Effect of maize DDGS addition on carcass and meat quality of lambs of native sheep breed

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ABSTRACT
The aim of the study was to characterize carcass and meat quality of lambs of native sheep breed, which were fed a diet containing maize dried distiller’s grains with solubles (DDGS). The experiment involved 20 ram lambs of the native sheep breed Polish Heath Sheep (Wrzosówka sheep), which were selected from a conservation herd. The lambs received meadow hay and straw ad libitum as well as about 0.4 kg of concentrate per animal. The control group (C) received a standard diet based on cereal components and soybean meal, and in the experimental group (D), soybean meal and part of barley and wheat were replaced with DDGS (the addition of 45% DDGS to the lamb concentrates). The fattening was carried out for 60 days (up to 8 months of age). The diet had no effect on carcass quality, proportion of cuts, basic chemical composition of the meat and cholesterol content. The intramuscular fat of lambs fed the DDGS diet had a higher proportion of linoleic acid (C18:2, n-6) and conjugated linoleic acid, and a lower proportion of linolenic acid (C18:3, n-3), which had a negative effect on the polyunsaturated fatty acids n-6:n-3 ratio in the intramuscular fat. The addition of DDGS to the diet had a beneficial effect on the sensory properties of lamb meat, in particular its taste.

Introduction

The rapid development of biofuel production has increased the availability of plant processing by products, mainly rapeseed meal and cake, as well as dried distiller’s grains with solubles (DDGS). Due to their high nutritive value and relatively low price, these feeds are considered an excellent component of concentrate mixtures for farm animals. Maize DDGS is most widely used in sheep nutrition (Schauer et al. 2008; Borzuta et al. 2014). It is characterized by a high content of crude protein (about 30%), including a high proportion of ruminal bypass protein (about 55%), as well as a high energy value (Schingoethe et al. 2009). DDGS can successfully replace both energy and protein components in the concentrate mixture, and due to a high content of polyunsaturated fatty acids (PUFA), mainly linoleic acid (C18:2), it can also modify the fatty acid profile of the meat. The optimum proportion of DDGS in a lamb diet is 20% of ration dry matter, although this ingredient may also replace barley and soybean meal up to 60% of ration dry matter (Schauer et al. 2008).

Wrzosówka sheep are used in the experiments in this study. This is a native breed of sheepskin sheep with characteristic grey wool, and belongs to the Northern European short-tailed sheep. Meat of this breed is considered a delicacy, and many consumers compare it to game meat due to its unique taste, aroma and colour. Just like sheep milk products, lamb meat is considered a functional food, namely, one that has a beneficial effect on the human body beyond its nutritional function. The health-promoting properties of sheep products are associated, among others, with the fatty acid profile of intramuscular fat, including the high content of unsaturated fatty acids (UFA) and conjugated linoleic acid (CLA). The incorporation of an UFA-rich source into lamb diets may contribute to improving the quality of lamb meat.

The objective of the experiment was to determine carcass and meat quality of native sheep lambs receiving a concentrate diet containing 45% DDGS.

Material and methods

Animals and feeding

The experiment involved 20 ram lambs of the native Wrzosówka sheep breed, which were selected from a conservation herd belonging to the National Research Institute of Animal Production. When the lambs reached 180 days of age, they were divided into two feeding groups, each having 10 animals. The initial body weight of the lambs was 16 kg. The animals were maintained in a semi-intensive system: received meadow hay and straw ad libitum as well as about 0.4 kg of concentrate per animal. The control group (C) received a standard diet based on cereal components and soybean meal, and in the experimental group (D), soybean meal and part of barley and wheat were replaced with DDGS (Table 1).

Analysis

The basic chemical composition of feeds was determined using the standard method procedure (AOAC 2007). Fatty acids of
concentrates were determined as methyl esters in hexane by gas chromatography with GC-2010 SHIMADZU with a Rtx2330 capillary column (105 m length × 0.32 mm × 0.2 μm); injection volume 1.0 μl; temperature programme 60–240°C; injector temperature 250°C and helium as the carrier gas, according to ISO 12966-2:2011, with slight modifications. The nutritive value of the concentrate diets was calculated with INRA-tion ver. 4.07. The fattening was carried out for 60 days (up to 8 months of age).

### Evaluation of carcass quality

The animals were slaughtered, and slaughter analysis was performed according to the procedures used at the National Research Institute of Animal Production (NRIAP 2009). Meat performance of the lambs was determined through post-slaughter carcass evaluation and the determination of the proportion of cuts and leg tissue content.

### Evaluation of meat quality

Chemical composition was determined based on the samples of *longissimus dorsi* muscle collected from chilled right carcass sides, between the 5–6th thoracic vertebrae and the 1st lumbar vertebra.

