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# INFLUENCE OF SPECIES AND NUTRITION ON FATTY ACIDS PROFILE AND CLA CONTENT IN MEAT FAT OF RUMINANTS

# UTJECAJ VRSTE I HRANIDBE NA PROFIL MASNIH KISELINA I SADRŽAJ CLA U MASNOĆI MESA PREŽIVAČA

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## SUMMARY

The share of differently saturated fatty acids was related to the animal species (Exp. I). The meat fat from young bulls and lambs, compared with that from kids, contained more UFA and less SFA (P<0.01). The greatest fatty acids content with one double binding was found in the fat of bulls and lambs (P<0.01). However, the meat fat of kids, contained much more PUFA (P<0.01) than that of bulls and lambs. As compared to the intermuscular fat of lambs and bulls the fat of kids was also characterized by a much higher linoleic acid content (P<0.01). The highest level of the CLA in configuration c9,t11 was observed in the fat of lambs (P<0.01) in relation to bulls and kids. Significant differences in this isomer content also appeared between the fat of bulls and lambs (P<0.05). In exp. II it was found that fat of Frisian sheep contained more PUFA in comparison with Berrichone du cher (P<0.05) and Polish merino sheep. The lowest palmitic acid content C16:0 was found in Frisian lamb fat (P<0.01). Alternatively, the ower amount of stearic acid C18:0 was found in the fat of Wrzosówka (P<0.01) than in the fat of Polish merino and Berrichone du cher. Significant differences in the oleic acid content in fat were detected between Wrzosówka and Berrichone du cher lambs. No clear influence of breed upon the linolic acid content C18:2 in interamuscular fat was noticed. Significant effect of the breed was observed in conjugated dienes of linoleic acid c9,t11. The highest level of this isomer was detected in the fat of Wrzosówka lambs. It had by 86.7 percent units more of this diene than Berrichone du cher and by 60 percent units more than Polish merino and by 19.1 percent units more than Frisian lambs (all differences were statistically significant; P<0.01). A significant influence of feeding on the muscle fat contet in the *longissimus dorsi* was notobserved (Exp. III). The most beneficial composition of fatty acids was found in the fat of lambs fed concentrate with linseed. In comparison to

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lambs fed green fodder as well as concentrate the amount of saturated fatty acids was lower by about 1.7 and 2.4 percent units respectively ($P<0.05$). The fat of lambs fed concentrate with linseed was characterized by both higher unsaturated fatty acids and conjugated dienes or linoleic acid cis-9 trans- 11 content. In comparison to lambs fed green fodder the amount was higher by about 2.1 and 10.1 percent units ($P<0.01$).A significant difference in the composition or fatty acids the muscle fat was also noted between lambs fed green fodder and concentrate. The fat at of lambs fed green fodder contained more polyunsaturated fatty acids ($P<0.05$) and slightly more conjugated dienes of linoleic acid c9,t11 than sheep fed concentrate.

Key words: ruminants, meat, fatty acids, CLA isomers

## INTRODUCTION

Unsaturated fatty acids and the n-3 : n-6 fatty acids ratio beneficially affect animals and human health. These acids also conjugated linoleic acid (CLA) active isomers and in them are important factors in preventing cardiovascular diseases. They may reduce the atherogenese, have anticarcinogenic and antioxidative properties and influence the cholesterol metabolism (Chin et al., 1992, 1994; Bartnikowska et al., 1993, 1999; Lee et al., 1994; Parodi, 1997; Seifer and Watkins, 1997; Jahreis, 1999; Munday et al., 1999; Walisiewicz-Niedbalska et al., 2002;).

The synthesis of polyunsaturated fatty acids appearing in animal organism .depends on the conversion of linol and linoleic acids as an effect of elongation and desaturation processes induced by elongase and desaturase enzymes (Hughes et al.,1982; Kemp and Lander, 1984, Harfoot and Hazefood, 1988; Parodi, 1997; Rafalski, 1997; Seifer and Watkins, 1997; Pariza et al., 2001; Scheeder et al., 2002; Slomma et al., 2001).

Linoleic acid isomers arise as an effect of enzymatic activity of symbiotic bacteria *Butyrivibrio fibrisolvens,* that occurs in the digestive tract of ruminants. These ruminal bacteria are able to convert the linoleic acid into conjugated (CLA) form with dominant cis-9, trans-11 configuration. A part of CLA-isomers is not subjected to further biohydrogenation, may be absorbed from the gastrointestinal tract and next incorporated into blood lipids, tissues and organs. Relatively great amounts can be found in meat fat or milk (Fogerty et al.,1988; Bartnikowska et al.,1993; Lin et al.,1995; Obiedzinski et al.,1998; Ktihne,1999; Pisulewski et al.,1999). Moreover, the rumen microorganisms are able to isomerize linoleic acids from configuration c9,t12 to c9,t11 (Hughes and Hunter,1982; Parodi,1997).

CLA isomers are characterized by health promoting activity and are helpful as obesity preventing factors. They also act as antisclerotic factors and stimulate the immune system (Chin et al.,1994; Lee et al.,1994; Park et al.,1997).

