



THE EFFECT OF HERBAL MIXTURE SUPPLEMENTATION ON THE FATTENING, SLAUGHTER AND SELECTED MEAT QUALITY PARAMETERS OF MERINO LAMBS*

Aldona Kawęcka*, Marta Pasternak, Iga Peist, Michał Puchała

Department of Sheep Breeding, National Research Institute of Animal Production, 32-083 Balice n. Kraków, Poland

*Corresponding author: aldona.kawecka@iz.edu.pl

Abstract

The aim of the research was to investigate the effect of herbal additives added to feed concentrate on the slaughter characteristics and meat quality of Merino lambs of two Polish breeds – Coloured Merino and Old Type Merino. Throughout the fattening period, the animals received some concentrate mixture *ad libitum* in the form of pellets supplemented with 10 g/kg or 20 g/kg of a herbal mixture consisting of fennel fruit, purple coneflower herb, minced garlic, and thyme. The content of dry matter, protein, fat, ash, cholesterol, and collagen was determined in meat samples (*Musculus quadriceps femoris*) collected after slaughter, the fatty acid profile and amino acid content were assessed also. In terms of the examined parameters, both between-breed differences and differences resulting from the diet were observed. Coloured Merino were characterized by higher average daily gains, higher hot and cold carcass weight and higher dressing percentage than Old Type Merino. Meat obtained from lambs of this breed was characterized by a higher level of PUFA-3 and a higher level of most amino acids. Old Type Merino lambs were characterized by a significantly higher *Musculus longissimus dorsi* (*m.l.d.*) fat thickness and *m.l.d.* area. The herbal mixture influenced the fat content in the meat, which was the lowest in the group of lambs that received a larger amount of the herbal supplement. The use of the herbal additive significantly reduced the n-6/n-3 PUFA ratio in the tested meat.

Key words: sheep, herb, meat, Merino lamb, quality

Merino are one of the oldest breed groups, numbering over 45 different breeds and varieties, widespread all over the world. During many years of selection that led to local adaptation, sheep have developed in a variety of environmental conditions, from the Mediterranean to continental European and Asian climates, as well as subtropical, warm and cold, dry areas (Ceccobelli et al., 2023). Merino breeding has a long tradition in Poland. Native Merino sheep are currently represented by three breeds: Polish Merino, Coloured Merino, and Old Type Polish Merino. Merino sheep are bred for wool and meat; in addition to excellent quality fine wool, they provide lambs with very good slaughter traits. Merino wool is one of the finest wools of all sheep breeds (16–24 µm). The seasonality of reproduction in Merino allows for regular production of lambs throughout the year (Niżnikowski et al., 2014; Kawęcka et al., 2022). With respect to these sheep breeds that are important for lamb production, there is no detailed characterization in terms of fattening parameters, carcass characteristics or meat quality of the Merino breed in Poland.

The sheep meat market is still a niche sector in Poland, and the consumption of this type of meat in the country is approximately 5 times lower than in the rest of Europe (Niżnikowski et al., 2017). However, the increasing

emphasis that consumers place on the health-promoting and functional aspects of food gives hope for improving the situation of sheep production in Poland. Sheep meat is a good source of protein, essential amino acids, microelements and is also the richest source of isomers of conjugated linoleic acid (CLA), which is associated with immunomodulatory properties, anti-cancer and anti-atherosclerosis, diabetes prevention, and reduction of body fat (Ciliberti et al., 2021; Prache et al., 2022). The composition and properties of meat are influenced by many factors, including nutrition. In recent years, the use of natural dietary supplements based on plant substances in the nutrition of farm animals has become increasingly popular. Phytogenic feed supplements, i.e. compounds of plant origin, are used in animal nutrition to improve their productivity by changing the properties of feed and improving the quality of animal products. These supplements can be dedicated to specific production groups, and their effect is multifaceted – they not only influence the taste and intake of feed, but also affect the rumen microflora and fermentation processes (Chaves et al., 2008). They also improve the milk yield and modify the chemical and microbiological composition of milk (Kawęcka and Radkowska, 2023; Rodríguez et al., 2019). The beneficial effects of herbal

*Funding: NRIAP Statutory task no. 01-13-04-11 – The use of herbal additives to improve the health and production results of small ruminants.

plants on livestock are observed in terms of improved feed intake, nutrient digestibility, regulation of the immune system, stimulation of the endocrine system, and indirect nutrient metabolism (Redoy et al., 2020). This effect is due to the presence of the most important bioactive ingredients in plants, such as saponins, alkaloids, phenolic compounds, tannins, and flavonoids. Therefore, as an alternative to synthetic growth stimulants (antibiotics), natural products (herbs and spices) are being considered as natural feed additives that enhance physiological functions and replace pharmacological substances (Garcia-Galicia et al., 2020; Odhaib et al., 2021).

In the case of pasture-raised animals, appropriately selected mixtures of herbs and grasses allow for better production results (Hutton et al., 2011; Sinhadipathige et al., 2012). However, when it comes to animals housed indoors, feed additives in the form of fresh herbs, dried herbs, extracts, oils or in the form of licks may have a beneficial effect on the above-mentioned aspects (Junkuszew et al., 2015). In Poland, in the central part of the country, in lowland areas, Merino sheep are kept in the indoor or indoor-pasture system.

The aim of the research was to investigate the effects of herbal additives added to feed concentrate on

the slaughter characteristics and meat quality of Merino lambs of two breeds.

