

MANAGEMENT OF LAMB NUTRITION AS A WAY FOR MODELING FATTY ACID PROFILES IN MEAT

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Abstract: In addition to nutritional value, a very important criterion for the selection of meat, for the modern consumer is the health aspect, i.e. the content of fat and the profile of fatty acids in meat. The content of fat and fatty acids, among other things, is conditioned by the feeding system and the rearing method. Lambs fed on pasture have a lower share of fat in the carcass than animals fed with a concentrated mixture, in a closed system. The recommended value for the ratio of polyunsaturated to saturated fatty acids is up to 0.45, and below 4.0 for the n-6 and n-3 fatty acids ratio. Taking into account that the influence of lamb nutrition on these relationships is significant, modelling of fatty acid composition should be directed to the lamb nutrition system which leads to a decrease in the content of saturated and an increase in the concentration of polyunsaturated (PUFA) fatty acids in meat. A feeding strategy involving a grazing feeding system of lambs results in a higher content of n-3 PUFA, CLA and a more favourable n-6/n-3 ratio of fatty acids, while the lamb meat originating from animals fed concentrated diets has a higher proportion of n-6 PUFA and a higher n-6 ratio/n-3 fatty acids, which exceeds the recommended value of 4.0. Conjugated linoleic acid (CLA) is of great importance since it has an anticancer, antidiabetic effect as well as an effect on the immune system, suggesting a direction for future research on lamb meat.

Keywords: lambs, fatty acids, grazing, CLA

Introduction

Meat, by its nutritional characteristics, primarily in terms of protein, fat, minerals and vitamin content, has a significant place in the human diet of modern times (Ramos *et al.*, 2020; Higgs, 2000; Celada *et al.*, 2015). Demographic growth, urbanization and rising purchasing power are increasing the demand for meat. On

the other hand, the popular perception of fats contained in meat indicates the risk of a range of health problems such as heart disease, stroke, diabetes and some types of tumors (Klir *et al.*, 2012). Consequently, food has lost its former primary role in providing nutrients for life, and has taken on many other roles, primarily related to human health status (Kaić *et al.*, 2013). As a result, consumer interests are increasingly driven by the knowledge of the quantity and quality of fats and fatty acids in certain types of meat (Saatchi *et al.*, 2013; Yarali *et al.*, 2014). It should be taken into account that the fat and individual fatty acids content in lamb meat depends on: genotype, animal age, gender, diet, rearing method and anatomical position of the muscle (Borys *et al.*, 2012; Ružić-Muslić *et al.*, 2014, Juárez *et al.*, Ružić, 1999; Ružić-Muslić *et al.*, 2013). Numerous studies have confirmed that fatty acid composition in ruminants is significantly influenced by the diet (Demirel *et al.*, 2006; Díaz *et al.*, 2005).

The aim of this paper is to examine the influence of nutrition management on the fatty acid profile of lamb meat.

The effect of nutrition management on the fatty acid profile of lamb meat

Lamb nutrition, as well as the way they are reared/housed, affects the fat content of the carcasses. (Ružić-Muslić *et al.*, 2007; Ružić-Muslić 2011). Fatty tissue is localized in the body cavities (renal, abdominal and pelvic fat), subcutaneous fat, fat between the muscles (intermuscular fat) as well as within the muscle, i.e. intramuscular fat. More than 90% of the animal body fat is triglycerides, while the remainder is mainly phospholipids and cholesterol (Grebens, 2004). Mioč *et al.* (2007) state that fat in sheep meat is in the form of triglycerides, phospholipids, stearides and sterin. Lambs fed on pasture have a lower share of fat in the carcass ($P < 0.001$) than lambs fed concentrated food indoors (Carrasco *et al.*, 2009; Cividini *et al.*, 2014; Perlo *et al.*, 2008), which is certainly a consequence of the increased physical activity of grazing lambs and the use of energy for movement (Ružić-Muslić *et al.*, 2012). Meat of lambs fed with concentrated nutrients or grazing and concentrated mixture, contains more fat tissue ($P < 0.001$), than meat of lambs fed exclusively with roughage (Perlo *et al.*, 2008).

The qualitative properties of lamb meat, in addition to the amount of fat, are determined by the content and profile of fatty acids, which, in addition to being important energy source, play a significant role in the immune status of the organism (Yaqoob and Calder, 2007). Fatty acids can be: saturated (do not contain a double bond in the chemical structure) and unsaturated (contain at least one double bond). Microorganisms in rumen of ruminants hydrogenate unsaturated fatty acids into saturated fatty acids (Klir *et al.*, 2012) The interest in fatty acid

composition mainly originates from the need to find ways to produce healthier meats, i.e. better ratio of polyunsaturated (PUFA) to saturated fatty acids, and balance between n-6 and n-3 PUFA (Wood *et al.*, 2003). In recent years, there has been an increasing interest in the ways of manipulating the fatty acid composition of meat. This is because meat is considered to be the main source of fat in the human diet, and in particular of saturated fatty acids, which have a detrimental effect on human health.

