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THE EFFECT OF DIETARY SUPPLEMENTATION WITH GUAR (*CYAMOPSIS TETRAGONOLOBA*) MEAL PROTEIN ON THE QUALITY AND CHEMICAL COMPOSITION OF PIG CARCASSES*

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Abstract

Recent research efforts have focused on replacing expensive imported genetically modified soybean meal (GM SBM) as a protein source in animal diets with guar meal characterized by similar nutritional characteristics, which could improve meat quality. The aim of this study was to determine the effect of guar meal protein fed to pigs on carcass quality and the content of major nutrients and fatty acids in the *longissimus lumborum* (LL) muscle. Pigs were divided into four groups. Control group (1) animals were fed diets containing SBM as the main protein source. In diets for experimental groups 2, 3 and 4, SBM protein was replaced with guar meal protein in 25%, 50% and 75%, respectively. It was found that SBM replacement with guar meal protein at 25% affected carcass weight and the lean content, fat content and protein content of the LL muscle. An analysis of linear correlations revealed a strong negative correlation between the concentrations of monounsaturated fatty acids (MUFAs) and saturated fatty acids (SFAs) in the LL muscle of pigs fed diets containing 25% of guar meal protein, which is nutritionally desirable. The results of this study suggest that the dietary inclusion of guar meal protein at up to 25% of SBM protein has no negative effects on the fattening performance of pigs. Meat quality was not affected by diets fortified with guar meal protein.

Key words: guar meal protein, meat quality, fatty acid, feeding, physicochemical parameters, *longissimus lumborum*

For many years, breeding and research programs in the active population of pigs have focused on improving fattening and slaughter traits, and the correlation between them (Żak et al., 2009). As a result, pork quality deteriorated, which was noted by consumers (Żak et al., 2014). Consumers evaluate the quality of meat upon purchase, and they generally focus on freshness (appearance and aroma), the production process and the product's origin. Therefore, attempts have been made to modify pig diets so as to improve the nutritional quality of meat (Decker and Park, 2010; Karpiesiuk et al., 2019; Świątkiewicz et al., 2021; Wood et al., 2003), including its fatty acid composition (Karpiesiuk et al., 2013). Soybean meal (SBM) is the principal component of pig diets, mainly due to its high protein content and quality, lysine-rich amino acid profile, and relatively low levels of antinutritional factors. At present, GM SBM accounts for more than 70% of protein in animal diets (Cromwell, 2000; Guzmán et al., 2016). The acquisition of non-GM soy is challenging due to increasing discrepancy between production volume and demand (Pach and Nagel, 2018). Considering this bottleneck, action is required to evaluate alternative feed components. Research has been conducted to increase the availability of low-cost and high-quality feed ingredients, safe for both animals and humans (Okorski et al., 2017, 2022; Pedersen et al., 2017; Schwarz et al., 2021). Non-GMO plant-based protein sources for livestock feed have also been studied (Cromwell et al., 2011), including food processing by-products such as rapeseed meal, distiller's dried grains with solubles (Świątkiewicz et al.,

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2021), legume seeds (faba bean, lupine, field pea), and imported feedstuffs. However, their use in pig nutrition is limited due to low availability and, in some cases, the presence of anti-nutritional factors.

To improve sustainability of pig production, alternative indigenous protein feedstuffs are needed. Guar meal is yet another alternative feed protein source that has recently attracted the interest of both researchers and practitioners. Guar, with the botanical name *Cyamopsis tetragonoloba* (L.) Taub., is an annual legume of the family Fabaceae, genus Cyamopsis. Due to its origin, it is relatively unknown and underutilized as a feed component in Poland. Guar is cultivated mostly in India, Pakistan and Africa (Saeed et al., 2017). This plant is not grown in Poland, but guar meal and guar-based protein products are imported. *Cyamopsis tetragonoloba* is the source of guar gum, and guar meal is a by-product of gum production. Although less palatable (trypsin inhibitor, saponins, polyphenols and β-galactomannan gum residue) and potentially toxic (polyphenols), guar meal has a great potential as an alternative protein source for livestock and poultry. It contains 59% to 60% crude protein (CP), and is less expensive than soybeans (Humphrey et al., 2018). Presence of beany flavour and toxicity of guar due to phenols restricts its consumption as food (Badr et al., 2014). Guar meal is available in different forms differing in quality, protein content and price ("Churi" – 320–400 g/kg, "Korma" – 480–580 g/kg and "MicroLam Korma" – 580–600 g/kg CP on a DM (dry matter) basis; Cyamopsis Biotech India Pvt. Ltd., 2015). "Korma" is most commonly used in animal nutrition (Pach and Nagel, 2018). Guar meal has a favorable fatty acid profile, which can contribute to improving the quality of animal products as well as human health (Chiofalo et al., 2018).