Material and methods

Animal material, diet, and slaughter evaluation

Twenty four 130-day-old male lambs of each of two native breeds (Old Type Merino and Coloured Merino), from flocks belonging to the National Research Institute of Animal Production (NRIAP), were used for the experiment. Lambs were firstly kept with their mothers until weaning at about 60 days of age, where they received supplementary crushed oats and hay. After weaning, they were placed in group pens and fed with good quality hay and given 300 g of concentrate mix (Table 1); they had constant access to fresh water and mineral licks. After a period of 10 days of adaptation, the experimental/fattening period began. In each breed three feeding groups were formed: group C – the control, with no herbs added to the feed concentrate, and groups H1 and H2, in which a herb mixture was added to the feed concentrate in the amount of 10 or 20 g/kg feed.

Table 1. Mixture ingredients for feeding groups

C mixture ingredients	(%)	H1 mixture ingredients	(%)	H2 mixture ingredients	(%)
concentrate mixture		concentrate mixture		concentrate mixture	
Barley meal	15	Barley meal	15	Barley meal	15
Oatmeal meal	15	Oatmeal meal	15	Oatmeal meal	15
Wheat meal	15	Wheat meal	15	Wheat meal	15
Soybean meal 46%	20	Soybean meal 46%	20	Soybean meal 46%	20
Dried grass	15	Dried grass	15	Dried grass	15
Wheat bran	15	Wheat bran	15	Wheat bran	15
Mineral and vitamin mixture	1.8	Mineral and vitamin mixture	1.8	Mineral and vitamin mixture	1.8
Calcium carbonate	2.1	Calcium carbonate	2.1	Calcium carbonate	2.1
Monocalcium phosphate	0.6	Monocalcium phosphate	0.6	Monocalcium phosphate	0.6
NaCl	0.5	NaCl	0.5	NaCl	0.5
Herbal mixture addition (g)	0	Herbal mixture addition (g)	10	Herbal mixture addition (g)	20

Table 2. Nutrient composition of experimental diets (DM basis)

Parameters (%)	C	H1	H2
Dry matter	89.82	88	87.87
Ash	6.4	8.21	8.03
Fat	5.26	2.45	2.6
Protein	18.11	18.24	18.31
Fibre	9.24	6.34	6.78
SFA	24.86	25.32	23.81
UFA	75.14	74.68	76.19
MUFA	47.14	26.16	25.91
PUFA	28.00	48.52	50.27
PUFA n-6	26.56	37.92	38.93
PUFA n-3	1.44	10.60	11.34
DFA	81.25	77.36	78.73
UFA/SFA	3.02	2.95	3.20
MUFA/SFA	1.90	1.03	1.09
PUFA/SFA	1.13	1.92	2.11
PUFA n-6/n-3	18.45	3.58	3.43

Explanations: SFA = saturated fatty acids; UFA = unsaturated fatty acid, MUFA = monounsaturated fatty acids, PUFA = polyunsaturated fatty acids, DFA = dietary fatty acids with a desirable (neutral or hypocholesterolemic) effect on humans.

A herbal mixture (dried) containing 4 components in equal amounts: fennel fruit (*Foeniculum vulgare*, fructus), purple coneflower herb (*Echinacea purpurea*, herb), minced garlic, and thyme was used as an addition to feed concentrate for lambs. The dried herbal mixture in an appropriate amount was pelleted with other ingredients into a total mixed food ration. The composition and results of chemical analysis of the feed concentrate for lambs used in the experiment are presented in Tables 1 and 2. The animals had constant access to fresh water, good quality hay and mineral licks. The slaughter was performed at an EU-licensed abattoir, following the normal commercial procedure. After 24 h of chilling at 4°C, the carcasses were separated into cuts (NRIAP, 2009).

Live and post-mortem measurements

During the experiment, measurements of body weight, ultrasound measurements of the surface of the *Musculus longissimus dorsi* (*m.l.d.*), and monitoring of feed intake were performed. After fattening, the lambs were subjected to experimental slaughter. The slaughter analysis was performed according to the procedures used in the MA PIB (NRIAP, 2009). Post-mortem evaluation of the carcass included estimation of slaughter yield, measurement of cuttings, determination of the weight of cuttings, and detailed dissection of the leg. Meat samples from the leg (*Musculus quadriceps femoris*) collected after slaughter were analysed to determine the chemical composition using standard methods, according to AOAC (2005), assessing dry matter, total protein, free fat, and ash content. The cholesterol content was determined using a GC-2010 Shimadzu gas chromatograph (Shimadzu Corp., Japan) equipped with a flame ionization detector and a Zebron

ZB-5 column with dimensions of 30 m × 0.25 mm × 0.5 µm (SOP M.023). Fatty acid composition of intramuscular fat (IMF) was analysed using a VARIAN 3400 gas chromatograph (Varian, Walnut Creek Instrument Division, USA), with an Rtx 2330 column (dimensions: 105 m × 0.32 mm × 0.2 µm). The collagen content in the meat was assessed using the spectrophotometric method after conversion from the hydroxyproline content, using its standard collagen content of 12.5% (AOAC Official Method 990.26). Contents of Asp, Thr, Ser, Glu, Pro, Gly, Ala, Val, Ile, Leu, Tyr, Phe, His, Lys, Arg, Cys, and Met were determined according to European Commission Regulation (EC) No. 152/2009 of 27/01/2009, Annex III F. Trp content was determined according to Determination of tryptophan content in alkaline hydrolysates of feed and biological material. SOP M.006 ed. 6 of January 27, 2020 (<https://cl.iz.edu.pl/wp-content/uploads/2024/03/zakres-akredytacji-AB-512.pdf>).