A total of 20 meat samples were evaluated. The meat samples were transported to the Central Laboratory of the National Research Institute of Animal Production, where standard methods (AOAC 2007) were used to determine dry matter, crude protein, crude ash and crude fat. Fat was extracted according to Folch (1975). Fatty acids were determined according to the same procedure as that used to determine the fatty acids in feeds. Cholesterol was determined with a GC-2010 SHIMADZU gas chromatograph equipped with a flame ionization detector and column ZB-5 (30 m × 0.25 mm × 0.5 μm); injection volume 1.0 μl; temperature programme 100–360°C; injector temperature 250°C; detector temperature 300°C and helium as the carrier gas.

The raw leg muscle (*m. biceps femoris*) was analysed for:

- pH value of meat 24 and 48 h postmortem, using a Hanna Instruments HI99163 pH meter equipped with a Hanna Instruments FC232D electrode;
- weight loss during cooking was determined on 1.5-cm-thick steaks in an electric cooker at 165°C to an internal temperature of 70°C, according to Boccard et al. (1981);
- L*, a* and b* colour coordinates, determined 48 h postmortem with a Minolta CR 400, using the Commission Internationale de l’Eclairage Lab scale: L* (lightness), a* (redness) and b* ( yellowness).

The roasted leg meat was organoleptically evaluated for aroma, taste, juiciness and tenderness according to the method of Baryko-Pikielna and Matuszewska (2014). A 5-point grading scale (5 = highest to 1 = lowest) was used. The sensory panel consisted of five members trained (ISO 8586:1993) in sensory profiling.

### Statistical analysis

The results are presented in tables in the form of means and standard deviation. The data obtained during the study were statistically analysed with Statistica ver. 10 (2011) using Student’s t-test for independent samples.

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### Table 1. Ingredient composition and nutritive value of concentrates (%).

| Item | C | DDGS |
|------|---|------|
| Wheat | 20 | 10 |
| Barley | 52 | 37 |
| Wheat bran | 5 | 5 |
| Soybean meal | 15 | 0 |
| Rapeseed | 5 | 0 |
| Polfarmix CJa | 3 | 3 |
| DDGS | – | 45 |

**Nutritive value**

| Dry matter (%) | 87.4 | 87.7 |
| Crude protein (%) | 19.2 | 19.3 |
| Crude fat (%) | 2.5 | 3.1 |
| Crude fibre (%) | 5.4 | 6.4 |
| PDIN (g) | 133 | 137 |
| PDIE (g) | 124 | 131 |
| UFV | 1.07 | 1.04 |

**Fatty acids composition (%)**

| Fatty acids | C12:0 | C14:0 | C16:0 | C16:1 | C18:0 | C18:1 | C18:2 n-6 | C18:3 | C20:0 |
|-------------|-------|-------|-------|-------|-------|-------|-----------|-------|-------|
| saturated fatty acids | 0.06 | 0.19 | 16.57 | 0.23 | 1.47 | 24.78 | 50.29 | 6.26 | 0.14 |
| unsaturated fatty acids | 0.01 | 0.05 | 12.83 | 0.09 | 1.67 | 25.72 | 56.53 | 0.21 | 0.17 |

Note: C indicates control group; DDGS – for experimental group.

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### Table 2. Weight of carcasses and measurements of half-carcasses (X±SD).

| Item | C | D |
|------|---|---|
| Initial weight (kg) | 16.18 ± 0.62 | 16.22 ± 0.66 |
| Final weight (kg) | 20.54 ± 0.4 | 20.34 ± 0.35 |
| Daily gain (g) | 72.6 ± 9.27 | 68.3 ± 9.62 |
| Weight of carcasses and measurements of half-carcasses (X±SD) |
| Leg circumference (cm) | 29.37 ± 2.25 | 28.4 ± 2.58 |

Note: C – control; D – DDGS; without letters – p > .05.

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**Note:** Type of mixture: C – for control group; DDGS – for experimental group.

*Polfarmix CJa in 1 kg (%): Ca 21, P 6.0, Na 8.0, Mg 2.5, (IU): vit. A 450000., vit. D3 100000; (mg) vit. E 1000; vit. C 500; vit. B1 30; vit. B6 30; 9 (μg) vit. B12 150; biotin 6000; (mg) Mn 2000; I 80; Fe 1500; Co 20; Se 15; PDIN – protein digested in the small intestine limited by N; PDIE – protein digested in the small intestine limited by energy; UFL – energy unit for meat production; SFA – saturated fatty acids; UFA – unsaturated fatty acids; MUFA – monounsaturated fatty acids; PUFA – polyunsaturated fatty acids; PUFA n-6 – polyunsaturated fatty acids family n-6; PUFA n-3 – polyunsaturated fatty acids family n-3.
Results

The concentrate diets fed to the lambs were isoproteic and isoenergetic (Table 1). The DDGS diet was characterized by a slightly higher fat and crude fibre content. The level of linoleic acid (C18:2) and PUFA n-6 was higher in the DDGS diet than in the control diet. The PUFA n-6/n-3 ratio was threefold higher in the DDGS diet.

