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Evaluation of the Growth Performance, Carcass Composition and Meat Quality of Broiler Chickens Fed Rations Containing Guar Meal and Enzyme Preparations

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SUMMARY

The study aimed to determine the growth performance, carcass composition, and meat quality of broiler chickens fed diets with different levels of guar meal and feed enzymes. A total of 240 one-day-old, sexed chicks were assigned to six equinumerous groups (C4, C8, R4, R8, V4 and V8), with five subgroups each. The birds were fed *ad libitum* with Starter (1–21 days of age), Grower (22–35 days) and Finisher (36–42 days) diets comprised of maize meal, soybean meal, guar meal (4% or 8%), oil, and mineral and vitamin additives, in the following a two-factor experimental design: group C4 – 4% guar meal without enzyme preparation, C8 – 8% guar meal without enzyme preparation, R4 – 4% guar meal + enzyme preparation R, R8 – 8% guar meal + enzyme preparation R, V4 – 4% guar meal + enzyme preparation V, V8 – 8% guar meal + enzyme preparation V. Enzyme preparation R contained beta-glucanase, hemicellulose and pentosanase, and enzyme preparation V contained α-galactosidase and beta-glucanase. The higher (8%) percentage of guar meal in broiler chicken diets was shown to significantly reduce body weight (by 8%) and increase the feed conversion ratio (by 3%). At the same time, it reduced the dressing percentage (by 2%) and carcass muscularity (by 3%). Diets supplemented with enzymes (R or V) did not improve growth performance and did not affect the dressing percentage, carcass muscularity or fatness. Crude ash content in the muscles was decreased by the use of 8% guar meal in broiler chicken feed but increased by enzyme supplementation. A higher level of guar meal reduced the content of fat (by 4%) and its quality, measured as the ratio between n6:n3 PUFAs and the atherogenic (AI), thrombogenic (TI) and HH (hypocholesterolaemic-to-hypercholesterolaemic fatty acids ratio) indices. The results of the study indicate that 4% guar meal inclusion in diets for broiler chickens, without the addition of enzymes, should be recommended.

KEY WORDS: guar meal, enzyme, performance results, carcass value, meat quality, broiler chickens

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INTRODUCTION

Guar (*Cyamopsis tetragonoloba* L. Taub), of the family Leguminosae, is a non-genetically modified legume grown on a commercial scale due to its high content of β-galactomannan, commonly known as guar gum (Sabahelkheir et al., 2012). Guar gum produced from *Cyamopsis tetragonoloba* L. is used, among other applications, as a thickener and stabilizer in the food industry and many other industries (Vishwakarma et al., 2012; Nidhina and Muthukumar, 2015). The residue left after extraction of mucilage from the seeds of guar bean *Cyamopsis tetragonoloba* L. is guar meal (Commission Regulation 2022). This material has variable (35–60%) content of crude protein depending on the predominant fraction (the endosperm, the seed, or the shell) (Lee et al., 2003; Sabahelkheir et al., 2012; Kshirsagar et al., 2021). Despite its high content of protein with a valuable amino acid composition, the inclusion of large amounts of this material (above 4%) in poultry diets is limited by the adverse effects of the presence of undesirable substances (Gharaei et al., 2012; Hussain et al., 2012; Saeed et al., 2019; Milczarek et al., 2022). Antinutrients found in guar meal include trypsin inhibitors, saponins, polyphenols, haemagglutinins, and residual concentrations of guar gum (Hussain et al., 2012; Hassan, 2013; Siva, 2018). The harmful effects attributed to the activity of trypsin inhibitors in guar meal has become a contentious issue, as Conner (2002), Lee et al. (2004) and Nasrala et al. (2015) demonstrated that they were present in guar meal in smaller amounts than in soybean meal. Hassan (2013) regarded saponins as the main guar meal component affecting growth performance. However, many researchers (Lee et al., 2004, 2005; Sabahelkheir et al., 2012; Rao et al., 2019) report 13–18% content of guar gum residue, mainly in the form of β-galactomannan, which is a highly viscous polysaccharide. β-Mannan is a linear chain of recurring units of D-mannose linked by β-1-4 glycoside and D-galactose or glucose bonds attached by α-1-6 glycoside bonds to β-mannan (Hsiao et al., 2006; Larhang and Torki, 2011). β-Mannan is regarded as the major antinutrient when large amounts of guar meal are used in poultry feeding (Lee et al., 2004; 2005; Hussain et al., 2012). The high content of galactomannans increases the viscosity of the gastrointestinal contents, thereby reducing nutrient absorption and gastrointestinal transit time (Lee et al., 2003; Gutierrez et al., 2007). One of the methods used to reduce the negative impact of galactomannose present in guar meal is to supplement the diet with enzymes hydrolysing β-mannan (Lee et al., 2005; Daskiran et al., 2004). However, Wankhede et al. (2019) and Haribhau et al. (2020) reported that adding enzyme preparations to diets with guar meal did not improve the growth performance of chickens. Many poultry feeding researchers have attempted to increase the content of guar meal in feed rations to levels that will not adversely affect the production performance, carcass features or economic performance of broiler chickens (Gheisarai et al., 2011; Imran et al., 2014; Reddy et al., 2017; Rajasekharet al., 2020; Kshirsagar et al. 2021), but no clear solution has been found. Furthermore, these researchers did not evaluate the meat quality of broiler chickens fed diets containing guar meal.

Therefore, research was undertaken to determine the growth performance, carcass composition, and meat quality of broiler chickens fed diets with varying percentages of guar meal and feed enzymes.

MATERIAL AND METHODS

Chemical analysis of guar meal and soybean meal

The content of dry matter (Method 934.01), crude protein (Method 954.01), crude fat (Method 920.39), crude fibre (Method 978.10) and crude ash (Method 930.05) in the materials were determined according to the methodology of the Association of Official Analytical Chemists (AOAC 2011). N-free extracts (NFE) were calculated as follows:

$$NFE = dry\ matter - (crude\ protein + crude\ fat + crude\ ash + crude\ fibre)$$

Fibre fractions were analysed using Van Soest and Wine's detergent method (1967) with alpha-amylase in an ANKOM^{220} Fibre Analyser (ANKOM Technology, New York, NY, USA). Determination of neutral detergent fibre (NDF) was on an ash-free basis and involved the use of sodium dodecyl sulphate (Merc 822050). Acid detergent fibre (ADF) was determined using hexadecyl-trimethyl-ammonium bromide (Merc 102342), while acid detergent lignin (ADL) was determined by hydrolysis of the ADF sample in 72% sulfuric acid. Hemicellulose (HCEL) and cellulose (CEL) were calculated according to the following formulas:

$$HCEL = NDF - ADF$$

$$CEL = ADF - ADL$$

The content of tannins was assayed in the protein materials (BN-90/91160-62) by extracting tannins using a mixture of ethyl alcohol, glycerine and water, creating a coloured complex with phosphomolybdenum-phosphowolfram reagent and measuring the absorption of the coloured solution at 700 nm. In addition, anti-trypsin activity was determined in the protein materials using a method developed by Smith et al. (1980), based on spectrophotometric measurement of absorption of casein degradation products by trypsin in the presence of an inhibitor.

Experiment design, birds and diets

The experiment was conducted in compliance with EU guidelines on the treatment of animals, including the protection of animals used for scientific purposes (Directive 2010/63/EU), and rules for the protection of farm animals at the time of killing (Council Regulation No. 1099/2009). Since no invasive procedures (causing pain, suffering or lasting harm) were planned or performed on living broilers, and all of them were killed solely for the use of their intestines, according to Polish law no explicit approval from an ethics committee was required before the research.

The experiment involved 240 Ross 308 chickens assigned to six equinumerous groups (C4, C8, R4, R8, V4 and V8). One-day-old sexed chicks were weighed (47.47±1.05g) and randomly placed in 30 metal cages (0.56 m^2) with eight birds per cage (four males and four females), resulting in five replications in each feeding group. All the cages were placed in one room, in an identical environment, and the chicks had unlimited access to feed and water. Throughout the rearing period, 24-hour electric lighting was used (35 lux in the first week, subsequently reduced to 5–10 lux). In the first week of the experiment, the ambient temperature was 32°C, after which it was reduced every 7 days by 1–2°C until it reached about 22°C in the final week of rearing. The 42-day rearing period was divided into three feeding stages: Starter (days 1–21), Grower (days 22–35) and Finisher (days 36–42). The feed rations were all in the form of mash. The diets were designed according to

recommendations for broiler chickens (Smulikowska and Rutkowski, 2005), with equal levels of energy and protein (Table 1).