Statistical analysis

The results are presented in the tables as means. The results were statistically processed using the SAS Enterprise Guide ver. 7.1 using two-way analysis of variance. Testing was performed at the significance level of $P \leq 0.05$ and $P \leq 0.01$. If a significant effect of a factor on the tested feature was found, the Tukey test was used. The following mathematical model was used for the analysis:

$$Y_{ijk} = \mu + a_i + b_j + (ab)_{ij} + E_{ijk}$$

where:

μ – average, a_i – breed, b_j – diet, $(ab)_{ij}$ – interaction (breed × diet), E_{ijk} – error.

Table 3. The influence of the studied factors on the fattening and slaughter characteristics of lambs (means ± SD)

Factors	Breed		Diet			P-value		
parameters	Coloured Merino	Old Type Merino	C	H1	H2	breed	diet	B×D
Initial weight (kg)	20.80	20.05	19.842	20.94	20.4	0.262	0.413	0.954
Final weight (kg)	43.57	43.58	43.25	42.47	41.1	0.791	0.110	0.009
Average daily gain (g/d)	378.12 a	349.51 b	364.34	357.5	369.1	0.035	0.789	0.499
Feed per kg of growth (kg)	4.15	4.23	4.21	4.28	4.08	0.789	0.666	0.161
<i>M.l.d.</i> thickness (cm)	2.61	2.68	2.58	2.69	2.66	0.216	0.410	0.491
<i>M.l.d.</i> fat thickness (cm)	0.28 A	0.33 B	0.33	0.33	0.31	0.012	0.312	0.320
<i>M.l.d.</i> area (cm ²)	8.13 a	8.96 b	8.39	8.71	8.53	0.04	0.728	0.636
Warm carcass weight (kg)	20.38 A	19.76 B	20.17	20.14	19.88	0.012	0.451	0.287
Cold carcass weight (kg)	19.78 A	19.14 B	19.55	19.51	19.29	0.009	0.681	0.301
Right half-carcass (kg)	9.69	9.05	9.57	9.08	9.47	0.118	0.552	0.652
Left half-carcass (kg)	10.10 A	9.73 B	9.97	9.97	9.83	0.003	0.471	0.333
Dressing percentage (%)	47.95 A	46.91 B	47.86	47.21	47.22	0.007	0.191	0.092
Leg weight (kg)	3.34 a	3.20 b	3.24	3.3	3.26	0.028	0.735	0.134

Explanations: C: control group (no additive); H1: additive level 10 g/kg feed; H2: additive level 20 g/kg feed.

A, B – $P \leq 0.01$; a, b – $P \leq 0.05$ – means in rows denoted using the different letters differ significantly.

Results

Table 3 presents the results of the analysis of the influence of breed and diet on the fattening and slaughter characteristics of the lambs. Statistically significant ($P \leq 0.05$) differences were noted in average daily gains, which were higher in the group of Coloured Merino than in the group of Old Type Merino. In terms of carcass properties, Coloured Merino lambs were characterized by significantly higher ($P \leq 0.01$) warm and cold carcass weights and a higher weight of the left half-carcass than Old Type Merino lambs. Dressing percentage ($P \leq 0.01$) and leg weight ($P \leq 0.05$) were also significantly higher in Coloured Merino. Merino lambs of the Old Type were characterized by a significantly higher *m.l.d.* fat thickness ($P \leq 0.01$) and *m.l.d.* area ($P \leq 0.05$). There was no effect of nutrition on the fattening and slaughter parameters of the lambs, and the interaction between the effects of both factors was noted only in the case of final weight.

Table 4 presents the results of the analysis of the influence of both factors on chemical composition and fatty acid content of the lamb meat. The content of protein, fat, and ash was similar in meat samples from lambs of both breeds. Statistically significant differences ($P \leq 0.05$) were recorded in the case of dry matter content, which was higher in lamb samples obtained from Coloured Merino. A significant effect ($P \leq 0.01$) of the diet on the fat level in meat samples was also observed. It was the highest in the control group and the lowest in the group of lambs that received a higher amount of the herbal sup-

plement. There was no influence of breed or diet on the content of cholesterol and collagen in the tested samples. No interaction was observed.

Significant differences between samples in relation to the effects of both tested factors were found in the fatty acid profile (Table 5). Meat samples from Old Type Merino were characterized by significantly higher contents of c16-1 ($P \leq 0.05$), CLA c9-t11, c20-4, and UFA ($P \leq 0.01$). In turn, Coloured Merino meat had significantly higher levels of CLA t10-c12 ($P \leq 0.05$) and c18, c18-3, c20, EPA, DHA, and SFA acids ($P \leq 0.01$). Statistically significant differences ($P \leq 0.01$) were observed in PUFA-3, the content of which in Coloured Merino lambs was significantly higher than in meat from Old Type Merino lambs. The n-6/n-3 PUFA ratio was almost twice as high ($P \leq 0.01$) in samples obtained from Old Type Merino lambs.

The use of the herbal supplement had a significant impact on the content of some fatty acids (Table 5). Samples from the group of lambs fed without supplement were characterized by significantly lower levels of c18-1, gamma18-3, c18-3, CLA t10-c12, c20-4, EPA, UFA, and MUFA, with the highest content of fatty acids among all groups c18, CLA t9-t11, and SFA. In the group receiving a higher addition of the herbal mixture, the highest levels of c18-1, CLA t10-c12, c20-4 and MUFA acids were observed, while in the group receiving a lower addition of the mixture, the highest levels of c18-3, CLA c9-t11, and UFA were observed. The use of the herbal additive significantly reduced the n-6/n-3 PUFA ratio in the tested meat.

