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Evaluation of Selected Parameters of Quality and Nutritive Value of Meat of Fattened Bulls Fed Diet with Distillers Dried Grains with Solubles (DDGS) from Wheat or Maize as a Source of Protein

Andrzej Łozicki, Maria Dymnicka, Ewa Arkuszewska*

Department of Animal Feeding and Feed Management, Warsaw University of Life Sciences, Ciszewskiego 8, 02–786 Warsaw, Poland

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The objective of this study was to evaluate the quality and nutritive value of meat of bulls receiving wheat or maize DDGS (distillers dried grains with solubles) as a source of protein in a feed ration. The Hereford bulls were fed maize silage, hay and concentrates. The factor differentiating the feeding of experimental groups was the composition of concentrates. All concentrates contained cereal meals, rapeseed cake, and additionally – depending on the group: soybean meal (group CC), wheat DDGS (group EC-1), and maize DDGS (group EC-2).

The feed ration was found not to affect the chemical composition of *Longissimus thoracis* muscle. All feeding groups were characterised by a similar total content of SFA, MUFA and PUFA. The EC-2 group was characterised by a significantly higher content of C18:1 *n*-7 acid as compared to the two other groups and of CLA when compared to EC-1 group. *L. thoracis* muscle of animals from CC group was characterised by the highest content of C14:1, C 16:1 *n*-9, C 17:1 and C20:1 *n*-9 acids, with the differences being statistically significant when compared to EC-2 group. In group EC-2 analyses demonstrated a statistically higher *n*-6/*n*-3 PUFA ratio, in respect of the other groups. Muscle of the animals from EC-2 group, compared to that of CC group, was characterised by a significantly higher content of α-tocopherol. Out of the analysed quality parameters of meat, only pH value in group EC-1 was higher than in EC-2 group.

INTRODUCTION

As a result of the increasing production of bioethanol from cereals, distillers dried grains with solubles (DDGS) have recently been gaining increasing significance as raw materials of feedstuffs. They are characterised by a high nutritive value for ruminants, owing to a high content of protein, a high contribution of dietary fibre being well digestible by the ruminants, and – in the case of DDGS from maize – also by a considerable fat content. Thanks to those properties, the DDGSs may replace concentrates in feed rations for ruminants, and with appropriately balanced structural fibre – they may also in part substitute for feed roughages [Cyriac *et al*., 2005; Vander Pol *et al*., 2009; Martin *et al*., 2007; Schingoethe, 2006]. In turn, due to a high content of protein, the DDGS may be applied in fatteners feeding as a substitute for high-protein feeds, *e.g.* soybean or rapeseed meal [Robinson *et al*.,, 2008; Koger *et al*., 2010; Łozicki *et al*., 2010; Szulc *et al*., 2010]. They may be administered directly to feed rations or used as a raw material in the production of concentrates. The application of DDGS as a source of protein in the concentrate with a specified energy value and protein content determines the contribution of other components. The administration of such feedstuffs in a diet may, in turn, affect the quality and nutritive value of meat. DDGS has also a high level of unsaturated fatty acid and contains vitamins, including B complex, A, D and E [Roeber *et al*., 2005; Sokół *et al*., 2010]. Owing to the high content of these components, the distillers dried grains with solubles applied in the feeding of fattening cattle (those from maize in particular) are likely to affect the quality as well as nutritive value of meat – fatty acid composition, vitamin E content and colour attributes of meat [Roeber *et al*., 2005; Gill *et al*., 2008; Depenbush *et al*., 2009; Aldai *et al*., 2010a, Dugan *et al*., 2010; Nade *et al*., 2012].

In view of the above, the objective of this study was to evaluate the quality and nutritive value of meat of young bulls receiving DDGS from wheat or maize as a source of protein substituting for the protein of soybean meal in a feed ration.

MATERIAL AND METHODS

The experiment was conducted in the years 2008–2009 on young Hereford bulls at a private farm in Konradowo in the north of Poland.

Animals and diets

Twenty four young bulls at the age of 8–9 months were divided into three groups, 8 animals each. The mean body weight of animals at the beginning of the experiment was equal and reached *ca.* 250 kg. The bulls were fattened for 8 months

* Corresponding Author: Tel. +48 22 5936665; Fax +48 22 5936569; E-mail andrzej_lozicki@sggw.pl (Dr. Andrzej Łozicki)

to a body weight of 500–550 kg. Over the experimental period, the animals were kept in pens, two animals in each.