Table 1.
Composition and nutritive value of diets

Ingredient	Diet					
	Starter		Grower		Finisher	
	C4, R4, V4	C8, R8, V8	C4, R4, V4	C8, R8, V8	C4, R4, V4	C8, R8, V8
Feedstuffs and feed additives						
Maize meal	49.59	50.09	54.98	55.59	56.77	57.37
Soybean meal	37.80	33.50	32.30	28.00	30.00	25.70
Guar meal	4.00	8.00	4.00	8.00	4.00	8.00
Oil	4.80	4.60	5.00	4.70	5.70	5.40
Lysine 98.5%	-	-	0.01	-	-	-
DL-methionine 99%	0.20	0.20	0.19	0.18	0.11	0.10
Limestone	1.30	1.30	1.33	1.34	1.30	1.31
2-Ca phosphate	1.45	1.45	1.32	1.32	1.25	1.25
NaCl	0.36	0.36	0.37	0.37	0.37	0.37
Premix*	0.50	0.50	0.50	0.50	0.50	0.50
Calculated nutrients per kg of diet:						
ME, MJ	12.84	12.85	13.11	13.10	13.38	13.37
crude protein, %	22.51	22.50	20.37	20.37	19.44	19.44
crude fibre, g	35.45	38.12	35.40	38.01	35.17	37.77
lysine, g	13.26	13.47	11.95	12.06	11.25	11.46
methionine, g	5.70	5.80	5.35	5.35	4.45	4.44
met + cys, g	9.38	9.18	8.75	8.45	7.71	7.42
Ca, g	9.66	9.62	9.31	9.31	8.97	8.96
P available, g	4.45	4.45	4.05	4.05	3.85	3.85
Na, g	1.66	1.65	1.69	1.68	1.68	1.68

C4 – 4% guar meal without enzyme preparation, C8 – 8% guar meal without enzyme preparation, R4 – 4% guar meal + enzyme preparation R, R8 – 8% guar meal + enzyme preparation R, V4 – 4% guar meal + enzyme preparation V, V8 – 8% guar meal + enzyme preparation V.

*One kilogram of starter/grower/finisher premix contained: vitamin A 2 400 000/2 000 000/2 000 000 IU; vitamin D_3 900 000/800 000/800 000 IU; vitamin E 9000/7000/7000 IU; vitamin K 700/600/600 mg; vitamin B_1 500/360/360 mg; vitamin B_2 1200/1000/1000 mg; vitamin B_6 800/700/700 mg; vitamin B_{12} 6000/6000/6000 g; vitamin PP 8000/6000/6000 mg; pantotenian calcium 2600/2400/2400 mg; vitamin B_9 300/200/200 mg; vitamin H 50 000/40 000/40 000 g; vitamin B_4 70 000/70 000/70 000 mg; Cu 3500/3000/3000 mg; Fe 15 000/12 000/12 000 mg; J 350/300/300 mg; Mn 20 000/18 000/18 000 mg; Zn 20 000/20 000/20 000 mg; Se 55/50/50 mg; antioxidant.

The nutritional value of the feed was calculated based on the chemical composition of the feed components and metabolizable energy, using equations (WPSA, 1989). The diets were prepared from

maize meal, soybean meal, guar meal (4% or 8%), oil, and mineral and vitamin additives (Table 1). The experiment was conducted in a two-factor design (Table 2).

Table 2.
Experiment design

Feeding group	Content in diets		
	Guar meal, %	Enzyme preparation*	
		R	V
C4	4	-	-
C8	8	-	-
R4	4	+	-
R8	8	+	-
V4	4	-	+
V8	8	-	+

* - Enzyme preparations R and V were added to feed rations at 200 $mg \cdot kg^{-1}$ each. Enzyme preparation R contains beta-glucanase, hemicellulase, and pentosanase. It acts in a wide pH range, owing to which pectinase and β-glucanase activity are maintained from the stomach to the small intestine. The active ingredient is endo-1,3(4)-beta-glucanase (E.C.3.2.1.6) produced by *Aspergillus aculeatus*. Enzyme preparation V is a complex of enzymes added to diets containing soybean meal and legume seeds. It contains α-galactosidase (E.C.3.2.1.22): min. 250 U/g (produced by *Saccharomyces cerevisiae*) and endo-1,3(4)-beta-glucanase (E.C.3.2.1.4): min. 1425 U/g (produced by *Aspergillus niger*). In enzyme preparation V, α-galactosidase hydrolyses indigestible oligosaccharides to monosaccharides digestible for birds and is used as an energy source. In addition, it partly decomposes galactomannans, thus decreasing the viscosity of gastrointestinal contents.

During the experiment, the chickens were weighed on rearing days 1, 21, 35 and 42, and their feed intake was measured. The data were used to calculate the feed conversion rate (FCR).

Assessment of carcass quality

At 42 days of age, eight birds with a body weight representative of their group were selected from each group and slaughtered. Fifteen minutes after slaughter the reaction (pH_1) was measured in their breast muscles (*m. pectoralis maior*). Next, the carcasses were cooled over 24 hours at 4°C, and then the reaction (pH_{24}) of the muscles was measured again. To calculate the dressing percentage, the weight of the cooled carcasses was determined, and simplified dissection analysis was performed as described by Ziołecki and Doruchowski (1989). During dissection, samples of breast muscles were taken for evaluation of physicochemical and organoleptic characteristics.

Water loss, expressed as water holding capacity (WHC), was determined using Grau and Hamm's method (1953), as modified by Pohja and Ninivaara (1957). The WHC value was based on the amount of water (expressed in %) lost by the sample of meat placed on filter paper (Whatman No. 4) and pressed between two glass plates. The area (cm^2) of the meat juice visible on the filter paper was measured with a planimeter, and the amount of free water was calculated, assuming that an area of 1 cm^2 corresponded to 10 mg of meat juice absorbed by the filter paper.

Instrumental evaluation of breast muscle colour was performed using a photocolorimeter in the CIE *L*a*b**system, where *L** represents the lightness of the colour, which is a spatial vector, while *a** and *b** are trichromatic coordinates (positive values of *a** correspond to the colour red, and negative to green, while positive b* values correspond to yellow, and negative to blue) (CIE, 2007).

The chroma index (*C**) and colour hue angle tone (*h*) were calculated using the results for colour parameters *a** and *b** (ISO 11037, 2011).

The proximate composition of the breast muscle was determined according to AOAC (2011). Fatty acid methyl esters (FAMEs) were analysed following fat extraction according to Folch (1957). Gas chromatographic (GC) analyses were performed using a Varian 450-GC gas chromatograph equipped with a flame ionization detector (air–hydrogen). A Select ™ Biodiesel for FAME capillary column (30 m 0.32 mm 0.45 μm) with a Select Biodiesel for FAME Fused Silica filling was used. The injector temperature was 250°C, detector temperature 300°C, and column temperature 100°C (initial) and 235°C (final). Helium was used as a carrier gas, with a flow rate of 1.5 ml per minute. The amount of each fatty acid was expressed as a percentage of total fatty acids. The atherogenic index (AI), thrombogenic (TI) index, and hypocholesterolaemic-to-hypercholesterolaemic fatty acids ratio (HH) were calculated as follows (Ulbricht and Southgate, 1991; Santos-Silva et al., 2002):

$$AI = \frac{\mathrm{C12{:}0} + 4 \times \mathrm{C14{:}0} + \mathrm{C16{:}0}}{\Sigma\mathrm{MUFA} + \Sigma(\mathrm{n{-}6}) + \Sigma(\mathrm{n{-}3})}$$

$$TI = \frac{\mathrm{C14{:}0} + \mathrm{C16{:}0} + \mathrm{C18{:}0}}{0.5 \times \Sigma\mathrm{MUFA} + 0.5 \times \Sigma(\mathrm{n{-}6}) + 3 \times \Sigma(\mathrm{n{-}3}) + \Sigma(\mathrm{n{-}3})/\Sigma(\mathrm{n{-}6})}$$

$$HH = \frac{\mathrm{C18{:}1n{-}9} + \mathrm{C18{:}2n{-}6} + \mathrm{C20{:}4n{-}6} + \mathrm{C18{:}3n{-}3} + \mathrm{C20{:}5n{-}3} + \mathrm{C22{:}5n{-}3} + \mathrm{C22{:}6n{-}3}}{\mathrm{C14{:}0} + \mathrm{C16{:}0}}$$

The organoleptic properties of the breast muscles were evaluated on a five-point scale after cooking in a 0.8% NaCl solution to 80°C in the geometric centre of the sample. The meat-to-water ratio was 1:2. The palatability, flavour, juiciness and tenderness of the meat was evaluated by a panel of eight people (Baryłko-Pikielna, 1975; Baryłko-Pikielna and Matuszewska, 2014), who were tested for sensitivity and sensory capacity and had experience in assessing meat and meat products. A five-point scale was applied to evaluate the following quality parameters: palatability (1 - least desirable, 5 - most desirable), flavour (1 - least desirable, 5 - most desirable), juiciness (1 - very dry, 5 - very juicy), tenderness (1 - very hard, 5 - very tender).