Dietary inclusion of guar meal has already been studied in poultry (Gutierrez et al., 2007), dairy cows (Rahman and Leighton, 1968) and sheep (Huston and Shelton, 1971). The inclusion of 2.5% untreated guar meal in a maize-SBM-based diet did not compromise the growth performance, feed intake, feed efficiency or meat yield of broilers (Conner, 2002). Guar meal that usually contains 14% to 20% residual guar gum can negatively affect the growth rate of broiler chickens and feed intake. McDonald et al. (1999) reported that 10% inclusion of guar gum in a white rice-based diet was associated with reduced body weight (BW) gain in weaner pigs. In contrast, high levels of guar meal can depress feed efficiency and animal growth due to the presence of antinutritional factors and poor palatability (Gutierrez et al., 2007). The effects of guar by-products on pig performance remain insufficiently investigated (Heo et al., 2009; Hasan et al., 2020). The inclusion of new ingredients in animal diets may affect the health and performance of animals. Alternative ingredients can replace traditional feed components when the latter have to be eliminated from the diet. Such a situation can be observed in the countries where the use of GM feeds is restricted by law. The use of GMOs in organic production is prohibited (Regulation (EU) 2018/848 of the European Parliament and of the Council of 30 May 2018 on organic production and labeling of organic products). Based on the current state of knowledge, we hypothesized that guar meal protein would not compromise meat quality. Therefore, the aim of the present study was to evaluate the effect of replacing SBM protein with guar meal protein in pig diets on carcass characteristics, meat quality and the fatty acid profile of the *longissimus lumborum* (LL) muscle.

Material and methods

Animals and diets

The experiment was conducted at the Animal Research Laboratory in Bałcyny, administered by the Department of Pig Breeding, University of Warmia and Mazury in Olsztyn (Poland). The experimental material comprised 64 F2 crossbred pigs produced by simple commercial crossbreeding [♀(♀ Polish Landrace × ♂ Polish Large White) × ♂ (♀ Pietrain × ♂ Duroc), with average initial BW of 30.1 kg. The animals were divided into four groups (16 animals per group), based on their initial BW, age and gender (8 ♂ and 8 ♀):

– group 1 (C – control) – where SBM was the main protein source,
– group 2 – where 25% of SBM protein was replaced with guar meal protein (4.9% and 3.4% of guar meal in the diet in the first and second stage of fattening, respectively),
– group 3 – where 50% of SBM protein was replaced with guar meal protein (9.9% and 6.8% of guar meal in the diet in the first and second stage of fattening, respectively),
– group 4 – where 75% of SBM protein was replaced with guar meal protein (14.6% and 10.3% of guar meal in the diet in the first and second stage of fattening, respectively).

Pigs were fed complete diets containing 17% and 15% of total protein, respectively (Pig Nutrient Requirements, 1993) (Table 1). Feed and water were available *ad libitum*. During the fattening period, all pigs were weighed at two-week intervals. The BW of pigs, feed intake and feed intake per kg BW gain (FCR) were recorded throughout the experiment. The chemical composition and metabolic energy of the experimental and control diets and guar meal are presented in Table 2. Samples of experimental diets were analyzed for nutrient content, including crude protein, crude fat, crude fiber, dry matter and crude ash, by standard methods, at the Analytical Laboratory of the Department of Animal Nutrition and Feed Science, University of Warmia and Mazury in Olsztyn.

The experiment was approved by the Local Ethics Committee for Animal Experimentation in Olsztyn (decision No. 55/2018).

Table 1. Feed ingredients and the chemical composition of diets

Specification	Group			
	1	2	3	4
1st stage of fattening (30–70 kg body weight)				
Soybean meal	21.50	16.20	10.90	5.50
Guar meal	–	4.90	9.90	14.60
Wheat	30.00	30.00	30.00	30.00
Barley	45.50	45.90	46.20	46.90
Premix*	3.00	3.00	3.00	3.00
2nd stage of fattening (70–110 kg body weight)				
Soybean meal	15.00	11.25	7.50	3.75
Guar meal	–	3.40	6.80	10.30
Wheat	25.00	25.00	25.00	25.00
Barley	57.50	57.85	58.20	58.45
Premix*	2.50	2.50	2.50	2.50

1 – group 1 (C – control) where SBM was the main protein source; 2 – group 2 where 25% of SBM protein was replaced with guar meal protein; 3 – group 3 where 50% of SBM protein was replaced with guar meal protein; 4 – group 4 where 75% of SBM protein was replaced with guar meal protein.

*Premix: lysine – 8.4%, methionine – 2%, methionine and cysteine – 2%, threonine – 2.5%, calcium – 17%, phosphorus – 2%, available phosphorus – 4%, total sodium – 4.4%, iron – 2000 mg, manganese – 1000 mg, zinc – 3500 mg, copper – 4000 mg, iodine – 26.6 mg, selenium – 6.6 mg, vitamins: A – 350 000 IU, D_3 – 50 000 IU, E – 1 400 mg, K_3 – 30 mg, B_1 – 30 mg, B_2 – 100 mg, B_6 – 60 mg, B_{12} – 500 mcg, folic acid – 40 mg, pantothenic acid – 350 mg, niacin – 400 mg, choline chloride – 7 500 mg, amino acids: L-lysine, L-threonine, DL-methionine, phytase, antioxidants.