The differentiating experimental factor in particular groups was the source of protein used in the experimental concentrates, *i.e.* wheat DDGS and maize DDGS applied as substitutes of soybean meal protein in the control group (Table 1). The choice of the soybean meal used in the control group resulted from its high nutritive value, which was a good point of reference for the DDGS products.

The percentage of individual components in concentrates was defined as to obtain feeds (concentrates) balanced in terms of protein and energy levels (Table 1). The percentage contribution of the investigated protein components varied, for the objective of their application in feed mixtures was to assure a balanced, appropriate level of protein, equal in all concentrates. The adopted protein content of the experimental concentrates was adjusted to maize silage, being the basic roughage applied in the fattening of young cattle. The administration of an equal level of rapeseed cake in all concentrates was, in turn, aimed at providing an additional source of protein, which was especially important while using maize DDGS being more scanty in that component. Owing to a high fat content, the rapeseed cake was additionally a good source of energy.

The recipes of the concentrates were developed at the Department of Animal Nutrition and Feed Science, Warsaw University of Life Sciences. The composition and nutritive value of the experimental concentrates were presented in Table 1. Fatty acid profiles of experimental concentrates were presented in Table 2.

Feed rations, including the experimental concentrates, were balanced according to IZ- INRA feeding standards [2001], using a computer software INRAtion ver. 3.3., with the initial assumption to obtain daily body weight gains of 1200 g at the beginning of the fattening period and later on body weight gains of 1300 g. The feed ration was based on maize silage, which was supplemented with hay and experimental concentrates. The animals were administered mixed roughages and a respective concentrate (Table 3).

TABLE 1. Composition and nutritive value of experimental concentrates.

Components / Nutritive value	CC (control concentrate)	EC-1 (experimental concentrate 1)	EC-2 (experimental concentrate 2)
	%		
Barley	24	28	20
Wheat	25	20	10
Oats	20	12	17
Rapeseed cake	15	15	15
Soybean meal	13	-	-
Wheat DDGS	-	22	-
Maize DDGS	-	-	35
Limestone	1	1	1
Mineral and vitamin premix	2	2	2
Chemical composition and nutritive value per 1 kg of concentrate			
Dry matter (%)	89.23	89.62	88.98
Crude ash (%)	5.79	5.70	6.39
Crude protein (%)	17.42	17.84	17.65
Crude fiber (%)	10.69	11.47	9.95
Ether extract (%)	3.61	4.26	6.87
NFC (%)	51.72	50.35	48.12
UFV	0.92	0.91	0.93
PDIN (g)	124	123	125
PDIE (g)	103	102	104

UFV – unit of energy for meat production; PDIN – protein digested in the small intestine depending on rumen degraded protein; PDIE – protein digested in the small intestine depending on rumen-fermented organic matter; CFU – fill unit for cattle.

TABLE 2. Fatty acid profile of experimental concentrates (% of total fatty acids).

Fatty acids	CC	EC-1	EC-2
C10:0	0.030	0.036	0.014
C12:0	0.025	0.030	0.017
C14:0	0.266	0.262	0.122
C14:1	0.108	0.168	0.052
C15:0	0.036	0.085	0.085
C16:0	17.598	18.265	13.722
C16:1 *n*-9	0.095	0.088	0.071
C16:1 *n*-7	0.456	0.457	0.265
C17:0	0.091	0.106	0.081
C17:1	0.068	0.067	0.042
C18:0	2.562	2.255	2.380
C18:1 *n*-9	42.297	39.400	35.298
C18:1 *n*-7	3.521	3.335	1.671
C18:2 *n*-6	24.235	27.334	40.661
C18:3 *n*-6	0.023	0.026	0.057
C18:3 *n*-3	2.798	2.822	2.261
C20:0	0.529	0.459	0.525
C20:1 n-9	1.354	1.353	0.714
C20:2 *n*-6	0.074	0.093	0.064
C20:3 *n*-6	0.027	0.029	0.017
C20:4 *n*-6	0.022	0.026	0.011
C24:0	0.240	0.237	0.217

TABLE 3. Percentage of feeds in kg of DM of diets and nutritive value of diets.

