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Fatty acid content in meat, heart, and liver of conventionally bred Polish Merino lambs

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Summary

The objective of our research was to establish differences in fatty acid profiles of fat in the muscle tissue and selected edible organs (liver, heart) of conventionally bred Polish Merino lambs. The importance of this research stems from the fact that the sheep products under analysis are considered to be functional food. Our research material consisted of 20 Polish Merino lambs from a conventional herd. Ram lambs were slaughtered at the age of 100 days (at weaning), when they weighed 26-28 kg. The fatty acid content was determined in the longissimus dorsi muscle, leg, liver and heart, by the Röse-Gottlieb method, according to AOAC 905.02, with a Hewlett-Packard 6890 gas chromatograph. Analysing the fatty acid profiles of lamb muscles and offal, we found that the general content of saturated fatty acids (SFA) was the lowest in the heart (48.36%), significantly higher in the liver (58.37%), longissimus dorsi muscle (57.25%), and adductor femoris (56.17%). Unsaturated fatty acids (UFAs) constituted 51.64% of total acids in the heart, where their content was higher than in the liver, in the sirloin and in the leg by 10.01 percentage points (pp) 7.89 pp and 7.81 pp respectively. The differences were confirmed statistically. An increased percentage of unsaturated acids contributed to better ratios of UFA/SFA and PUFA/SFA, which amounted, respectively, to 1.07 and 0.43 for the heart, and to less than 1.00 and 0.30 for the other tissues, testifying to a high nutritional value of the heart. A comparative analysis of the results has shown that, from the nutritional point of view, the most favourable fatty acid composition – that is, the lowest content of saturated fatty acids and the highest of unsaturated fatty acids – as well as a favourable UFA/SFA ratio, was found in the heart, followed by muscles and the liver. We can conclude that meat and offal from conventionally bred lambs, fed on the mother's milk and the farmer's own crops, without genetic modifications qualify as wholesome products with high nutritional and health value.

Keywords: lambs, meat, offal, fatty acids

Lamb meat comes from young animals, slaughtered before the 6th month of their lives. Particularly sought-after lamb meat is that of light animals, in weight groups of 13-16 kg and 17-22 kg, slaughtered in the 50-100th day of their lives. Such meat contains proteins of high biological value, but has a low caloric value. Owing to its taste and nutritional qualities, sheep meat should be more appreciated and eaten more often (10, 20). The wholesomeness of sheep meat results not only from its fat content, but also from the quality of the fat, that is, the fatty acid composition, which determines the taste and smell of meat. The fatty acid content in the meat of ruminants depends chiefly on their species, age, fatty tissue location, and feeding (1-3, 6, 8, 9, 14, 18). Many authors have been able to modify the fatty acid profile of fat in slaughter animals by using food additives in the form of vegetable and fish oil (5, 7, 12, 15, 16, 19, 22-24). During slaughter and post-slaughter processing, entrails are removed from the animal's carcass, undergo a veterinary inspection, and are then sorted based on their suitability for eating and processing. Pursuant to the act of 27th June 1997 on offal (Journal of Laws no. 96, item 592), edible offal includes blood, tongue, heart, liver, lungs, kidneys, spleen, and stomach. Each meat/food processing plant must utilise offal that it produces. The utilisation of offal appears to be an important problem, since it is not only slaughter lambs, but also carcasses, that can be exported. Slaughter by-products, and the internal organs of sheep (liver, heart, kidneys) in particular, are rarely used as food. Considering the high nutritional value of such offal, its possible use as food merits further investigation (17).

The objective of our research was to establish differences in the fatty acid profiles of the muscle tissue and selected edible organs (liver, heart) of conventionally bred Polish Merino lambs. The importance of this research stems from the fact that the sheep products under analysis are considered to be functional food. In addition to being nutritious and wholesome, food products described as functional (good for one's health) should also reduce the risk of illness in the consumer. Such products provide a new opportunity for the Polish sheep industry.

