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Effect of different shares of protein feeds in diets and of cold storage time on the physical properties of broiler chicken's meat

Wpływ różnego udziału pasz białkowych w mieszankach oraz czasu przechowywania w warunkach chłodniczych na cechy fizyczne mięsa kurcząt brojlerów

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ABSTRACT

The study aimed at evaluating the effect of feeding broiler chickens with diets containing faba bean and cold storage time on the physical properties of *m. pectoralis major*. The study material comprised 24 muscles from chickens split into 3 feeding groups. Birds from the control group (I) were fed with compound feeds containing soybean meal as the only high-protein component, whereas the starter/grower diets administered to experimental chickens contained faba bean in the proportion 8/15% - group II and 16/22% - group III, as a partial substitute for soybean meal. No effect of the feeding method on acidity and water absorption capacity of the muscle was observed. Muscles of chickens fed with mixes with a higher share of faba bean were characterised by higher yellow saturation, colour intensity and hue in comparison to other groups. The storage time had no effect on their physical properties; a decrease was only recorded in pH_{24} of the evaluated muscles, which testifies to the correct course of glycolytic transformations. To sum up, it must be stated that a higher share of faba bean in chicken diets modifies muscle colour only, but cold storage time has no impact on the evaluated physical characteristics of muscles.

Keywords: broiler chickens, feeding, *m. pectoralis major*, physical properties, storage time

STRESZCZENIE

Celem przeprowadzonych badań było określenie wpływu żywienia kurcząt brojlerów mieszankami zawierającymi śrutę bobikową oraz czasu przechowywania w warunkach chłodniczych na cechy fizyczne *m. pectoralis major*. Materiał badawczy stanowiły 24 mięśnie pochodzące od kurcząt rzeźnych z 3 grup żywieniowych. Kurczęta grupy kontrolnej (I) żywiono mieszankami, w których jedynym surowcem wysokobiałkowym była poekstrakcyjna śruta sojowa, natomiast do mieszanek starter/grower kurcząt doświadczalnych w miejsce części śruty poekstrakcyjnej sojowej wprowadzono śrutę z bobiku w udziale 8/15% - grupa II lub 16/22% - grupa III. Nie stwierdzono wpływu zastosowanego żywienia na kwasowość i wodochłonność mięśni. Większym nasyceniem barwy żółtej, intensywnością i odcieniem cechowały się mięśnie kurcząt żywionych mieszankami z wyższym udziałem bobiku w porównaniu do pozostałych grup. Czas przechowywania mięśni w warunkach chłodniczych nie miał wpływu na ich właściwości fizyczne, odnotowano jedynie spadek pH_{24} ocenianych mięśni, co świadczy o prawidłowym przebiegu przemian glikolitycznych. Reasumując, stwierdzić należy, że wprowadzenie wyższego udziału bobiku do mieszanek dla kurcząt modyfikuje jedynie barwę mięśni, natomiast czas przechowywania w warunkach chłodniczych pozostaje bez wpływu na oceniane cechy fizyczne mięśni.

Ključne riječi: cechy fizyczne, czas przechowywania, kurczęta brojlery, *m. pectoralis major*, żywienie