Components / Nutritive value	CC	EC-1	EC-2
	% of DM		
Maize silage	43	43	43
Hay	12	12	12
Concentrate	45	45	45
Nutritive value per 1 kg of DM			
UFV	0.92	0.91	0.93
PDIN (g)	86.64	85.63	86.75
PDIE (g)	89.27	84.72	90.26

Evaluation of meat quality and nutritive value

On termination of the experiment, all animals were slaughtered in a commercial slaughterhouse. After 24-h chilling of the carcasses, meat samples were collected from *Musculus longissimus thoracis*. The samples were next transported to a laboratory of the Department of Animal Nutrition and Feed Science, Warsaw University of Life Sciences, divided into 2–2.5 cm thick portions and packed in polyethylene bags.

The samples to be used for the assessment of technological parameters were kept under cold stored conditions for another 48 h and analysed 72 h after slaughter. Cold storage was also applied to the samples that were determined for TBARS level 3 and 7 days after slaughter. The other samples – to be assayed for the proximate chemical composition, fatty acid profile and vitamin E content, were packed in polyethylene bags and stored at a temperature of –20°C until analysed.

Quality parameters of meat

For the shear test a Zwick 1120 tensile tester was used. Muscle samples weighing about 150 g were immersed for 24 h in a 1% NaCl solution under cold storage conditions (4°C). Afterwards, the samples were removed from the brine, immersed for 30 s in boiling water to denature meat surface layers and baked at 180°C. Heat treatment was continued until the internal temperature in the geometric centre of the sample reached 76°C. Ten minutes after reaching the desired temperature, the samples were removed from the oven, cooled at room temperature, and maintained under cold storage conditions (4°C) for 24 h. Shear force was determined at room temperature using rectangular samples with a square cross-section (20 ×20 mm) and a Warner–Bratzler shear machine. Determinations were made perpendicular to the muscle fibres until the sample was cut completely. The result was the maximum force needed to shear the sample. Cross-head speed was 30 mm/min until an initial tension of 2 N was obtained and 50 mm/min during the proper test.

Production yield was determined based on the difference between sample weight before brining and after thermal treatment and cooling – the result represents meat mass gain during brining and meat mass loss during cooking.

Colour (L* lightness – black = 0, white = 100; a* redness – red = positive values, green = negative values, and b* yellowness – yellow=positive values, blue = negative values) was measured with a Minolta CR-200 chroma meter at five locations in a 2-cm slice of MT muscle. The values obtained were averaged.

For the drip loss measurement, samples of MT muscle were weighed (approx. 300 g), sealed in a polyethylene bag and maintained under cold storage conditions (4°C) for 24 h, after which the exudate was collected and the amount of drip loss was expressed as a percentage of initial muscle weight.

Measurement of pH was performed using a Hanna HI-98240 pH meter (Hanna Instruments) with an FC 231D puncture electrode.

Chemical composition of meat

Chemical composition of the muscle was determined according to AOAC methods [2005]. Dry matter was determined after the samples were dried in a laboratory drier (105°C to constant weight). Protein and fat contents of LT were determined by Kjeldahl and Soxhlet methods, respectively.

Fatty acids

For fatty acids profile analysis, lipids were extracted according to the method by Folch *et al.* [1957] and fatty acids were esterified following the standard AOAC method [2005]. The fatty acids analysis was conducted using a TRACE GC ULTRA gas chromatograph (Thermo Electron Corporation) on a SUPELCOWAX™ 10 Capillary GC Column (30 m x 0.25 mm x 0.25 μm) under the following conditions of the separation process: carrier gas – helium at a flow rate of 1.5 mL/min, injector temperature – 220°C, column temperature – 190°C – 3 min, –3°C/min, –220°C–35 min, and detector temperature – 250°C.

Vitamin E

The quantitative determinations of α-tocopherol were performed using HPLC conducted with electrochemical detection according to ESA – Application note. One gram of tissue was homogenised and extracted with 5 mL of a hexane:ethanol mixture (50:50) with the addition of 0.01% butylhydroxyanisole (BHA). The tocopherols were extracted by mixing in Vortex for 60 min in the dark at about 4°C in hermetic vessels. The contents were then centrifuged in the Eppendorf 4250 centrifuge for 10 min at 11,000 rpm and at 4°C. Afterwards, the hexane phase was collected. The prepared sample (1 mL) was evaporated under gaseous nitrogen atmosphere and the dry residue was dissolved in 200 μL mobile phase and then placed in an auto-sampler's carrousel at 4°C.