Statistical analysis

The results were analysed by statistical methods using a two-way analysis of variance, according to the following mathematical model:

$$Y_{ijk} = \mu + E_i + G_j + (ExG)_{ij} + e_{ijk}$$

where:

Y_{ijk} − value for trait
μ − overall mean
E_i − effect of enzyme preparation, i = 1, 2, 3 (C, R and V)
G_j − effect of guar meal level, j = 1, 2 (4 and 8)
$(ExG)_{ij}$ − interaction between enzyme preparation and guar meal level
e_{ijk} – sampling error

The significance of differences between mean values was verified at the significance level $\alpha \leq 0.05$. The data were tested using the post-hoc Duncan test. The results were processed with STATISTICA PL 13.3 software (2022).

RESULTS

The nutritional value of the guar and soybean meal used in the experiment is presented in Table 3.

Table 3.
Chemical composition of feed

Item	Guar meal	Soybean meal
Proximate composition,%		
Dry matter	91.50	90.00
Crude ash	4.56	6.37
Crude protein	48.02	45.58
Crude fat	3.53	1.54
Crude fibre	10.01	3.73
N-free extracts	25.38	32.78
Fibre fraction, %		
Neutral detergent fibre – NDF	19.28	11.54
Acid detergent fibre – ADF	11.37	7.82
Lignine – ADL	0.50	1.51
Cellulose – CEL	10.87	6.31
Hemicellulose – HCEL	7.91	3.72
Anti-nutritional factors, g/kg		
Trypsin inhibitors	1.20	1.20
Tannins	11.80	15.40

The analysed guar meal contained more crude protein (by 2.44 p.p.) and crude fibre (by 6.28 p.p.), including neutral detergent fibre (by 7.74 p.p.) and acid detergent fibre (by 3.55 p.p.) compared with soybean meal. The assayed amount of trypsin inhibitors was identical in both materials, but soybean meal contained more tannins (by 0.36 p.p.).

The weight of broiler chickens varied significantly after just three weeks of rearing (Table 4).

Table 4.
Rearing performance of broiler chickens

Item	Guar meal (G)	Enzyme (E)			mean	P-value			SEM
		C	R	V		E	G	ExG	
Body weight, g									
21 days	4	889	880	870	880^{a}	0.01	0.01	0.84	10.21
	8	794	780	774	783^{b}				
	mean	842^{a}	830^{b}	822^{c}					
35 days	4	2098	2088	2106	2098^{a}	0.01	0.01	0.49	17.39
	8	1937	1918	1942	1931^{b}				
	mean	2018^{a}	2004^{b}	2024^{a}					
42 days	4	2648^{a}	2611^{b}	2621^{b}	2627^{a}	0.01	0.01	0.01	22.39
	8	2411^{d}	2384^{e}	2460^{c}	2418^{b}				
	mean	2528^{a}	2500^{b}	2543^{a}					
Feed intake, g									
1–21 days	4	53	52	52	52^{a}	0.03	0.02	0.13	0.55
	8	53	48	49	50^{b}				
	mean	53^{a}	50^{b}	50^{b}					
22–35 days	4	148	135	165	139	0.05	0.82	0.27	2.45
	8	142	127	145	138				
	mean	145^{a}	131^{b}	140^{ab}					
36–42 days	4	180^{a}	165^{b}	165^{b}	170	0.01	0.11	0.04	1.78
	8	178^{a}	166^{b}	179^{a}	174				
	mean	179^{a}	165^{c}	172^{b}					
1–42 days	4	380^{a}	352^{b}	353^{b}	362	0.01	0.84	0.01	3.49
	8	373^{a}	341^{b}	373^{a}	363				
	mean	377^{a}	346^{c}	363^{b}					
Feed conversion ratio, kg/kg									
1–21 days	4	1.31	1.32	1.31	1.31^{b}	0.13	0.04	0.12	0.02
	8	1.43	1.41	1.29	1.40^{a}				
	mean	1.37	1.37	1.30					
22–35 days	4	1.70^{bc}	1.64^{c}	1.62^{c}	1.66^{b}	0.10	0.01	0.01	0.03
	8	1.78^{b}	1.74^{bc}	1.94^{a}	1.82^{a}				
	mean	1.74	1.69	1.78					
36–42 days	4	2.29	2.21	2.25	2.24^{b}	0.40	0.01	0.71	0.04
	8	2.55	2.47	2.41	2.47^{a}				
	mean	2.42	2.34	2.33					
1–42 days	4	1.71	1.65	1.65	1.67^{b}	0.36	0.05	0.89	0.02
	8	1.76	1.67	1.72	1.72^{a}				
	mean	1.74	1.66	1.69					

G - guar meal (4% or 8% in diet), E - enzyme preparation: C - without enzyme preparation, R - enzyme preparation R, V - enzyme preparation V, SEM - standard error of the mean, a, b, c, d, e - means with different superscripts are significantly different at $P \leq 0.05$.

Chickens fed diets containing 4% guar meal weighed about 11% more ($P \leq 0.05$) than birds receiving diets with twice that level of guar meal (8%). The use of enzyme preparations (R or V) in the diets did not improve their nutritional value, as chickens fed diets without enzymes weighed more, irrespective of the percentage of guar meal. Evaluation of the efficiency of enzymes showed that enzyme preparation R was more efficient than preparation V ($P \leq 0.05$). Similarly, following the Grower diet period, birds receiving diets containing 4% guar meal had higher body weight (by about 8%) than those fed diets with 8% guar meal. In the second rearing period, enzyme preparation V was shown to be more efficient than preparation R, as the weight of birds receiving diets containing this enzyme was similar to that of C4 and C8 chickens, while those fed diets with enzyme preparation R weighed the least. At the end of rearing, chickens fed diets containing a lower percentage of guar meal were significantly heavier (by about 8.6%). The body weight of birds receiving diets with enzyme preparation V was close to that of C4 and C8 birds, while those fed diets with enzyme preparation R weighed significantly less.

Chickens fed Starter ($P \leq 0.05$) and Grower ($P > 0.05$) diets with 8% guar meal consumed less feed than birds receiving 4% guar meal, but the opposite was observed in the Finisher period. The inclusion of enzyme preparations (V or R) in the diets decreased feed intake in each rearing period. Throughout the rearing period, the lowest ($P \leq 0.05$) intake was noted for birds fed diets containing enzyme preparation R.

The feed conversion ratio of the diets depended only on the percentage of guar meal (except in the Grower period). Birds fed diets containing a higher level (8%) of this protein feed converted significantly more (by 5% for Starter and by 9% for Grower and Finisher). The use of different enzyme preparations in the diets non-significantly ($P > 0.05$) reduced feed intake (preparation R by 8 g and preparation V by 5 g).

Enzyme preparations (R or V) added to feed rations for broiler chickens had no effect on carcass composition, but the guar meal level determined the birds' body weight before slaughter and thus their cold carcass weight and muscularity (Table 5).

Table 5.
Slaughter results of broiler chickens

Item	Guar meal (G)	Enzyme (E)			mean	P-value			SEM
		C	R	V		E	G	ExG	
Body weight before slaughter, g	4	2605	2547	2620	2591 [a]	0.43	0.01	0.99	24.56
	8	2454	2397	2460	2437 [b]				
	mean	2530	2472	2540					
Chilled carcass weight, g	4	1919	1866	1940	1908 [a]	0.24	0.01	0.90	18.70
	8	1784	1728	1773	1761 [b]				
	mean	1851	1797	1856					
Dressing percentage, %	4	73.64	72.27	74.10	73.67[a]	0.46	0.12	0.47	1.16
	8	72.72	72.06	72.07	72.28[b]				
	mean	73.18	72.66	73.08					
Share in chilled carcass, %									
Muscles total	4	52.12	51.86	53.05	52.34[a]	0.25	0.01	0.36	0.36
	8	52.08	49.70	50.84	50.87[b]				
	mean	52.10	50.78	51.94					
including:									
Breast	4	31.14	30.71	31.48	31.11	0.32	0.05	0.59	0.34
	8	30.32	28.51	30.12	29.65				
	mean	30.73	30.80	29.61					
Thigh	4	12.86	12.55	13.33	12.91	0.74	0.95	0.24	0.16
	8	13.22	12.98	12.53	12.89				
	mean	13.04	12.74	12.93					
Drumstick	4	8.44	8.58	8.22	8.41	0.43	0.80	0.62	0.11
	8	8.64	8.26	8.18	8.36				
	mean	8.54	8.42	8.20					
Skin with subcutaneous fat	4	11.12	10.97	9.95	10.68	0.36	0.71	0.67	0.26
	8	10.67	11.39	10.59	10.88				
	mean	10.89	11.18	10.27					
Abdominal fat	4	1.25	1.46	0.81	1.17	0.08	0.75	0.10	0.07
	8	1.41	1.08	1.15	1.21				
	mean	1.33	1.27	0.98					

G - guar meal (4% or 8% in diets), E - enzyme preparation: C - without enzyme preparation, R – enzyme preparation R, V - enzyme preparation V, SEM - standard error of the mean, a, b - means with different superscripts are significantly different at $P \leq 0.05$.