Material and methods

Our research material consisted of 20 Polish Merino lambs (ram lambs) from a conventional herd bred in the Kujawsko-Pomorskie province. The lambs were fed on their mothers' milk for 100 days (classic system), and, in the second week after birth, received hay and crushed oats. In the 2nd month, oats were replaced with concentrate (CJ), and carrots were introduced. Lambs had unlimited access to feedstuff.

Ram lambs were slaughtered at the age of 100 days (at weaning), when they weighed 26-28 kg. The fatty acid content was determined in the longissimus dorsi muscle, semimembranosus muscle, liver and heart, by the Röse-Gottlieb method, according to A.O.A.C no. 905.02, with a Hewlett-Packard 6890 gas chromatograph.

We processed the obtained figures statistically, calculating the mean value ($\overline{x}$) and the standard error of the mean (SEM), based on a single-factor analysis of variance (analysed material). The significance of differences in the fatty acid content between particular organs was estimated with the Duncan test.

Results and discussion

Table 1 shows percentage data concerning the fatty acid content in the lipid fraction of the longissimus dorsi muscle, semimembranosus muscle, liver and heart. From the dietary perspective, it is particularly worth noting that palmitic acid (C16:0) and stearic acid (C18:0) have a higher percentage content in muscles, by approximately 24% and 20% respectively, and in the liver, by over 19% and 27%, compared to the other saturated acids (myristic acid and margaric acid). Diaz et al. (11), in their research on the content of fatty acids in the longissimus dorsi muscle of lambs from Spain, Great Britain, Germany and Uruguay, also established that the most abundant among saturated acids were palmitic acid, at 22.58% to 24.66% of total acids, and stearic acid, at 12.56% to 19.78%, depending on the lamb breed. These values are lower than those obtained in our research. A high content of palmitic and stearic acids, as reported by Bodkowski et al. (4), is most probably the reason why sheep fat has such a distinctive smell. Similarly, research by Borowiec and Augustyn (5) as well as by Gabryszuk et al. (13), showed a lowered content of C14:0 and C15:0 acids, and an increased content of C18:0 in the sirloin and liver. Piwczyński et al. (21) examined the relationship between the quality of meat from milk lambs and their growth rate, and found significant differences in the content of particular saturated acids: the interstitial fat of lambs with a higher growth rate contained more of C14:0, C16:0, and C17:0, whereas the fat of lambs with a lower growth rate was richer in C18:0.

As regards unsaturated fatty acids, which play a particularly important role in the human body, we found clear differences in the content of oleic acid (C18:1), which was the highest in the semimembranosus muscle (over 29%), then in the longissimus dorsi muscle (over 28% of total acids), followed by the heart (over 24%) and the liver (over 22%). In research conducted by Borys and Borys (8, 9) on the effect of the sheep breed on selected health quality parameters of lamb meat, the content of C16:1 and C17:1 in the interstitial fat of the adductor femoris was close to the one established in our research. The content of C18:1, however, was considerably higher, ranging from 36.53% to 43.81%, depending on the lamb breed. Similarly, in research by Diaz et al. (11), the content of C18:1 ranged between 39.05% and 40.51% (depending on the breed), and was higher than in the longissimus dorsi muscle of the lambs examined in our research.

In terms of nutrition, the most important role is played by polyunsaturated acids (PUFA), which cannot be produced either in the human or in the animal body. Among others, they include linoleic acid (C18:2 n-6) and α-linolenic acid (18:3 n-3), which can be transformed within families. The

Tab. 1. Content of fatty acids in muscles and organs of lamb (n = 20; $\overline{x}$ ± SEM)

