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Fattening bulls on maize silage and concentrate supplemented with vegetable oils

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ABSTRACT

An experiment was carried out on 44 Black-and-White Lowland bulls allocated to 4 groups and fattened from 184 to 530 kg average body weight to investigate animal performance and meat quality when fed diets with balanced energy:protein ratio according to the INRA system. Diets consisted of maize silage and concentrate for the control group, supplemented with linseed, rapeseed oil cake, rape seed oil as additional fat sources for the experimental groups. Six animals from each group were slaughtered at the end of the experiment. The physical and chemical properties of meat, and its individual fatty acid and cholesterol contents were estimated. Average body weight gains of animals were similar in all groups reaching about 1.35 kg day^{-1}. The fat content increased to about 5% in dry matter with about 50% fat from linseed or rapeseed oil cake, enriched the lipids of *M. longissimus dorsi* in essential and unsaturated fatty acids, conjugated linoleic acid and decreased the cholesterol level, which was particularly marked when feeding the diet supplemented with rapeseed oil cake. The highest ratio of hypocholesterolemic to hypercholesterolemic acids was also found in the meat of animals fed diet with rapeseed oil cake.

KEY WORDS: bulls, fattening, vegetable oils, fat composition, fatty acids, meat properties

INTRODUCTION

The combination of maize silage with concentrate appears to be one of the most effective diets for fattening bulls, but their meat contains fat with a high ratio of saturated (SFA) to unsaturated (UFA) acids (Scollan et al., 1997; Givens et al., 2000). The fatty acid profile of meat fat can be modified by supplementing diets for ruminants with vegetable or fish oils, with biohydrogenation in the rumen being an important factor influencing changes in fatty acid profiles in meat tissue or milk fat (Kennelly, 1996; Stasiniewicz et al., 2000). Deposition of fatty acids in beef fat has become of interest during recent decades since it is now considered that polyunsaturated fatty acids, particularly of the n-3 family, in the diet for humans can prevent numerous disorders such as heart disease (Sheard, 1998), promote brain development and visual acuity in infants (Hoffmann et al., 1993), modulate autoimmunity (Calder, 1997; Grimble, 1998) and inflammatory disorders (Simopoulos, 1991). They are also believed to be involved in the pathophysiology of major depression (Maes, 1999).

The aim of the present study was to assess the effect of feeding fattening bulls with maize silage and concentrate diets supplemented with rape seed oil, rapeseed oil cake or linseed on bulls performance, meat quality, fatty acid proportions and cholesterol level in deposited meat tissue fat.

MATERIAL AND METHODS

Animals and feeding

The experiment was carried out on 44 Black-and-White Lowland bulls with an average 72% (50.0 to 87.5) HF blood share and average initial weight of 184±40 kg fattened to 530±10 kg final body weight. The animals were divided into four groups of 11 according to an analogue method taking into account initial body weight and HF blood share. Initial and final body weights were determined as mean weights before morning feeding for two successive days. The animals were kept in individual stalls equipped with an automatic drinking bowls and a slatted floor lined with rubber matting.

The bulls were given diets containing silage of whole maize plant, pelleted concentrate mixture (ϕ = 8 mm) and rapeseed oilmeal as a high-protein supplement. This was the basal diet for control group C, and was supplemented with different sources of fat in the experimental groups: ground linseed – group L, rapeseed oil cake – group RC or rape seed oil – group RO. The energy and protein value of feeds, components of concentrate mixtures (Table 1) and daily rations were established according to IZ-INRA (1997) feeding standards using WINWAR

TABLE 1

Ingredient composition of concentrate mixtures, %

Feed components	Concentrate mixtures			
	C[1]	L[1]	RC[1]	RO[1]
Triticale	57.5	62.5	56.0	54.7
Wheat bran	24.5	4.5	10.5	23.3
Soyabean oilmeal	15.0	11.0	1.5	14.3
Linseed ground	-	19.0	-	-
Rapeseed oil cake	-	-	29.0	-
Rape seed oil	-	-	-	4.8
Mineral mixture[2]	0.6	0.6	0.6	0.6
Binder	0.5	0.5	0.5	0.5
Limestone	1.9	1.9	1.9	1.8

[1] C – control; L – with ground linseed; RC – with rape seed oil cake; RO – with rape seed oil

[2] contained, g kg^{-1}: 102 P, 165 Ca, 46 Mg, 92 Na; mg/kg: 122.5 Cu, 315 Zn, 1075 Fe, 8.0 Co, 810 Mn

ver. 1.6 (2000), WINMIX ver. 1.7 (2000) and INRAtion ver. 2.63 (1998/99) software. Concentrate mixtures for experimental groups were formulated to include increased fat content but similar level of cereals, crude protein, PDI and UFV as in control diet.