Table 2. Chemical composition and metabolic energy of the experimental and control diets

Specification	Group								
	1			2		3		4	
	guar meal	1st stage	2nd stage	1st stage	2nd stage	1st stage	2nd stage	1st stage	2nd stage
Dry matter (%)	91.54	90.86	90.82	90.89	90.78	90.96	90.92	91.02	91.01
Crude protein (%)	48.86	17.09	15.35	17.40	14.69	17.70	15.57	17.03	15.39
Crude fat (%)	4.89	0.96	0.84	1.22	1.03	1.34	1.33	1.47	1.75
Crude fiber (%)	7.15	2.75	3.21	3.54	3.26	3.55	3.80	3.82	4.10
Crude ash (%)	4.82	4.28	3.62	4.37	3.59	4.19	3.65	4.42	3.19
Calcium* (g/kg)	6.89**	6.89	5.71	7.23	5.95	7.59	6.18	7.91	6.43
Phosphorus* (g/kg)	4.39**	4.39	4.20	4.47	4.25	4.56	4.31	4.63	4.37
Lysine* (%)	1.90**	1.09	0.90	1.05	0.87	1.02	0.85	0.98	0.82
Methionine + cysteine* (%)	1.10**	0.61	0.56	0.61	0.55	0.61	0.55	0.61	0.53
Threonine* (%)	1.50**	0.67	0.58	0.66	0.57	0.65	0.59	0.64	0.56
Tryptophan* (%)	0.70**	0.21	0.19	0.22	0.19	0.22	0.19	0.23	0.20
Metabolizable energy* (MJ)	13.00**	13.00	12.93	13.16	13.04	13.33	13.15	13.48	13.27
Fatty acids:									
Linoleic (%)	43**								
Linolenic (%)	4**								
Oleic (%)	27**								
Palmitoleic (%)	14**								
Stearic (%)	6**								
Antinutritional factors:									
Trypsin inhibitor (mg/g)	3.96**								
Saponin (%)	0.38**								
Guar gum (%)	≤5**								
Tannin (%)	1.71**								

1 – group 1 (C – control) where SBM was the main protein source; 2 – group 2 where 25% of SBM protein was replaced with guar meal protein; 3 – group 3 where 50% of SBM protein was replaced with guar meal protein; 4 – group 4 where 75% of SBM protein was replaced with guar meal protein. *Calculated value – WinPasze, **Chemical composition and metabolic energy of guar meal from Launtop Polska.

Slaughter and sample collection

The animals were slaughtered in a meat processing plant after 99 days of fattening, at average BW of 112.2 kg. The slaughter and carcass evaluation were carried out in accordance with the relevant meat industry regulations. The slaughter involved stunning followed by severing major blood vessels. Subsequently, the carcasses were scalded, depilated, eviscerated, closed longitudinally, and weighed.

Carcass lean content was classified according to the EUROP system using the SYDEL CGM (Lorient,

France; Capteur Gras/Maigre) ultrasonic device operated by authorized and trained personnel. The CGM is a handheld device equipped with an optical probe, which is used to determine the thickness of the loin muscle and the fat layer by measuring light reflection. Measurements of backfat thickness and the *longissimus dorsi* muscle were used to calculate the meat content of pig carcasses based on the following regression equation:

$$LMCCGM = 59.42 + 0.1322M2 - 0.6275T2$$

T2 – thickness of backfat between the 3rd and the 4th rib, 6 cm from the line of carcass partition; M2 – thickness of the LL muscle, 6 cm from the line of carcass partition, which is measured within 45 min after stunning.

The carcasses were cold stored at a temperature of 2–4°C for 24 h. Samples of the LL muscle were collected from the right side of each carcass (16 per group), at the level of the 1st–3rd lumbar vertebrae. Average backfat thickness – backfat thickness was measured on chilled half-carcasses, at five points:

– at the thickest point over the shoulder,
– on the back, behind the last rib,
– over the cranial edge of *m. gluteus medius* (loin I),
– over the middle of *m. gluteus medius* (loin II),
– over the caudal edge of *m. gluteus medius* (loin III).

The samples were packaged in polyethylene bags and transported to the laboratory in isothermal containers with ice. Meat quality was evaluated 48 h *post mortem*.

Loin eye area was determined as follows: at the intersection of the fillet between the last thoracic vertebra and the first lumbar vertebra, a complete cross-sectional outline of the *longissimus dorsi* muscle was made on the cephalic plane (on wax paper). On this contour, the 'eye' surface of the fillet was measured by planimetry.

Meat quality

Proximate chemical composition and collagen content

Meat samples were assayed for the content of dry matter, total protein (Kjeldahl method), crude fat (Soxhlet extraction without hydrolysis), crude ash (AOAC, 2007) and hydroxyproline which was converted into collagen content using a conversion factor of 7.25 (PN-ISO 3496:2000).