The important dietetic sources of CLA isomer c9,t11 are ruminant meat and milk, but the number of publications, in which exact data regarding CLA concentration are presented, is not very great.

The purpose of the investigations presented was to determine the variability of fatty acids pattern, their CLA concentration, with consideration of ruminant species and also differences in the meat fat parameters in lambs of different breeds and fed different diets. The synthesis of three experiments is presented.

## MATERIALS AND METHODS

### Experiment I

The isomer c9,t11 of conjugated linoleic acid (CLA) content as well as that of fatty acids

saturated to a different extent were determined in intermuscular fat of the *longissimus dorsi* (LD) muscle of three species of ruminants. The muscle samples were taken from 20 fattened young Red-and-White bulls (about 8.5 months old, born in November-December), from 20 Frisian rams (about 5 months old, born in February-March) and from 20 White graded male goats (about 5 months old, born in February-March).

The animal were reared on a farm belonging to the Association of Ecological Food Producers "Ekoland" in Poreby-Laziska, Poland. Male kids, goats and bulls were brough to this farm and with ram lambs born in Poreby-Laziska, were kept in similar environmental conditions. In the period from May through July the animals were fed the same feeds, *i.e.* pasture green forage, concentrate (25% ground barley, 25% ground oats, 25% ground wheat and 25% soyabean bran), meadow hay, fodder carrot and mineral supplement. The diets were calculated according to INRA system (1988) for each animal species. The average daily ration for young bulls contained 4.78 UG[1], 461 g PDIN[2] and 51 1 g PDIE[3]. The lambs received daily 1.19 UG, 104 g PDIN and 116 g PDIE, while the young goats 0.78 UG, 69 g PDIN and 78 g PDIE. The used feedstuffs and diets are given in Table 1.

the level of CLA isomer c9,t11. Analyses were conducted at the Human Medicine Academy, Department of Bromathology, Wroclaw, Poland. The material for analyses was prepared according to the AOAC methods (1990). Minced samples of meat were extracted with Folch's mixture (chloroform and methanol, 2:1). The lipid fraction from extracted fat, after adding water, centrifuging and filtrating through an anhydrous sodium sulphate, was hydrolysed in 0.5 M KOH methanol and finally estrified with 14 % BF3 in methanol. In order to determine the fatty acid profile and the level of CLA (c9,t11), the fatty acid methyl esters (1 ml) were transferred to a 4410 PU chromatograph (Phillips) with a flame ionization detector. The separation was conducted in a Rtx-2330 capillary column covered with a bound stationary phase (10 % cyanidepropylphenyl, 90 % biscyanidepropyl-polisyloxane) 20 (µm thick, 105 m long and 0.25 mm in diameter. The separation was conducted at a programme temperature: initial isotherm 30' in 160C, the carrier gas - helium 80 PSI. For the identification of the CLA the Sigma standards were used.

On the basis of the fat and fatty acids (FA) content in meat, the FA profile was calculated. The fat and fatty acids content was also determined in the feeds given to animals.

**Table 1. Share of fatty acids in used feeds in experiment I (% in total FA)**
**Tablica 1. Udio masnih kiselina u korištenom krmivu (hrani u pokusu I) (% ukupnih MK)**

| Feedstuffs - Krmivo | SFA | MUFA | PUFA | C18:2 | CLA C18:2;c9,t11 |
|---|---|---|---|---|---|
| Meadow hay - Livadno sijeno | 32.1 | 22.0 | 45.9 | 17.7 | 0.0 |
| Pasture green forage - Zeleno krmivo s pašnjaka | 36.8 | 12.1 | 51.1 | 12.2 | 0.0 |
| Carrots - Mrkva | 47.9 | 2.1 | 50.0 | 47.6 | 0.0 |
| Concentrate - Koncentrat | 22.0 | 40.6 | 37.4 | 35.5 | 0.0115 |

After three months of feeding on experimental diets all animals were slaughtered and samples of LD muscle taken. In the LD intermuscular fat the fatty acids content was determined, together with

To evaluate the significance of differences between species in the fatty acids content the one-factor analysis of variance and Duncan's test were used.

[1] UG- units of growth
[2] PDIN - protein digestible in intestine, nitrogen, when N is not limited in rumen
[3] PDIE - protein digestible in intestine, energy, when E is not limited in rumen.

Experiment II

The studies were conducted on breeds: Polish merino, Berrichone du cher, Frisian and Polish primitive breed called Wrzosówka (20 animals from each breed). The animals were fed on concentrate and meadow hay (an average feed ration during fattening contained 0.81 kg DM, 0,59 UG and 77 g PDIN). After this period all young rams were slaughtered and samples were taken from *longissimus dorsi* (LD) muscles. Fatty acids profile and CLA content dienes (cis-9 trans-11) were determined in intermusclar fat, extracted from LD muscle.

