N32.16
* E-mail: izzzdkw@by.onet.pl

LIPID PROFILE OF INTRAMUSCULAR FAT IN FATTENED KIDS DEPENDING ON BREED AND AGE

BRONISŁAW BORYS[1*], JACEK SIKORA[1], ANDRZEJ BORYS[2], STANISŁAW GRZEŚKIEWICZ[2]

[1]National Research Institute of Animal Production, 32-083 Balice/Krakow,
[2]Meat and Fat Research Institute, 4 Jubilerska St., 04-190 Warsaw, Poland

In light of current research findings, goat meat (especially kid meat) is considered to be one of the most valuable kinds of meat in terms of health-promoting qualities. It is low in fat, has a favourable lipid profile (composition of fatty acids and CLA content) and is relatively low in cholesterol. Considering current nutritional preferences, goat meat is considered to have special dietetic value and taste. The use of goats for meat production has attracted growing interest from researchers. This is reflected in both review papers (e.g. BANSKALIEVA et al. 2000, PIENIAK-LENDZION 2002) and results of studies that compared the quality of kid and lamb meat (GRUSZECKI et al. 1999, NIEDZIÓŁKA et al. 2005, SHERIDAN et al. 2003).

The quality of goat meat is significantly affected by both genetic factors (breed, crossbreeding scheme) and environmental factors (age, weight standard, management and fattening method, type of feed). The available literature, especially that in Poland, has relatively few studies concerning the effect of these factors on the quality of kid meat, particularly in terms of its health quality. Therefore, the aim of the present study was to determine the effect of breed and age of kids on the cholesterol content of their muscle tissue, the fatty acid profile of intramuscular fat, and the resultant health quality parameters.

Material and methods

The study was carried out in 2002 and 2003 in two replications using 88 Saanen (S) and Alpine (A) kids (castrated at 14 days of age on average) and F_1 crosses of Anglo-Nubian goat bucks × Saanen goats (AN×S).

Throughout the experiment, kids were kept in 3 breed groups under the same management and feeding conditions. Kids suckled their mothers during the first 20 days of age and were fed after weaning based on milk replacer and Fernando concentrate until 60 days of age. From 60 to 180 days of age, kids were fattened semi-intensively under controlled feeding conditions, in accordance with National Research Institute of Animal Production standards (PRACA ZBIOROWA 2001). The rations contained hay, ensiled hay and Fernando and Dossche 360 concentrates. Experimental slaughter was performed on kids that were randomly selected from the breed groups at 90 (at approx. 20 kg body weight on average) and 180 days of age (at approx. 30 kg body weight on average). The numbers of animals in each group are given in Table 1.

Cholesterol content was determined in the *m. longissimus dorsi* and fatty acid profile was determined in the intramuscular fat extracted from this muscle. Cholesterol content was determined colourimetrically at a wavelength of 570 µm using colour reactions of cholesterol with a 10% acetic acid and $FeCl_3$ solution diluted 100-fold in sulphuric acid. Samples were prepared in accordance with a procedure used at the Main Laboratory of the National Research Institute of Animal Production: a muscle sample was homogenized in a mixture of chloroform and methanol (2/1), evaporated, saponified, extracted with hexane, re-evaporated, and determined colourimetrically. Fatty acid profile was determined using gas chromatography by determining acids in the form of methyl esters. The samples were prepared in accordance with the method of FOLCH et al. (1957), in which they were homogenized in a mixture of chloroform and methanol (2/1) and the solvent was evaporated. The evaporation residue was then saponified (0.5 N NaOH in methanol) and esterified (BF_3 in methanol). The resultant methyl esters of fatty acids were determined in hexane extracts using a VARIAN 3400 gas chromatograph, the CP-WAX 58 (FFAP) acid-modified polyethylene glycol column and an 8200CX autosampler.

To determine the health quality parameters of fatty acid profile, the index of atherosclerosis (IA) and the index of thrombosis (IT) were calculated using the formula of ULBRICHT and SOUTHGATE (1991), as shown in Table 3.