INTRODUCTION

Over the past dozen or so years the highest (among all species of meat received from farm animals) upward trend both in production and consumption has been noted for poultry meat (Windhorst, 2017; Tallentire et al., 2018). The continuing growth of consumption is due to the nutritional and dietary value of the meat as well as its easy preparation for consumption. The increasing demand of broiler chicken meat forced the producers of poultry to look for ways of enhancing their efficiency. Thanks to intensive breeding works and the development of the feed industry, the birds' rearing time was considerably reduced while the rate of growth and weight as well as the share (in particular) of breast muscles in the carcass increased concurrently (Tallentire et al. 2016). Unfortunately, improvement in the production performance of chickens resulted in new problems. Through excessive genetic selection internal organs of broiler chickens are on the functional limit. The incidence of damage and quality conditions of muscles (mainly the breast muscles) of chickens such as PSE (pale, soft, exudative), WH (white stripping), SM (spaghetti meat) increased several times (Kuttappan et al., 2016; Maiorano, 2017; Petracci et al., 2015; Soglia et al., 2018). From the point of view of meat processing plants, defective meat is of limited processing quality, whereas from the consumer's perspective – culinary quality (Magdelaine et al., 2008; Zdanowska-Sąsiadek et al., 2013). Major characteristics of the quality of meat are its physical characteristics such as: acidity, colour and water holding capacity (WHC). The reaction of meat (pH) reflects the rate of post-mortem glycolysis. Gardzielewska et al. (2003) recount that 15 minutes after slaughter the pH of normal muscles ranges from 5.8 to 6.3, whereas in muscles showing DFD and PSE defects it is ≥6.4 and ≤5.7, respectively. Generally, low pH values (PSE meat) are accompanied by more drip loss and lighter colour, while this is opposite for high pH values (DFD meat) (Swatland, 2008; Garcia et al., 2010). Studies (Dal Bosco et al., 2013; Osek et al., 2013; Lipiński et al., 2019) showed that the physical characteristics of muscles depended on how the chickens were fed. A dominant protein component of broilers' diet is soybean meal. For various reasons attempts are made to substitute it with other high-protein feeds. Faba bean enjoys considerable interest among nutritionists as it contributes to the good effects of rearing and slaughter value (Shargh and Azari, 2010; Laudadio et al., 2011; Osek et al., 2013; Usayran et al., 2014). However, when introducing it into the diet of birds, the effect on physical properties of meat must be taken into account (Laudadio et al., 2011; Dal Bosco et al., 2013; Usayran et al., 2014; Rubio and Molina, 2016). Dal Bosco et al. (2013) write that a 16% addition of faba bean to the diet significantly increases the pH of breast muscles but it has no effect on the water holding capacity and colour of meat, whereas Laudadio et al. (2011) and Osek et. al. (2013) did not observe any effect of faba bean on the reaction of muscles.

The study aimed at evaluating the effect of feeding broiler chickens with diets containing faba bean and cold storage time on the physical properties of breast muscles (*m. pectoralis major*).

MATERIAL AND METHODS

Research material

The study material comprised 24 breast muscles from Ross 308 broiler chickens split into 3 feeding groups (I, II, III). Over the first 21 days of rearing the chicks received starter diets and over the following 14 days – grower diets. The compound feeds were prepared from corn meal, post-extraction soybean meal, oil and mineral and vitamin additives. The experimental factor was faba bean meal added to starter/grower diets as follows: group I (control) – without faba bean, group II – 8%/15% of faba bean meal, and group III – 16%/22% of faba bean meal (Table 1).

On the final day of the feeding experiment 8 birds were selected from each group with a body weight representative for the specific group. Next, they were slaughtered. During simplified slaughter analysis breast muscles were sampled for evaluation of their physical properties. The muscles were stored in foil bags in a cold store (temp. 0-4°C).

Table 1. Ingredient and nutrient composition of diets

Item	Starter			Grower		
	'	''	'''	'	''	'''
Ingredients, %						
corn	49.92	44.59	39.37	55.285	45.245	41.22
faba bean	-	8.00	16.0	-	15.00	22.00
soybean meal	41.50	38.00	34.50	36.00	29.50	26.00
rapeseed oil	4.70	5.50	6.20	5.00	6.50	7.00
L-lysine HCl, DL-methionine, limestone, 1- Ca phosphate, NaCl, premix starter/ grower*	3.88	3.91	3.93	3.715	3.755	3.78
Nutritive value per 1 kg of diets						
ME, MJ		12.7			13.0	
raw protein, %		22			20	
lys, %		1.29			1.17	
met + cys, %		0.93			0.88	
Ca, %		0.98			0.93	
P available, %		0.45			0.40	
Na, %		0.16			0.17	

*premix starter in starter diets, premix grower in grower diets

Physical analyses

The concentration of hydrogen ions (pH) in breast muscles (*m. pectoralis major*) of each bird was measured using a Testo 205 Set pH-meter after 15 minutes and then 24 and 72 hours after slaughter.

The water holding capacity (WHC) of breast muscles was determined *post mortem* after 24 and 72 hours. WHC was determined using Grau and Hamm's method (1953), as modified by Pohja and Ninivaara (1957), based on the amount of free water (expressed in %) lost by a sample of meat placed on blotting paper and pressed constantly between two glass plates. The surface of the drip (cm^2) was measured by means of a planimeter and the amount of free water was calculated assuming that 1 cm^2 of the drip binds 10 mg of muscle juices absorbed by the blotting paper.

Meat colour was evaluated *post mortem* after 24 and 72 hours using a trichromatic colorimeter. The colour was described based on the L*a*b* system. In the applied measurement system L* stands for lightness, that is a spatial vector, while a* and b* are tri-chromatic coordinates, where a* as a positive value corresponds to red, as a negative value to green, positive b* to yellow, and negative b* to blue (CIE 1976).