Fat extraction from fat tissue was carried out using Folch method and the Philips PU 4410 gas chromatograph equipped with a combustion-ionizing detector. Separation was carried out in the Rtx-2330 capillary tubes covered with bounded stationary phase (10 % cyanopropylphenyl, 90 % biscyano-prophyl polisyloxane) 20 µm thick, 105 cm long and with *a* diameter of 0.25 mm. The separation was conducted in programmed temperature: beginning isoterm - 3C/min to 180 ºC - 17 minutes in temperature of 180 ºC for 5 minutes to 210 ºC - 20 minutes in temperature of 210 ºC. Other parameters of separation: detector - 230 ºC, injection chamber - 220 ºC, capillary tube - 160 ºC, carrier gas - Hel 80 PSI. Identification of fatty acids was performed by comparing retention times of obtained files with standards. Chromatographic analyses were carried out in Department of Animal Products Technology, Agriculture University in Wroclaw.

Experiment III

The studies on the influence of differentiated nutrition of lambs on composition of fatty acids including conjugated dienes of linoleic acid (c9,t11) in the intermuscular fat were conducted on *s* 60 young Polishmerino rams (3 groups of 20 heads) that in the period of 60 days were fed diets according to the following scheme:

group I - concentrate and meadow hay

group II - concentrate with linseed, meadow hay

group III - pasture green fodder

Diets for particular groups were determined according to the INRA system. In an average dosage, lambs from group I received the following: 0.81 kg DM, 0.59 UG and 77 g PDIN; group II - 0.83 kg DM, 0.62 UG and 74 g PDIN; group 3 - 0.86 kg s.m., 0.60 UG and 76 g PDIN.

During the experiment chemical composition as well as the fatty acids content in fat were determined three times in green fodder and twice in concentrate, hay and linseed at the beginning of the experiment, after 30 days and towards the end.

After 60 days of the experiment all lambs were slaughtered and the samples of *longissimus dorsi* muscles and peri-renal fat were taken. The composition of fatty acids with the conjugated dienes of linoleic acid (cis-9 trans-11) were determined in the fat extract from the *longissimus dorsi* muscle and in the peri-renal fat as well.

Chemical analyses of fatty acids were conducted in the laboratory of the Department of Animal Products of Institute of Food Technology in Wroclaw as in experiment II. All data were statistically evaluated by one-way variance analysis and Duncan test.

## RESULTS AND DISCUSSION

Experiment I

The highest concentration of polyunsaturated fatty acids (PUFA) was found in the pasture forage, of unsaturated fatty acids (UFA) in the concentrate, while of saturated fatty acids (SFA) in the carrot. The higest linoleic acid (C 18:2) content, the precursor of the CLA, was found in the concentrate. In neither of the feeds offered the presence of the CLA in configuration c9,t11 was observed. The amount of linoleic acid C 18:2, consumed in the diets by young bulls, lambs and kids was 15.2, 4.0 and 2.2 g/head, respectively (Table 2).

The share of differently saturated fatty acids was related to the animal species (Table 3). The fat from bulls and lambs, compared with that from kids, contained more UFA and less SFA ($P<0.01$). The

greatest fatty acids content with one double binding was found in the fat of bulls and lambs (P<0.01) However, the fat of kids contained much more PUFA (P<0.01) than that of bulls and lambs. As compared to the intermuscular fat of lambs and bulls the fat of kids was also characterized by a much higher linoleic acid content (P<0.01). The highest level of the CLA in configuration c9,t11 was observed in the fat of lambs (P<0.01) in relation to bulls and kids. Significant differences in this isomer content also appeared between the fat of bulls and lambs (P<0.05).

**Table 2. C18:2 n-6 intake in daily ration in experiment I (g/day/head)**
**Tablica 2. Unos C18:2 n-6 u dnevnom obroku u pokusu I (g/dan/grlo)**

| Animals - Životinje | Intake from - Unos iz | | | |
|---|---|---|---|---|
| | Pasture green forage<br>Zeleno krmivo s pasnjaka | Hay<br>Sijeno | Carrot<br>Mrkva | Concentrate<br>Koncentrat |
| Young fattening bulls - Mladi tovni bikovi | 4.75 | 3.33 | 2.06 | 5.09 |
| Lambs - Janjci | 0.49 | 0.67 | 0.62 | 2.25 |
| Goat kids - Kozlići | 0.43 | 0.67 | 0.21 | 0.90 |