The results were analysed statistically using the least square means (LSM) procedure of the SAS packet (General Linear Model – GLM) in a three-factorial system of breed group, age at slaughter and replication (SAS/STAT 1995). The significance of differences between kid breeds was estimated using Duncan's test. Only first-degree significant interactions were accounted for in the tables and analysis of the results.

Results

Breed of kids. The breeds of goats compared and the crossing of Saanen goats with Anglo-Nubian bucks did not result in significant differences in the cholesterol content of the kids' *m. longissimus dorsi*, with a tendency towards higher cholesterol content (by an average of 7.6%; NS) in Alpine kids in relation to both Saanen and AN×S animals (Table 1).

In terms of the fatty acid profile of intramuscular fat, there were fairly clear and partly significant differences between Alpine kids and Saanen and AN×S animals. The fat of Alpine kids contained significantly more saturated fatty acids (SFA), mainly due to the higher content of stearic acid C18:0 (one of the principal fatty acids – by 14.1% on average) and lauric acid C12:0 (by 55.9%), with a similar content of palmitic acid C16:0 (the second dominant acid in the group of saturated acids), in the kids of all breeds (Table 1).

The intramuscular fat of Alpine kids differed significantly from that of the others also in the total content of unsaturated fatty acids (UFA; lower by 5.6% on average), with a significantly lower content of monounsaturated fatty acids (MUFA; by 9.6%) (Table 2). The lower MUFA content in group A was mostly due to the lowest content of the dominant oleic acid C18:1 in this group (by 9.5% on average, $P \leq 0.05$), while the content of palmitoleic acid C16:1 was significantly higher in AN×S kids compared to purebred S and A kids, by 20.0 and 26.3%, respectively ($P \leq 0.001$).

No statistically significant differences were found in the content of individual and total PUFA according to the breed of the kids. However, the intramuscular fat of purebred kids (A and S) contained an average of 20.4% more PUFA than that of AN×S kids (Table 2), although PUFA content showed high variation (variation coefficients v = 30 to 85%).

Purebred Saanen and Alpine kids (S and A) did not show clear differences in the CLA content of intramuscular fat, while AN×S kids had a significantly higher content of this health-promoting component, by 34.7% on average ($P \leq 0.05$).

Varying results were obtained for health quality parameters based on the fatty acid profile. Generally the most favourable parameters were shown by Saanen kids in terms of intramuscular fat except the least favourable (highest) Ω6:Ω3 PUFA ratio (Table 3). AN×S kids were intermediate. They had the least favourable PUFA:SFA ratio (14.9% lower than in the other breed groups; NS) and the most favourable Ω6:Ω3 PUFA ratio (6.8 and 15.9 lower than in groups A and S; NS). The least favourable health parameters were characteristic of the fat of Alpine kids. It had an unfavourably statistically lower UFA:SFA ratio (by 11.0% on average) and a significantly higher index of thrombosis (by 14.4% on average; $P \leq 0.01$), but favourably the highest PUFA Ω3 content (by 14.1% on average; NS).

Table 1. Cholesterol content of muscle tissue (mg /100 g tissue) and SFA content of intramuscular fat (g/100 g fat)

Trait	Breed [B]			Age at slaughter [A]		Replication [R]		SEM
	S	A	F_1 AN×S	90	180	I	II	
Number	28	31	29	51	37	33	55	
Cholesterol; mg	69.0	74.9	70.2	76.4A	66.3A	66.3A	76.5A	1.701
SFA[1]	42.93A	46.10Aa	43.09a	45.41A	42.61A	42.35A	45.67A	0.557
C 12:0	0.33	0.46	0.26	0.52A	0.18a	0.26	0.44	0.067
C 14:0	2.41	2.76	2.89	3.23A	2.15A	1.84A	3.53A	0.190
C 16:0	21.41	22.33	22.50	22.38	21.78	20.68A	23.49A	0.300
C 18:0	17.62	19.34a	16.29a	18.04	17.47	17.48	18.02	0.430