Measurement of lipid peroxidation indices – TBARS

Malondialdehyde, the most abundant product of all lipid peroxidation products, was measured using thiobarbituric acid (TBA) according to Uchiyama & Mihara [1978] technique. The absorbance was measured at the wavelength of 535 nm with a Tecan Infinite M200 analyser (Tecan Group Ltd. Switzerland). The results represent the concentration of thiobarbituric acid reactive substances (TBARS) in the samples. The meat tissue was homogenised in 1% potassium chloride and centrifuged at 2000 ×*g* for 15 min at 4°C. The supernatant was used for the analysis and the tissues were placed in the reaction solution (1% phosphoric acid, 2% butylated hydroxytoluene, 1% potassium chloride and 0.4% TBA). The solution was heated at 95°C for 60 min prior to the analysis.

Statistical analysis

Results obtained were developed statistically using the ANOVA procedure of one-way analysis of variance with Statgraphics 6.0 Plus software. The significance of differences between groups was identified using the F-test. The analysis investigated the effect of feeding on the specified parameters. Results were presented in tables as mean values of parameters, standard errors of the means and the statistical significance of the effect.

RESULTS AND DISCUSSION

Results of production and slaughter performance were alike in all groups [Łozicki *et al*., 2010].

TABLE 4. Chemical composition of *Longissimus thoracis* muscle (%).

Components	Experimental group			SE	*P*-value
	CC	EC-1	EC-2		
Dry matter	24.283	24.265	24.203	0.358	0.984
Crude protein	21.824	21.285	21.541	0.307	0.473
Crude ash	0.976	0.998	1.001	0.013	0.243
Ether extract	1.557	1.568	2.005	0.303	0.504

Owing to various contents of fat and differences in fatty acid composition, the DDGSs applied in the feed concentrates may affect fat content of muscle as well as fatty acid profile.

The analysis of the chemical composition of the examined *Longissimus thoracis* muscle did not demonstrate any differences between the groups in the content of particular nutrients (Table 4). The muscle of all groups was characterised by a low content of intramuscular fat and even though its highest level was observed in the group receiving the concentrate with maize DDGS (EC-2), the differences in respect of the other groups were not confirmed statistically. The observed higher content of fat in *L. thoracis* of the animals from EC-2 group could have been due to a higher content of that component in the concentrate containing maize DDGS and to a slightly higher energy value of the whole feed ration in that group.

Table 5 displays results of fatty acid profile analysis of intramuscular fat of *Longissimus thoracis* muscle. The analysis of the fatty acid composition of *L. thoracis* intramuscular fat did not reveal any differences between the groups in the total content of saturated fatty acids (SFA). No differences were either observed between the feeding groups in the contents of the most hypersterolemic fatty acids, *i.e.* C12:0, C14:0 and C16:0.

Also the total content of monounsaturated fatty acids (MUFA) was at a similar level in all groups examined. Statistically significant differences were only noted for individual fatty acids. In EC-2 group, the content of C18:1 *n*-7 acid ($p \leq 0.01$) was significantly higher when compared to the other groups. In turn, in the case of C14:1 ($p \leq 0.05$), C 16:1 *n*-9 ($p \leq 0.05$), C 17:1($p \leq 0.05$), and C20:1 *n*-9 acids ($p \leq 0.05$), the highest contents were determined in meat of CC group, with the values being significantly higher as compared to the EC-2 group. The results of study indicate that it is difficult to modify the content and composition of SFA and MUFA in meat by the type of diet. Their content is linked to a greater extent with the total content of intramuscular fat. In the present study, the content of fat in the muscle was similar in all groups.

The feed rations administered to the animals were also observed not to affect the total content of polyunsaturated fatty acids (PUFA) in meat. Statistically significant differences in contents of individual fatty acids were noted only in the case of conjugated linoleic acid (CLA) ($p \leq 0.05$), the highest concentration of which was determined in meat of EC-2 group and turned out to be statistically significant compared to the respective value noted in EC-1 group. The highest concentration of CLA in the EC-2 group may be linked with a high fat content of the administered concen-

TABLE 5. Fatty acid profile and n-6/*n*-3 fatty acids ratio in raw *Longissimus thoracis* muscle.