**Table 3. The %-share of fatty acids in total fatty acids of the intermuscular fat (mean ± SD) (Exp. I)**
**Tablica 3. Postotak udjela masnih kiselina u ukupnim masnim kiselinama u međumišićnom tkivu (sredina, ±SD) (Pokus I)**

| Groups of fatty acids<br>Skupine masnih kiselina | Share in total fatty acids (%) - Udio u ukupnim masnim kiselinama (%) | | |
|---|---|---|---|
| | Young fattened bulls<br>Mladi tovni bikovi | Lambs<br>Janjci | Kids<br>Kozlići |
| SFA | $47.19^{A}$ | $48.04^{AB}$ | $49.90^{B}$ |
| | ±3.87 | ±4.25 | ±4.90 |
| UFA | $52.78^{A}$ | $51.96^{AB}$ | $50.09^{B}$ |
| | ±3.25 | ±3.73 | ±4.01 |
| MUFA | $45.34^{A}$ | 43.50^ | $40.59^{B}$ |
| | ±2.96 | ±3.10 | ±3.74 |
| PUFA | $7.43^{A}$ | $8.46^{AB}$ | $9.50^{B}$ |
| | ±0.91 | ±1.02 | ±0.90 |
| CLA | $4.74^{A}$ | $5.05^{AB}$ | $6.33^{B}$ |
| | ±0.90 | ±0.91 | ±0.79 |
| CLA | $0.62^{Aa}$ | $1.28^{B}$ | $0.98^{b}$ |
| c9,t11 | ±0.14 | ±0.27 | ±0.19 |

Means marked with the same letters differ significantly: capital letters - differences significant at P≤0.01, small letters - differences significant at P≤0.05.

Prosjek označen istim slovima razlika je značajna: velika slova – razlike značajne kod P≤0.01, mala slova - razlike značajne kod P≤0.05

Data concerning the fatty acid content, groups and particular acids in the meat (mg/100g) demonstrated, that as in the case of their percentage share, differences occurred between the species (Table 4). The highest fat content was obtained in lamb meat (4.10) and beef (3.86), the lowest from the meat of goat kids (3.17 %).The greatest amount of SFA per 100 g of LD muscle was found in lambs and the smallest in kid goats. Lamb meat also contained the greatest amount of UFA (principally of PUFA), linoleic acid and its conjugated form CLA (c9,t11). The quantity of this isomer in the lambs' meat was more than twice higher than in beef and 1.7 times higher than in the meat of goat kids. In the meat of kids the quantity of isomer c9,t11 was about 1.3 times higher than in beef. The effect of species on the fatty acid composition of intermuscular fat in animals maintained in similar environmental conditions and fed on the same feeds was also observed by other authors (Gruszecki et al.,1999). In those studies the meat of young male kid goats was characterized by a significantly higher levels of UFA and PUFA than those observed in the lamb meat.

**Table 4. The content in meat of fatty acid groups in total fatty acids of the LD muscle fat (mean, ± SD) (Exp. I)**

**Tablica 4. Sadržaj skupina masnih kiselina u mesu u ukupnim masnim kiselinama LD mišićne masnoće (prosjek, ± SD) (Pokus I)**

| Fatty acids - Masne kiseline | mg/IOOg muscle - mg/100 g mišića | | |
|---|---|---|---|
| | Young fattened bulls Mladi bikovi | Lambs - Janjci | Kids - Kozlići |
| SFA | 1753.2$^{AB}$ | 1890.8$^{B}$ | 1518.5$^{A}$ |
| % u odnosu na bikove | ±166.1 | ±189.2 | ±164.9 |
| % in relation to bulls | 100.0 | 107.8 | 86.6 |
| UFA | 1960.8$^{A}$ | 2045. 1$^{A}$ | 1524.3$^{B}$ |
| % u odnosu na bikove | ±158.1 | ±200.3 | ±162.2 |
| % in relation to bulls | 100.0 | 104.3 | 77.7 |
| MUFA | 1684.4$^{A}$ | 1712.1$^{A}$ | 1235.2$^{B}$ |
| % u odnosu na bikove | ±173.5 | ±196.1 | ±153.2 |
| % in relation to bulls | 100.0 | 101.6 | 73.3 |
| PUFA | 276.0$^{A}$ | 332.9$^{B}$ | 289.10^ |
| % u odnosu na bikove | ±41.9 | ±48.4 | ±34.1 |
| % in relation to bulls | 100.0 | 120.6 | 104.7 |
| CLA | 176.1$^{3}$ | 198.7" | 192.6" |
| % u odnosu na bikove | ±32.5 | ±35.1 | ±39.6 |
| % in relation to bulls | 100.0 | 112.9 | 109.4 |
| CLA (c9,t11) | 23.0$^{Aa}$ | 50.38$^{B}$ | 29.82$^{ABa}$ |
| % u odnosu na bikove | ±4.5 | ±12.7 | ±7.5 |
| % in relation to bulls | 100.0 | 218.8 | 129.5 |

Means marked with the same letters differ significantly: capital letters - differences significant at P≤0.01, small letters - differences significant at P≤0.05.

Prosjeci označeni istim slovima razlika je značajna: velika slova – razlike značajne kod P≤0.01, mala slova - razlike značajne kod P≤0.05

In the presented investigation it was found that the fat from lamb meat had a significantly higher CLA (c9,t11) content than the fat from the other two ruminant species. This may indicate that the process of trans-estrification, that accurs in the rumen leading to the creation of conjugated forms of PUFA (mainly CLA) is much more efficient in lambs than in the other two species.

It has been shown that, when evaluating the differences between species in the CLA configuration c9,t11 content in meat, the attention must also be paid to differences between breeds (Borys and Borys, 2001).