Fatty acids (%)	Muscles				Organs			
	longissimus dorsi		semimembranosus		heart		liver	
$C_{14:0}$	4.69^{a}	0.63	4.80^{a}	0.67	2.47^{b}	0.48	2.13^{b}	0.79
$C_{15:0}$	0.63	0.05	0.64	0.05	0.42	0.04	0.69	0.11
$C_{16:0}$	25.57^{a}	0.69	25.04^{a}	0.79	20.68^{b}	1.07	21.24^{b}	0.79
$C_{17:0}$	1.55^{a}	0.10	1.51^{a}	0.12	1.35^{b}	0.07	2.55^{c}	0.25
$C_{18:0}$	24.04^{a}	2.92	23.37^{a}	2.34	23.46^{a}	1.37	29.74^{b}	1.81
$C_{15:1}$	0.25	0.02	0.22	0.02	0.35	0.01	0.27	0.04
$C_{16:1}$	2.29^{a}	0.14	2.57^{a}	0.13	3.03^{b}	0.09	2.43^{a}	0.35
$C_{17:1}$	0.91^{a}	0.06	1.07^{b}	0.07	1.56^{b}	0.03	0.84^{a}	0.10
$C_{18:1}$	28.32^{a}	2.01	29.54^{a}	1.50	26.31^{b}	0.53	22.8^{c}	1.22
$C_{18:2n6}$	6.34^{a}	0.67	6.52^{a}	0.57	13.34^{b}	1.68	7.44^{c}	0.51
$C_{20:2}$	0.42	0.08	0.36	0.07	0.30	0.07	0.60	0.08
$C_{18:3n6}$	0.48	0.04	0.48	0.04	0.69	0.05	0.54	0.03
$C_{18:3n3}$	0.22	0.06	0.25	0.02	0.19	0.03	0.20	0.02
$C_{20:4n6}$	3.36^{a}	0.08	2.63^{a}	0.17	7.04^{b}	0.58	5.65^{c}	0.55

Explanations: means in rows with different superscript letters (a, b, c) differ significantly at ($p \leq 0.05$)

n-6 family is more active biologically. Arachidonic acid (C20:4 n-6) is one of the metabolites of linoleic acid, and has many important regulating functions in the body. Is a precursor of tissue hormones it such as prostaglandins, throboxanes or leukotrienes. One has to keep in mind that these eicosanoids, even in small amounts, have a high biological activity, and therefore eating too much acids of the n-6 family is unhealthy, since it may cause thrombotic lesions (20, 25).

As shown in Table 1, concerning polyunsaturated fatty acids, the concentrations of linoleic acid (C18:2) and arachidonic acid (C20:4 n-6) in the heart were significantly higher than in the liver – by 5.9 percentage points (pp) and 1.39 pp, respectively, in the longissimus dorsi muscle – by 7.00 pp and 3.68 pp, and in the leg – by 6.82 pp and 4.4 pp.

The results shown in Table 1 indicate that muscles (sirloin, leg) had a similar fatty acid content, which is evidenced by the lack of significant differences between the longissimus dorsi muscle and the semimembranosus muscle in terms of percentage contents of acids. Compared with the liver, the heart contained significantly higher amounts of C16:1 (by 0.6 pp), C17:1 (by 0.72 pp), C18:1 (by 3.51 pp), and C18:2 (by 5.9 pp); and lower amounts of C18:0 (by 6.28 pp), C17:0 (by 1.2 pp), and C20:2 (by 0.30 pp). Muscles significantly differed from offal in terms of their fatty acid content. Fat in muscles (longissimus dorsi and semimembranosus) was richer in most of the fatty acids, except for stearic acid, which was more abundant in the liver, as well as C17:1 and C18:2, whose amounts were greater in the heart.