Fatty acid profile

Fat was extracted by the Soxhlet method (AOAC, 2007). Fatty acids were separated and determined by gas chromatography in a gas chromatograph (CP-3800, Varian, Walnut Creek, California, USA). Fatty acid methyl esters (FAMEs) were prepared according to the modified Peisker method (methanol:chloroform:concentrated sulfuric acid, 100:100:1, v/v) (Żegarska et al. 1991). The resulting FAMEs were stored in sealed tubes and were analyzed by gas chromatography-flame ionization detection (GC-FID; column: 50 m × 0.25 mm × 0.25 µm). The temperature of the GC injection port was set to 225°C in split mode (split ratio 50:1) with helium as the carrier gas at a constant flow rate of 1.2 mL min^{-1}. Detector temperature was 250°C and column temperature was 200°C. Fatty acids were identified by comparing their retention times with those of pure FAME standards (Sigma-Aldrich, St. Louis, Missouri, USA) and peaks in the analyzed samples. The relative content of fatty acids was expressed as the percentage of the total surface area of all fatty acids detected in each sample.

pH value

The pH value of muscle tissue was measured in the LL muscle at the level of the 1st–3rd lumbar vertebrae, 45 min after bleeding (pH45) and after 24 h of carcass chilling (pH24), with the use of the WTW 3310 pH meter and a combination electrode (WTW-Wissenschaftlich-Technische Werkstaetten GmbH, Weilheim, Germany) calibrated with the same standard solutions of pH 4.01 and 7.00 at 20°C. Their adjustment was additionally tested at the beginning and during the measurements on a regular basis.

Color measurements

The fresh-cut surface of the LL muscle at the level of the 1st–3rd lumbar vertebrae was scanned 15 min after bloom. The surface color of meat samples was determined with a spectrophotometer (MiniScan XE Plus, Hunter Lab, an aperture of 31.8 mm, 10° observer, illuminant D65). The instrument was calibrated prior to sampling using a white and black tile. The investigated parameters were measured at a wavelength range of 400 to 700 nm with the resolution of 10 nm. Color parameters were described according to the L*a*b* standard, and average spectral distributions at selected measurement points were processed statistically. Instrumental color measurements were taken in ten different locations and averaged to represent the value for each sample.

Water-holding capacity

The water-holding capacity (WHC) of meat (i.e. the ability of meat to retain its own water) was determined by the Grau and Hamm (1953) method. Ground meat samples, 0.3 g each (weighed accurately to 0.001 g), placed on Whatman No. 1 paper-filter, were exposed to 2 kg pressure between two glass plates for a period of 5 min. Thereafter, the area of two spots created by extruded meat juice and meat, respectively, was determined (in cm^2) with a planimeter. In order to determine the percentage of free water in meat, the infiltrate area (in cm^2) calculated as the difference in the areas of these two spots was divided by the weight of the sample.

Statistical analysis

The results were processed statistically by one-way analysis of variance (ANOVA) for orthogonal designs. Diet (0%, 25%, 50%, 75% guar meal protein) was the fixed effect and animal was the random effect in the statistical model. The significance of differences between group means was determined by Duncan's test at $P \leq 0.05$

and P≤0.01. Linear regression coefficients were calculated to determine the strength of the relationships between saturated fatty acids (SFAs) and monounsaturated fatty acids (MUFAs); SFAs and hypocholesterolemic acids (DFAs); SFAs and hypercholesterolemic acids (OFAs); polyunsaturated fatty acids (PUFAs) and DFAs; PUFAs and OFAs; DFAs and OFAs in the LL muscle. The correlations between the individual groups of fatty acids in the LL muscle were determined by calculating Pearson's correlation coefficients. The calculations were performed using Statistica PL software ver. 13.3.

Results

Fattening performance of pigs

The production results were previously published in a paper "The effect of partial replacement of soybean meal protein with guar (*Cyamopsis tetragonoloba*) meal protein on the cost-effectiveness of pig fattening" (Karpiesiuk et al., 2018).

Slaughter value of carcass

Carcass quality parameters are presented in Table 3. Pigs fed diets containing 75% guar meal protein had the lowest average carcass weight. Since all animals were slaughtered at the same time, this fact points to the lowest growth rate of group 4 pigs. The difference between groups 1 and 2 vs. groups 3 and 4 was highly significant. Average carcass lean content was very high, ranging from 58.46% to 59.99%, and a significant difference was found between groups 1 and 2. Loin eye area varied across groups.

Chemical composition and quality of meat (*longissimus lumborum* muscle)

The proximate chemical composition and quality parameters of LL muscle are presented in Table 4. The total protein content of the LL muscle differed significantly between group 2 vs. groups 3 and 1. The dietary inclusion levels of guar meal protein did not affect the pH of meat No significant differences in the crude fat, ash and collagen content as well as in the values of L*, a* and b* were found between treatments. The WHC influences the juiciness of cooked meats, which may affect consumers' perceptions of tenderness. Significant differences were observed in water-holding capacity between groups 1 and 3 and 4 (P≤0.05).