Based on the results of analysis (L*a*b* colour parameters) the psychometric saturation, i.e. intensity (C*) and hue (H*) of the colour were calculated from the following formulas (ISO 11037:2011):

$$C^* = [(a^*)^2 + (b^*)^2]^{0.5}$$

$$H^* = \log(b/a).$$

The change in meat colour during storage was calculated using the Clydesdale (1976) formula:

$$\Delta E^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{0.5})$$

L* describes lightness, a* – red-green chromaticity, b* – yellow-blue chromaticity.

Statistical analysis

The results were analysed by statistical methods using two-way analysis of variance: pH, WHC and colour as well as one-way analysis of variance – ΔE*. The significance of differences between mean values was verified using Duncan's test at the significance level α=0.05 (Stat. Soft. Inc. 2015).

RESULTS AND DISCUSSION

Replacement of part of the soybean meal with faba beans (group II and III) in diets for broiler chickens did not affect their final body weight (1.87 – 1.92 kg), feed intake (2.90 – 3.00 kg) and feed conversion ratio (1.59 – 1.60 kg) on the 35th day of rearing.

The addition of different amounts of faba bean to diets had no effect on the *post mortem* concentration of hydrogen ions in the muscles of broiler chickens after 15 minutes, 24h and 72h (Table 2).

The post-mortem glycolysis was slower than described by Gardzielewska et al. (2003) for normal meat post mortem after 24h. Mehaffey et al. (2006) indicate that a rapid decrease in pH can result in the paleness of meat and reduce its capacity to hold water.

Table 2. Acidity changes of breast muscles of broiler chickens during storage

Feeding group (F)		Value of pH			Mean
		pH_1	pH_{24}	pH_{72}	
I		6.33	5.81	5.67	5.94
II		6.19	5.79	5.78	5.91
III		6.22	5.80	5.78	5.93
Mean		6.24 a	5.80 b	5.74 b	-
Influence	T	P<0.05			
	F	0.903			
	T x F	0.113			
	SEM	0.031			

a, b – values in rows with different letters differ significantly (P ≤ 0.05)

The lack of effect of mixes containing faba bean on the acidity of breast muscles confirms the results of studies obtained by Laudadio et al. (2011) and Osek et al. (2013). Dal Bosco et al. (2013) write that a 16% addition of faba bean to the mix significantly increases (5.73 vs 5.86) pH_{24} of breast muscles. Also Osek et al. (2017) demonstrated a significant effect of soaked faba bean included in broiler chickens' feed mixes on the acidity of their breast muscles *post mortem* both after 15 minutes and 24 hours. 15 minutes after slaughter the lowest (P≤0.05) pH_1 was noted in the muscles of birds receiving mixes containing faba bean soaked in water for 12 hours, while it was slightly higher in birds from the control group and from the group fed with faba bean soaked in water for 24 hours. The fastest rate of glycolysis was recorded in the muscles of chickens fed with mixes containing faba bean soaked in water for twenty-four hours. After 24h of cooling their pH was 0.74 lower and it was significantly (P≤0.05) lower than in the muscles of birds from the control group, but the recorded values demonstrate that the meat was free of quality defects.

Another evaluated physical parameter was the water holding capacity of broiler chickens' breast muscles (Table 3).

Table 3. Water holding capacity (WHC) of meat during storage in cooling conditions

Feeding group (F)		Storage time (T)		Mean
		T24	T72	
I		11.55	11.83	11.69
II		10.32	11.02	10.67
III		11.42	11.89	11.66
Mean		11.10	11.58	-
Influence	T		0.352	
	F		0.267	
	T x F		0.506	
SEM			0.085	

No effect of the feeding method and cold storage time on the water holding capacity of breast muscles was identified. Similarly, Dal Bosco et al. (2013) write that a 16% addition of faba bean to the broiler chicken's feed mix has no effect on the water holding capacity of breast muscles, whereas Laudadio et al. (2011) showed a

significant decrease in that parameter in the muscles of chickens fed with the mix containing 31% of faba bean.

The addition of faba bean (irrespective of the share) to mixes fed to broiler chickens had a significant effect on the colour parameters of breast muscles (Table 4).