Fatty acids	Experimental groups			SE	*P*-value
	CC	EC-1	EC-2		
	% of total fatty acids				
SFA	44.610	46.685	45.056	0.999	0.322
C10:0	0.047	0.049	0.048	0.003	0.890
C12:0	0.075	0.075	0.074	0.004	0.957
C14:0	1.924	2.123	2.081	0.182	0.723
C16:0	22.701	23.429	22.624	0.500	0.468
C15:0	0.524	0.554	0.500	0.033	0.522
C16:0	22.701	23.429	22.624	0.500	0.468
C17:0	0.949	0.953	0.817	0.003	0.080
C18:0	18.227	19.340	18.761	0.759	0.592
C20:0	0.122	0.122	0.118	0.008	0.906
C24:0	0.038	0.037	0.030	0.005	0.411
MUFA	37.930	35.822	36.403	1.152	0.429
C14:1	0.374^{a}	0.368^{a}	0.323^{b}	0.013	0.023
C16:1 *n*-9	0.308^{a}	0.295^{a}	0.249^{b}	0.014	0.017
C16:1 *n*-7	2.044	2.015	1.989	0.142	0.964
C17:1	0.658^{A}	0.584	0.479^{B}	0.040	0.016
C18:1 *n*- 9	30.523	28.501	28.172	0.937	0.182
C18:1 *n*-7	3.159^{B}	3.161^{B}	4.122^{A}	0.171	0.0007
C20:1 *n*-9	0.103^{A}	0.100^{a}	0.082^{Bb}	0.005	0.012
C24:1 *n*-9	0.057	0.053	0.044	0.007	0.398
PUFA	15.385	15.923	16.952	1.769	0.818
C18:2 *n*-6	8.751	9.790	10.855	1.124	0.431
C18:3 *n*-6	0.165	0.145	0.141	0.011	0.279
C18:3 *n*-3	1.014	0.922	0.788	0.087	0.211
CLA	0.572	0.551^{b}	0.706^{a}	0.464	0.058
C20:2 *n*-6	0.079	0.089	0.101	0.011	0.354
C20:3 *n*-6	0.502	0.489	0.542	0.083	0.895
C20:4 *n*-6	2.691	2.566	2.509	0.384	0.944
C20:5 *n*-3	0.414	0.343	0.287	0.053	0.257
C22:4 *n*-6	0.280	0.247	0.271	0.035	0.799
C22:5 *n*-3	0.820	0.691	0.683	0.112	0.629
C22:6 *n*-3	0.095	0.087	0.066	0.010	0.165
PUFA *n*-3	2.344	2.044	1.825	0.250	0.357
PUFA *n*-6	12.469	13.328	14.421	1.570	0.683
PUFA *n*-6/*n*- 3	5.524^{Bb}	6.195^{Ba}	8.280^{A}	0.224	0.004

AB – differences among selected rows ($P \leq 0.01$); ab – differences among selected rows ($P \leq 0.05$); SFA – calculated sum of fatty acids presented in the study that contain no double bonds; MUFA – calculated sum of fatty acids presented in the study that contain 1 double bond; PUFA – calculated sum of fatty acids presented in the study that contain 2 or more double bonds; CLA – conjugated linoleic acids; Σ *n*-6- calculated sum of all *n*-6 fatty acids presented in the study; Σ *n*-3- calculated sum of all *n*-3 fatty acids presented in the study; *n*-6/*n*-3 – calculated ratio of *n*-6 to *n*-3 fatty acids

trate and with a high content of C18:2 *n*-6 acid in that fat (Table 2), for CLA is synthesised from this acid in the rumen during biohydrogenation to stearic acid [Bauman *et al*., 2000]. The increase in CLA content of meat, at the higher content of fat in a food ration, was reported by, among others, Duckett *et al.* [2002]. In the presented experiment, despite the balanced energy value, the higher content of fat occurred in the EC-2 concentrate containing maize DDGS rich in that component. Furthermore, when administering DDGS from maize with feed rations for fattened heifers, Depenbusch *et al.* [2009] observed an increase in contents of CLA and PUFA in meat along with the increasing contribution of DDGS, which may also be linked with a high fat content of that DDGS. CLA is implicated in the inhibition of carcinogenesis, the reduction of atherosclerosis, modification of the immune response, the distribution of body fat and a reduction in body – fat deposits [Williams, 2000].