Chickens fed diets containing less (4%) guar meal had higher ($P \leq 0.05$) pre-slaughter weight and cold carcass weight, and their total percentage of muscles ($P \leq 0.05$) was higher compared with those receiving diets with 8% guar meal. No effect of the diet on carcass fatness was noted.

Neither the addition of an enzyme preparation (of either type) nor the guar meal level in the feed rations for broiler chickens affected ($P > 0.05$) the physical characteristics of the breast muscles, except their water retention capacity (Table 6).

Table 6.
Physical properties of breast muscles of broiler chickens

Item	Guar meal (G)	Enzyme (E)			mean	P-value			SEM
		C	R	V		E	G	ExG	
pH_1	4	6.40	6.37	6.42	6.40	0.72	0.22	0.35	0.03
	8	6.42	6.55	6.43	6.46				
	mean	6.41	6.46	6.42					
pH_{24}	4	5.71	5.60	5.79	5.70	0.21	0.17	0.36	0.02
	8	5.66	5.61	5.63	5.63				
	mean	5.69	5.61	5.71					
WHC (%)	4	15.35^{ab}	15.01^{ab}	18.55^{a}	16.30	0.19	0.29	0.02	1.02
	8	20.11^{a}	13.06^{ab}	9.73^{b}	14.30				
	mean	17.73	14.03	14.14					
*L**	4	50.64	49.94	50.28	50.28	0.81	0.66	0.89	0.38
	8	49.84	49.56	50.40	49.90				
	mean	50.24	49.75	50.34					
*a**	4	3.20	3.21	3.02	3.14	0.95	0.90	0.82	0.09
	8	3.12	3.17	3.21	3.17				
	mean	3.16	3.19	3.11					
*b**	4	2.30	2.33	2.09	2.24	0.81	0.51	0.76	0.22
	8	1.50	2.22	2.07	1.93				
	mean	1.90	2.27	2.08					
$C^* = [(a^*)^2 + (b^*)^2]^{0.5}$	4	4.22	4.05	3.97	4.08	0.92	0.61	0.56	0.15
	8	3.59	4.03	4.14	3.92				
	mean	3.91	4.04	4.05					
$h = \log(b^*/a)$	4	0.53	0.62	0.53	0.56	0.58	0.67	0.87	0.05
	8	0.42	0.59	0.55	0.52				
	mean	0.48	0.60	0.54					

G - guar meal (4% or 8% in diets), E - enzyme preparation: C - without enzyme preparation, R - enzyme preparation R, V - enzyme preparation V, *L** - lightness, *a** - redness, *b** -yellowness, *C** - chroma, *h* - hue, WHC - water holding capacity, SEM - standard error of the mean, a, b - means with different superscripts are significantly different at $P \leq 0.05$.

An interaction between the enzyme and guar meal level affected the water retention capacity of the breast muscles. Significantly ($P \leq 0.05$) better WHC was noted for the muscles of birds fed diets containing 8% guar meal and enzyme preparation V (group V8) compared with those fed diets containing the same amount of guar meal but no enzymes (group C8) or diets with enzyme preparation V and 4% guar meal (group V4).

The type of diet influenced the proximate composition of the breast muscles (Table 7).

Table 7.
Proximate composition of breast muscles of broiler chickens

Item	Guar meal (G)	Enzyme (E)			mean	P-value			SEM
		C	R	V		E	G	ExG	
Dry matter	4	25.18	25.56	25.04	25.26				
	8	24.98	24.93	25.19	25.04	0.28	0.06	0.08	0.07
	Mean	25.08	25.24	25.11					
Crude ash	4	1.21	1.23	1.22	1.22[a]				
	8	1.19	1.21	1.22	1.21[b]	0.01	0.01	0.19	0.01
	Mean	1.19[b]	1.22[a]	1.22[a]					
Crude protein	4	22.48	23.07	22.56	22.70				
	8	22.54	22.69	22.80	22.67	0.09	0.82	0.15	0.07
	Mean	22.51	22.88	22.68					
Crude fat	4	1.49	1.27	1.25	1.34[a]				
	8	1.26	1.04	1.17	1.15[b]	0.10	0.03	0.68	0.04
	Mean	1.37	1.15	1.21					

G - guar meal (4% or 8% in diets), E - enzyme preparation: C - without enzyme preparation, R - enzyme preparation R, V - enzyme preparation V, SEM - standard error of the mean, a, b - means with different superscripts are significantly different at $P \leq 0.05$.

The content of crude ash and crude fat in the muscles was decreased by diets with 8% guar meal compared with diets with half that level of this protein material ($P \leq 0.05$). On the other hand, enzyme preparation R or V added to diets for broiler chickens increased the crude ash content in the breast muscles ($P \leq 0.05$).

Supplementation of feed rations containing 4% or 8% guar meal with enzyme preparation R or V significantly influenced the fatty acid profile of the breast muscles of broiler chickens (Table 8).

Table 8.
Main fatty acid profile (% of total FA) of breast muscles of broiler chickens

Item	Guar meal (G)	Enzyme (E)			mean	P-value			SEM
		C	R	V		E	G	ExG	
C 14:0	4	0.39	0.39	0.39	0.39^{b}	0.03	0.01	0.05	0.01
	8	0.46	0.42	0.42	0.43^{a}				
	Mean	0.43^{a}	0.40^{b}	0.40^{b}					
C 16:0	4	14.84^{bc}	14.91^{b}	14.14^{c}	14.63^{b}	0.11	0.01	0.01	0.16
	8	15.00^{b}	15.95^{a}	15.93^{a}	15.63^{a}				
	Mean	14.91	15.42	15.03					
C 18:0	4	5.30	5.40	5.29	5.33	0.47	0.65	0.26	0.03
	8	5.29	5.33	5.44	5.35				
	Mean	5.29	5.36	5.36					
C 20:0	4	0.12^{b}	0.13^{a}	0.11^{c}	0.12	0.01	0.17	0.01	0.01
	8	0.11^{c}	0.12^{b}	0.12^{b}	0.12				
	Mean	0.12^{b}	0.13^{a}	0.11^{b}					
C 22:0	4	0.06^{d}	0.09^{a}	0.08^{b}	0.08^{a}	0.01	0.01	0.01	0.01
	8	0.06^{d}	0.07^{c}	0.07^{c}	0.07^{b}				
	Mean	0.06^{b}	0.08^{a}	0.08^{a}					
C 18:1	4	48.34^{ab}	48.21^{ab}	48.54^{a}	48.36^{a}	0.01	0.01	0.02	0.09
	8	48.48^{ab}	47.54^{c}	48.09^{b}	48.04^{b}				
	Mean	48.41^{a}	47.87^{b}	48.31^{a}					
C 20:1	4	0.86^{b}	0.88^{a}	0.84^{c}	0.86^{a}	0.01	0.01	0.02	0.01
	8	0.82^{d}	0.82^{d}	0.81^{d}	0.82^{b}				
	Mean	0.84^{a}	0.85^{a}	0.82^{b}					
C 18:2	4	19.57^{a}	19.33^{ab}	19.99^{a}	19.63^{a}	0.40	0.02	0.01	0.12
	8	19.58^{a}	19.23^{ab}	18.62^{b}	19.14^{b}				
	Mean	19.57	19.28	19.30					
C 20:2	4	0.33^{c}	0.36^{a}	0.36^{a}	0.35	0.01	0.47	0.04	0.01
	8	0.34^{c}	0.36^{a}	0.35^{b}	0.35				
	Mean	0.33^{c}	0.36^{a}	0.35^{b}					
C 18:3	4	5.02^{a}	5.00^{a}	5.09^{a}	5.04^{a}	0.01	0.01	0.01	0.05
	8	5.11^{a}	4.71^{b}	4.63^{b}	4.81^{b}				
	Mean	5.06^{a}	4.85^{b}	4.86^{b}					
C 20:3	4	0.41^{c}	0.47^{a}	0.46^{a}	0.45^{a}	0.01	0.01	0.02	0.01
	8	0.40^{c}	0.44^{b}	0.43^{b}	0.42^{b}				
	Mean	0.40^{c}	0.45^{a}	0.44^{b}					
C 20:4	4	1.37	1.52	1.57	1.48^{a}	0.01	0.01	0.23	0.03
	8	1.19	1.40	1.48	1.35^{b}				
	Mean	1.28^{c}	1.46^{b}	1.52^{a}					