SFA - Σ: C8:0, C10:0, C12:0, C14:0, C15:0, C16:0, C17:0, C18:0, C20:0, C22:0
AA - P≤0.01; aa - P≤0.05; [1] B×A interaction significant at P≤0.01, SEM - standard error of the mean

Table 2. UFA content of intramuscular fat (g/100g fat)

Trait	Breed [B]			Age at slaughter [A]		Replication [R]		SEM
	S	A	F_1 AN×S	90	180	I	II	
UFA[1]	56.77A	53.46Aa	56.45a	54.14A	56.97A	56.79	54.33	0.534
MUFA[1]	45.18a	41.49Aa	46.65A	40.48A	48.40A	45.14	43.74	0.836
C 16:1	2.00B	1.90A	2.40AB	2.08	2.12	2.30A	1.89A	0.070
C 18:1[1, 2]	42.46b	38.90ab	43.51a	37.63A	45.62A	41.40	41.85	0.778
PUFA	11.59	11.98	9.79	13.66A	8.57A	11.65	10.59	0.563
C 18:2	6.53	6.64	5.44	7.90A	4.51A	6.13	6.27	0.359
C 18:3	0.51	0.53	0.59	0.60A	0.48A	0.48A	0.61A	0.021
C 20:4	2.76	2.97	2.13	3.10a	2.14a	2.56	2.68	0.181
C 20:5	0.27	0.31	0.22	0.34	0.19	0.27	0.26	0.023
C 22:6	0.14	0.17	0.13	0.20A	0.10A	0.15	0.15	0.013
CLA[1]	46.2B	43.9A	60.7AB	56.4a	44.1a	38.2A	62.4A	0.027

MUFA = Σ C14:1, C15:1, C16:1, C17:1, C18:1, C20:1; C22:1;
PUFA = Σ C18:2, SKL, C18:3, C20:2, C20:3, C20:4; C20:5; C22:4, C22:5, C22:6
AA, BB - P≤0.01; aa, bb - P≤0.05; Interactions: [1] - B×A (P≤0.01); [2] - B×R (P≤0.05); SEM - standard error of the mean

Age of kids. The age of kids had a significant differentiating effect on the cholesterol content of muscle tissue, and the muscles of animals slaughtered at 90 days of age contained significantly more cholesterol than those of older animals slaughtered at 180 days of age (by 15.2%; P≤0.01) (Table 1).

The age of kids had a significant effect on the fatty acid profile of intramuscular fat. Compared to 90-day-old kids, SFA content in 180-day-old kids decreased (by 6.2%, P≤0.01) and most differences concerned acids with shorter carbon chains (C12:0 and C14:0 – a decrease by 65.4 and 33.4%, respectively), with a highly similar content of dominant saturated acids C16:0 and C18:0 (Table 1).

Table 3. Health parameters of the fatty acid profile of intramuscular fat

Trait	Breed [B]			Age at slaughter [A]		Replication [R]		SEM
	S	A	F_1 AN×S	90	180	I	II	
UFA:SFA[1,2]	1.362A	1.194Aa	1.320a	1.233a	1.351a	1.373A	1.211A	0.027
PUFA:SFA	0.273	0.263	0.228	0.308A	0.202A	0.279	0.231	0.012
DFA:OFA	3.026	2.777	2.795	2.743	2.989	3.019a	2.713a	0.068
PUFA Ω3	1.28	1.42	1.21	1.58A	1.03A	1.60A	1.01A	0.066
PUFA Ω6:Ω3[2]	8.423	7.598	7.083	7.979	7.424	6.090A	9.313A	0.361
IA	0.435	0.491	0.457	0.496A	0.426A	0.409A	0.513A	0.013
IT[1]	0.751A	0.858AB	0.749B	0.836A	0.736A	0.722A	0.850A	0.019

UFA = MUFA + PUFA; DFA = UFA + C18:0; OFA = SFA - C18:0
PUFA Ω3 = Σ C18:3, C20:5; C22:5, C22:6; PUFA Ω6 = Σ C18:2, C20:2, C20:3, C20:4; C22:4,
IA (index of atherosclerosis) = Σ (12:0, C14:0, C16:0) : UFA
IT (index of thrombosis) = Σ (14:0, C16:0, C18:0) : Σ (MUFA + PUFAΩ3 and Ω6 + PUFAΩ3:Ω6)
AA, BB - P≤0.01; aa - P≤0.05; Interactions: [1]B×A - P≤0.01; [2] B×R - P≤0.05; SEM - standard error of the mean