Pellets of concentrate mixtures were produced using Type H-710 Rofama-Rogoźno (Poland) equipment after treatment at 185°C and 6 atm. for 1 sec. with steam. Pellet bathes were stored for no longer than 3 months.

Daily rations were established for each 30 kg body weight gain compartment and changed every 30±2 days. The feeding schedule was intended to contain from 2.5 to 4.5 kg of concentrate mixture in the daily ration and from 7 to 18 kg of maize silage, but in practice the animals received silage *ad libitum*. Rapeseed oilmeal (from 0.4 to 0.5 kg day^{1}) and concentrate mixture were given once daily to a separate box in the crib. Rapeseed oilmeal was offered only until the animals reached 450 kg body weight.

Sampling and analysis

At the end of the fattening period 6 bulls of each group were chosen at random, slaughtered and meat samples of *M. longissimus dorsi* were taken for fatty acids analysis in extracted fat by gas chromatography on Pye Unicam GC104 equipment using a 30 m long Supelcowax 10 column (f=0.53 mm), and cholesterol estimation on Pye Unicam GC106 using a 30 m long (f=0.53 mm) HP5 column. The physical and chemical properties of meat were estimated as described by Strzetelski et al. (1998). Nutrient content in feeds was determined according to AOAC (1990) methods.

The results were subjected to statistical analysis using one way analysis of variance according to Statgraphics Plus ver. 6.0 (1992).

RESULTS

The crude fat content in experimental feed mixtures was from 2.5- in group RC to 3.3-fold more in group L than in the unsupplemented control mixture (Table 2). Daily crude fat intake in groups averaged (g): C - 200.4; L - 372.4 ; RC - 313.4 and RO - 365.3, and oil supplement representing 0, 56.8, 45.8 and 44.1%, respectively, of total fat in the mixtures. The content of fat in dry matter of the whole ration of the respective groups was 2.7, 5.2, 4.3 and 4.8%. The concentrate mixture with rapeseed oil cake contained the highest level of crude protein and the lowest level of energy (UFV) and protein digestible in the intestine (PDI).

Daily intake of silage, concentrate, dry matter and PDIN did not differ among the groups. Crude protein intake in group RC was higher than in group L ($P<0.05$). Average maize silage intake during the experimental period was, as planned in the schedule of experiment, about 12 kg day^{-1} (Table 3). Diets for groups C and RO contained more PDIE than PDIN but this difference was small and after recalculation for UFV amounted to +2.3 g UFV^{-1}. In groups L and RC, PDIN exceeded PDIE and differences expressed as (PDIE – PDIN)/UFV were –1.4 g and –7.6 g UFV^{-1}, respectively for groups. Intake of PDIE in groups C and RO was greater than in groups L and RC ($P<0.01$ or 0.05). Energy intake (UFV) was slightly greater in groups L and RO than in other two groups, significant differences were found between group RC in relation to groups L and RO ($P<0.01$).

Daily body weight gain was assumed to 1300 g day^{-1}. This value was quite close to obtained in all groups and amounted about 1348±13 g day^{-1} (Table 4), but in the range of body weight from 350 to 450 kg daily gains were from 1400 to 1580 g day^{-1} (Figure 1) in accordance with energy content (UFV) of consumed feeds. The growth rate of fattening bulls in all groups was similar and linear during the fattening period (Figure 2). Complete feed, dry matter and nutrients efficiency did not differ between the groups, but a significant difference was found in UFV efficiency as groups RC and C utilized energy better than group RO ($P<0.05$).