	a4	20.86^{bc}	21.05^{bc}	20.16^{c}	20.69^{b}				
SFA	8	21.08^{b}	22.02^{a}	22.10^{a}	21.74^{a}	0.15	0.01	0.02	0.17
	Mean	21.97	21.53	21.13					
	4	78.07^{a}	77.98^{ab}	78.85^{a}	78.30^{a}				
UFA	8	78.12^{a}	77.14^{bc}	77.03^{c}	77.43^{b}	0.18	0.01	0.01	0.17
	Mean	78.09	77.56	77.94					
	4	51.38	51.30	51.39	51.36				
MUFA	8	51.51	51.00	51.55	51.35	0.22	0.98	0.43	0.08
	Mean	51.44	51.15	51.47					
	4	26.69^{ab}	26.68^{ab}	27.47^{a}	26.94^{a}				
PUFA	8	26.61^{ab}	26.14^{bc}	25.49^{c}	26.08^{b}	0.74	0.01	0.02	0.17
	Mean	26.65	26.40	26.48					
	4	4.17^{b}	4.17^{b}	4.23^{b}	4.19^{b}				
PUFA n6/n3	8	4.07^{c}	4.39^{a}	4.34^{a}	4.26^{a}	0.01	0.01	0.01	0.02
	Mean	4.12^{b}	4.28^{a}	4.28^{a}					
	4	0.21^{bc}	0.21^{bc}	0.20^{c}	0.21^{b}				
AI	8	0.22^{b}	0.23^{a}	0.23^{a}	0.23^{a}	0.19	0.01	0.03	0.01
	Mean	0.21	0.22	0.22					
	4	0.40^{b}	0.40^{b}	0.38^{b}	0.39^{b}				
TI	8	0.40^{b}	0.43^{a}	0.44^{a}	0.42^{a}	0.11	0.01	0.01	0.01
	Mean	0.40	0.41	0.42					
	4	4.88^{b}	4.85^{b}	5.18^{a}	4.97^{a}				
HH	8	4.81^{b}	4.45^{c}	4.47^{c}	4.58^{b}	0.10	0.01	0.01	0.06
	Mean	4.85	4.65	4.82					

G - guar meal (4% or 8% in diets), E - enzyme preparation: C - without enzyme preparation, R - enzyme preparation R, V - enzyme preparation V, SEM - standard error of the mean,
a, b, c, d - means with different superscripts are significantly different at $P \leq 0.05$.

The use of 8% guar meal in the diets resulted in an increased ($P \leq 0.05$) share of myristic (C14:0) and palmitic (C16:0) acids, and thus total saturated fatty acids (SFA), in the lipid profile of the muscles. Thus, the muscles of those chickens had lower proportions ($P \leq 0.05$) of unsaturated fatty acids (UFA), including polyunsaturated fatty acids (PUFA). Enzymes (of either type) added to the feed rations reduced ($P \leq 0.05$) the share of C14:0, C18:1 and C18:3 and increased ($P \leq 0.05$) the levels of C 20:3, C20:4 and C22:0, but did not affect the share of SFA and UFA (including MUFA and PUFA). The n6:n3 PUFA ratio and AI, TI and HH values were significantly ($P \leq 0.05$) less favourable in the muscles of birds fed diets containing more guar meal (8%) and supplemented with enzymes.

Statistical analysis of the sensory quality of the breast muscles demonstrated that the enzyme preparations (either type) added to the diets did not affect the characteristics evaluated and that the inclusion of guar meal influenced tenderness and palatability as well as the mean value of the four features of the breast muscles (Table 9).

Table 9.
Sensory evaluation of breast muscles of broiler chickens

Item	Guar meal (G)	Enzyme (E)			mean	P-value			SEM
		C	R	V		E	G	ExG	
Flavour	4	4.46	4.46	4.32	4.42	0.15	0.24	0.63	0.06
	8	4.61	4.75	4.32	4.56				
	mean	4.54	4.61	4.32					
Juiciness	4	4.21^{b}	4.21^{b}	4.36^{ab}	4.26	0.21	0.15	0.04	0.08
	8	4.50^{ab}	4.86^{a}	4.07^{b}	4.47				
	mean	4.36	4.53	4.21					
Tenderness	4	4.36	4.43	4.57	4.45^{b}	0.32	0.02	0.15	0.06
	8	4.64	5.00	4.57	4.73^{a}				
	mean	4.50	4.71	4.57					
Palatability	4	4.36^{c}	4.53^{bc}	4.68^{abc}	4.52^{b}	0.27	0.03	0.02	0.06
	8	4.82^{ab}	5.00^{a}	4.46^{bc}	4.76^{a}				
	mean	4.59	4.77	4.57					
Mean of traits	4	4.35^{b}	4.41^{b}	4.48^{b}	4.41^{b}	0.15	0.03	0.04	0.06
	8	4.64^{ab}	4.90^{a}	4.36^{b}	4.63^{a}				
	mean	4.50	4.66	4.42					

G - guar meal (4% or 8% in diets), E - enzyme preparation: C - without enzyme preparation, R - enzyme preparation R, V - enzyme preparation V, SEM - standard error of the mean, a, b, c, d - means with different superscripts are significantly different at $P \leq 0.05$.

Muscles of chickens fed diets containing more guar meal (8%) were more tender and more palatable, with a higher mean for all traits. An interaction between the two experimental factors was observed for palatability and juiciness and for the mean value of the four features.

DISCUSSION

Corner et al. (2002), Lee et al. (2004) and Biel et al. (2019) claim that protein content in guar meal can range from 35% to 60%, depending on the cultivar and the proportions of its fractions (endosperm and shell). The mean protein content (48.02%) of the meal analysed in the present study was similar to that determined by Gharaei et al. (2012), Siva et al. (2018), Haribhau et al. (2020) and Milczarek et al. (2022). The amount of protein in soybean meal was slightly lower than that reported by Smulikowska and Rutkowski (2018). The guar meal used in the present study contained twice as much (10.01%) crude fibre as guar beans with low content of crude fibre determined by Pathak et al. (2011), Nidhina and Muthukumar (2015) and Rao et al. (2019). Higher content (11.75%) of crude fibre in guar meal was also found by Rajasekhar et al. (2020). According to Rao et al. (2019), trypsin inhibitors and highly viscous galactomannan polysaccharide are the main nutrients in guar meal. The level of trypsin inhibitors in guar meal in the present study was similar to the amount detected in soybean meal, which does not corroborate the results reported by Conner (2002), Lee et al. (2004), and Nasrala et al. (2015), who found lower content of trypsin inhibitors in guar meal than in soybean meal. Sabahelkheir et al. (2012) claimed that the content of available carbohydrates and tannins in

guar meal is controlled by genetic or environment factors. They showed 4.5% tannins in the endosperm of six guar genotypes.

The lack of effect of the enzyme preparation containing galactosidase added to feed rations with guar meal corroborates the findings of Sagar et al. (2017). The authors observed no effect of galactosidase added (at 2 IU/kg) to diets containing 3% or 6% guar meal on the body weight of chickens. Similarly, Nasrala et al. (2015), in their evaluation of chicken rations with various percentages (0%, 2.5%, 5%, 7.5% and 10%) of guar meal, supplemented with Hemicell enzyme and protease, found no variation in weight gain, except in birds fed diets containing 10% guar meal, which weighed less ($P \leq 0.05$). El-Masry et al. (2017) report that chicken diets containing 5% guar meal and β-mannanase (Hemicell HT (0.03%)) substantially improved the growth performance of birds compared with chickens fed diets with an identical percentage of guar meal but no enzymes. Gharaei et al. (2012), Mishra et al. (2013), and Hafsa et al. (2015) claim that a high level of guar meal in the diet of broiler chickens has a negative effect on their growth performance. Lee et al. (2005) recommended 5% inclusion of guar meal with the addition of β-mannanase in broiler chicken diets as a safe level. Similarly, Mohayayee and Karimi (2012) showed that in broiler chicken diets supplemented with β-mannanase, the optimum amount of guar meal having no adverse influence on growth performance is 6%, while a higher guar meal percentage results in weight loss. According to Zangiabadi and Torki (2010), β-mannanase supplementation of a diet containing guar meal eliminates the negative effects of galactomannans by hydrolysing them. Thus, supplementing the diet with this enzyme helps achieve higher weight gains in broiler chickens (Daskiran et al., 2004). A lack of significant impact of feed rations containing a multi-enzyme formula and 10% guar meal on the body weight of broiler chickens after 42 days of rearing was demonstrated by Haribhau et al. (2020). Similarly, Wankhede et al. (2019) observed no significant influence of diets containing 10%, 12.5%, 15%, 17.5% or 20% toasted guar meal and β-mannanase (500 g/t or 750 g/t) on the final body weight of broiler chickens.

In contrast to our study results, Mohayayee and Karimi (2012) showed that feed intake decreased in broiler chickens fed diets with increasing levels of guar meal, while the addition of β-mannanase improved FI. Similarly, Afrouzi et al. (2015) noted that 5% guar meal in diets for broiler chicks (±enzyme) had no impact on feed intake, but when guar meal was included at 10% in diets without enzymes, the feed intake significantly declined (4098.21 vs 4346.07 g). Hassan (2013) and Hafsa et al. (2015) reported lower feed consumption in broilers fed more than 5% guar meal. In contrast, Wankhede et al. (2019) reported an increase in feed intake in chickens fed rations with increasing levels of guar meal (10%, 12.5%, 15%, 17.5%, and 20%), with or without β-mannanase (500 or 750 g/t).