Total UFA content increased with age (by 5.2%, P≤0.01) as a result of a marked increase in the content of MUFA acids only (Table 2). The MUFA content of 180-day-old kids was 19.6% higher than in 90-day-old kids, mainly thanks to a 21.2% higher content of the dominant oleic acid C18:1 (both differences significant at P≤0.01). A reverse pattern was found for the group of PUFA, where the content of all PUFA in the fat of older kids was lower. Total PUFA content of intramuscular fat was 37.3% lower in 180-day-old than in 90-day-old kids, with respective differences in the content of individual acids ranging from 20.0% for C18:3 to 50.0% for C22:6 (all differences significant at P≤0.01).

The intramuscular fat of kids fattened to 90 days of age contained more CLA, and the difference in relation to 180-day-old animals was 27.9% and was significant at P≤0.05 (Table 2).

The effect of kid age on the analysed health quality parameters of fat was significant but inconsistent (Table 3). Compared to 180-day-old lambs, 90-day-old lambs were characterized by a favourably higher PUFA:SFA ratio and a higher Ω3 PUFA content (by 52.5 and 53.4%, respectively; P≤0.01), an unfavourably wider Ω6:Ω3 PUFA ratio, and higher indices of atherosclerosis (IA) and thrombosis (IT) – by 7.5%, 16.4 and 13.6%, respectively (all differences significant at P≤0.01).

Replication. The year of study had a significant differentiating effect on the cholesterol content of muscle tissue and, to a lesser degree, on the fatty acid profile of intramuscular fat. The muscles of kids from replication II contained more cholesterol than the muscles of kids from the first replication (by 15.4%; P≤0.01). The intramuscular fat of kids from replication II had a generally less favourable fatty acid profile than that of kids from replication I, with large and statistically significant differences confirmed for saturated acids only (by a total of 7.8% more in replication II than in replication I, significant at P≤0.01). No significant differences were found between the replications in the total content of unsaturated acids and the monoand polyunsaturated subgroups (Table 2), with significant (P≤0.01) differences in content of two acids: palmitoleic C16:1 and linolenic C18:3.

It is worth noting the higher CLA content of intramuscular fat from kids in replication II than in replication I, by 63.4% (P≤0.01).

These differences in the composition of fatty acids were reflected in the analysed health quality parameters of intramuscular fat, which were consistently more favourable for lambs in replication I (Table 3). Compared to lambs in replication II, their fat had higher UFA:SFA, PUFA:SFA and DFA:OFA ratios and a higher content of Ω3 PUFA acids, with favourably lower Ω6:Ω3 PUFA ratio and indices of atherosclerosis (IA) and thrombosis (IT).

Discussion

Cholesterol. The cholesterol content of muscle tissue from the analysed kids ranged from 60 to 80 mg/100 g of fresh tissue, which is considered normal for the meat of farm animals (BAROWICZ and JANIK 1998). The values obtained (73.2 mg on average) were higher than those reported by PARK et al. (1991) for the muscles of weaned Alpine and Nubian kids (57.8 mg/100 g tissue on average) and by KALINOWSKA and PUSTKOWIAK (2000) for Polish White Improved and its crosses with Boer and Anglo-Nubian (58.6 mg/100 g tissue on average).

The higher cholesterol content of the muscles in 90-day-old kids than in 180-day-old kids could be due to naturally more intensive cholesterol synthesis in the bodies of youngest animals, resulting from their physiological needs. This is reflected in the studies of other authors with lambs (ARSENOS et al. 2000, BORYS et al. 2003). The lower cholesterol content in the oldest kids could be due to the differences in nutrition, as evidenced by the studies quoted by HANCZAKOWSKI et al. (2000), which indicate that the presence of animal protein in the diet (i.e. mother's milk or powdered milk in milk replacer) increases the cholesterol content of animal tissues.