Total SFA, particularly of C 14:0; C 15:0 and C 16:0, content in the lipids of *M. longissimus dorsi* of animals fed rations with RC was lower than on the other diets ($P<0.05$) leading to a pronounced increase of the UFA: SFA ratio ($P<0.01$). At the same time, the content of polyunsaturated fatty acids of the n-6 family with 18, 20 and 22 carbon atoms in the molecule was higher in this fat but this difference was not always significant (Table 5). The proportion of hypocholesterolemic to hypercholesterolemic acids in the meat of animals from group RC was higher than in the remaining groups ($P<0.01$). The content of SFA, UFA and UFA:SFA ratio in fat of

TABLE 2

Nutrient contents in feeds used in experiment, in 1 kg of feed

Feed	Dry matter g	Crude protein g	Ether extract g	Crude fibre g	Ash g	UFV	PDIN g	PDIE g
Maize silage	347	29	9.8	74.7	18.9	0.28	18	23
Rapeseed oilmeal	885	345	23.1	130.7	66.1	0.94	222	139
Rapeseed oil cake	894	325	148	137.7	62	0.69	200	89
Lineseed ground	916	218	331	101	38	1.32	127	60
Rape seed oil	992	-	980	-	15	2.80	-	-
Feed mixtures								
C[1]	881	164	23	44	30	0.98	113	107
L[1]	888	165	75	45	28	1.09	110	97
RC[1]	884	178	58	63	34	0.92	116	91
RO[1]	886	156	70	42	29	1.05	107	101

[1] C – control; L – with linseed; RC – with rapeseed oil cake; RO – with rape seed oil

TABLE 3

Daily intake of feeds and nutrients

Feed and nutrient	Groups				SE
	C[1]	L[1]	RC[1]	RO[1]	
Maize silage, kg	11.97	11.42	11.52	12.68	0.229
Concentrate mixture, kg	3.32	3.37	3.34	3.35	0.011
Rapeseed oilmeal, kg	0.29	0.28	0.30	0.30	0.03
Dry matter, kg	7.34	7.21	7.21	7.63	0.810
Crude protein, g	993^{ab}	984^{a}	1030^{b}	991^{ab}	7.047
PDIN, g	656	639	660	654	4.254
PDIE, g	672^{Bb}	629^{ABa}	610^{Aa}	671^{Bb}	6.586
UFV	6.89^{ABab}	7.12^{Bbc}	6.58^{Aa}	7.34^{Bc}	0.077

[1] C – control; L – with ground linseed; RC – with rapeseed oil cake; RO – with rape seed oil

^{a,b,c} – $P<0.05$

^{A,B} – $P<0.01$

$$SE = \sqrt{\frac{s^2}{n}}$$

TABLE 4

Body weight, daily gains and feed utilization

Item	Groups				SE
	C[1]	L[1]	RC[1]	RO[1]	
Initial body weight, kg	184	184	184	184	3.905
Final body weight, kg	529	529	528	530	0.934
Fattening period, days	253	259	261	256	3.986
Body weight gain, $g \cdot day^{-1}$	1367	1342	1328	1356	13.79
Feed utilization per 1 kg gain					
Maize silage, kg	8.76	8.53	8.70	9.38	0.230
Concentrate mixture, kg	2.44	2.53	2.53	2.48	0.028
Rapeseed oilmeal, kg	0.21	0.21	0.22	0.22	0.04
Dry matter kg	5.38	5.39	5.45	5.65	0.071
Crude protein, g	727	737	779	734	8.721
PDI, g	481	471	461	483	5.381
UFV	5.04^{a}	5.34^{ab}	4.97^{a}	5.44^{b}	0.069

[1] C – control; L – with ground linseed; RC – with rapeseed oil cake; RO – with rape seed oil