Our results coincide with the findings of Nasrala et al. (2015), who demonstrated that enzyme supplementation improved feed conversion in chickens fed diets containing lower (2.5% and 5%) levels of guar meal and that enzyme supplementation of diets containing 7.5% and 10% guar meal could not eliminate their adverse impact on the feed conversion rate (FCR). Ahmed and Abou-Elkhair (2016) noted improvement in the FCR of chickens fed diets containing 7.5% vs 10% guar meal with carbohydrase enzymes. Afrouzi et al. (2015) found that FCR improved after Hemicell enzyme was included in diets containing 5% and 10% guar meal. In contrast, Haribhau et al. (2020) demonstrated that multi-enzyme formulas added (at any dose) to diets containing 10% guar meal did not affect the feed conversion ratio. Wankhede et al. (2019) fed chickens diets with varying percentages (10%,

12.5%, 15%, 17.5%, and 20%) of guar meal, supplemented with β-mannanase (500 g/t or 750 g/t), and found that FCR was not impoved by the enzyme or negatively affected by larger amounts of the protein component. Irrespective of the percentage of guar meal (2%, 4%, or 6%) in chicken feed rations with or without β-mannanase, Siva et al. (2018) found no differences in the feed conversion ratio between groups.

The decline in dressing percentage observed in the present study at the higher level of guar meal in the diet is in line with the findings of Kamran et al. (2002), Gheisarai et al. (2011), Afrouzi et al. (2015), and Nasrala et al. (2015). Kamran et al. (2002) found that the dressing percentage decreased from 66.2% to 61.3% when the content of guar meal in the feed ration increased from 0% to 15%. A smaller decrease in the dressing percentage of chickens (70.32% vs 71.50%) after introducing guar meal (5% and 10%) to the diet was observed by Afrouzi et al. (2015). Nasrala et al. (2015) noted that increasing levels of guar meal (0%, 2.5%, 5%, 7.5% and 10%) in experimental diets for chickens resulted in a directly proportional decrease (from 79.08% to 71.68%) in dressing percentage; however, enzyme-supplemented diets (β-mannase) improved the dressing percentage (by more than 2 p.p.). Ahmed and Abou-Elkhair (2016) noted that when carbohydrase enzymes were added to diets containing 7.5% guar meal, the dressing percentage was comparable to that obtained in the control group. Irrespective of the guar meal level (10%, 12.5%, 15%, 17.5% or 20%) in chicken feed rations with or without β-mannanase, Wankhede et al. (2019) found no differences in the dressing percentage or in meatiness and abdominal fat between groups. Afrouzi et al. (2015) demonstrated that 5% guar meal added to broiler chicken feed (with or without enzyme supplementation) had no impact on breast yield, while breast yield decreased (33.6% vs 32.93%) when guar meal in the diet was doubled. El-Masry et al. (2017) showed that the weight of breast muscles decreased (579.06 g vs 521.87 g) when 5% guar meal was included as a partial replacement for soybean meal; however, feed rations supplemented with β-mannanase (0.03%) increased breast yield. Ahmed and Abou-Elkhair (2016) observed a decline in the share of abdominal fat in chickens receiving diets containing 7.5% guar meal supplemented with carbohydrase enzymes. Mohayayee and Karimi (2012) established that birds fed diets with a high level (9% and 12%) of guar meal (± β-mannanase) had higher abdominal fat levels than in the group of control chickens and chickens fed diets with a low level (4%) of guar meal, by 22% and 16%, respectively. In contrast, Reddy et al. (2017) found no impact of toasted guar meal (6%, 9%, 12%, 15% and 18%) in feed rations on the fatness of broiler chickens. Similarly, Rao et al. (2019) reported no significant influence of guar meal added to feed rations for broiler chickens at 6%, 12% and 18% on their abdominal fat.

The physical characteristics of meat, such as acidity, colour and water holding capacity (WHC), are among the key features testifying to its quality. According to researchers (Soglia et al., 2018; Dong et al., 2020), the incidence of broiler chicken meat defects such as PSE (pale, soft, exudative) and DFD (dark, firm, dry) meat has recently increased. Meat with defects is of limited technological and culinary value (Dong et al., 2020). Defect-free meat has adequate acidity (pH), reflecting the rate of post-mortem glycolysis. According to Gardzielewska et al. (2003), the pH of normal meat measured 15 minutes after slaughter should range from 5.8 to 6.3, while DFD and PSE mean are characterized by $pH \leq 5.7$ and > 6.3, respectively. In the present study, the quality evaluation of the breast muscles of chickens fed diets containing guar meal, based on the level of acidity 45 minutes after slaughter (pH_1) and following the classification proposed by Trojan and Niewiarowicz (1971),

revealed signs of the DFD defect. The authors reported that DFD meat has $pH_1 \geq 6.4$, while the pH_1 of normal meat ranges from 5.9 to 6.2.

Water holding capacity is one of the most important indicators of the technological suitability of meat for processing. It can positively affect the juiciness, shelf life, colour and texture of meat. The present study corroborated our own previous results (Milczarek et al., 2022), indicating that various inclusion levels of guar meal do not affect the water retention capacity or colour parameters of breast muscles. Colour is the first characteristic noticed by the consumer and greatly impacts meat acceptance, especially for fresh poultry products. *L** parameter values were typical of normal muscles, since, according to Qiao et al. (2001), the colour lightness (*L**) of normal breast muscle falls within the range of 48–53. Garcia et al. (2010) claimed 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 red-saturated (3.78 vs 2.42), but they did not differ (4.93 vs 4.82) in the *b** parameter. According to Liang et al. (2014) and Petracci and Cavani (2012), poultry meat is categorized as PSE-like if the lightness (*L**) is greater than 53 and the pH at 24 h post-mortem (pH_{24}) is less than 5.7.

The proximate composition of the broiler chickens' breast muscles can be considered typical (Dal Bosco et al., 2013, Milczarek and Osek, 2019). Our earlier study (Milczarek et al., 2022) found no impact of guar meal included in broiler chicken diets on the proximate composition (dry matter, crude ash, crude fat, or crude protein) of the muscles.

The composition and share of fatty acids in the breast muscle lipid fraction are known to depend on the birds' diet (Dal Bosco et al., 2013; Milczarek and Osek, 2019; Milczarek et al., 2022). The significant decrease in the share of linolenic acid (C18:3) in the muscles when guar meal was included in the diet of broiler chickens is consistent with our earlier findings (Milczarek et al., 2022). The n6:n3 PUFA ratio and the calculated values of the atherogenicity (AI) and thrombogenicity (TI) indexes, as well as the ratio of hypocholesterolemic and hypercholesterolemic fatty acids (HH), testify to the unfavourable impact of higher levels of guar meal in broiler chicken feed on the healthiness of breast muscles. Turan et al. (2007) stress that low AI and TI values indicate high quantities of anti-atherogenic fatty acids in oil or intramuscular fat. Ouraji et al. (2009) reported that AI and TI higher than 1 are harmful to human health. The lower the AI and TI values, the healthier the food. This is because there is a clear relationship between fatty acids in food and their contribution to the prevention of cardiovascular disease (Turan et al., 2007; Cutrignelli et al., 2008).

The available literature includes no research results on the impact of guar meal in broiler chicken diets on the sensory characteristics of breast muscles. Our study showed that the breast muscles of broiler chickens fed diets containing 8% guar meal were more tender and tastier than the muscles of chickens receiving 4% guar meal. The addition of enzyme preparations to the diets had no influence ($P > 0.05$) on the sensory evaluation of the breast muscles.

CONCLUSION

The results of our study suggest that 4% guar meal inclusion in feed rations for broiler chickens, without the addition of enzyme preparations containing beta-glucanase, hemicellulose and pentosanase or α-galactosidase and beta-glucanase, should be recommended. Twice that level of guar meal (8%) significantly reduced growth performance, dressing percentage and carcass muscularity, as well as the quantity and quality of fat in the breast muscles. The addition of enzyme preparations

to diets containing 8% guar meal did not influence the rearing performance or carcass composition of broiler chickens.