The lack of effect of the breed components studied and the concurrent significant effect of replication on cholesterol concentration in the muscle tissue of the kids support the view that environmental factors have a greater and more consistent effect than genetic factors on the concentration of cholesterol in animal food products (BORYS and PISULEWSKI 2001).

Fatty acid profile. The present study showed a significant but varying effect of breed or breed components on the composition of fatty acids in the intramuscular fat of fattened kids. Generally, in light of the analysed parameters of health quality, the most favourable fatty acid profile was found in the fat of Saanen kids, followed by Anglo-Nubian × Saanen and Alpine kids. To a certain degree, the unfavourable effect of crossing the Anglo-Nubian breed on the composition of fatty acids in the crossbreds is confirmed by the findings of KALINOWSKA and PUSTKOWIAK (2000). The intramuscular fat of Anglo-Nubian × Polish White Improved goats had a clearly lower proportion of PUFA and a less favourable PUFA:SFA ratio. The available literature contains few studies concerning the effect of breed or crossbreeding scheme on the lipid profile of muscle tissue in kids. Comparison of the relevant data for pure breeds of goats in a review by BANSKALIEVA et al. (2000) shows considerable differences in the lipid profile of intramuscular fat in kids of different breeds. However, these results were obtained under very diverse conditions and using fat extracted from different muscles.

The changes found in the fatty acid profile of the muscles of kids aged 90 and 180 days were probably the cumulative effect of different factors, but above all resulted from natural changes in the function of developing bodies and nutritional differences. The present study showed that the increase in age from 90 to 180 days of age was paralleled by significant changes in the total SFA content, but not in the major saturated acids (C16:0 and C18:0). This is not confirmed by the results obtained by ZYGOYIANNIS et al. (1992, after: BANSKALIEVA et al. 2000), who found that the proportion of stearic acid C18:0 in the depot fat of suckling kids

decreased with the increasing age of kids.
For unsaturated acids, a significant increase in the MUFA content (including the dominant C18:1) and a concurrent decrease in the content of all PUFA acids were found as the kids became older. These results are partly not confirmed by BAS et al. (1987, after BANSKALIEVA et al. 2000), who observed the MUFA content of subcutaneous fat to decrease as the weaned kids grew older.
The unfavourable changes in the health-promoting properties of kid meat with age are shown by a decrease in the Ω3 PUFA and CLA content and by changes in the PUFA:SFA and Ω6:Ω3 PUFA ratios. The lack in the available literature of comparable data concerning the effect of age on the fatty acid profile of intramuscular fat of kids prevents a more complete discussion of the results obtained. However, by analogy to studies performed with other ruminant species, e.g. lambs (BORYS and BORYS 2001, CIURYK and KACZOR 2001), it is generally concluded that from the viewpoint of health quality, unfavourable changes in the profile of acids occur in the meat of kids as they grow older.
The significant effect of replication in terms of several components and parameters analysed is evidence of the significant effect of other factors (mainly environmental factors) that were not controlled in the study conducted.
The statistically significant first degree interactions (mainly breed ×age and breed × replication) show the mutual effect of these factors on the analysed parameters of the lipid profile of muscle tissue in kids.

Summary

Breed of kids had no effect on cholesterol concentration in the muscle tissue, and the statistically significant differences according to age and replication resulted from the natural physiological differences due to the age of kids and from the variation of environmental factors.
Overall, the most favourable profile of fatty acids in terms of health quality was found in the fat of Saanen kids, followed by the fat of Anglo-Nubian × Saanen (by far the highest CLA content) and Alpine kids.
The fatty acid profile of intramuscular fat in kids changed unfavourably between 90 and 180 days of age, mainly because of the increased MUFA content and the decreased PUFA (including Ω3 PUFA) and CLA content.

In general, from the viewpoint of health-promoting qualities, the meat of kids slaughtered in the lower weight and age standard (90 days) was characterized by a more favourable lipid profile, whereas the effect of breed was fairly evident but largely inconsistent.