Muscles of chickens fed with mixes with a higher share of faba bean showed higher (P<0.05) yellow saturation (b*), colour intensity (C*) and hue (H*) in comparison to muscles of birds from other groups. However, no effect of muscles' cold storage time on the evaluated colour parameters was found.

L* parameter values measured are typical of normal muscles, since according to Qiao et al. (2001) the colour lightness L* of a normal breast muscle ranges from 48 to 53; values above 53 mean the colour of the muscles is lighter, and below 46 – it is darker. Barbut (1997) claimed the optimal lightness range of chicken and turkey fillets was around 49-50. A significant decrease (44.62 *vs* 46.77) in the lightness of breast muscle colour after adding 31% of faba bean to the mix fed to broiler chickens was shown by Laudadio et al. (2011). According to Kirkpinar et al. (2001), the colour of poultry meat desired by consumers is characterised by lower L* values and higher a* and b* values, which is also connected with adequately high and low pH15.

Garcia et al. (2010) demonstrated that breast muscles free of quality defects, in comparison to those classified as PSE, were of significantly darker colour L* (47.38 *vs* 52.53), and were more (P≤0.05) red-saturated (3.78 *vs* 2.42), but they did not differ (4.93 *vs* 4.82) in terms of parameter b* (P>0.05).

Dal Bosco et al. (2013) write that breast muscles of chickens receiving a feed mix containing 16% of faba bean were slightly darker (55.25 *vs* 57.10), and were more red-saturated (5.54 *vs* 4.42) and yellow-saturated (2.93 vs 2.20) compared to control groups (P>0.05).

The measured L, a and b parameters were used for calculating the colour change ratio (ΔE*) for meat during storage (Figure 1).

Table 4. Parameters of meat colour during storage in cooling conditions

	Feeding group (F)		Storage time (T)		Mean
			T24	T72	
L*	I		49.20	48.12	48.67
	II		48.05	48.38	47.97
	III		50.09	49.52	49.11
	Mean		49.10	48.77	-
		T		0.529	
	Influence	F		0.167	
		T x F		0.706	
	SEM			0.345	
a*	I		2.81	3.36	3.09
	II		3.33	3.50	3.38
	III		3.07	2.99	2.69
	Mean		3.11	3.27	-
		T		0.134	
	Influence	F		0.068	
		T x F		0.191	
	SEM			0.075	
b*	I		3.07	3.08	3.07 b
	II		2.93	3.43	3.18 b
	III		4.38	4.24	4.31 a
	Mean		3.46	3.58	-
		T		0.704	
	Influence	F		P<0.05	
		T x F		0.694	
	SEM			0.173	
C*	I		4.27	4.67	4.47 b
	II		4.54	5.05	4.79 b
	III		5.46	5.32	5.39 a
	Mean		4.75	5.01	-
		T		0.252	
	Influence	F		P<0.05	
		T x F		0.442	
	SEM			0.122	
H*	I		0.80	0.72	0.76 b
	II		0.71	0.74	0.73 b
	III		0.93	0.92	0.92 a
	Mean		0.81	0.79	-
		T		0.741	
	Influence	F		P<0.05	
		T x F		0.713	
	SEM			0.030	

a, b – values in column with different letters differ significantly (P ≤ 0.05)

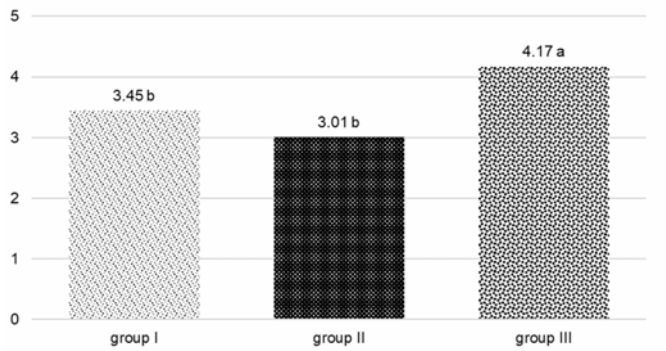

Figure 1. Absolute colour difference (ΔE*) of breast muscles (a, b – values with different letters differ significantly)

A significantly larger colour change (ΔE*) was found in m. pectoralis major of broiler chickens fed with diets containing more faba bean meal compared to muscles of birds from other groups.

CONCLUSIONS

To sum up, it should be stated that a higher share of faba bean in chicken diets modifies muscle colour only, while cold storage time has no impact on any of the evaluated physical characteristics of muscles.

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