REFERENCES

1. Afrouzi H.N., Rezaei M., Taghizadeh V. (2015). Effect of guar meal and Hemicell enzyme on performance and carcass characteristics in broiler chicks. Animal Production Research, 4 (4): 75–87.
2. Ahmed H.A., Abou-Elkhair R.M. (2016). Potential application of guar meal in broiler diet. Asian Journal of Animal and Veterinary Advances, 11 (5): 280–287. doi:https://doi.org/10.3923/ajava.2016.280.287.
3. AOAC International (2011). Official Methods of Analysis of AOAC International. Current through revision 4. 18th Edition. Gaithersburg, Maryland, USA.
4. Baryłko-Pikielna N. (1975). Zarys Analizy Sensorycznej Żywności; WNT: Warszawa, Poland, 268 pp.
5. Baryłko-Pikielna N., Matuszewska I. (2014). Sensory analysis of food. Basics – Methods – Applications; 2nd ed.; Scientific Publishing PSFT, Poland, 375 pp.
6. Biel W., Jaroszewska A. (2019). Compositional and Nutritional Evaluation of Guar (Cyamopsis tetragonoloba L.) Meal. Animal Nutrition and Feed Technology, 19: 385-393. doi:https://doi.org/10.5958/0974-181X.2019.00036.2.
7. BN-90/79160-62. (1990). Colorimetric Method. In Tannin Determination; Polski Komitet Normalizacyjny: Warsaw, Poland.
8. CIE (2007). Draft Standard 014-4.3/E: Colorimetry – Part. 4: CIE 1976 L*a*b* colour space. Vienna, Austria: 8.
9. COMMISSION REGULATION (EU) 2022/1104 of 1 July 2022 amending Regulation (EU) No 68/2013 on the Catalogue of feed materials. https://www.stradalex.eu/en/se_src_publ_leg_eur_jo/toc/leg_eur_jo_3_20220704_177/doc/ojeu_2022.177.01.0004.01.
10. Conner S.R. (2002). Characterization of guar meal for use in poultry rations. Ph.D. Dissertation. Texas A&M University, College Station, TX.
11. Council Regulation (EC) No 1099/2009 of 24 September 2009 on the protection of animals at the time of killing. Off. J., L 303: 1–30.
12. Cutrignelli M.I., Calabrò S., Bovera F., Tudisco R., D'Urso S., Marchiello M., Piccolo V., Infascelli F. (2008). Effects of two protein sources and energy level of diet on the performance of young Marchigiana bulls. 2. Meat quality. Italian Journal of Animal Science, 7(3): 271–285. doi:https://doi.org/10.4081/ijas.2008.271.
13. Dal Bosco A., Ruggeri S., Mattioli S., Mugnai C., Sirri F., Castellini C. (2013). Effect of faba bean (Vicia faba var. minor) inclusion in starter and growing diet on performance, carcass and meat characteris-tics of organic slow-growing chickens. Italian Journal of Animal Science, 12 (4): 472–478. doi:https://doi.org/10.4081/ijas.2013.e76.
14. Daskiran M., Teeter R.G., Fodge D.W., Hsiao H.Y. (2004). An evaluation of endo-β-D-mannanase (Hemicell) effects on broiler performance and energy use in diets varying in β-mannan content. Poultry Science, 83: 662–668. doi:https://doi.org/10.1093/ps/83.4.662.
15. Directive 2010/63/EU of the European Parliament and of the Council of 22 September 2010 on the protection of animals used for scientific purposes. Off. J., L 276, 33–79.

16. Dong M., Chen H., Zhang Y., Xu Y., Han M., Xu X., Zhou G. (2020). Processing Properties and Improvement of Pale, Soft, and Exudative-Like Chicken Meat: a Review. Food and Bioprocess Technology, 13: 1280–129. doi:https://doi.org/10.1007/s11947-020-02464-3.
17. El-Masry K.N., Ragaa N.M., Tony M.A., El-Banna R.A. (2017). Effect of dietary inclusion of guar meal with or without β-mannanase supplementation on broiler performance and immunity. Pakistan Journal of Nutrition, 16 (5): 341–350. doi:https://doi.org/10.3923/pjn.2017.341.350.
18. Folch J., Lees M., Sloane Stanley G.H. (1957). A simple method for the isolation and purification of total lipids from animal tissues. Journal of Biological Chemistry, 226(1): 497–509.
19. Gharaei M.A., Dastar B., Nameghi A.H., Tabar G.H., Shams Shargh M. (2012). Effects of Guar meal with and without β-mannanase enzymes on performance and immune response of broiler chicks. International Research Journal of Applied & Basic Sciences, 3: 2785–2793.
20. Gheisarai A.A., Zavareh M.S., Toghyani M., Bahadoran R., Toghyani M. (2011). Application of incremental program, an effective way to optimize dietary inclusion rate of guar meal in broiler chicks. Livestock Science, 140: 117–123. doi:https://doi.org/10.1016/j.livsci.2011.02.018.
21. Garcia R.G., Freitas L.W. de, Schwingel A. W., Farias R.M., Caldara F.R., Gabriel A.M.A., Graciano J.D., Komiyama C.M., Almeida Paz I.C.L. (2010). Incidence and physical properties of PSE chicken meat in a commercial processing plant. Brazilian Journal of Poultry Science, 12: 233–237. doi:https://doi.org/10.1590/S1516-635X2010000400003.
22. Gardzielewska J., Jakubowska M., Buryta B., Karamucki T., Natalczyk-Szymkowska W. (2003). Relationship between pH1 and the quality of broiler meat. Medycyna Weterynaryjna, 59: 426–428.
23. Grau R., Hamm R. (1953). Eine einfache Methode zur Bestimmung der Wasserbindung im Muskel. Naturwissenschaften, 40: 29.
24. Gutierrez O., Zhang C., Cartwright A.L., Carey J.B., Bailey C.A. (2007). Use of Guar By-Products in High-Production Laying Hen Diets. Poultry Science, 86: 1115–1120. doi:https://doi.org/10.1093/ps/86.6.1115.
25. Hafsa S.H.A., Basyony M.M., Hassan A.A. (2015). Effects of partial replacement of soybean meal with different levels of guar korma meal on growth performance, carcass traits and blood metabolism of broiler chickens. Asian Journal of Poultry Science, 9 (3): 112–122.
26. Haribhau G.A., Lakshmi K.V., Alexander G., Gurram S. (2020). Effect of supplementation of multiple enzymes to the diets containing variable protein sources on performance and nutrient utilization in commercial broilers. Tropical Animal Health and Production, 52: 1739–1744. doi:https://doi.org/10.1007/s11250-019-02185-6.
27. Hassan S.M. (2013). Effects of Guar meal, Guar gum and saponin rich Guar meal extract on productive performance of starter broiler chicks. Academic Journals, 8 (21): 2464–2469. doi:https://doi.org/10.5897/AJAR2013.6875.
28. Hsiao H.Y., Anerson D.M., Date N.M. (2006). Level of β-mannan in soybean meal. Poultry Science, 85: 1430–1432.
29. Hussain M., Rehman A., Khalid M. (2012). Feeding value of guar meal and the application of enzymes in improving nutritive value for broilers. World's Poultry Science Journal, 68 (2): 253-268. doi:https://doi.org/10.1017/S0043933912000311.

30. Imran M., Pasha Saima T.N., Akram M., Mehmood K., Sabir A.J. (2014). Effect of β- mannanase on broilers performance at different dietary energy level. Global Veterinaria, 12: 622–626. doi:https://doi.org/10.5829/idosi.gv.2014.12.05.83128.
31. ISO 11037. (2011). Sensory analysis — guidelines for sensory assessment of the colour of products. Standards Policy and Strategy Committee UK, Geneva, Switzerland. p. 1–18.
32. Kamran M., Pasha T.N., Mahmud A., Ali Z. (2002). Effect of commercial enzyme (Natugrain) supplementation on the nutritive value and inclusion rate of guar meal in broiler rations. International Journal of Poultry Science, 1(6): 167–173.
33. Kshirsagar R.B., Thakur P.P., Jadhav B.A. (2021). Nutritional enhancement of crackers by incorporation of guar meal protein isolate. The Pharma Innovation Journal, 10(9): 479–482.
34. Larhang R.A., Torki M. (2011). Evaluating Performance of Broilers Fed Guar Mealincluded diet Supplemented by Enzyme. Researches of the First International Conference. Babylon and Razi Universities. Babylon. Iraq, 243–247.
35. Lee J.T., Bailey C.A., Cartwright A.L. (2003). Guar meal germ and hull fractions differently affect growth performance and intestinal viscosity of broiler chickens. Poultry Science, 82: 1589–1595. doi:https://doi.org/10.1093/ps/82.10.1589.
36. Lee J.T., Connor A.S., Haq A.U., Cartwright A., Bailey C. (2004). Quantitative measurement of negligible trypsin inhibitor activity and nutrient analysis of guar meal fractions. J. Journal of Agricultural and Food Chemistry , 52: 6492-6495. doi:https://doi.org/10.1021/jf049674+.
37. Lee J.T., Connor-Appleton S., Bailey C.A., Cartwright A.L. (2005). Effects of guar meal by-product with and without beta-mannanase Hemicell on broiler performance. Poultry Science, 84 (8): 1261-1267. doi:https://doi.org/10.1093/ps/84.8.1261.
38. Liang R., Li N., Wang R., Zhu L., Mao Y., Niu L. (2014). The establishment of evaluating PSE-like chicken meat in summer. Food and Fermentation Industries, 40(08): 231–237. doi:https://doi.org/10. 13995/j.cnki.11-1802/ts.2014.08.043.
39. Milczarek A., Osek M. (2019). Effectiveness evaluation of use of various protein feeds for broiler chicken feeding. Annals of Animal Science, 19(4): 1063–1081. doi:https://doi.org/10.2478/aoas-2019-0056.
40. Milczarek A., Pachnik M., Osek M., Świnarska R. (2022). Rearing Performance and Carcass Composition of Broiler Chickens Fed Rations Containing Guar Meal at Graded Levels. Agriculture, 12, 1385. doi:https://doi.org/10.3390/agriculture12091385.
41. Mishra A., Sarkar S.K., Ray S., Haldar S. (2013). Effects of partial replacement of soybean meal with roasted guar korma and supplementation of mannanase on performance and carcass traits of commercial broiler chickens. Veterinary World, 6 (9): 693–697. doi:https://doi.org /10.14202/vetworld.2013.693-697.
42. Mohayayee M., Karimi K. (2012). The effect of guar meal (germ fraction) and β-mannanase enzyme on growth performance and plasma lipids in broiler chickens. African Journal of Biotechnology, 11 (35): 8767–8773. doi:https://doi.org /10.5897/AJB11.3012.
43. Nasrala M.M., Waly A.H., Habib H.H., Abdel Magied H.A., Assaf I.M.M., Ouda M.M. (2015). Effects of dietary inclusion of guar korma meal levels with or without enzyme supplementation on performance of local strain chicks (Anshas). Egyptian J. Nutrition and Feeds, 18(2): 323–331. doi:https://doi.org /10.21608/ejnf.2015.104491.