References

ARSENOS G., ZYGOYJANNIS D., KUFIDIS D., KATSAOUNIS N., STAMATARIS C. (2000) The effect of breed, slaughter weight and nutritional management on cholesterol content of lamb carcasses. Small Ruminant Research 36, 275-283.

BANSKALIEVA V., SAHLU T., GOETSCH A.L. (2000) Fatty acid composition of goat muscles and fat depots: a review. Small Ruminant Research 37, 255-268.

BAROWICZ T., JANIK A. (1998) Cholesterol w mięsie zwierząt rzeźnych. Przegląd Hodowlany 4, 6-8.

BORYS B., BORYS A. (2001) Wartość rzeźna i jakość mięsa jagniąt lekkich typu mlecznego i tuczonych do masy ciała 35-45 kg. Roczniki Naukowe Zootechniki, Supl., 11, 115-124.

BORYS B., JARZYNOWSKA A., BORYS A. (2003) Jakość zdrowotna mięsa lekkich jagniąt rzeźnych w zależności od wieku i genotypu. Zeszyty Naukowe Przeglądu Hodowlanego 68 (3), 63-71.

BORYS B., PISULEWSKI P.M. (2001) Jakość oraz możliwości kształtowania prozdrowotnych właściwości spożywczych produktów owczarskich. Roczniki Naukowe Zootechniki, Supl., 11, 67-86.

CIURYK S., KACZOR U. (2001) Wpływ standardu wagowego na wybrane parametry użytkowości mięsnej tryczków mieszańców po maciorkach polskiej owcy długowełnistej i trykach rasy Charo-

lais. Roczniki Naukowe Zootechniki, Supl., 11, 125-132.
FOLCH J., LEES M., STANLEY G.H.S. (1957). A simple method for the isolation and purification of total lipids from animal tissues. Journal of Biological Chemistry, 226: 247-262.
GRUSZECKI T., LIPECKA CZ., SZYMANOWSKA A., WIERCIŃSKI J., JANKUSZEW A. (1999) Skład kwasów tłuszczowych w wewnątrzmięśniowym tłuszczu owiec i kóz. Zeszyty Naukowe Przeglądu Hodowlanego 43, 87-94.
HANCZAKOWSKI P., SZYMCZYK B., SZCZUREK W. (2000) Wpływ podstawowych składników pokarmowych pasz na poziom cholesterolu w tkankach zwierząt. Przegląd Hodowlany 9, 21-23.
KALINOWSKA B., PUSTKOWIAK H. (2000) Zawartość kwasów tłuszczowych i cholesterolu w mięsie i podrobach koźląt tuczonych do masy ciała 16 kg. Zeszyty Naukowe AR Wrocław, 399, 165-168.
NIEDZIÓŁKA R., PIENIAK-LENDZION K., HOROSZEWICZ E. (2005) Comparison of the chemical composition and fatty acids of the intramuscular fat of goat kid and ram lambs meat. Electronic Journal of Polish Agricultural Universities, Animal Husbandry 8, 3, http://www.ejpau.media.pl/volume8/issue3/art-11.html
PARK Y.V., KOUASSI M.A., CHIN K.B. (1991) Moisture, total fat and cholesterol in goat organ and muscle meat. Journal of Food Science, 56, 1191-1193.
PIENIAK-LENDZION K. (2002) Owce i kozy źródłem żywności funkcjonalnej. Przegląd Hodowlany 7, 6-10.
PRACA ZBIOROWA (2001) Normy żywienia bydła, owiec i kóz. Opracowane według INRA (1988). Redakcja: Rajmund Ryś., Instytut Zootechniki Kraków, Wydanie II.
SAS/STAT (1995) User's guide.
SHERIDAN R., HOFFMAN L.C., FERREIRA A.V. (2003) Meat quality of Boer goat kids and Mutton Merino lambs. Commercial yields and chemical composition. Animal Science 76, 63-71.
ULBRICHT T.L., SOUTHGATE D.A. (1991) Coronary hart disease: seven dietary factors. Lancet 338, 985-992.