The analysis of sums of PUFA *n*-3 and PUFA *n*-6 acids demonstrated that the group receiving maize DDGS in the concentrate (EC-2) displayed a lower content of total PUFA *n*-3 and a higher content of total PUFA *n*-6 when compared to the other groups. The differences observed were, however, not confirmed statistically. Nevertheless, that group was characterised by a significantly higher PUFA *n*-6/*n*-3 ratio ($p \leq 0.01$) in respect of the other two groups examined (by 51% compared to the control group and by 20% compared to the group receiving wheat DDGS). The higher *n*-6/*n*-3 acids ratio in muscle of the animals administered the concentrate with DDGS from maize, likewise the higher content of CLA in muscle of the bulls from that group may result from the highest content of fat in the concentrate containing maize DDGS and from a high content of C 18:2 *n*-6 acid in that fat (Table 2).

Dugan *et al.* [2010], while applying increasing doses of DDGS from wheat (from 20 to 60%/kg DM feed ration) in feed rations for fattened heifers, did not demonstrate any changes in SFA nor MUFA concentrations in meat. In contrast, the increasing doses of DDGS in the feed ration were observed to be accompanied by the increasing total CLA content. The highest total content of PUFA, including Σ PUFA *n*-3 and *n*-6, was observed by these authors at a 40% dose of DDGS in DM of the feed ration.

In turn, Szulc *et al.* [2010] were substituting soybean meal with maize DDGS in concentrates for intensively-fattened young bulls. They did not note any statistically significant differences between the control and experimental groups for most of the determined fatty acids. Only the content of C18:2 acid was significantly higher in meat of the animals receiving DDGS in feed concentrates. In addition, those authors did not observe any significant differences between the groups in total contents of SFA, MUFA and PUFA, although in the case of PUFAs their higher content was noted in the group administered DDGS. In the case of our study, meat of the bulls from the group administered maize DDGS in the concentrate was also characterised by the highest concentration of C18:2 acid, however the differences observed as compared to the other groups were not statistically significant. A higher content of that acid in meat of the animals receiving DDGS from maize may be due to a high content of that acid in DDGS as well as to its higher intake with concentrates containing maize DDGS.

TABLE 6. Content of α-tocopherol and level of TBARS in raw *Longissimus thoracis* muscle.

Item	Experimental groups			SE	*P*-value
	CC	EC-1	EC-2		
α-Tocopherol	μg/g of fresh tissue mass				
	0.3862[b]	0.4022	0.4121[a]	0.006	0.0357
TBARS	nmol/g of fresh tissue mass				
3 days after slaughter	0.417	0.466	0.435	0.044	0.735
7 days after slaughter	0.483	0.519	0.541	0.041	0.616

ab – differences among selected rows ($P \leq 0.05$).

In a research by Koger *et al*. [2010], the control group was receiving soybean meal in feed rations whereas the experimental groups were administered wet or dried distillers grains. A higher content of C17:0 acid and lower contents of C18:0, C18:1t, C16:1c9, and C 18:2 c9c12 acids and of the total PUFA were noted in the control group. The increased concentration of PUFA resulting from maize DDGS administration with feed rations was also observed by Gill *et al.* [2008].

Aldai *et al.* [2010a], when substituting barley meal with maize or wheat DDGS in doses of 20 to 40% of feed ration, did not demonstrate any impact of the feed ration on SFA content in meat. The content of MUFAs was higher in the group fed based on barley meal, whereas that of PUFA in the groups receiving distillers grains in the feed rations. The content of CLA was alike in all feeding groups.

Significant from the viewpoint of dietetic value and quality of meat is also vitamin E content of meat. Table 6 presents contents of α-tocopherol in the analyzed *Longissimus thoracis* muscle. In both groups receiving DDGS with feed concentrates analyses demonstrated a higher content of α-tocopherol when compared to the control group. However, a statistically significant difference was only observed in the case of the group receiving DDGS from maize ($p \leq 0.05$).