Analysing fatty acid profiles of lamb muscles and offal, we found that the general content of saturated fatty acids (SFA) was the lowest in the heart (48.36%), and significantly higher in the liver (58.37%), in the sirloin (57.25%), and in the leg (56.17%). The unsaturated fatty acid (UFA) content in the heart constituted 51.64% of total acids, and was higher than the UFA concentrations in the liver, in the sirloin, and in the leg by 10.01 pp, 8.89 pp, and 7.81 pp, respectively. These differences were confirmed statistically. A similar pattern was observed by Kaczor et al. (17), who compared the fatty acid profiles of the longissimus dorsi muscle, liver, and heart. The muscle contained significantly more SFAs (by approx 1%) than the liver of lambs, whereas the heart had the lowest percentage of these acids. As established by Markiewicz and Gruszecki (18), SFAs in the longissimus dorsi muscle of cross-bred ram lambs were at 44.25% to 54.48%, depending on the housing system, and UFAs at 45.52% to 55.75%.

However, in research by Diaz et al. (11), the content of SFAs in the longissimus dorsi muscle was smaller than it was in our study, ranging from 41.44% (for Spanish lambs) to 48.23% (for German lambs). A higher percentage of unsaturated fatty acids has a positive effect on the health quality and taste of lamb meat (20).

As shown in Table 2, among the tissues analysed in the present study, the heart had the highest content of PUFAs (20.56% of all acids), whereas their lowest content was found in muscles (10.82% and 10.24%). With MUFAs constituting more than 31% of total acids, the longissimus dorsi muscle, semimembranosus muscle, and heart were richer in, these acids than the liver, in which they amounted to approximately 27% of total acids. Similar results concerning MUFA and PUFA concentrations in the longissimus dorsi muscle were obtained by other authors (8, 9, 11, 18). The PUFA levels presented by Kaczor et al. (17), that is, 27.16% for the heart, 18.56% for the liver, and 6.28% for the sirloin, differ slightly from our results. Gabryszuk et el. (13) found that the percentage of MUFAs in lamb sirloin was higher than in the liver, which is consistent with our findings.

The tendency for the accumulation of larger amounts of PUFAs in offal than in muscle tissue, observed in our research (Table 2), was confirmed by Borowiec and Augustyn (5).

Clear differences between the fatty acid profiles of interstitial fat, the liver, and the heart, is another of our findings confirmed by results obtained by other authors regardless of genetic and environmental factors (5, 13, 15, 17).

An increased percentage of unsaturated acids contributed to better ratios of UFA/SFA, MUFA/SFA, and PUFA/SFA, which were, respectively, 1.07, 0.64, and 0.43 for the heart and below 0.80, 0.60, and 0.30 for the other tissues (Table 2).

Significantly higher UFA/SFA ratios in lamb muscles with both lower and higher growth rates – 1.68 and 1.55, respectively – were obtained by Piwczyński et al. (21). According to the literature, the UFA/SFA ratio in human diet should be close to 2, and, apart from the content of fatty acids of various saturation, it

Tab. 2. Profiles of fatty acids in muscles and organs of lambs (n = 20; $\bar{x}$ ± SEM)

Fatty acids (%)	Muscles				Organs			
	longissimus dorsi		semimembranosus		heart		liver	
SFA	57.25[a]	2.41	56.17[a]	1.88	48.36[b]	1.91	58.37[a]	1.32
MUFA	31.93[a]	2.10	33.59[a]	1.57	31.08[a]	0.59	26.59[b]	1.50
PUFA	10.82[a]	0.66	10.24[a]	0.77	20.56[b]	2.29	15.04[c]	0.95
UFA	42.75[a]	2.41	43.83[a]	1.88	51.64[b]	1.91	41.63[a]	1.32
UFA/SFA	0.75[a]	0.08	0.78[a]	0.06	1.07[b]	0.10	0.72[a]	0.04
MUFA/SFA	0.56	0.07	0.60	0.05	0.64	0.02	0.46	0.03
PUFA/SFA	0.19[a]	0.02	0.18[a]	0.02	0.43[b]	0.08	0.26[a]	0.02
PUFA/MUFA	0.34[a]	0.05	0.30[a]	0.05	0.66[b]	0.08	0.57[b]	0.03

Explanations: as in Tab. 1.

is a very significant indicator of meat quality (4, 20, 25).