The differences between species, observed in the present investigations, are confirmed by the earlier results of Chin et al. (1994), that the isomer c9,t11 content in the meat of lambs is about twice higher than found in veal and beef meat. The higher isomer c9,t11 content in lamb meat has also been reported by Obiedzinski et al.(1998).

Experiment II

The lowest level of saturated fatty acids was found in Wrzosówka lambs fat in comparison to Polish merino and Berrichone du cher lambs ($P<0.01$). Morover, the differences in its content appeared between Polish merino and Frisian breed. Frisian lamb intermuscular fat had lower level of these acids by about 5.3 percent units ($P<0.05$).

At the same time, fat of the Wrzosówka lambs had the highest amount of unsaturated fatty acids. In the monounsaturated fatty acids, essential differences were found only between Wrzosówka and Polish merino lambs (Table 5).

Bigger differences in the MUFA content in the intermuscular fat detected were an effect of genetic variability. The highest content was found in Wrzosówka sheep. In comparison with Berrichone du cher this difference was significant ($P<0.01$). Moreover, it was detected that the fat of Frisian sheep contained more PUFA in comparison with Berrichone du cher ($P<0.05$) and more than Polish merino sheep. The lowest palmitic acid C16:0 content was found in Frisian lamb fat ($P<0.01$). Alternatively, the least amount of stearic acid C 18:0 was contained in the fat of Wrzosówka ($P<0.01$) than in the fat of Polish merino and Berrichone du cher. Significant differences in the oleic acid content in the fat were detected between Wrzosówka and Berrichone du cher lambs. No clear influence of breed upon the linolic acid C18:2 content in interamuscular fat was noticed.

Significant effect of the breed was observed in conjugated dienes of linoleic acid c9,t11. The highest level of this isomer was detected in the fat of Wrzosówka lambs. It had by 86.7 percent units more of this diene than Berrichone du cher and by 60 percent units more than Polish merino and by 19.1 percent units more than Frisian lambs (all differences were statistically significant; $P<0.01$).

The differences in fat content between both sheep breeds and types, that are shown in present research have been confirmed in other works (Radzik,1999; Bodkowski, 2000; Borys and Borys, 2000). The present research results indicate a negative effect of upgrading on the fatty acids content of sheep intermuscular fat. The most optimal fatty acids content was detected in the fat of primitive sheep - Polish Wrzosówka, less optimal configuration was found in graded sheep Polish merino, Frisian and Berrichone du cher.

The influence of breed was also visible in unsaturated fatty acids content: oleic C18:l and linoleic C18:2 acids and biologically active conjugated dienes of linoleic acid c9 t11, which are very important from dietetic point of view. The biggest amount of them was found in fat of Wrzosówka and Frisian, lower amount was stated in Polish merino and Berrichone du cher lambs. The results were obtained under the same environmental and feeding conditions.

**Table 5. The % share of fatty acids profile in total fatty acids in intermuscular fat of longissimus dorsi muscles of different sheep breeds (mean, ± SD) (Exp. II)**

**Tablica 5. Postotak udjela profila masnih kiselina u ukupnim masnim kiselinama u međumišićnoj masnoći mišića longissimus dorsi raznih pasmina ovaca (prosjek, ± SD) (Pokus II)**

| Fatty acids groups<br>Skupine masnih kiselina | Polish merino<br>Poljski merino | Berrichone du cher | Frisian | Wrzosówka |
|---|---|---|---|---|
| SFA | $56.28^{Aa}$ | $55.27^{A}$ | $53.43^{b}$ | $51.17^{Bb}$ |
| | ±2.36 | ±2.11 | ±1.71 | ±2.21 |
| UFA | $43.69^{A}$ | $44.73^{a}$ | $46.55^{a}$ | $48.83^{Bb}$ |
| | ±1.98 | ±2.89 | ±2.21 | ±3.76 |
| In them: - u tome: | | | | |
| MUFA | $38.07^{A}$ | $39.28^{A}$ | $40.23^{AB}$ | $42.05^{B}$ |
| | ± 2.11 | ±3.11 | ±2.34 | ±2.88 |
| PUFA | $5.62^{a}$ | $5.45^{Aa}$ | $6.32^{b}$ | $6.78^{Bb}$ |
| | ±0.35 | ±0.30 | ±0.62 | ±0.41 |
| Cl6:0 | $26.54^{AB}$ | $28.89^{A}$ | $24.15^{B}$ | $25.19^{AB}$ |
| | ±0.84 | ±2.35 | ±1.89 | ±3.23 |
| Cl8:0 | $22.05^{Aa}$ | $19.41^{b}$ | $18.32^{bc}$ | $16.11^{Bc}$ |
| | ±0.94 | ±1.33 | ±1.67 | ±1.88 |
| Cl8;l | $33.67^{ab}$ | $32.85^{a}$ | $33.89^{ab}$ | $35.34^{b}$ |
| | ±1.16 | ±1.89 | ±2.62 | ±2.21 |
| Cl8:2 | 4.32 | 4.40 | 4.20 | 4.68 |
| | ±0.46 | ±0.33 | ±0.28 | ±0.51 |
| C18:2 *izomerc9t11* | $0.35^{Aa}$ | $0.30^{Ab}$ | $0.47^{B}$ | $0.56^{C}$ |
| | ±0.06 | ±0.05 | ±0.09 | ±0.07 |
| Cl8:3 | $0.63^{A}$ | $0.54^{A}$ | $1.57^{B}$ | $1.33^{B}$ |
| | ±0.23 | ±0.14 | ±0.27 | ±0.33 |

Means marked with the same letters differ significantly: capital letters - differences significant at P≤0.01, small letters - differences significant at P≤0.05.