Table 4. The influence of the breed and diet on chemical composition of lamb meat

Factors	Breed		Diet			P-value		
parameters	Coloured Merino	Old Type Merino	C	H1	H2	breed	diet	B×D
Total solids (%)	24.44 a	23.82 b	24.37	24.26	23.72	0.043	0.187	0.184
Ash (%)	1.05	1.06	1.06	1.06	1.04	0.520	0.606	0.739
Fat (%)	1.99	2.10	2.41 A	1.91 B	1.84 B	0.609	0.007	0.369
Protein (%)	20.13	19.68	19.88	20.12	19.68	0.102	0.381	0.283
Cholesterol (mg/100 g)	0.68	0.69	0.69	0.69	0.69	0.373	0.373	0.832
Collagen (%)	0.54	0.54	0.56	0.53	0.52	0.771	0.393	0.872

Explanations: Table 3.

Table 5. The influence of the studied factors on fatty acids content of lamb meat

Factors	Breed		Diet			P-value		
parameters	Coloured Merino	Old Type Merino	C	H1	H2	breed	diet	B×D
1	2	3	4	5	6	7	8	9
c14	2.54	2.75	2.82	2.51	2.63	0.284	0.586	0.434
c16	24.58	25.07	25.26	24.69	24.59	0.231	0.408	0.562
c16-1	1.51 b	1.66 a	1.50	1.61	1.64	0.035	0.262	0.682
c18	17.57 A	15.64 B	17.71 A	15.76 C	16.24 B	0.001	0.006	0.507
c18-1	38.58	38.73	37.22 b	39.24 a	39.44 ba	0.641	0.023	0.532
c18-2	9.31	9.62	9.92	9.71	8.82	0.572	0.164	0.865

Table 5 – contd.

1	2	3	4	5	6	7	8	9
gamma18-3	0.13	0.13	0.11 B	0.14 A	0.14 A	0.618	0.002	0.836
c20	0.10 A	0.08 B	0.09	0.09	0.09	0.002	0.364	0.281
c18-3	0.66 A	0.47 B	0.49 C	0.62 A	0.56 B	0.001	0.009	0.001
CLA c9-t11	0.02 B	0.05 A	0.03 B	0.05 A	0.03 B	0.001	0.002	0.456
CLA t10-c12	0.02 a	0.01 b	0.01 b	0.01 b	0.02 a	0.053	0.026	0.036
CLA c9-c11	0.02	0.03	0.03	0.02	0.02	0.063	0.28	0.534
CLA t9-t11	0.06	0.06	0.08 A	0.05 B	0.05 B	0.720	0.001	0.291
c22	0.05	0.05	0.05	0.04	0.05	0.828	0.871	0.666
c20-4	3.99 B	4.84 A	3.90 a	4.61 b	4.78 b	0.003	0.035	0.631
EPA	0.21 A	0.15 B	0.14 b	0.20 a	0.20 a	0.001	0.035	0.005
DHA	0.26 A	0.17 B	0.18	0.21	0.24	0.001	0.235	0.115
SFA	45.18 A	44.03 B	46.34 A	43.47 B	44.01 B	0.002	0.000	0.068
UFA	54.81 B	55.96 A	53.65 C	56.52 A	55.99 B	0.002	0.000	0.068
MUFA	40.08	40.39	38.72 b	40.85 a	41.08 a	0.496	0.022	0.516
PUFA	14.72	15.57	14.92	15.66	14.91	0.260	0.637	0.915
PUFA n-6	13.44	14.59	13.93	14.47	13.75	0.115	0.677	0.999
PUFA n-3	1.14 A	0.79 B	0.82	1.04	1.01	0.000	0.053	0.000
PUFA n-6/n-3	11.89 B	20.12 A	21.16 A	14.01 B	13.95 B	0.000	0.000	0.000

Explanations: C: control group (no additive); H1: additive level 10 g/kg feed; H2: additive level 20 g/kg feed. A, B – $P \leq 0.01$; a, b – $P \leq 0.05$ – means in rows and denoted using the different letters differ significantly. C14:0 = myristic acid; C16:0 = palmitic acid; C16:1 = palmitoleic acid; C17:0 = heptadecanoic acid; C18:0 = stearic acid; C18:1 11t = trans-vaccenic acid; C18:1 9c = oleic acid; C18:2 n6 = linoleic acid; C18:3 n-6 = gamma-linolenic acid; C18:3 n-3 = alpha-linolenic acid; C20:4 n-6 = arachidonic acid; C20:5 n-3 = eicosapentaenoic acid; C22:6 n-3 = docosahexaenoic acid; conjugated linoleic acid (CLA): 9c11t, CLA 10t12c, CLA c9-c11, CLA 9t11t; SFA = saturated fatty acids, MUFA = monounsaturated fatty acids, PUFA = polyunsaturated fatty acids.