Table 3. Slaughter value of carcass

Specification	Group			
	1 N=16	2 N=16	3 N=16	4 N=16
Carcass weight (kg)	92.20 A±1.28	93.52 A±1.18	86.50 B±1.49	83.87 B±1.77
Dressing percentage (%)	79.98±0.61	79.96±0.46	78.82±0.55	78.66±0.88
Lean content (%)	59.99 a±0.28	58.46 b±0.54	59.43±0.41	58.96±0.51
Average backfat thickness (mm)	18.31±0.84	19.36±0.87	17.64±0.99	18.63±0.99
Loin eye area (cm^2)	55.47±1.50	56.40±1.52	55.55±1.24	52.78±3.48

a, b – means in the same row with different letters differ significantly (P<0.05).
A, B – means in the same row with different letters differ significantly (P<0.01).
1– group 1 (C – control) where SBM was the main protein source; 2 – group 2 where 25% of SBM protein was replaced with guar meal protein; 3 – group 3 where 50% of SBM protein was replaced with guar meal protein; 4 – group 4 where 75% of SBM protein was replaced with guar meal protein.

Table 4. Chemical composition and quality of meat (*m. longissimus lumborum*)

Specification	Group			
	1 N=16	2 N=16	3 N=16	4 N=16
Dry matter (%)	25.75±0.22	25.76±0.30	25.42±0.12	25.62±0.10
Total protein (%)	21.38 b±0.28	22.02 a±0.13	21.31 b±0.13	21.76±0.05
Crude fat (%)	1.58±0.18	1.26±0.25	1.41±0.13	1.54±0.09
Crude ash (%)	1.16±0.01	1.13±0.01	1.14±0.01	1.16±0.01
Collagen (%)	0.45±0.05	0.40±0.01	0.44±0.06	0.44±0.04
pH_{45}	6.29±0.08	6.07±0.09	6.15±0.10	6.28±0.12
pH_{24}	5.48±0.02	5.54±0.04	5.51±0.02	5.52±0.01
Water-holding capacity (cm^2)	6.70 a±0.33	6.35±0.37	6.23 b±0.21	6.14 b±0.19
Color lightness (L*)	55.61±1.09	56.27±1.06	56.75±1.11	54.92±0.32
Redness (a*)	7.27±0.54	6.82±0.62	6.50±0.67	7.17±0.52
Yellowness (b*)	14.36±0.54	14.21±0.22	14.11±0.14	13.95±0.24

a, b, c, d – means in the same row with different letters differ significantly (P<0.05).
A, B – means in the same row with different letters differ significantly (P<0.01).
1 – group 1 (C – control) where SBM was the main protein source; 2 – group 2 where 25% of SBM protein was replaced with guar meal protein; 3 – group 3 where 50% of SBM protein was replaced with guar meal protein; 4 – group 4 where 75% of SBM protein was replaced with guar meal protein.

Table 5. Fatty acid profile of the *longissimus lumborum* muscle of pigs (g/100 g total fatty acids) – means and standard errors

Specification	Group			
	1 N=16	2 N=16	3 N=16	4 N=16
C 10:0	0.15±0.006	0.14 b±0.005	0.16 a±0.006	0.15±0.007
C 12:0	0.13 a±0.006	0.12 B±0.004	0.14 Aa±0.009	0.12B±0.006
C 14:0	1.64 Cd±0.032	1.56 BDb±0.014	1.70 Ac±0.031	1.62 Ba±0.023
C 14:1	0.03 b±0.0001	0.02 B±0.0001	0.04 Aa±0.0024	0.03 b±0.0023
C 15:0	0.05 B±0.0045	0.06 b±0.0053	0.07 Aa±0.0066	0.06 b±0.0081
C 16:0	28.47±0.271	28.68±0.084	28.64 a±0.243	28.10 b±0.262
C 16:1	4.55 A±0.087	4.08 Bb±0.117	4.57 A±0.269	4.25 a±0.166
C 17:0	0.23 BD±0.021	0.25 Bb±0.020	0.37 A±0.057	0.33 Ca±0.045
C 17:1	0.27 Bb±0.029	0.24 BD±0.019	0.44 A±0.063	0.35 BCa±0.046
C 18:0	13.40 B±0.396	14.87 Aa±0.415	13.95 b±0.490	13.99 b±0.351
C 18:1 c9	44.85 Aa±0.396	43.77 b±0.502	43.18 B±0.326	44.21±0.359
C 18:2	3.82 b±0.272	3.81 b±0.200	4.02±0.181	4.26 a±0.184
C 18:3	0.24±0.021	0.22 B±0.008	0.25±0.009	0.27 A±0.023
C 20:0	0.24 B±0.008	0.27 A±0.004	0.26±0.007	0.24 B±0.020
C 20:1	0.90±0.043	0.86±0.022	0.87±0.046	0.85±0.037
C 20:2	0.16 a±0.017	0.15 B±0.009	0.16 a±0.006	0.21 Aa±0.039
C 20:4	0.72±0.038	0.78±0.065	0.78±0.121	0.85±0.046
C 22:0	0.11±0.007	0.11±0.011	0.11±0.010	0.10±0.008
SFA	44.42 Bd±0.458	46.05 Aa±0.434	45.69 c±0.453	44.72 b±0.636
UFA	56.42 A±0.458	54.82 BD±0.434	55.17 bB±0.453	56.13 aC±0.636
MUFA	50.60 a±0.444	48.98 b±0.619	49.09 b±0.532	49.68±0.464
PUFA	4.96 b±0.332	4.96 b±0.271	5.21±0.304	5.59 a±0.248
n-3	0.24±0.021	0.22±0.008	0.25±0.009	0.27±0.023
n-6	4.58±0.311	4.69±0.264	4.92±0.299	5.17±0.229
DFA=UFA+C18:0	69.48 A±0.264	69.32 Ab±0.075	68.77 B±0.234	69.77 Aa±0.297
OFA=C14:0+C16:0	30.51 B±0.264	30.68 Ba±0.075	31.22 Aa±0.234	30.22 Bb±0.297