Table 1 shows the fatty acid composition of beef, veal, lamb and pork.

Table 1. Fatty acid profile of beef, veal, lamb and pork meats, expressed in g*10⁻² g edible portion (Williams, 2007)

Fatty acids	Beef	Veal	Lamb	Pork
C14:0	0.096	0.034	0.101	0.010
C15:0	0.012	0.006	0.016	0.000
C16:0	0.607	0.215	0.842	0.250
C17:0	0.028	0.009	0.051	0.000
C18:0	0.356	0.119	0.644	0.130
Total	1.149	0.409	1.730	0.400
C14:1	0.025	0.007	0.004	0.000
C16:1	0.082	0.033	0.066	0.030
C18:1	1.103	0.356	1.995	0.390
C20:1	0.015	0.048	0.010	0.010
Total	1.205	0.399	2.066	0.430
C18:2n-6	0.204	0.090	0.321	0.120
C18:3n-3	0.048	0.022	0.072	0.010
C20:3n-6	0.020	0.012	0.009	0.003
C20:4n-6	0.076	0.056	0.094	0.019
C20:4n-3	0.031	0.028	0.028	0.000
C20:5n-3	0.051	0.033	0.044	0.006
C20:6n-3	0.006	0.003	0.013	0.004
Total	0.448	0.259	0.603	0.200

It is evident that lamb meat with a total content of monounsaturated and polyunsaturated fatty acids (2.066 g) contains significantly more favourable fatty acids compared to unfavourable saturated fatty acids (1.730 g). Cvrtila *et al.* (2007) state that monounsaturated and polyunsaturated the fatty acids in lamb meat together account for about 70%, while the remaining 30% are saturated fatty acids. Ruminant meat is known to have a lower and less favourable ratio of unsaturated and saturated fatty acids (UFA/SFA) to non-ruminant meat. However, the ratio of n-6 and n-3 is low and is more favourable to human health than non-ruminant meat

(Klir et al., 2012). It is well known that a high content of saturated fatty acids in foods contributes to the onset of cardiovascular disease, arteriosclerosis, hypertension, hypercholesteremia (McAfee et al., 2010). The recommended value for the polyunsaturated to saturated fatty acids ratio is up to 0.45 and below 4.0 for the n-6 to n-3 fatty acids ratio (Wood and Enser, 1997; Klir et al., 2012). Therefore, the intention is to model the fatty acid profiles in lamb meat, through nutrition, and more precisely to optimize the ratio of unsaturated and saturated fatty acids.

Saturated fatty acids predominate in the meat of lambs whose primary food is milk, which is a consequence of the fatty acid composition of sheep's milk, which is dominated by this type of fatty acids (Díaz et al., 2003). Also, in this period, since these are non-functional ruminants, the biohydrogenation of fatty acids is negligible. When lambs are weaned and start eating more solid foods, the content of saturated fatty acids decreases (Radzik-Rant et al., 2012).

The influence of dietary management on fatty acid content of lamb meat has been studied by a number of authors. Cividini et al. (2008, 2014) find that grazing lamb meat has a significantly higher n-3 PUFA, CLA and more favourable n-6/n-3 fatty acid ratio ($P < 0.001$), while the lamb meat originating from animals fed concentrated diet has a higher content of n-6 PUFAs and a higher ratio of n-6/n-3 fatty acids, exceeding the recommended value of 4.0. In the intramuscular fat of lambs fed concentrated feed, a higher share of oleic acid was found. According to some authors, the concentration of this acid may increase due to an increase in the activity of the $\Delta 9$ desaturase enzyme, which synthesizes oleic from stearic acid (Griinari, 2000). Examining the impact of 3 feeding systems: grazing, closed and combined, on the fatty acid profile of lambs, Boughalmi and Araba (2016) have found that meat of lambs fed a concentrated mixture in a closed system had higher contents of palmitic and oleic acids. Contrary to this, lambs in the grazing feeding system had more CLA, linolenic, n-6 and n-3 fatty acids ($P < 0.01$), which can be explained by the fact that grass contains 1-3% fat, with C18: 3 n-3, are represented with 55-65%. The effect of grazing and concentrated fattening of lambs on the fatty acid profile of muscle and fat tissue was examined by Rowe et al. (1999) on samples of *m. longissimus dorsi*.