Table 6. The influence of the studied factors on amino acids content of lamb meat

Factors	Breed		Diet			P-value		
parameters	Coloured Merino	Old Type Merino	C	H1	H2	breed	diet	B×D
Asp	19.16 A	17.98 B	18.91	18.41	18.29	0.007	0.324	0.324
Thr	9.59 a	9.01 b	9.64	9.17	9.05	0.026	0.173	0.477
Ser	7.82	7.69	8.03	7.69	7.56	0.531	0.344	0.157
Glu	30.40 A	28.27 B	30.09	29.31	28.46	0.001	0.079	0.434
Pro	7.21 a	6.70 b	7.13	7.03	6.66	0.030	0.220	0.377
Gly	9.33	8.84	9.19	9.21	8.82	0.055	0.357	0.561
Ala	11.67 a	11.06 b	11.50	11.52	11.03	0.027	0.246	0.253
Val	9.64	9.30	9.52	9.62	9.23	0.124	0.309	0.440
Ile	9.34 A	8.74 B	9.11	9.07	8.90	0.001	0.518	0.581
Leu	15.82	15.31	15.68	15.59	15.38	0.086	0.694	0.524
Tyr	9.43 A	8.46 B	8.95	8.93	8.88	0.001	0.883	0.862
Phe	8.44 A	7.68 B	7.98	8.06	8.08	0.000	0.993	0.920
His	7.14 A	6.11 B	6.46	6.74	6.57	0.002	0.872	0.994
Lys	18.90	17.87	18.26	18.48	18.31	0.060	0.941	0.563
Arg	13.67	12.29	12.64	12.88	13.26	0.255	0.821	0.826
Cys	2.34	2.41	2.41	2.37	2.36	0.219	0.851	0.668
Met	5.54	5.65	5.69	5.62	5.51	0.397	0.445	0.932
Trp	2.42	2.19	2.52	2.15	2.23	0.083	0.067	0.263

Explanations: Table 3.

The interaction of the analysed factors was observed in relation to PUFA-3 and PUFA n-6/n-3. This effect was also noticeable in the content of c18-3, CLA, t10-c12, and EPA acids.

Table 6 presents the results of the analysis of the influence of the tested factors on the amino acid content in the lamb meat. The levels of amino acids such as Asp, Thr, Glu, Pro, Ala, Ile, Tyr, Phe, and His were higher in samples from Coloured Merino, and the differences were statistically significant. No statistically significant differences were observed depending on the effect of the herbal supplement used. There were no interactions that would indicate a common influence of both factors on the obtained results.

Discussion

Despite not being very large, the sheep population in Poland is characterized by great diversity, including 30 breeds and varieties. Sheep genetic resources protection programmes, implemented consistently for many years, have allowed the rescue of many native breeds associated with specific regions of Poland. The dynamic development of protected populations has created an opportunity for the development of the market for local sheep products, as well as the wide use of the species in ecosystem services and on ecological and agritourist farms. However, the basic form of sheep use in Poland is for meat, while the large diversity of breeds in the sheep population translates into a large variation in the quality of the obtained carcasses and meat (Kawęcka et al., 2022). This analysis provided information on the differences between two native Merino breeds in terms of fattening and slaughtering characteristics as well as meat quality. This allowed for the first comprehensive characterization of these breeds after they were included in the genetic resources protection programme. Additionally, understanding the effects of feed supplementation with herbal supplements may be useful when planning intensive production of Merino lambs.

The influence of breed and diet on fattening and slaughter characteristics

Research concerning fattening and slaughter characteristics can be found in many publications, and interbreed differences have been confirmed by many authors. Breed has a large impact on carcass morphology, but it is a complex and difficult factor to assess, and the results vary depending on the selected criterion, such as carcass weight or animal age (Prache et al., 2022). In the case of breeds that differ in phenotype and performance, the differences are usually noticeable. Suliman et al. (2021) assessed fattening performance, carcass characteristics, chemical composition, and meat quality in lambs of three native Saudi sheep breeds: Awassi, Harri, and Najdi. The authors found that breed had an impact on carcass characteristics and meat composition and quality. Final

live weight was significantly higher in Awassi lambs, although slaughter efficiency was highest in Harri lambs. The few studies conducted in Poland on the Polish Merino breed have shown that it is a breed that achieves good results in terms of reproductive characteristics and has good meat and carcass characteristics (Niżnikowski et al., 2014). When comparing the slaughter value of Polish Merino and Berrichon du Cher ram lambs in an intensive housing system, a significant influence of the breed was found on dressing percentage, carcass weight, and half-carcass weight, as well as on the thickness of the fat layer over the rib eye area.

This study focuses on two breeds from one cosmopolitan Merino breed group – Old Type Polish Merino and Coloured Merino. The analyses show that the breed had an impact on the average daily gain, which was significantly higher in the group of Coloured Merino than in the group of Old Type Merino. Coloured Merino lambs were characterized by significantly higher warm and cold carcass weight and a higher left half-carcass weight than Old Type Merino lambs. Dressing percentage and leg weight were also significantly higher in Coloured Merino. Old Type Merino lambs were characterized by a significantly higher *m.l.d.* fat thickness and *m.l.d.* area. Based on the above research, it can be concluded that much better parameters and fattening characteristics were found in Coloured Merino lambs. Research by Cloete et al. (2012) comparing the slaughter and meat characteristics of mutton (Dorper) sheep, wool Merino and dual-purpose Merino (Dohne Merino and South African Mutton Merino), showed large differences in terms of meat utility.

When assessing the impact of the diet containing the herbal supplement on the fattening and slaughter characteristics of Merino sheep, a certain tendency towards higher daily gains and lower feed consumption per kg of gain can be noticed in the case of sheep fed with a higher level of the herbal supplement, but these differences were not statistically significant. Similarly, Orzuna-Orzuna et al. (2021) in a study in which lambs were fed with a mixture of broadleaf herbs, showed a tendency to improved average daily gain and increased carcass weight. However, according to Redoy et al. (2020), dietary supplementation with plantain and garlic leaves improved daily gain and feed conversion rate, which were higher in herb-supplemented groups. Somasiri et al. (2013), using mixtures consisting of plantain, chicory, white clover, and red clover in the pasture, obtained a faster growth rate and higher final body weight. The results of a study by Sheng et al. (2019) indicate that adding essential oil to the diet of lambs can increase growth, dressing percentage, and improve meat quality. Sultan (2022) examined the effects of *Curcuma longa* addition to the Awassi male lambs' ration on production efficiency and carcass quality. Supplementation improved overall body weight gain, daily body weight gain, slaughter weight, and hot and cold carcass weight. The author also showed that the lambs fed with the *Curcuma longa* supplement showed

better dressing percentage and rib eye area than lambs of the control group.