Fattening and slaughter traits

The final body weight of the control group lambs was slightly higher than that in the group receiving DDGS, but the differences were not statistically significant (Table 2). No significant differences were found for the other carcass quality parameters such as cold carcass weight, half-carcass weight and carcass measurements. The proportion of valuable cuts (including leg, saddle and best end of neck) in half-carcass was similar at 42% (Table 3). The use of DDGS in the diet had no significant effect on the proportion of meat in the leg, although it was slightly higher in group C (74.4%) than in the DDGS group (71.9%) (Table 4). No differences were observed in the proportion of other tissues, that is, fat and bones.

Chemical composition of meat and fatty acid profile

The addition of 45% DDGS to the lamb concentrates did not have any effect on the basic chemical composition of the meat and cholesterol content (Table 5). The intramuscular fat of DDGS-fed lambs had a higher proportion of linoleic acid (C18:2 n-6) and CLA, as well as a lower proportion of linolenic acid (C18:3 n-3) (Table 6).

Physicochemical and organoleptic properties of meat

The meat of lambs from the studied feeding groups did not have any effect on the basic chemical composition of the meat and cholesterol content (Table 5). The intramuscular fat of DDGS-fed lambs had a higher proportion of linoleic acid (C18:2 n-6) and CLA, as well as a lower proportion of linolenic acid (C18:3 n-3) (Table 6).

Table 3. Weight of carcass cuts (g) (X± SD).

| Item                  | C   | D   | p-Value |
|-----------------------|-----|-----|---------|
| Neck                  | 257.5 ± 80.26 | 242.0 ± 74.88 | .77     |
| Middle neck           | 235.0 ± 34.16 | 222.0 ± 41.62 | .63     |
| Best end of neck      | 250± 22 ± 62.58 | 244.0 ± 93.77 | .92     |
| Saddle                | 261.25 ± 54.52 | 268.0 ± 76.86 | .89     |
| Shoulder              | 533.75 ± 66.6 | 483.0 ± 82.71 | .38     |
| Skirt with ribs and brisket | 726.25 ± 153.37 | 686.0 ± 186.66 | .74     |
| Leg                   | 1040.0 ± 157.96 | 950.0 ± 207.97 | .65     |
| Fore shank            | 135.0 ± 17.32 | 129.0 ± 20.43 | .65     |
| Hind shank            | 222.5 ± 18.48 | 207.0 ± 35.11 | .45     |

Note: C – control; D – DDGS; without letters – p > .05.

Table 4. Tissue composition of leg (g) (X± SD).

| Item     | C         | D         | p-Value |
|----------|-----------|-----------|---------|
| Meat     | 743.75 ± 106.25 | 664.0 ± 168.94 | .44     |
| Fat      | 52.05 ± 21.02  | 44.0 ± 16.73  | .52     |
| Bones    | 203.75 ± 21.36 | 215.0 ± 27.61 | .53     |

Note: C – control; D – DDGS; without letters – p > .05.

Discussion

Fattening and slaughter traits

The replacement of soybean meal and part of barley and wheat grain with maize DDGS in the concentrate mixture for lambs had no negative effect on carcass quality and the weight of cuts. The lack of DDGS effect on the quality of lamb carcasses was observed in earlier studies (Schauer et al. 2008; Whitney & Braden 2010; Felix et al. 2012; Borzuta et al. 2014). As reported by Schauer et al. (2008), carcass quality does not deteriorate even when a high (60%) proportion of DDGS (% DM – dry matter) is used in the diet; however, at higher rates DDGS may decrease weight gains, although it does not reduce feed intake (Felix et al. 2012). Research shows that high DDGS inclusion rates may cause mineral (mainly phosphorus and sulphur) imbalances (Felix et al. 2012). In our study, we did not obtain a significant difference in the final body weight of the lambs fed the diet with 45% DDGS in relation to the control group. Other than that, no symptoms indicative of polioencephalomalacia were observed.

Chemical composition of meat and fatty acid profile

In the present study, no effect of supplementing the concentrate with DDGS on the basic chemical composition of the meat was observed, as was the case in Borzuta et al. (2013). Borzuta et al. (2014) obtained similar results for dry matter and protein percentage and also for cholesterol content after adding 15% DDGS to the diet. As regards the percentage of fat, the statistically significant differences they obtained were much greater, although these could result from the higher energy value of the concentrate, which in addition to 15% DDGS also contained 5% linseed. In our study, the concentrate diets were isoproteic and isoenergetic. Likewise, Whitney and Braden (2010) observed a linear increase in fat percentage in the meat of lambs fed a diet with 20% DDGS.