a, b, c, d – means in the same row with different letters differ significantly (P<0.05).

A, B, C, D – means in the same row with different letters differ significantly (P<0.01).

1 – group 1 (C – control) where SBM was the main protein source; 2 – group 2 where 25% of SBM protein was replaced with guar meal protein; 3 – group 3 where 50% of SBM protein was replaced with guar meal protein; 4 – group 4 where 75% of SBM protein was replaced with guar meal protein.

Fat acid composition of meat

There are no published reports on the effects of guar meal on the content of nutrients and fatty acids in pork. Table 5 presents the percentage share of individual fatty acids in the intramuscular fat of pigs. In the SFA group, significant differences were found in the content of lauric acid (C 12:0) between group 3 vs. groups 2 and 4 (P≤0.01), and between groups 3 and 1 (P≤0.05); in the content of myristic acid (C 14:0) between groups 2 and 4 vs. groups 3 and 1 (P≤0.01), between groups 1 and 3, and between groups 2 and 4 (P≤0.05); in the content of pentadecanoic acid (C15:0) between groups 3 and 1 (P≤0.01), and between group 3 vs. groups 2 and 4 (P≤0.05); in the content of palmitic acid (C 16:0) between groups 3 and 4; in the content of margaric acid (C17:0) between group 3 vs. groups 4, 1 and 2 (P≤0.01), and between groups 4 and 2 (P≤0.05); in the content of stearic acid (C 18:0) between groups 2 and 1 (P≤0.01), and between group 2 vs. groups 3 and 4 (P≤0.05); in the content of arachidic acid (C 20:00) between group 2 vs. groups 1 and 4 (P≤0.01). In the MUFA group, significant differences were noted in the content of myristoleic acid (C 14:1) between group 3 vs. groups 2 and 1, between groups 4 and 2 (P≤0.01), and between group 3 vs. groups 1 and 4 (P≤0.05); in the content of palmitoleic acid (C 16:1) between groups 1 and 3 vs. group 2 (P≤0.01), and between groups 4 and 2 (P≤0.05); in the content of margaroleic acid (C17:1) between group 3 vs. groups 1 and 2 (P≤0.05); in the content of oleic acid (C18:1) between groups 1 and 3 (P≤0.01), and between groups 1 and 2 (P≤0.05). Significant differences were observed in SFA concentrations between groups 2 and 1 (P≤0.01), between groups 2 and 4, and between groups 3 and 1 (P≤0.05). Significant differences were noted in UFA concentrations between group 1 vs. groups 2 and 3, between groups 4 and 2 (P≤0.01), and between groups 4 and 3 (P≤0.05). Significant differences

were observed in MUFA concentrations between group 1 vs. groups 2 and 3 (P≤0.05). Significant differences were found in PUFA concentrations between group 4 vs. groups 1 and 2 (P≤0.05). The recommended PUFA/SFA ratio (P:S) should be higher than 0.4. In this study, the PUFA/SFA ratio ranged from 0.109 in group 2 to 0.124 in group 4. Dietary guar meal did not reduce the concentrations of PUFAs in the intramuscular fat of pigs.

Linear regression

A linear regression analysis revealed a significant relationship between the concentrations of MUFAs and SFAs in the experimental groups (Figure 1). An increase in the SFA content of meat samples was accompanied by a significant (P≤0.05) decrease in MUFA concentrations. The content of guar meal in pig diets had no significant effect on the MUFA/SFA ratio (Figure 2).