The influence of breed and diet on meat quality

The quality of lamb meat is influenced by many factors, and knowledge about their importance requires further research, accompanied by continuous assessment of consumer and industry requirements. Management practices should take into account internal factors such as the breed, sex, age, and body weight of the animals at slaughter, as well as the genes and meat quality that relate to these factors. Despite the influence that breed may have on meat quality, some authors place greater importance on other factors, such as the age of the animal and the type of feed. According to these authors, breed plays only a secondary role (Navajas et al., 2008). In the present study, the content of protein, fat, and ash was at a similar level in meat samples from both breeds. Significant differences were observed only in the case of dry matter content, which was higher in samples obtained from Coloured Merino. Latorre et al. (2011) compared meat samples obtained from four sheep breeds (Polled Dorset, White Suffolk, Meat Merino, and Corriedale), finding no differences in the basic composition of the meat. Suliman et al. (2021), in the above-mentioned comparison of Saudi sheep breeds, found no significant differences in the content of dry matter, protein or intramuscular fat between the breeds, and the only significant differences concerned the ash content.

The cholesterol content in samples from Merino sheep was 68 mg/100 g. Authors examining other breeds reported similar values of 63.5 mg/100 g (Polidori et al., 2011) and 74.22 mg/100 g (Kawęcka et al., 2016). It can therefore be concluded that lamb meat is a valuable product, considering that the daily cholesterol intake recommended by the World Health Organization is no more than 300 mg (Belhaji et al., 2021). The collagen content in the tested samples did not differ between breeds and amounted to 0.54%, while Komprda et al. (2012) observed significant between-breed differences in collagen content. Junkuszew et al. (2020) determined collagen in lamb meat at a higher level of 1.31%. Collagen is the main component of intramuscular connective tissue, and its level significantly affects the quality of meat. The more collagen there is in meat, the lower its digestibility, nutritional value, and tenderness. In sheep meat, the collagen content is much lower than in beef meat, which has a positive impact on its consumption value (Janicki and Buzala, 2013).

The fatty acid composition of sheep meat may vary depending on breed, fatness, muscle type and lipid content, but the main influencing factor is diet (Prache et al., 2022). In this study, between-breed differences in fatty acid profiles were observed. The n-6/n-3 PUFA ratio was more favourable in the Coloured Merino, and these differences resulted from a much higher share of n-3 PUFA in the meat of this breed; the situation was similar for other native Polish breeds (Kawęcka and Miksza-Cybul-

ska, 2016). Differences in the content of all PUFA acids, including n-3 acids, in four different breeds were found by Ringdorfer et al. (2015), which resulted in a varied n-6/n-3 ratio. Similar observations were made by Ciliberti et al. (2021) in five local Italian breeds, for which the ratio ranged from 2 to 7.2.

The composition of fatty acids in muscle depends on the lipid composition of the diet, fatty acid synthesis, desaturation and differences in the use of various fatty acids in the animal's body. Many studies have shown that the share of herbs and botanical diversity of pastures improves the health value of lamb meat by increasing the content of acids belonging to the UFA group and reducing the content of SFA (Odhaib et al., 2021). Our study reported a beneficial effect of herbal supplementation on the profile of fatty acids in meat fat. It increased the content of those fatty acids which are beneficial from the point of view of human health, as well as significantly reducing the n-6/n-3 PUFA ratio, although this was not within the recommended range due to intensive feeding of lambs with a complete mixture. The content of the most important n-6 and n-3 PUFAs (arachidonic acid, eicosapentaenoic acid, and docosahexaenoic acid) in lamb meat depends on the amount of their precursors – linoleic acid (LA; n-6) and α -linolenic acid (ALA; n-3) in the feed. Due to the high LA content in cereal grains, lambs fed intensively with concentrates are characterized by higher n-6/n-3 ratios in their meat compared to lambs fattened extensively on pastures (Komprda et al., 2012). Similar conclusions were found by Zhao et al. (2022), observing a reduction in this parameter as a result of the use of herbs in the diet. According to Redoy et al. (2020), the content of saturated fatty acids in lamb meat was lower and unsaturated fatty acids higher in all groups supplemented with herbs, compared to the control group.

Meat is rich not only in fatty acids, but also in amino acids, which are necessary for the growth, development and maintenance of the body's health. They perform many important functions, including taking part in the synthesis of proteins and peptides (Belhaj et al., 2021). The tested Merino meat was characterized by the presence of many valuable amino acids. Between-breed differences in their content could be observed, as the levels of amino acids such as Asp, Glu, Pro, Ala, Tyr and exogenous Thr, Ile, Phe and His were higher in samples from Coloured Merino than in those from Old Type. Exogenous amino acids are particularly important for health because the body cannot synthesize them on its own, and their deficiency may lead to disease disorders. The composition of amino acids also affects the nutritional value of protein and the sensory properties of meat. In research conducted by Sun et al. (2022), regarding Qianhua Mutton Merino and Small-tail Han, it was found that the content of individual amino acids and total amino acids was significantly higher in Merino, which confirms the variability resulting from breed differences. In our studies, we found no effect of diet on the amino acid content in lamb. However, Zhao et al. (2022) investigated the effect

of a diet containing *Allium mongolicum* Regel extract, a typical herb of the *Allium* family, rich in a variety of active ingredients such as flavonoids, essential oils and polysaccharides, on Han breeds. The authors demonstrated that *Allium* can regulate lipid metabolism and support the deposition of free amino acids and unsaturated fatty acids in the *longissimus dorsi* muscle of lambs. It can therefore be used to improve the body health and meat quality of lambs in production.