The higher content of vitamin E increases the nutritional values of meat, but also improves its oxidative stability [Faustman *et al*., 1998; Roeber *et al*., 2001; Lauzurica *et al*., 2005]. By suppressing the oxidation process of fatty acids of meat or by stabilization of oxymyoglobin, vitamin E affects the improvement of such meat parameters as: colour, odour or texture [Arnold *et al*., 1993]. These authors demonstrated the positive effects of vitamin E in meat at its content above 3.5 μg/g of fresh tissue. In the case of our experiment, meat of bulls from all groups was characterised by a higher content of α-tocopherol.

The content of vitamin E in meat is determined by its intake with feed rations and by its source [Yang *et al*., 2002; Realini *et al*., 2004]. Koger *et al*. [2010], when applying different doses of dry and wet distillers grain in experimental rations and soybean meal in the control group, at various intakes of α-tocopherol with feed rations, did not observe any statistically significant differences in its contents in the meat

samples from particular groups. In our experiment, animals from all groups were receiving the same quantity of vitamin E with the vitamin-mineral mix, however its intake from the other components of the concentrates differed. Literature data point to a higher content of this vitamin in DDGS from maize and wheat compared to soybean meal [Chhorn & Yildirim-Aksoy, 2008].

Table 6 presents also TBARS level in the analysed *Longissimus thoracis* muscle. No statistically significant differences were observed between the groups in the concentration of fat oxidation index (TBARS) in muscle both in the first measurement made 3 days after slaughter and in the second measurement performed 7 days after slaughter. In the first measurement, the highest value of this index was noted in EC-1 group, whereas in the second measurement – in EC-2 group. In contrast, all groups were characterised by a tangible increase in TBARS level between the measurements.

The lack of statistically significant differences in TBARS level between the groups may indicate a similar course of fat oxidation processes in individual groups. Literature data show that PUFAs are especially susceptible to oxidation [Johns *et al*., 1989]. In the examined meat, despite the lack of significant differences between the groups, the highest content of PUFAs was demonstrated in EC-2 group (Table 5). This group was additionally characterised by a higher level of TBARS in the second measurement and by its highest increase between the measurements (Table 6).

A correlation between TBARS level in meat and PUFAs content of meat was emphasised by, among others, Koger *et al*. [2010]. In their research, in the case of meat of the animals receiving high doses of wet or dry DGS (40%) in feed rations, the highest content of PUFAs was accompanied by a higher TBARS level. The increase in the level of this index was also observed in the consecutive days after slaughter. When applying various doses of DDGS in feed rations for fatteners, Gill *et al*. [2008] did not demonstrate the diet to affect TBARS level in meat despite differences in PUFAs content. In turn, Realini *et al*. [2004] observed the stabilizing effect of vitamin E on lipids oxidation with the TBARS level increasing successively after slaughter.

Apart from the evaluation of the nutritive value of meat, of outmost significance is also the assessment of its sensory and technological parameters. They determine both meat evaluation by consumers and its usability for processing.

Out of the physicochemical and technological parameters of meat determined in this study significant differences between the feeding groups were observed in pH values ($p \leq 0.05$), that turned out to be the highest in *L. thoracis* of the animals from EC-1 group (Table 7). Meat of those animals was, additionally, characterised by the lowest shear force. However, when compared to the other experimental groups those differences were not statistically significant. Values of the other analysed parameters determining, among other things, the colour and texture of meat were similar in all groups. In the case of colour components, no statistically significant differences were observed for both cooled and thermally-treated meat. Nonetheless, cooled meat of the animals from the EC-2 group was characterised by higher values of L* and a* colour parameters.

TABLE 7. Selected parameters of meat quality.

Parameters	Experimental groups			SE	*P*-value
	CC	EC-1	EC-2		
pH	5.515^{b}	5.696^{a}	5.466^{b}	0.057	0.0243
Shear force (N/cm^2)	82.253	61.200	74.462	8.759	0.258
Penetration force (N)	39.312	38.253	36.987	3.122	0.871
Free drip (%)	0.562	0.337	0.475	0.094	0.257
Color components of cooled meat					
Color L*	36.541	35.308	37.064	0.522	0.0727
Color a*	21.583	20.903	22.067	0.668	0.478
Color b*	0.04	-0.801	0.522	0.450	0.134
Color components of thermally-treated meat					
Color L*	57.418	58.851	57.322	0.728	0.273
Color a*	9.058	9.018	9.128	0.253	0.952
Color b*	6.671	6.937	6.703	0.169	0.490
Meat mass increase during brining (%)	4.475	4.950	4.275	0.315	0.319
Drip loss during thermal treatment (%)	39.300	39.487	40.412	1.807	0.797
Production yield (%)	63.062	63.487	63.462	0.817	0.919

ab – differences among selected rows ($P \leq 0.05$).