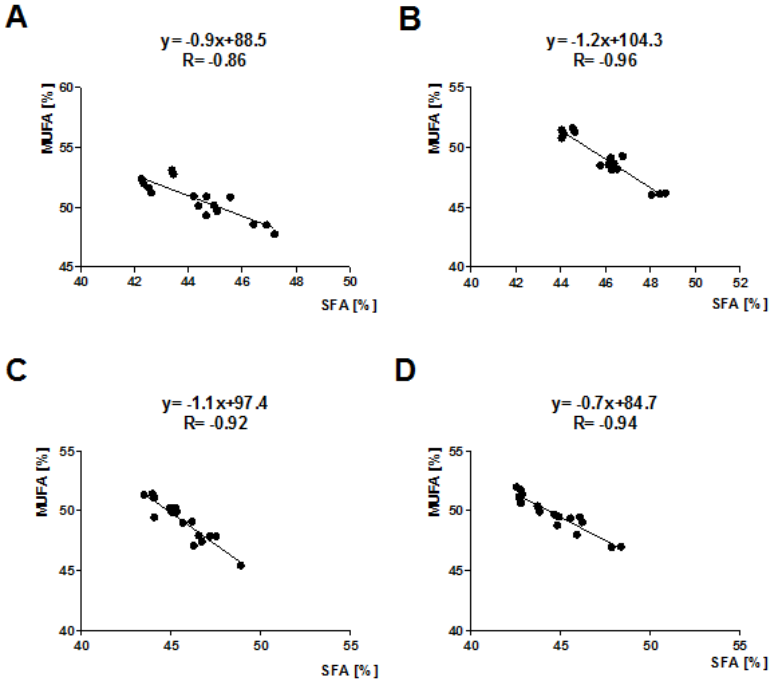

Figure 1. Linear regression between the concentrations of MUFAs (%) and SFAs (%) in the *longissimus lumborum* muscle; A – group 1, B – group 2, C – group 3, D – group 4

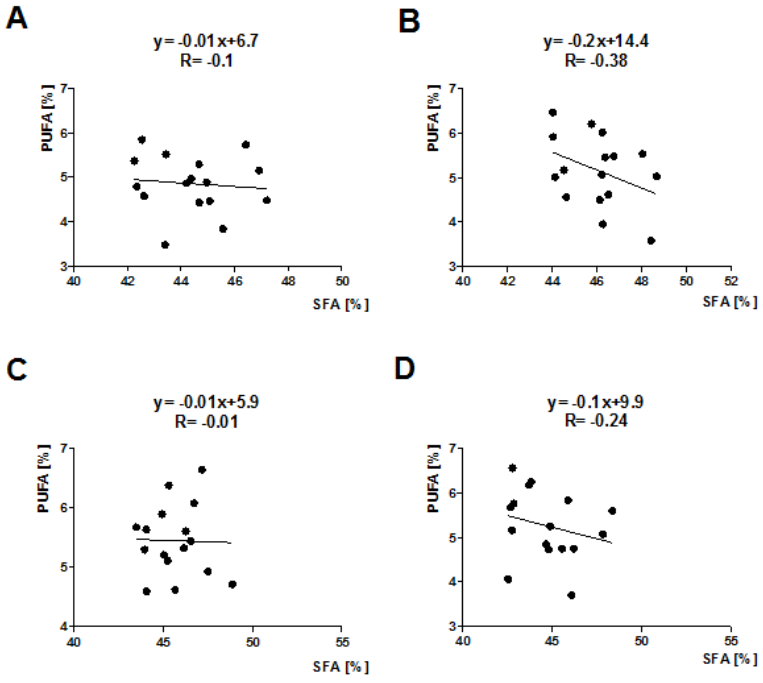

Figure 2. Linear regression between the concentrations of PUFAs and SFAs in pig diets: A – group 1, B – group 2, C – group 3, D – group 4

Discussion

The inclusion of new feed ingredients in the diet may exert varied effects on animals' growth performance and meat quality. Owusu-Asiedu et al. (2006) reported that guar gum diets fed for 14 days to growing pigs decreased their feed intake by 227 g/d. In a study by Heo et al. (2009), pigs fed diets containing 3, 6, 9 and 12% of guar meal were characterized by significant differences in ADG which reached 693 and 616 g in animals receiving 9% and 12% of guar meal, respectively, compared with 757 g in group 1, and 727 and 722 g in animals fed 3% and 6% of guar meal, respectively. Carcass quality characteristics similar to those determined in the present study were reported by Fiedorowicz-Szatkowska et al. (2017) for finishing pigs fed diets containing different sources of vegetable protein.

The chemical composition of meat is affected by the chemical composition of animal diets and feed additives such as vegetable fat or animal fat (Kołacz et al., 2004). In a previous study investigating the effect of rearing (fatteners kept indoors in pens with or without straw bedding) and feeding conditions (complete diets or diets with the addition of alfalfa green forage in summer or alfalfa hay in winter) on meat quality, Karpiesiuk et al. (2013) noted a higher percentage content of protein (23.70%) and fat (1.82%) in LL muscle samples. In a study of finishing pigs fed diets containing different sources of vegetable protein (SBM, faba bean, rapeseed meal), Fiedorowicz-Szatkowska et al. (2017) reported similar concentrations of dry matter (25.83%), crude ash (1.11%) and protein (22.53%) to those determined in this experiment. Active acidity (pH45) was typical of normal-quality meat. The values of pH24 (5.41–5.76) indicated that DFD meat was not present. Water-holding capacity (the ability of meat to retain its own water) is an important determinant of the processing suitability of meat. Natural drip loss is an indicator of weight loss during meat storage and distribution. Exudative meat is a significant problem in the meat processing industry because the low ability of meat to retain its own water adversely affects the quality of the final product (Otto et al., 2004). Gatta et al. (2013) reported no significant differences in the chemical composition or quality of meat from pigs fed diets containing SBM, faba beans (18%) or peas (20%).