The fatty acid profile indicates the nutritional value of meat. The group of fatty acids of special physiological importance for humans includes PUFA, of which linoleic acid (C18:2) and linolenic acid (C18:3) are essential fatty acids (EFA). These acids are not produced in the body and are precursors of other EFA, such as arachidonic (AA, C20:4 n-6), eicosapentaenoic (EPA, C20:5, n-3) and docosahexaenoic acids (C22:6 n-3). Another polyunsaturated fatty acid that has many health-promoting benefits is CLA. It was found to be present primarily in the muscle tissue and in the milk fat of ruminants. Lamb meat is the richest source of CLA, whereas other kinds of meat contain no or trace amounts of this component (Milewski 2006). As recommended by ISSFAL (2004), the human diet should include fats with a low (2:1) n-6 to n-3 fatty acids ratio. Our study shows that the presence of DDGS in lamb concentrates allows modifying the fatty acid profile of meat fat.
The level of PUFA and the PUFA n-6/n-3 ratio are easily altered by the dietary supply of fatty acids. The meat of native Polish Heath sheep lambs fed the DDGS diet was characterized by a significant increase (p ≤ .01) in the content of C18:2 n-6 (9.73 vs. 6.39%, respectively) and CLA (1.59 vs. 0.58%, respectively) due to the dietary supply of C18:2 – one of the CLA precursors. The meat of control lambs was found to contain more of linoleic acid (C18:3; n-3), which was reflected in a higher proportion of PUFA n-3 in the overall fatty acid pool. The introduction of DDGS in the concentrates not only had a beneficial effect on the CLA content, but also caused a deterioration in n-6/n-3 PUFA in relation to the control group (13.61 vs. 7.06). The higher CLA content is due to the effect of DDGS on the ruminal fermentation process and biohydrogenation. A rich source of neutral detergent fiber, DDGS stimulates ruminal biohydrogenation (Sackman et al. 2003) and the development of cellulolytic bacteria. Studies with cattle showed that higher DDGS amounts may reduce rumen content pH (Felix & Loerch 2011) and thus adversely affect fibre and protein digestibility and the biohydrogenation process, in addition to inhibiting the proliferation of cellulolytic bacteria.

Physicochemical and organoleptic properties of meat

The use of DDGS in the diet did not increase the lightness of meat compared to that in the control group. Borys et al. (2013) reported no significant differences in meat colour lightness (L*), depending on the feeding method, but observed a tendency for increased redness (a*) in the meat of lambs fed a diet high in DDGS and for decreased yellowness (b*) in the meat of pastured lambs receiving a DDGS diet. In our study, the b* parameter decreased in the group supplemented with DDGS. Felix et al. (2012) observed muscle lightness (L*) to increase with increasing proportion of DDGS in the lamb concentrate, but according to the same authors, the instrumentally determined differences would be undetectable by the average consumer. The lack of substantial changes in the colour of Wrzosówka sheep lamb meat is beneficial because this breed is valued not only for the taste and aroma, but also for the colour of the meat, which is similar to that of game meat.

A study by Whitney and Braden (2010) with Rambouillet lambs showed that DDGS added to the diet at 20% (DM basis) improves meat juiciness, tenderness and flavour intensity. In our study, meat from the DDGS-fed group had better taste, tenderness and more delicate texture, which contributed to a higher overall score of the meat. Chung et al. (2006) concluded that fatty acid profile may determine the sensory properties of the meat, whereas Crouse et al. (1982) reported that taste is highly correlated with the proportion of oleic acid (C18:1; r = .33) and linoleic acid (C18:3; r = .33). During heat treatment, UFA are changed to volatile aromatic compounds of the aldehyde and alkane groups. Wen (2013) reported that autoxidation of UFA such as linoleic acid (C18:1) during heat treatment led to hydroperoxide formation, which in turn increases the production efficiency of alkenes. Farmer (1994) reported that a change in meat flavour may be associated with the n-6/n-3 acids ratio. The experiment revealed no statistically significant differences in meat flavour, despite the differences in PUFA n-6/n-3.

Conclusions

The DDGS supplementation of the lamb concentrate diets had no significant effect on carcass quality and the basic chemical
composition of the lamb meat. The intramuscular fat of meat from the native Wrzosówka sheep lambs fed the DDGS diet had a higher content of linoleic acid (C18:2 n-6) and CLA. Sensory evaluation of the meat was more favourable for the group receiving DDGS. According to the testers, roasted meat was tastier, more delicate and more tender.

**Disclosure statement**

No potential conflict of interest was reported by the authors.

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