Prosjek označen istim slovima razlika je značajna: velika slova – razlike značajne kod P≤0.01, mala slova - razlike značajne kod P≤0.05

## Experiment III

Chemical analyses of feeds, which make the components of diets revealed significant differences in the profile of fatty acids (Table 6). The highest amount of fat was found in linseed (ca.36 %), concentrate and meadow hay contained ca. 3.4 % and green fodder contained only about 0.6 %. The highest unsaturated fatty acids content was observed in the linseed fat (ca. 88 %), then pasture grass (ca. 77 %) and the lowest amount in concentrate and green fodder (ca. 60 %).

**Table 6. Chemical composition (%) and %-fatty acids share in total fatty acids content (Exp. III)**
**Tablica 6. Kemijski sastav (%) i % udjela masnih kiselina u sadržaju ukupnih masnih kiselina (Pokus III)**

| Nutrients - Hranjive tvari | Concentrate Koncentrat | Pasture green fodder Zelena krma s pašnjaka | Meadow hay Sijeno s pašnjaka | Linseed Sjemenke lana |
|---|---|---|---|---|
| Dry matter - Suha tvar | 84.6 | 14.6 | 93.2 | 92.8 |
| Crude protein - Sirove bjelančevine | 17.60 | 4.67 | 11.43 | 25.46 |
| Crude fat - Sirova masnoća | 3.41 | 0.65 | 3.49 | 36.06 |
| SFA | 38.6 | 25.2 | 37.8 | 12.2 |
| MUFA | 35.2 | 8.2 | 16.5 | 20.3 |
| PUFA | 26.1 | 66.7 | 45.6 | 67.5 |
| C18:2 | 23.5 | 53.7 | 19.4 | 19.0 |
| C18:3 | 2.1 | 12.4 | 25.2 | 47.2 |

**Table 7. The %-share of fatty acids of fat of *longissimus dorsi* in total of fatty acids in lambs (mean ± SD) (Exp. III)**
**Tablica 7. Postotak udjela masnih kiselina masnoće mišića longissimus dorsi u ukupnim masnim kiselinama u janjaca (prosjek, ± SD) (Pokus III)**

| Fatty acids Masne kiseline | Concentrate - Koncentrat | Concentrate with linseed Koncentrat sa sjemenkama lana | Pasture green fodder Zelena krma s pašnjaka |
|---|---|---|---|
| C 16:0 | 26.537 ±0.839 | 26.126 ±0.841 | 25.965 ±1.092 |
| C 16:1 | 3.467 ±0.518 | 3.470 ±0.327 | 3.475 ±0.366 |
| C 17:0 | 1.467 ±0.330 | 1.590 ±0.116 | 1.526 ±0.100 |
| C 18:0 | $22.053^{A}$ ±0.938 | $21.125^{B}$ ±0.754 | $21.930^{A}$ ±0.964 |
| C 18:1 | 33.671 ±1.156 | 33.955 ±0.542 | 33.686 ±1.017 |
| C 18:2 | $4.328^{A}$ ±0.461 | $4.847^{B}$ ±0.392 | $4.139^{A}$ ±0.482 |
| C 18:2 c9,t11 | $0.351^{A}$ ±0.028 | $0.595^{B}$ ±0.073 | $0.540^{C}$ ±0.063 |
| C 18:3 | $0.633^{A}$ ±0.131 | $0.787^{B}$ ±0.064 | $0.850^{B}$ ±0.146 |
| C 19:0 | $0.338^{A}$ ±0.046 | $0.350^{B}$ ±0.033 | $0.383^{Bb}$ ±0.038 |
| C 20:0 | $0.1\ 11^{A}$ ±0.024 | $0.094^{B}$ ±0.008 | 0.101 ±0.013 |
| C 20:1 | $0.044^{A}$ ±0.009 | $0.048^{A}$ ±0.005 | $0.065^{B}$ ±0.011 |
| C20:4 | $0.225^{A}$ ±0.049 | $0.308^{B}$ ±0.058 | $0.307^{B}$ ±0.043 |
| C 22:1 | $0.041^{A}$ ±0.006 | $0.050^{B}$ ±0.005 | $0.043^{A}$ ±0.005 |
| C22:4 | $0.080^{A}$ ±0.009 | $0.127^{B}$ ±0.012 | $0.126^{B}$ ±0.017 |
| SFA | $56.30^{a}$ ±1.071 | $54.994^{b}$ ±0.879 | $55.916^{a}$ ±1.241 |
| UFA | $43.69^{A}$ ±1.279 | $45.006^{B}$ ±1.015 | 44.093 ±2.172 |
| In them: - u tome: | | | |
| MUFA | 38.07 ±2.093 | 38.342 ±1.676 | 38.131 ±1.952 |
| PUFA | $5.62^{Aa}$ ±0.410 | $6.664^{B}$ ±0.387 | $5.962^{Ab}$ ±0.547 |

