the present study for the *m. longissimus* of French Lop. Nakyinsige et al. [36] showed colour changes of an entirely different nature for the *m. longissimus* of New Zealand White, i.e. a decrease in all colour parameters (L*, a*, b*) between the 1st and the 7th day post-slaughter.

There was no effect of sex (P>0.05) on the colour parameters analysed in the present study, similarly to the results reported by Carrilho et al. [7] on the quality of the *m. longissimus* of hybrid rabbits analysed 48 hours post-slaughter. Maj et al. [29] also found no differences in the colour parameters of *m. longissimus* and *m. biceps femoris* between male and female New Zealand Whites. In contrast, in research including different rabbit breeds (New Zealand White, Californian and Flemish Giant), Maj et al. [31] showed an impact of sex on the a* value of *m. biceps femoris.* Redness was higher in males than in females – by 0.57 units (P≤0.05) 45 minutes post-slaughter and by 0.73 units (P≤0.01) 24 hours post-slaughter.

Research has shown that the type of muscle affects the colour parameters of the meat, due to different muscle structure [17, 25]. In the present study the type of muscle affected the a* and b* values of the rabbit meat, but did not influence its lightness (P>0.05). *Musculus biceps femoris* had a higher value of a^*_{45min} and a^*_{24h} as compared to *m. longissimus dorsi*, both in males (a^*_{45min} 3.53 higher; a^*_{24h} 0.59 higher; P≤0.01) and in females (a^*_{45min} 3.38 higher; a^*_{24h} 0.49 higher; P≤0.01). For both males and females the *m. biceps femoris* was characterised by significantly (P≤0.01) higher b^*_{45min} (by 2.04 and 0.29) and b^*_{24h} (by 1.47 and 2.28) as compared to *m. longissimus dorsi.* After 7 days of storage the b* value of the *m. longissimus dorsi* increased significantly and was significantly (P≤0.01) higher than the b* value for *m. biceps femoris*, by 1.35 for males and by 3.10 for females. Daszkiewicz et al. [12] and Dalle Zotte et al. [11] showed a significant impact of muscle type on the colour of rabbit meat measured 24 hours post-slaughter. According to these authors the *m. longissimus* was lighter than the leg muscles (59.8 vs. 57.2 and 54.8-56.8 vs. 61.4-62.0, respectively) and less red (1.9 vs. 6.0 and 2.8-3.5 vs. 6.5-7.6, respectively). The colour changes reported by Maj et al. [31] in *m. longissimus* and *m. biceps femoris* were opposite to those observed in the present study. In all the analysed breed groups they found an increase in L* and a decrease in a* and b* in the *m. longissimus* between 45 minutes and 24 hours post-slaughter. In the case of *m. biceps femoris* all colour parameters increased during this period.

The drip loss (Table 3) measured 24 hours post-slaughter in the *m. longissimus dorsi* of the French Lop rabbits ranged from 1.31% to 1.49% and was similar to the drip obtained by Apata et al. [1] for different rabbit breeds (0.80-2.47%). Bianchi et al. [4] and Chwastowska-Siwiecka et al. [8] showed a lower drip loss for hybrid rabbits (1.11-1.17%), Californian rabbits (0.74%) and the New Zealand White breed (0.91%). Higher drip loss for hybrid rabbits was also reported by Dal Bosco et al. [10] (1.69-2.34%) and Marounek et al. [33] (3.76-4.56%). In the present research the meat stored for 7 days had a greater drip loss (by 2.03-2.08 pp.; P≤0.01) than the meat stored for 24 hours. Nakyinsige et al. [36] reported a lower drip loss of rabbit meat measured 7 days post-slaughter in research on New Zealand White rabbits (not stunned: 1.50%, stunned: 1.44%). In the present research no

Table 3 – Tabela 3

Parameters of water holding capacity of muscles of French Lop Rabbits

Wyróżniki wodochłonności mięsa królików rasy baran francuski

Trait Cecha	Time of measurement Czas pomiaru		Males – Samce		Females – Samice		Effect (P-value) – Wpływ	
			m. longissimus dorsi LSM ±SE	*m. biceps femoris* LSM ±SE	*m. longissimus dorsi* LSM ±SE	*m. biceps femoris* LSM ±SE	sex płeć	type of muscle rodzaj mięśnia
Drip loss (%) Wyciek naturalny (%)	24 h	I	1.31 ±0.15	–	1.49 ±0.15	–	ns	–
	7 dni	II	3.34 ±0.15	–	3.57 ±0.15	–	ns	–
	Effect of time of measurement Wpływ czasu pomiaru		I – II**		I – II**			
Free water (%) Woda wolna (%)	24 h	I	55.01^{A} ±1.21	50.81^{B} ±1.21	53.95^{A} ±1.21	49.25^{B} ±1.21	ns	**
WHC (cm^2)	24 h	I	7.56^{A} ± 0.25	6.64^{B} ±0.25	7.33^{A} ±0.25	6.03^{C} ±0.25	*	**
Cooking loss (%) Wyciek termiczny (%)	24 h	I	20.72^{Aa} ±0.74	21.85^{A} ±0.74	23.16^{ABb} ±0.74	20.07^{AC} ±0.74	ns	ns