44. Nidhina N., Muthukumar S.P. (2015). Antinutritional factors and functionality of protein – rich fractions of industrial guar meal as affected by heat processing. Food Chemistry, 173: 920–926. https://doi.org /10.1016/j.foodchem.2014.10.071.
45. Ouraji H., Shabanpur B., Abediankenari A., Shabani A., Nezami A., Sudagar M., Faghani S. (2009). Total lipid, fatty acid composition and lipid oxidation of Indian white shrimp (Fenneropenaeus indicus) fed diets containing different lipid sources. Journal of the Science of Food and Agriculture, 89: 993–997. doi:https://doi.org/10.1002/jsfa.3545.
46. Pathak R., Singh M., Henry A. (2011). Genetic diversity and interrelationship among cluster bean (Cyamopsis tetragonoloba) genotypes for qualitative traits. Indian Journal of Agricultural, 81: 402–406.
47. Petracci M., Cavani C. (2012). Muscle growth and poultry meat quality issues. Nutrients, 4(1): 1–12. .3390/nu4010001.
48. Pohja M.S., Niinivaara F.P. (1957). Die Bestimmung der Wasserbindung des Fleisches mittels der Konstantdruckmethode. Fleischwirtschaft, 9: l93–195.
49. Qiao M., Fletcher D.L., Smith D.P., Northcutt J.K. (2001). The effect of broiler breast meat color on pH, moisture, water holding capacity, and emulsification capacity. Poultry Science, 80: 676–678. doi:https://doi.org/10.1093/ps/80.5.676.
50. Rao M.H., Redd V.R., Rao S.V., Kumar M.S., Kumar N.N., Gurram S., Raghunandhan T. (2019). Effect of commercial guar meal (CGM) on the performance and nutrient utilization in broilers. Indian Journal of Animal Sciences, 89(5): 556–561.
51. Rajasekhar K.V., Prakash B., Vijaya Lakshmi K., Rama Rao S.V., Raju M.V.L.N. (2020). Effect of feeding diet with alternate protein sources and quality protein maize on performance and nutrient utilization in broiler chickens. Tropical Animal Health and Production, 52: 2297–2302. doi:https://doi.org/10.1007/s11250-020-02251-4.
52. Reddy E.T., Reddy V.R., Preetham V.C., Rao S.V.R, Rao D.S. (2017). Effect of dietary inclusion of graded levels of toasted guar meal on performance, nutrient digestibility, carcass traits, and serum parameters in commercial broiler chickens. Tropical Animal Health and Production, 49: 1409–1414. doi:https://doi. org/10.1007/s11250-017-1341-5.
53. Sabahelkheir M.K., Abdalla A.H., Nouri S.H. (2012). Quality Assessment of Guar Gum (Endosperm) of Guar (Cyamopsis tetragonoloba). ISCA Journal of Biological Sciences, 1: 67–70.
54. Saeed M., Ayasan T., Alagawany M., El-Hack M.E.A., Abdel-Latif M.A., Patra A.K. (2019). The Role of ß-Mannanase (Hemicell) in Improving Poultry Productivity, Health and Environment. Brazilian Journal of Poultry Science, 21: 1–8. doi:https://doi.org/10.1590/1806-9061-2019-1001.
55. Santos-Silva J., Bessa R.J.B., Santos-Silva F. (2002). Effect of genotype, feeding system and slaughter weight on the quality of light lambs: II. Fatty acid composition of meat. Livestock Production Science, 77: 187–194. doi:https://doi.org/10.1016/S0301-6226(02)00059-3.
56. Siva M., Purushothaman M.R., Senthilkumar S. (2018). Effect of Raw and Toasted Guar Meal Feeding on Production Performance of Broiler Chicken. Indian Veterinary Journal, 95: 12–15.
57. Smith C., van Megen W., Twaalfhoven L., Hitchcock C. (1980). The determination of trypsin inhibitor levels in foodstuffs. Journal of the Science of Food and Agriculture, 31: 341–350. doi:https://doi.org/10.1002/jsfa.2740310403.

58. Smulikowska S., Rutkowski A. (2005). Standards and Recommendations of Poultry Nutrition. Recommended allowances and nutritive value of feedstuffs. In Poultry Feeding Standards, 4th ed., The Kielanowski Institute of Animal Physiology and Nutrition PAS and Polish Branch of WPSA, Jabłonna, Poland, 136 pp.
59. StatSoft Inc. (2022) Statistica (data analysis software system), version 13.1. Tulsa, OK.
60. Sagar L.V., Venkateswarlu M., Narasimha J., Raghunandan T. (2017). Effect of α-Galactosidase supplementation to toasted guar (Cyamopsis tetragonoloba) meal based diets on body weiht and serum biochemical parameters in commercial layers. The Pharma Innovation Journal, 6(7): 1021–1023.
61. Soglia F., Mazzoni M., Petracci M. (2018). Spotlight on avian pathology: current growth-related breast meat abnormalities in broilers. Avian Pathology, 48: 1–3. doi:https://doi.org/10.1080/03079457.2018.1508821.
62. Trojan M., Niewiarowicz A. (1971). Method of identifying of water broiler chicken meat and observations on the frequency of this anomaly. Postępy Drobiarstwa, 13: 47–50.
63. Turan H., Sönmez G., Kaya Y. (2007). Fatty acid profile and proximate composition of the thornback ray (Raja clavata L. 1758) from the Sinop coast in the Black Sea. Journal of FisheriesSciences.com, 1(2): 97–103. doi:https://doi.org/10.3153/jfscom.2007012.
64. Ulbricht T.L.V., Southgate D.A.T. (1991). Coronary heart disease: Seven dietary factors. Lancet, 338: 985–992. doi:https://doi.org/10.1016/0140-6736(91)91846-M.
65. Van Soest P.J., Wine R.H. (1967). Use detergents in the analysis of fibrous feeds, Preparation of fibre residues of low nitrogen content, Determination of cell-wall constituents., Journal of AOAC International, 50 (1): 50–55. doi:https://doi.org/10.1093/jaoac/50.1.50.
66. Vishwakarma R.K., Shivhare U.S., Nanda S.K. (2012). Physical properties of guar seeds. Food and Bioprocess Technology, 5 (4): 1364–1371. doi:https://doi.org/10.1007/s11947-011-0514-x.
67. Wankhede S.M., Deshmukh A.D., Rekhate D.H., Manwar S.J., Ali S.S., Korde J.P. (2019). Effect of different levels of roasted guar (Cyamopsis tetragonoloba L.) korma with or without ß-mannanase supplementation on performance and carcass traits of broilers. Indian Journal of Animal Research, 53 (11): 1469–1474. doi:https://doi.org/10.18805/ijar.B-3687.
68. WPSA (1989). European Tables of Energy Values for Poultry Feedstuffs. WORLD'S POULTRY SCIENCE ASSOCIATION. Nutrition of the European Federation of Branches. Subcommittee Energy of the Working Group, Beekbergen, The Netherlands, ed. 3, 104 pp.
69. Zangiabadi H.R., Torki M. (2010). The effect of a β-mannanase based enzyme on growth performance and humoral immune response of broiler chickens fed diets containing graded levels of whole dates. Tropical Animal Health and Production, 42: 1209–1217. doi:https://doi.org /10.1007/s11250-010-9550-1.
70. Ziołecki J., Doruchowski W. (1989). The method of estimation of poultry slaughter analysis (in Polish). Poznań, COBRD, 22 pp.