Means marked with the same letters differ significantly: capital letters - differences significant at P≤0.01, small letters - differences significant at P≤0.05.
Prosjek označen istim slovima razlika je značajna: velika slova – razlike značajne kod P≤0.01, mala slova - razlike značajne kod P≤0.05

A significant influence of feeding on the muscle content fat in the *longissimus dorsi* was not observed. Its amount varied between 2.81 % (in lambs fed on green fodder) to 2.97 % (in lambs fed on concentrate supplemented with linseed). However, significant differences in the profile of fatty acids were observed (Table 7). The most beneficial composition of fatty acids was found in the fat of lambs fed on concentrate with linseed. In comparison to lambs fed on green fodder as well as concentrate the amount of saturated fatty acids was lower by about 1.7 and 2.4 percent units respectively (P<0.05). Fat of lambs fed concentrate with linseed was characterized by both, higher unsaturated fatty acids and conjugated dienes or linoleic acid cis-9 trans-11 content. In comparison to lambs fed green fodder the amount was higher by about 2.1 and 10.1 percent units (P<0.01). The significant difference in the composition or fatty acids of the muscle fat was also noted between lambs fed green fodder and concentrate. Fat of lambs fed green fodder contained more polyunsaturated fatty acids (P<0.05) and slightly more conjugated dienes of linoleic acid c9, t11 than sheep fed concentrate.

Some differences in the profile of fatty acids in peri-renal fat were also observed. Similar saturated fatty acids content was noted in the fat of lambs of all groups. No differences between feeding groups in the range of unsaturated fatty acids were noted (Table 8). In contrast to lambs fed on green fodder or concentrate, the fat of animals fed concentrate with linseed contained about 9.6 (P<0.05) and 15.7 (P<0.0l) percent units more of PUFA, respectively. The conjugated dienes of linoleic acid cis-9 trans-11 content in peri-renal fat of lambs fed green fodder and concentrate with an addition of linseed was relatively at the same level and about 29 percent units (P<0.0l) higher than in lambs fed on concentrate.

**Table 8. The %-share of fatty acids of perirenal fat in lambs (mean ± SD) (Exp. III)**
**Tablica 8. Postotak udjela masnih kiselina perirenalne masnoće u janjaca (prosjek, ± SD) (Pokus III)**

| Fatty acids<br>Masne kiseline | Concentrate - Koncentrat | | Concentrate with linseed<br>Koncentrat sa sjemenkama lana | | Pasture green fodder<br>Zelena krma s pašnjaka | |
|---|---|---|---|---|---|---|
| C 16:1 | 4,344 | ±0,926 | 4,219 | ±0,419 | 4,454 | ±0,481 |
| C 17:0 | 0,869 | ±0,049 | 0,848 | ±0,039 | 0,863 | ±0,044 |
| C 18:0 | 26,599$^{a}$ | ±0,636 | 26,093$^{b}$ | ±0,773 | 26,491 | ±0,964 |
| C 18:l | 27,470 | ±0,965 | 27,649 | ±0,870 | 27,651 | ±0,610 |
| C 18:2 | 3,124$^{A}$ | ±0,647 | 3,73 1$^{B}$ | ±0,413 | 3,306$^{A}$ | ±0,229 |
| C18:2 c9,t11 | 0,282$^{A}$ | ±0,047 | 0,393$^{B}$ | ±0,021 | 0,40 1$^{B}$ | ±0,057 |
| C 18:3 | 0,680$^{A}$ | ±0,043 | 0,758$^{B}$ | ±0,037 | 0,678$^{A}$ | ±0,047 |
| C 19:0 | 0,529 | ±0,036 | 0,550 | ±0,022 | 0,540 | ±0,045 |
| C20:0 | 0,336$^{A}$ | ±0,026 | 0,325$^{A}$ | ±0,019 | 0,359$^{B}$ | ±0,023 |
| C 20:1 | 0,1 34$^{a}$ | ±0,028 | 0,116$^{b}$ | ±0,012 | 0,133$^{a}$ | ±0,018 |
| C 20:4 | 0,1 16$^{a}$ | ±0,017 | 0,110$^{A}$ | ±0,006 | 0,127$^{Bb}$ | ±0,022 |
| C 22:1 | 0,066$^{A}$ | ±0,009 | 0,070$^{A}$ | ±0,005 | 0,080$^{A}$ | ±0,011 |
| C 22:4 | 0,077 | ±0,009 | 0,081 | ±0,005 | 0,076 | ±0,010 |
| SFA | 62,93$^{a}$ | ±1,16 | 62,147$^{b}$ | ±0,614 | 62,355 | ±1,241 |
| UFA | 37,056$^{a}$ | ±1,09 | 37,874$^{b}$ | ±0,596 | 37,666$^{b}$ | ±0,851 |
| In them: U njima | | | | | | |
| MUFA | 32,77 | ±1,49 | 32,801 | ±0,768 | 33,080 | ±0,790 |
| PUFA | 4,27$^{Aa}$ | ±0,64 | 5,073$^{B}$ | ±0,407 | 4,586$^{b}$ | ±0,264 |