Colour is one of the key criteria of meat quality assessment by consumers. It has been pinpointed by, among others, Liu *et al*. [1996]. The red colour of meat is determined by myoglobin. Its oxidation to metmyoglobin affects negatively the colour of meat [Liu *et al*., 1996]. The oxidation of myoglobin is correlated with oxidation of fatty acids, which in turn may be linked with poorer stability of meat colour and, consequently, with its deterioration [Arnold *et al*., 1993; Wood & Enser, 1997]. In addition, the oxidation of fatty acids results in the synthesis of ketone compounds and aldehydes, that have been reported to negatively affect the odour as well as colour of meat [Liu *et al*., 1996; Jakobsen & Bertelsen, 2000].

Leupp *et al*. [2009], who were applying a 30% addition of maize DDGS in feed rations for fattened steers, did not demonstrate any differences in L*, a* and b* colour parameters when compared to the control group. Also the shear force and cooking losses were alike in both groups. Those authors emphasise, however, that with 30% contribution of DDGS in the feed rations, the meat was more juicy and was characterised by more intensive aroma. Roeber *et al*. [2005], when substituting soybean meal and whole dried plants of maize in feed rations with dry or wet distillers grain in doses of 12.5%, 25% and 50%, did not observe them to affect L* colour parameter. In contrast, they demonstrated higher values of a* parameter in all groups receiving distillers grains, and lower values of b* parameter – compared to the control group –

only in the group receiving the 25% dose of wet cereal distillers grain. In the second experiment, where extraction soybean meal and maize silage were substituted with 10, 20 and 40% doses of dry or wet distillers grain, higher values of L* parameter were determined in the control group and in groups administered 20 and 40% doses of dried distillers grains, whereas the highest values of a* parameter – in the control groups and groups receiving the 10% addition of dry or wet distillers grains. Based on the results from both experiments, those authors stated that a high contribution of DDGS in a feed ration (from 40 to 50% DM) might exert a negative effect on colour stability of meat. In addition, they did not demonstrate any influence of the increasing doses of DDGS in the feed rations on meat tenderness. Koger *et al.* [2010], when substituting soybean meal and partly dry-rolled maize in feed rations with 20 and 40% addition of dry or wet distillers grain, did not observe them to affect colour parameters of meat. What is more, they did not demonstrate any differences between groups in meat tenderness and cooking losses. In contrast, the effect of different types of distillers grains on meat colour was confirmed by Gill *et al*. [2008]. They demonstrated a darker colour of meat (L* parameter) originating from animals administered a 15% dose of wet distillers grains from maize, when compared to the group receiving the same dose of wet distillers grain from sorghum in the feed ration. In turn, Roeber *et al*. [2005] point to the presence of xanthophylls in DDGS, being oxygen derivatives of carotenoids. Their intake with feed is likely to affect the coloration of meat. Also in our experiment, meat of the animals receiving the concentrate with maize DDGS was characterised by higher values of colour parameters L* and a*. Aldai *et al*. [2010b], when introducing DDGS from wheat or maize to feed rations for fattened young bulls, did not demonstrate the feed rations to influence the proximate composition and L* value of meat as well as the shear force and cooking losses measured in different time intervals.

SUMMARY

The application of wheat and maize derived DDGS as a source of protein in concentrates for fatteners had no impact on the proximate chemical composition of *Longissimus thoracis* muscle. In addition, the feed ration was found not to affect the total contents of SFAs, MUFAs and PUFAs. Worthy of attention is, however, a higher content of CLA and a higher PUFA *n*-6/*n*-3 ratio in meat of the animals receiving DDGS from maize. The administration of the feed concentrate with maize DDGS was also found to positively increase the content of α-tocopherol in meat. In contrast, no effect of the feed ration was observed on fat oxidation extent. The feed concentrates with different protein components administered to the fattened young bulls were also shown not to affect most of the analysed quality parameters of meat.

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