Table 2. Effect of diet on fatty acid content of MLD lambs (Rowe *et al.*, 1999)

Fatty acids	Pasture	Fodder mixture	Significance
C18:0 stearic acid	30.11±0.42	23.51±0.36	p<0.01
C18:1n-9 oleic acid	30.73±0.40	38.21±0.44	p<0.01
C18:2 n-6 linoleic acid	2.63±0.14	3.85±0.13	p<0.01
C18:32 n- arachidonic acid	0.32±0.05	0.21±0.03	p<0.01
SFA	55.07±0.43	49.36±0.54	p<0.01
MUFA	31.73±0.35	40.68±0.49	p<0.01
PUFA	5.36±0.40	4.74±0.40	p<0.01

SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids

Meat of lambs fed solely on pasture had a higher content of saturated fatty acids (stearic and arachidonic), which can be explained by a higher intake of pasture food that promotes the activity of rumen microflora, which performs the biohydrogenation of fatty acids, increasing the content of SFA. Omega 3 fatty acids, which the pasture is rich in, is essential to the human body (they reduce the risk of cancer, inflammation, arthritis, they are important for the cognitive functions of the brain), but they are not synthesized. Particularly important is the content of ω -3 fatty acids, especially eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) in meat, which have a positive effect on human health.

However, it must be taken into account that a higher amount of unsaturated fatty acids, especially PUFA, creates preconditions for easier oxidation, which adversely affects the organoleptic properties of meat (Kaić *et al.*, 2013). In this case, the use of antioxidants is indicated, and fresh, voluminous nutrients are a rich source of antioxidants such as tocopherols, carotenoids, and phenolic compounds. Petrova *et al.* (1994) reports that concentrate-based diets lead to a greater amount of carbohydrate available, which shortens the retention time of food in rumen and reduces the biohydrogenation of polyunsaturated fatty acids. Also, the content of n-3 polyunsaturated fatty acids (PUFA) is higher in the meat of lambs fed hay (Table 3).

Table 3. Chemical composition of grass hay and concentrate pellet (Demirel et al., 2006)

Composition	Grass hay	Concentrate
Dry matter (%)	89.2	89.9
Crude protein (%)	10.2	16.4
Ether extract (%)	3.6	3.6
Ash (%)	8.8	7.9
NDF (%)	32.6	23.5
Metabolizable energy, MJ/kg DM ^b	8.28	10.45
<i>Fatty acid content and composition, % fatty acids</i>		
C14:0	2.7	0.4
C16:0	17.8	18.5
C16:1	1.9	0.5
C18:0	2.4	3.5
C18:1 <i>n</i> - 9	13.2	22.1
C18:2 <i>n</i> - 6	23.6	51.8
C18:3 <i>n</i> - 3	38.2	3.0

In lambs fed this diet, a 3.5-fold increase in linolenic acid (C18: 3 *n*-3) was observed in *m. longissimus thoracis*, relative to those fed with concentrate, which is a reflection of the high content of the same fatty acid in hay (Table 4). In the same study, the share of eicosapentaenoic acid EPA (C20: 5 *n* - 3) was 2.5 times higher, of docosapentaenoic acid - DPA (C22: 5 *n* - 3) 3 times and docosahexaenoic acid DHA 2.5 times higher in lambs fed diet based on hay. The levels of linoleic (C18: 2 *n* - 6) and arachidonic acids (C20: 4 *n* - 6) in lambs fed concentrated feed were higher compared to lambs fed hay because grain contains high levels of C18: 2 *n* - 6 and C20 : 4 *n* - 6, which are linoleic acid metabolites, obtained by enzymatic desaturation and elongation (Gurr et al., 2008). The share of C18: 2 *n* - 6 was almost twice as high and C20: 4 *n* - 6 was 1.5 times higher in lambs fed concentrated feed compared to lambs fed hay.

Table 4. Breed, feed and interaction effects on fatty acid composition of *longissimus thoracis* of lambs fed different forage: concentrate ratio (mg/100 g muscle) (Demirel et al., 2006)

Fatty acid	FEED		BREED		SED	Breed	Feed	Breed × feed
	Grass hay	Concentrate	Kivircik	Sakiz				
C14:0	75	59.9	74.6	59.9	2.76	***	***	n.s.
C16:0	446	385	470	360	11.0	***	***	n.s.
C16:1	40.6	21.1	36.5	35.2	1.98	n.s.	***	n.s.
C18:0	424	321	419	325	14.1	***	***	*
C18:1	758	608	746	621	21.3	***	***	*
C18:2 n – 6	96.6	190	150	137	2.86	***	***	n.s.
C18:3 n – 3	46.7	13.0	31.9	27.9	0.92	***	***	n.s.
C20:4 n – 6	26.2	39.0	35.6	29.5	1.18	***	***	*
C20:5 n – 3	25.4	10.8	18.2	17.9	0.84	n.s.	***	n.s.
C22:5 n – 3	15.7	5.6	10.7	10.6	0.46	n.s.	***	n.s.
C22:6 n – 3	7.8	3.0	5.1	5.6	0.25	n.s.	***	*
Total FA	2086	1791	2128	1748	26.7	***	***	***