Conclusions

Analysing the influence of breed and diet on the fattening and slaughter characteristics of lambs, different effects of these factors on the tested parameters were found. Even though both breeds come from one breed group, Merino, many significant differences were noted between them in slaughter performance, fatty acid profile, and amino acid content. Coloured Merino was characterized by better fattening and slaughter parameters, and the meat obtained from these lambs contained more valuable fatty acids and amino acids. The effect of the diet on the level of fat in meat samples was observed. The content of this ingredient was the lowest in the group of lambs that received a higher amount of the herbal supplement. The use of the herbal supplement had a significant impact on the content of fatty acids. In the group receiving a higher addition of the herbal mixture, the highest level of unsaturated fatty acids was observed. The use of the herbal additive also significantly reduced the n-6/n-3 PUFA ratio in the tested meat.

Declaration of competing interest

The authors declare no conflict of interest.

References

- AOAC International (2005). Official Methods of Analysis. 18th Edition, Association of Official Analytical Chemists, Washington DC, Method 935.14 and 992.24.
- Belhaj K., Mansouri F., Melhaoui R., Taaifi Y., Sindic M., Boukharta M., Serghini C.H., Elamrani A. (2021). Trace element content, amino acid composition and fatty acid profiles and of Timadidite's lamb meat, raised in an agro-silvo-pastoral system of the Moroccan middle-Atlas. E3S Web Conf., 240, 01005.
- Ceccobelli S., Landi V., Senczuk G., Mastrangelo S., Sardina M.T., Ben-Jemaa S., Persichilli C., Karsli T., Bălțeanu V.-A., Raschia M.A., Poli M.A., Ciappesoni G., Muchadeyi F.C., Dzomba E.F., Kunene N.W., Lühken G., Deniskova T.E., Dotsev A.V., Zinovieva N.A., Zsolnai A., Anton I., Kusza S., Carolino N., Santos-Silva F., Kawęcka A., Świątek M., Niznikowski R., Špehar M., Anaya G., Granero A., Perloiro T., Cardoso P., Grande S., De Los Santos B.L., Danchin-Burge C., Pasquini M., Martínez Martínez A., Delgado Bermejo J.V., Lasagna E., Ciani E., Sarti F.M., Pilla F. (2023). A comprehensive analysis of the genetic diversity and environmental adaptability in worldwide Merino and Merino-derived sheep breeds. Genet. Sel. Evol., 55: 24.
- Chaves A.V., Stanford K., Gibson L.L., McAllister T.A., Benchaar C. (2008). Effects of carvacrol and cinnamaldehyde on intake, rumen fermentation, growth performance, and carcass characteristics of growing lambs. AFST, 145: 396–408.
- Ciliberti M.G., Santillo A., Marino R., Ciani E., Caroprese M., Rillo L., Matassino D., Sevi A., Albenzio M. (2021). Lamb meat quality and carcass evaluation of five autochthonous sheep breeds: Towards biodiversity protection. Animals, 11: 3222.
- Cloete J.J.E., Hoffman L.C., Cloete S.W.P. (2012). A comparison between slaughter traits and meat quality of various sheep breeds: Wool, dual-purpose and mutton. Meat Sci., 91: 318–324.
- García-Galicia I.A., Arras-Acosta J.A., Huerta-Jimenez M., Rentería-Monterrubio A.L., Loya-Olguin J.L., Carrillo-Lopez L.M., Tirado-Gallegos J.M., Alarcon-Rojas A.D. (2020). Natural oregano essential oil may replace antibiotics in lamb diets: Effects on meat quality. Antibiotics, 9: 248.
- Hutton P.G., Kenyon P.R., Bedi M.K., Kemp P.D., Stafford K.J., West D.M., Morris S.T. (2011). A herb and legume sward mix increased ewe milk production and ewe and lamb live weight gain to weaning compared to a ryegrass dominant sward. Anim. Feed Sci. Technol., 164: 1–7.
- Janicki B., Buzala M. (2013). Effect of collagen on technological quality of meat (in Polish). Żywn. Nauka Technol. Jakość, 2: 19–29.
- Junkuszew A., Milerski M., Bojar W., Szczepaniak K., Le Scouarnec J., Tomczuk K., Dudko P., Studzińska M.B., Demkowska-Kutrzeba M., Bracik K. (2015). Effect of various antiparasitic treatments on lamb growth and mortality. Small Rumin. Res., 123: 306–313.
- Junkuszew A., Nazar P., Milerski M., Margetin M., Brodzki P., Bazewicz K. (2020). Chemical composition and fatty acid content in lamb and adult sheep meat. Arch. Anim. Breed., 63: 261–268.
- Kawęcka A., Miksza-Cybulska A. (2016). Quality of lamb meat obtained from native breed rams (in Polish). Rocz. Nauk. Zoot., 43: 277–283.
- Kawęcka A., Radkowska I. (2023). Comparison of the quality of mountain sheep milk obtained from animals kept on a natural and organic mountain pasture. Ann. Anim. Sci., 23: 275–283.
- Kawęcka A., Sosin E., Sikora J. (2016). Evaluation of carcass and meat quality in native Wrzosówka lambs fed linseed-supplemented diet. Żywn. Nauka Technol. Jakość, 104: 68–78.
- Kawęcka A., Pasternak M., Miksza-Cybulska A., Puchała M. (2022). Native sheep breeds in Poland – importance and outcomes of genetic resources protection programmes. Animals, 12: 1510.
- Komprda T., Kuchlík J., Jarošová A., Dračková E., Zemánek L., Filipčík B. (2012). Meat quality characteristics of lambs of three organically raised breeds. Meat Sci., 91: 499–505.
- Latorre E., Karmelic J., Quinteros C., Reyes S., Vargas M. (2011). Evaluación del valor nutritivo de las carnes de cordero híbridos Polled Dorset, White Suffolk, Meat Merino y raza Corriedale a los 130 y 150 días del nacimiento (in Spanish). Proc. XXXVI Congreso de Sociedad Chilena de Producción Animal (SOCHIPA), Ortega F. (ed.). Instituto de Investigaciones Agropecuarias INIA, INIA Karampangue, Punta Arenas, Chile.
- Navajas E.A., Lambe N.R., Fisher A.V., Nute G.R., Bünger L., Simm G. (2008). Muscularity and eating quality of lambs: Effects of breed, sex and selection of sires using muscularity measurements by computed tomography. Meat Sci., 79: 105–112.
- Niznikowski R., Oprządek A., Świątek M., Czub G., Głowacz K., Ślęzak M. (2014). Slaughter value and meat quality of Polish Merino and Berrichon du Cher ram lambs in intensive housing system. Acta Sci. Pol., Zoot., 13: 41–50.
- Niznikowski R., Rokicki T., Łaba S., Krajewski K. (2017). Strategic situation of the sheep-farming sector in Poland – breeding, market and economic conditions (in Polish). Prz. Hod., 4: 1–6.
- NRIAP (2009). Assessment of the utility of lamb meat according to the requirements and methods used in the European Union countries; NRIAP: Cracow, Poland, 32.
- Odhaib K., Alallawee M., AL-Mousawi Z. (2021). Utilization of herbal remedies to improve ruminant performance: A review. AJVS, 14.
- Orzuna-Orzuna J.F., Dorantes-Iturbide G., Lara-Bueno A., Mendoza-Martínez G.D., Miranda-Romero L.A., López-Ordaz R., Hernández-García P.A. (2021). Productive performance, carcass traits, and meat quality in finishing lambs supplemented with a poly-herbal mixture. Agriculture, 11: 942.
- Polidori P., Ortenzi A., Vincenzetti S., Beghelli D. (2011). Dietary properties of lamb meat and human health. Mediterr. J. Nutr. Metab., 4: 53–56.
- Prache S., Schreurs N., Guillier L. (2022). Review: Factors affecting sheep carcass and meat quality attributes. Animal, 16: 100330.