Means marked with the same letters differ significantly: capital letters - differences significant at P<0.01, small letters - differences significant at P≤0.05.
Prosjek označen istim slovima razlika je značajna: velika slova – razlike značajne kod P≤0.01, mala slova - razlike značajne kod P≤0.05

It was observed that the fatty acids content of intramuscular and peri-renal fat as well as the conjugated forms of linoleic acid content, was significantly influenced by feeding. The highest CLA content was noted in the fat of lambs fed concentrates enriched with linseed or grazed in a pasture.

The results obtained point to the possibilities of successful fat enrichment of lamb meat in beneficial groups of fatty acids and CLA. Similar observations were noted by other authors (Chin et al., 1992; Bartnikowska et al.,1993, 1999, Borys and Borys, 2001) who found that the fat of pigs and poultry may be relatively easily modified by application of feeds enriched with unsaturated fatty acids and CLA. There has been, however, no research done concerning the increase of CLA content in other species of ruminant animals such as lambs or kids.

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## SAŽETAK

Udio različito zasićenih masnih kiselina povezan je s vrstom životinje (Pokus I). Masnoća mesa mladih bikova i janjaca u usporedbi s masnoćom mesa kozlića sadržavala je više UFA i manje SFA (P<0.01). Najveći sadržaj masnih kiselina s jednom dvostrukom vezom nađen je u masnoći mladih bikova i janjaca (P< 0.01), Međutim, masnoća mesa kozlića sadržavala je mnogo više PUFA (P<0.01) nego masnoća bikova i janjaca. U usporedbi s međumišićnom masnoćom janjaca i bikova masnoću kozlića također je obilježavao mnogo veći sadržaj linolne kiseline (P<0.01). Najveća razina CLA u konfiguraciji c9,t11 zapažena je u masnoći janjaca (P<0,01) u odnosu na bikove i kozliće. Značajne razlike u sadržaju ovog izomera također su se pojavile između masnoće bikova i janjaca (P< 0,05). U Pokusu II ustanovljeno je da masnoća frizijskih ovaca sadrži više PUFA u usporedbi s ovcama Berrichone du cher (P<0.05) i više od poljske merino ovce. Najveći sadržaj palmitinske kiseline C16:0 nađen je u masnoći frizijskih janjaca (P< 0.01) Za razliku, manja količina stearične kiseline C18:O nalazila se u masnoći Wrzosówke (P< 0.01) nego u masnoći poljske merino ovce i ovce Berrichone du cher. Značajne razlike u sadržaju oleinske kiseline u masnoći otkrivene su između Wrzosówke i ovce Berrichone du cher. Nikakav očit utjecaj pasmine na sadržaj linolne kiseline C18:2 u međumišićnoj masnoći nije zabilježen. Značajan utjecaj pasmine primijećen je u srodnim dienima linolne kiseline c9,t11. Najviša razina ovog izomera otkrivena je u masnoći Wrzosówka janjaca. Iznosila je 86.7 % jedinica više ovog diena nego Berrichone du cher i 60% jedinica više od

poljske merinoovce te 19.l % jedinica više od frizijskih janjaca (sve su razlike statistički značajne (P< 0.01). Značajan utjecaj hranidbe na sadržaj masnoće mišića longissimus dorsi nije zabilježen (Pokus III). Najkorisniji sastav masnih kiselina nađen je u masnoći janjaca hranjenih koncentratom sa sjemenkama lana. U usporedbi s janjcima hranjenim zelenim krmivom kao i koncentratom količina masnih kiselina bila je oko 1.7 odnosno 2.4 % jedinica niža (P<0.05). Masnoću janjaca hranjenih koncentratom sa sjemenkama lana obilježio je i veći sadržaj nezasićenih masnih kiselina i srodnih diena ili linolne kiseline cis-9 trans-11. U usporedbi s janjcima hranjenim zelenim krmivom količina je bila oko 2.1 i 10.1% jedinica viša (P<0.01). Značajna razlika u sastavu ili masnim kiselinama masnoće mišića također je zamijećena između janjaca hranjenih zelenim krmivom i koncentratom. Masnoća janjaca hranjenih zelenim krmivom imala je više polunezasićenih masnih kiselina (P<0.05) i nešto više srodnih diena linolne kiseline c9,t11 nego ovce hranjene koncentratom.

Ključne riječi: preživači, meso, masne kiseline, CLA izomeri