Modelling the fatty acid composition of lamb meat, through certain feeding strategies, with an emphasis on conjugated linoleic acid (CLA) has been the subject of research by a number of authors (*Schmid et al. 2006, Garcia et al. 2008, Serra et al. 2009*). Conjugated linolenic acid consists of a group of geometric and positional isomers of linolenic acid, which are attributed with anticancer, antidiabetic effect, as well as effect on the immune system and bone metabolism. The highest concentrations of CLA have been found in lamb meat (4.3-19 mg/g fat). *Santos-Silva (2002)* finds higher concentrations of CLA in meat of lambs fed on pasture, compared with lambs fed with concentrated mixture (7.1 vs. 3.2 mg/g fat), which is attributed to the high content of PUFA in grass (especially n-3 18: 3 with a ratio n-6: n-3 of about 1: 3-5). *Noble et al. (1974)* find that in order to increase CLA in *m.semimembranosus* of lambs, after the grazing season, the best results are obtained by a nutritional treatment involving a combination of fish oil and linseed rich in linoleic fatty acid (C18: 3 n- 3). CLA has an anticancer, anti-diabetic effect, as well as a positive effect on the immune status, cardiovascular system and bone mineralization. According to *Dhiman et al. (2001)*, pasture-fed ruminant products have 300-500% more CLA compared to products from ruminants fed with 50%

hay and silage and 50% concentrated nutrients, which clearly indicates the importance of nutrition management that will result in an increase in CLA content in ruminant meat and even lambs.

Conclusion

The concentration and profile of fatty acids in meat, affect its nutritional value, as well as the health status of people, preventing or increasing the risks of cancer, cardiovascular disease, diabetes. Fat content and fatty acid content in lambs depend on: genotype, age, gender, diet and lambs rearing/housing system. Nutrition management has a significant place and provides the opportunity to model the composition of meat and fatty acids, which contributes to the improvement of fat content, the optimal ratio of saturated and polyunsaturated fatty acids, as well as a more favourable ratio of n-6/n-3. Nutrition of lambs consisting of pasture and hay compared to the concentrated diet will imply a lower carcass fat content and a higher concentration of n-3 PUFA, CLA and a more favourable n-6/n-3 fatty acid ratio. Omega 3 fatty acids, which the pasture is rich in, are essential for the human body (reduce the risk of cancer, inflammation, arthritis, they are important for cognitive brain function), but they are not synthesized. Conjugated linoleic acid (CLA) is of great importance, since it has an anticancer, antidiabetic effect as well as an effect on the immune system, indicating a direction for future research on lamb meat.

Menadžment u ishrani jagnjadi kao put modeliranja profila masnih kiselina u mesu

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Rezime

Pored nutritivne vrednosti, veoma važan kriterijum pri odabiru mesa, za savremenog potrošača je i zdravstveni aspekt, odnosno sadržaj masnog tkiva i profil masnih kiselina u mesu. Sadržaj masti i masnih kiselina, je između ostalog uslovljen sistemom ishrane i načinom držanja. Jagnjad hranjena na paši imaju manji udeo masnog tkiva u trupu od grla hranjenih koncentrovanom smešom, u zatvorenom sistemu. Preporučena vrednost za odnos polinezasićenih i zasićenih masnih kiselina iznosi do 0.45 a ispod 4.0 za odnos između n-6 i n-3 masnih kiselina. Imajući u vidu da je uticaj ishrane jagnjadi na navedene odnose značajan,

modeliranje masnokiselinskog sastava treba usmeriti na sistem ishrane jagnjadi koji dovodi do smanjenja udela zasićenih a povećanje koncentracije polinezasićenih (PUFA) masnih kiselina u mesu. Strategija hranjenja koja podrazumeva pašni sistem ishrane jagnjadi, rezultira većim sadržajem n-3 PUFA, CLA i povoljnijim n-6/n-3 odnosom masnih kiselina, dok meso jagnjadi hranjene koncentrovanom hranom ima veći udeo n-6 PUFA i veći odnos n-6/n-3 masnih kiselina, što prevazilazi preporučenu vrednost od 4.0. Konjugovana linolenska kiselina (CLA) ima veliki značaj, obzirom da ima antikancerogeni, antidijabetični efekat kao i efekat na imuni sistem, što ukazuje na smernicu budućih istraživanja na jagnjećem mesu.

Ključne reči: jagnjad, masne kiseline, paša, n-3 PUFA, CLA

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