a, b, c (A, B, C) – means within the same row with different lower-case (capital) letters are significantly different at P≤0.05 (P≤0.01)

a, b, c (A, B, C) – średnie oznaczone różnymi małymi (dużymi) literami w wierszach różnią się przy P≤0,05 (P≤0,01) *P≤0.05, **P≤0.01, ns – not significant – różnice nieistotne statystycznie

effect of sex was found on the level of drip loss (P>0.05), similarly to the results of a study conducted by Murshed et al. [35], who analysed the meat quality of male and female rabbits of a breed indigenous for Bangladesh and reported a high drip loss of 2.74-2.78%.

The amount of free water noted for the French Lop is similar to the value reported by Apata et al. [1] (50.20-62.37%). Dal Bosco et al. [10] showed a higher level of free water for hybrid rabbits, amounting to 62.92-66.70%. In the present study the level of free water in the *m. biceps femoris* was 4.45 pp. lower than in the *m. longissimus dorsi* (P≤0.01). There were no differences in the level of free water between males and females (P>0.05), which is in agreement with the results of research conducted by Carrilho et al. [7] on hybrid rabbits.

The water holding capacity of the meat (WHC) expressed as cm^2 was similar to the results reported by Daszkiewicz et al. [12] for New Zealand White (6.97-7.45 cm^2). Higher WHC values were reported by Łabecka [26] for New Zealand White (12.18 cm^2), Vienna Blue (12.09 cm^2), and Danish White (11.44 cm^2). In contrast, Maj et al. [32] observed a wide range of WHC for Castorex rabbits, from 8.75 to 13.09 cm^2. However, the sample preparation methodology used by Maj et al. [32] differed from that used in the present study. In our research the type of muscle had a significant effect on drip area. The *musculus biceps femoris* had a larger drip area in comparison with the *m. longissimus dorsi* (by 14.9%; P≤0.01), showing a lower capacity to retain internal moisture. Moreover, the WHC (cm^2) was affected by sex, with meat from males having a larger drip area (by 9-12%; P≤0.05) than that of females.

The cooking loss of meat from the French Lop ranged from 20.07% to 23.16%. Chwastowska-Siwiecka et al. [8] showed a similar level of cooking loss for the meat of Californian rabbits (19.37%) and New Zealand White (23.54%). A lower value for this trait (11.20-12.10%) was reported by Bianchi et al. [5] for hybrid rabbits. Rybarczyk et al. [43] reported cooking loss of 23.82-25.44% for wild rabbits, while Apata et al. [1], Dal Bosco et al. [10] and Nakyinsige et al. [36] obtained a higher cooking loss, ranging from 28.93% to 36.81% for hybrids and New Zealand White. In the present research no effect of sex (P>0.05) was found on cooking loss. Similarly, Yalçin et al. [46] found no difference in the cooking loss of meat from male and female New Zealand White rabbits (P>0.05), but reported a very high mean value of 38.73%. High cooking loss (27.69-28.22%) was also reported by Murshed et al. [35] following analysis of meat from a rabbit breed indigenous to South Asia.

The differences found between the literature and the present results for water holding capacity of rabbit meat are linked to the direction and rate of the biochemical changes taking place in the post-mortem muscle. These biochemical processes are strongly influenced by a variety of other factors, especially those connected with the pre-slaughter treatment of animals. Trocino et al. [45] reported that high pH of meat caused an increase in water holding capacity. Moreover, the available literature indicates that the slaughter method has a significant influence (P≤0.05) on the capacity of meat to retain internal moisture [1, 36].

The content of water and intramuscular fat in the meat from French Lop rabbits (Table 4) was in agreement with results obtained by Apata et al. [1] (67.48% and 2.65%, respectively). A higher value for intramuscular fat in the *m. longissimus dorsi* (1.78-2.28%) and *m. bices femoris* (3.02-4.28%) was reported by Kowalska and Piechocka [23]. Kowalska