- Redoy M.R.A., Shuvo A.A.S., Cheng L., Al-Mamun M. (2020). Effect of herbal supplementation on growth, immunity, rumen histology, serum antioxidants and meat quality of sheep. *Animal*, 14: 2433–2441.
- Ringdorfer F., Huber R., Velik M., Finotti E. (2015). Effect of genotype, birth type and sex on lamb carcass and meat quality. *Proc. Tagungsband der 3. Professional Conference Sheep and Goats, Dobrna 2369: TurboLamm*, pp. 121–129.
- Rodríguez R., Suazo C., Balocchi O., Alomar D. (2019). Milk production and quality from ewes grazing a plantain-chicory mixture or a grass-based permanent sward. *Small Rumin. Res.*, 170: 91–96.
- Sheng W., Lang X., Wang C., Liu L., Zhou R., Song S., Wu J. (2019). Effects of oregano essential oil on growth performance, slaughter performance and meat quality of sheep. *Chin. J. Anim. Nutr.*, 31: 2823–2829.
- Sinhadipathige S.C.S., Kenyon P.R., Kemp P.D., Morris S.T., Morel P.C.H. (2012). Can herb-clover mixes increase lamb liveweight gains in spring? *ProNZG*, pp. 137–141.
- Somasiri S., Kenyon P., Kemp P., Morel P., Morris S. (2013). Herb and clover mixes increase average daily gain (ADG) of finishing lambs in different seasons. *Proc. 22nd International Grassland Congress*, Michalk D.L., Millar G.D., Badgery W.B., Broadfoot K.M. (eds). New South Wales Department of Primary Industry, Kite St., Orange New South Wales, Australia, pp. 575–576.
- Suliman G.M., Al-Owaimer A.N., El-Waziry A.M., Hussein E.O.S., Abulfatah K., Swelum A.A. (2021). A comparative study of sheep breeds: fattening performance, carcass characteristics, meat chemical composition and quality attributes. *Front. Vet. Sci.*, 8: 647192.
- Sultan K. (2022). Effect of *Curcuma longa* supplementation in post-weaning lambs ration on performance, carcass and meat quality. *J. Anim. Feed Sci.*, 31: 175–181.
- Sun L., Jiang H. (2022). Research on meat quality of Qianhua Mutton Merino sheep and Small-tail Han sheep. *Open Life Sci.*, 17: 1315–1323.
- Zhao Y., Zhang Y., Bai C., Ao C., Qi S., Cao Q., Erdene K. (2022). Effects of the dietary inclusion of *Allium mongolicum* Regel extract on serum index and meat quality in Small-tailed Han Sheep. *Animals*, 13: 110.

Received: 14 VIII 2024

Accepted: 25 IX 2024