Color is an important attribute of meat quality, which affects consumer preferences and is significantly correlated with other qualitative traits. The fat and fatty acids contained in guar meal can alter the fatty acid content of meat. In a study by Schwarz et al. (2021), mean values of the a* color component in the CIE Lab system were lower than those determined in the current study. The applied dietary treatments had no significant effect on muscle color (L*, a* and b*), which is consistent with the results of recent studies by Alonso et al. (2010), Dannenberger et al. (2012) and Guo et al. (2011).

Health professionals worldwide recommend a reduction in the overall consumption of SFAs, trans-fatty acids (TAs) and cholesterol, while emphasizing the need to increase the intake of n-3 polyunsaturated fats (Griel and Kris-Etherton, 2006). Nutrition is a promising route for regulation of the meat fatty acid profile (Świątkiewicz et al., 2021). In pigs, dietary fatty acids are incorporated directly into tissue lipids, unlike in cattle and sheep, in which dietary PUFAs are hydrogenated in the rumen. The methods of manipulating the fatty acid composition in meat still arouse considerable interest, mostly because saturated fatty acids are believed to be implicated in formation of blood clots leading to heart attack, cardiovascular diseases, and type 2 diabetes (Kouba et al. 2003). Most often, the goal of the manipulation is to improve the PUFA:SFA ratio. Some investigations are focused on the types of PUFAs and the lower n-6:n-3 PUFA ratio in the diet, as high amounts of PUFA n-3 are beneficial for health (Cameron et al., 2000). The fatty acid profile of meat and meat products can be improved through dietary modifications (Karpiesiuk et al., 2013). This is an important finding since humans should limit the consumption of SFAs to prevent cardiovascular diseases (Aranceta and Pérez-Rodrigo, 2012). It is generally accepted that for every 1% increase in energy from SFAs, LDL cholesterol levels reportedly increase by 1.3 to 1.7 mg/dL (0.034 to 0.044 mmol/L) (Mensink et al., 2003). Fiedorowicz-Szatkowska et al. (2017) found lower SFA levels in pigs fed diets containing faba beans, whereas Milczarek and Osek (2016) demonstrated that partial replacement of SBM with peas in pig diets led to an increase in PUFA concentrations in the LL muscle. In the current experiment, the PUFA/SFA ratio was generally low (the highest value was 0.124). Modification of the fatty acid composition of meat involving an increase in the proportion of PUFAs at the expense of SFAs would be beneficial for human health (Biondi et al., 2020). In a study by Prandini et al. (2011), the meat of heavy slow-growing pigs fed diets containing peas, faba beans and SBM was characterized by higher PUFA content and an over two-fold higher PUFA/SFA ratio, compared with the respective values noted in the present study. Hăbeanu et al. (2018) reported that pig diets supplemented with 5% hempseeds exerted a beneficial influence on the content of n-3 fatty acids in the LL muscle. Dietary fats have a considerable effect on the fatty acid profile of meat (Janiszewski et al., 2016).

In a study by Świątkiewicz et al. (2021), the influence of the dietary fatty acid profile on the quality of pig meat was confirmed in this research. The results showed that the corn DDGS included in pigs' diet significantly influenced the fatty acid profile in meat. The saturated dietary fats (beef tallow and coconut oil) improved the meat quality traits. The P:S ratio was decreased but was not below the safe level; however, these observations indicate that there may be limitations in the use of such diets with saturated fat content higher than in that of the present experiment. Based on the results of Arjin et al. (2022), it can be concluded that the supplementation of perilla cake in the growing pig diet improved product performance, in particular, the average daily gain, without affecting

carcass traits and meat quality, except the lightness. At the same time, the supplementation of this biomass in pig diet elevated the fatty acid compositions in backfat, abdominal fat, and the *longissimus dorsi* muscle. In addition, perilla cake supplementation enhanced the polyunsaturated fatty acid content, especially C18:3n3, in their tissues, as well as the ΣPUFA/ΣSFA and n6/n3 ratios. On the basis of the obtained results, perilla cake has the potential to be used in pig diet to enhance pork quality, as an alternative functional meat that has a high n3 fatty acid content for consumer health concerns.

Conclusions

Meat quality was similar in all experimental groups and remained within the limits for normal meat, which indicates that guar meal had no negative effect on the qualitative attributes of meat. The inclusion of 25% guar meal protein in pig diets had a beneficial effect on carcass weight, and meat in this dietary treatment had lower lean content and higher protein content. The meat of pigs fed diets containing 25% guar meal protein had the highest protein content. Dietary supplementation with guar meal protein affected the fatty acid profile of meat, but the present findings are inconclusive and require further investigation. The strongest negative correlation (R=–0.96) was found between the concentrations of MUFAs and SFAs in group 2 (25% guar meal protein) where the MUFA/SFA ratio was most undesirable from the perspective of consumer health. The results of this study suggest that the dietary inclusion of guar meal protein at up to 25% of SBM protein has no negative effects on the fattening performance of pigs. The supplementation of pig diets with guar meal protein at 50% and 75% may reduce performance, but meat quality was not affected by guar meal treatments.

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