Tański and Brzostowski (25), analysing the fatty acid profiles of the interstitial fat of Pomeranian and Ile de France sheep, also observed that the amount of unsaturated fatty acids (UFA) was greater than that of saturated fatty acids (SFA), which results in a favourable UFA/SFA ratio (1.01 for the Pomeranian sheep and 1.00 for Ile de France sheep). The MUFA and PUFA concentrations in the lamb leg reported by Borys and Borys (8) are higher by 12.09 pp and by 3.64 pp, respectively, than the values found in our research.

A comparative analysis of the results shows that, from the nutritional point of view, the most favourable fatty acid composition – that is, the lowest content of saturated fatty acids and the highest of unsaturated fatty acids – as well as a favourable UFA/SFA ratio, was found in the heart, followed by muscles and the liver.

We can conclude that meat and offal from conventionally bred animals, fed on the mother's milk and the farmer's own crops, without genetic modifications qualify as wholesome products and can be considered as functional food.

References

1. *Arsenos G., Kufidis D., Zygoyiannis D., Katsaounis N., Stamataris C.*: Fatty composition of lambs of indigenous dairy Greek breeds of sheep as affected by post-weaning nutritional management and weight at slaughter. Meat. Sci. 2006, 73, 55-65.
2. *Atti N., Mahouachi M.*: Effect of feeding system and nitrogen source on lamb growth, meat characteristics and fatty acid composition. Meat. Sci. 2009, 81, 344-348.
3. *Baranowski A., Gabryszuk M., Jóźwiak, Bernatowicz E., Chyliński W.*: Fattening performance, slaughter indicators and meat chemical composition in lambs fed the diet supplemented with linseed and mineral bioplex. Anim. Sci. Pap. and Rep. 2007, 25, 35-44.
4. *Bodkowski R., Patkowska-Sokoła B., Popiołek R., Jabłońska J.*: Skład kwasów tłuszczowych w tłuszczu podskórnym, śródmięśniowym, okołonerkowym i wewnątrzmięśniowym u tryczków rasy merinos polski. Zesz. Nauk. Prz. Hod. 1999, 43, 27-33.
5. *Borowiec F., Augustyn R.*: Effect of dietary unsaturated fatty acids on some indicators in blood plasma and fatty acid content in selected tissues of fattening lambs. Journal Central European Agriculture 2009, 10 (1), 13-18.
6. *Borys B., Bernacka H., Niedbalska M., Szewczyk M.*: Charakterystyka wybranych parametrów otłuszczenia tusz i mięśni jagniąt oraz ich współzależności z zawartością cholesterolu w mięsie. Rocz. Inst. Przem. Mięsn. i Tłuszcz. 2006, 44, 43-57.
7. *Borys B., Borys A.*: Effect of the form of rapeseed and linseed in lamb diets on some health quality parameters of meat. Ann. Anim. Sci. 2005, 5, 159-169.
8. *Borys B., Borys A.*: Wpływ rasy owiec na wybrane parametry jakości zdrowotnej mięsa jagnięcego. Zesz. Nauk. Przegl. Hod. 2002, 63, 69-79.
9. *Borys B., Borys A.*: Zawartość składników prozdrowotnych w tłuszczach zapasowych i śródmięśniowym tuczonych jagniąt w zależności od genotypu i płci. Rocz. Nauk. Zoot. 2001, 11, 101-113.
10. *Brzostowski H., Kłobukowski J., Tański Z., Wiśniewska-Pantak D., Ciborska J., Sowińska J.*: Wybrane wskaźniki wartości odżywczej białka i jakości mięsa jagniąt owcy pomorskiej i jej mieszańców po trykach ras mięsnych. Zesz. Nauk. Przegl. Hod. 2002, 63, 61-67.