Table 4 – Tabela 4

Chemical composition of French Lop Rabbits

Skład chemiczny mięsa królików rasy baran francuski

Specification Wyszczególnienie	Males – Samce		Females – Samice		Effect (P-value) – Wpływ	
	m. longissimus dorsi LSM ±SE	*m. biceps femoris* LSM ±SE	*m. longissimus dorsi* LSM ±SE	*m. biceps femoris* LSM ±SE	sex płeć	type of muscle rodzaj mięśnia
Water(%) Woda (%)	75.41 ±0.38	74.69 ±0.38	75.67 ±0.38	75.22 ±0.38	ns	ns
Crude protein (%) Białko ogólne (%)	22.23 ±0.21	22.35 ±0.21	22.49 ±0.21	21.95 ±0.21	ns	ns
Intramuscular fat (%) Tłuszcz śródmięśniowy (%)	1.12 ±0.10	1.30 ±0.10	1.18 ±0.10	1.39 ±0.10	ns	ns
Water/crude protein ratio Woda/białko	3.39 ±0.04	3.34 ±0.04	3.36 ±0.04	3.42 ±0.04	ns	ns

ns – not significant – różnice nieistotne statystycznie

[22] obtained crude protein content (21.8-22.2%) similar to our results and higher values for intramuscular fat content (1.87-1.98%) in New Zealand White rabbits. In the present study sex did not affect the chemical composition of the rabbit meat, similarly to the results reported by Murshed et al. [35]. Zając [47] and Maj et al. [32] showed a significant effect of sex ($P<0.05$) on intramuscular fat and crude protein content. Gašperlin et al. [15] reported a significant difference ($P<0.05$) between males and females in intramuscular fat content, amounting to 0.6 pp. According to Daszkiewicz et al. [12] there was a significant difference in fat ($P\leq0.05$) and crude protein ($P\leq0.01$) content and in the water/crude protein ratio ($P\leq0.01$) between the *m. longissimus* and the leg muscle. In contrast, in our study the chemical composition of the muscles analysed was similar ($P>0.05$).

To conclude, the study on the quality of meat of 90-day-old French Lop rabbits showed no effect of sex or muscle type ($P>0.05$) on the pH of the meat. However, there was a significant decrease in pH after 7 days of cold storage at +2 ºC ($P\leq0.01$). Colour space parameters were not affected by sex ($P>0.05$). An influence of the type of muscle on the chromatic components of colour ($P\leq0.01$) was noted. The L* value decreased ($P\leq0.01$) between 45 minutes and 7 days post-slaughter in females and between 24 h and 7 days in both sexes. The results of the colour analysis showed significant changes in redness (a*) and yellowness (b*) depending on the type of muscle and the time after slaughter ($P\leq0.01$). There was no effect of muscle type or sex on drip loss ($P>0.05$). The results indicate that drip loss increased after 7 days of storage ($P\leq0.01$). The *musculus biceps femoris* had lower content of free water ($P\leq0.01$) than the *m. longissimus dorsi*. No difference was revealed in the free water content between males and females ($P>0.05$). The *musculus biceps femoris* had a larger drip area in comparison with the *m. longissimus dorsi* (by 14.9%; $P\leq0.01$), indicating a lower water holding capacity. Moreover, the area of WHC (cm^2) was an influenced by sex ($P\leq0.05$). The results obtained showed no effect of muscle type or sex ($P>0.05$) on the cooking loss of the rabbit meat. The chemical composition of the French Lop rabbits was also not found to be influenced by muscle type or sex ($P>0.05$).

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Agnieszka Ludwiczak, Marek Stanisz, Marta Bykowska,
Joanna Składanowska, Łukasz Sikora, Piotr Ślósarz

Wpływ płci, czasu przechowywania i rodzaju mięśnia na jakość mięsa królików rasy baran francuski

Streszczenie

Celem pracy było określenie wpływu płci, czasu przechowywania i rodzaju mięśnia (*m. longissimus dorsi* i *m. biceps femoris*) na cechy jakościowe mięsa królików rasy baran francuski. Mięśnie pozyskano z tusz 12 samców i 12 samic ubitych w wieku 90 dni. Badania obejmowały pomiar pH, parametrów barwy wg CIE L*a*b*, wodochłonności oraz oznaczenie składu chemicznego. Nie stwierdzono wpływu płci i rodzaju mięśnia na pH (P>0,05) w 45 minut, 24 godziny i 7 dni po uboju. Stwierdzono wpływ czasu przechowywania na pH mięśni (P≤0,01) w przyjętych terminach pomiaru po uboju. Parametry barwy mięsa króliczego nie były zróżnicowane w zależności od płci, stwierdzono natomiast istotny wpływ czasu przechowywania (P≤0,01) oraz wpływ rodzaju mięśnia na indeks czerwieni i żółci (P≤0,01). Mięso królicze przechowywane przez 7 dni charakteryzowało się wyższym wyciekiem naturalnym w porównaniu do mięsa badanego 24 godziny po uboju (1,31-1,49% w porównaniu do 3,34-3,57%; P≤0,05). U obu płci mięsień *biceps femoris* cechował się większą wodochłonnością (cm^2) (P≤0,01) w porównaniu do *m. longissimus dorsi*. Nie wykazano wpływu rodzaju mięśnia oraz płci (P>0,05) na wielkość wycieku termicznego. Nie stwierdzono również wpływu rodzaju mięśnia oraz płci (P>0,05) na skład chemiczny mięsa królików rasy baran francuski.

SŁOWA KLUCZOWE: baran francuski / płeć / czas pomiaru / jakość mięsa