11. *Díaz M. T., Alvarez I., De La Fuente J., Sańudo Campo M. M., Oliver M. A., Font Furnols M., Montossi F., San Julińn, Nute G. R., Cańeque V.*: Fatty acid composition of meat from typical lamb production systems of Spain, United Kingdom, Germany and Uruguay. Meat Sci. 2005, 71, 256-348.
12. *Díaz M. T., Velasco S., Cańeque V., Lauzurica S., Ruiz De Huidobro F., Perez C.*: Use of concentrate or pasture for fattening lambs and its effect on carcass and meat quality. Small Rum. Res. 2002, 43, 257-268.
13. *Gabryszuk M., Czauderna M., Baranowski A., Strzałkowska N., Jóźwik A., Krzyżewski J.*: The effect of diet supplementation with Se, Zn and vitamin E on cholesterol, CLA and fatty acid contents of meat and liver of lambs. Anim. Sci. Pap. Rep. 2007, 25, 25-33.
14. *Gruszecki T., Klewiec J., Lipiec A., Lipiec CZ., Junkuszew A., Baranowski A.*: Skład frakcji lipidowej w mięśniach jagniąt tuczonych w zależności od systemu żywienia. Rocz. Nauk. Zoot. Suppl. 2001, 11, 133-138.
15. *Ivan M., Mir P. S., Koening K. M., Rode L. M., Neill L., Entz T., Mir Z.*: Effects of dietary sunflower seed oil on rumen protozoa population and tissue concentration of conjugated linoleic acid in sheep. Small Rum. Res. 2001, 41, 215-227.
16. *Jeromino E., Alves S. P., Prates J. A. M., Santos-Silva J., Bessa R. J. B.*: Effect of dietary replacement of sunflower oil with linseed oil on intramuscular fatty acids of lamb meat. Meat Sci. 2009, 83, 499-505.
17. *Kaczor U., Ciuryk S., Pustkowiak H.*: Zawartość kwasów tłuszczowych i cholesterolu w mięśniach, sercu i wątrobie jagniąt polskiej owcy długowełnistej. Zesz. Nauk. AR Wrocław 2000, 399, 160-164.
18. *Markiewicz J., Gruszecki T. M.*: Evaluation of muscle tissue at lambs fattening indoor and on pasture. Ann. Univ. Mariae Curie-Skłodowska Lublin, Sectio E 2004, 59, 173-179.
19. *Migdał W., Pieszka M., Barowicz T., Janik A., Wojtysiak D., Pustkowiak H., Nowak J., Kozioł J.*: Modyfikowanie profilu kwasów tłuszczowych mięsa zwierząt rzeźnych – za i przeciw. Rocz. Inst. Przem. Mięsn. 2008, 46, 111-122.
20. *Milewski S.*: Mięso i mleko owcze. Weterynaria w terenie 2008, 3, 51-53.
21. *Piwczyński D., Borys B., Mroczkowski S., Jarzynowska A.*: Wstępna charakterystyka cech rzeźnych i jakości mięsa jagniąt mlecznych w zależności od ich tempa wzrostu. Rocz. Nauk. Zoot. Suppl. 2001, 11, 171-180.
22. *Ponnampalam E. N., Sinclair A. J., Egan A. R., Ferrier G. R., Leury B. J.*: Dietary manipulation of muscle long-chain omega-3 and omega-6 fatty acids and sensory properties of lamb meat. Meat Sci. 2002, 60, 125-132.
23. *Radzik-Rant A., Rant W.*: Wpływ oleju lnianego stosowanego w diecie maciorek karmiących na profil kwasów tłuszczowych tkanki zapasowej. Ann. Univ. Mariae Curie-Skłodowska Lublin EE 2007, 25, 21-27.
24. *Simopoulos A. P.*: Essential fatty acids in health and chronic disease. Am. J. Clin. Nutr. 1999, Suppl., 70, 560-569.
25. *Tański Z., Brzostowski H.*: The quality of meat obtained from Pomeranian sheep, Ile de France sheep and their crossbreds periodically stored in freezing conditions. Pol. J. Food Nutr. Sci. Vol. 1051. 2000, 3, 165-168.

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