^{a,b} – $P<0.05$

$$SE = \sqrt{\frac{s^2}{n}}$$

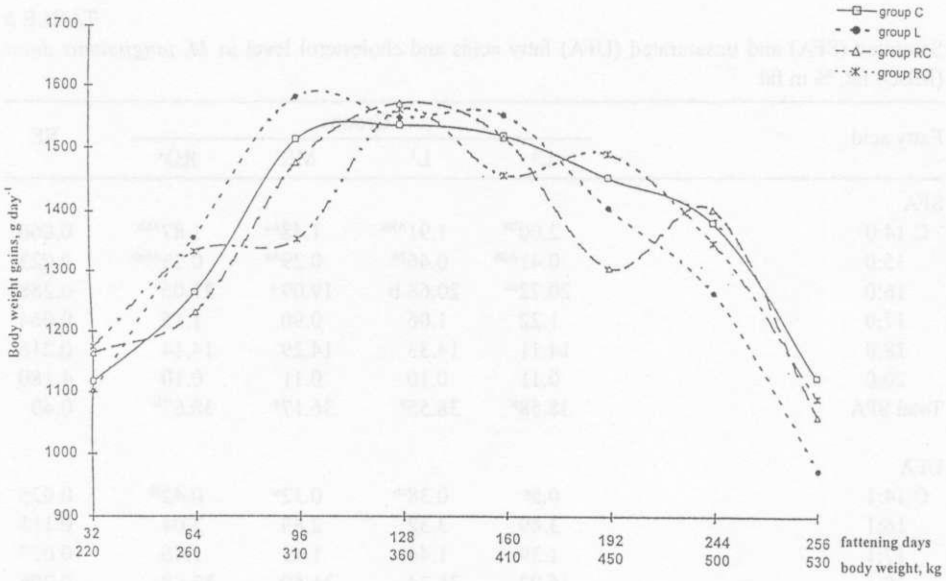

Figure 1. Daily body weight gains in the experimental period

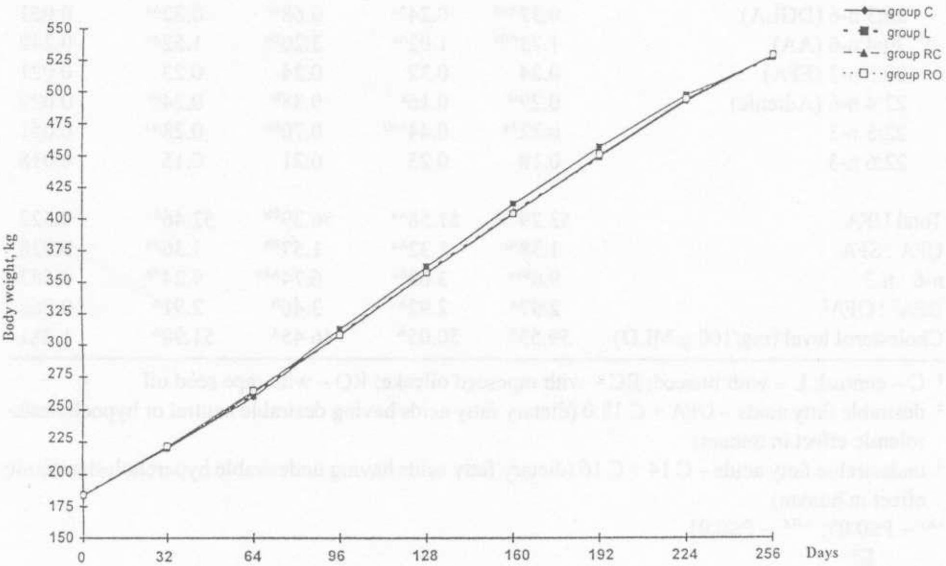

Figure 2. Growth rate of fattening bulls

TABLE 5

Saturated (SFA) and unsaturated (UFA) fatty acids and cholesterol level in *M. longissimus dorsi* (MLD) fat, % in fat

Fatty acid	Groups				SE
	C[1]	L[1]	MR[1]	RO[1]	
SFA					
C 14:0	2.00^{Bb}	1.91^{ABb}	1.48^{Aa}	1.87^{Abb}	0.066
15:0	0.41^{ABb}	0.46^{Bb}	0.29^{Aa}	0.35^{Abab}	0.023
16:0	20.72^{ab}	20.68 b	19.09^{a}	21.06^{b}	0.288
17:0	1.22	1.06	0.90	1.15	0.064
18:0	14.11	14.33	14.29	14.14	0.216
20:0	0.11	0.10	0.11	0.10	4.180
Total SFA	38.58^{b}	38.55^{b}	36.17^{a}	38.67^{b}	0.40
UFA					
C 14:1	0.5^{a}	0.38^{ab}	0.32^{a}	0.42^{ab}	0.025
16:1	3.49	3.32	2.89	3.04	0.113
17:1	1.39	1.44	1.43	1.46	0.057
18:1	36.92	35.74	35.69	37.69	0.706
18:2 n-6	6.80^{ab}	6.28^{a}	9.09^{b}	6.07^{a}	0.492
18:2 conjugated (CLA)	0.21^{a}	0.29^{ab}	0.31^{b}	0.20^{a}	0.016
18:3 n-3 ALA	0.33^{Aa}	1.28^{Cc}	0.63^{Bb}	0.27^{Aa}	0.088
18:3 n-6	0.10^{b}	0.04^{a}	0.07^{ab}	0.09^{b}	0.009
20:1	0.28^{ab}	0.23^{a}	0.26^{ab}	0.29^{b}	0.009
20:2 n-6	0.13^{a}	0.15^{ab}	0.19^{b}	0.16^{ab}	0.008
20:3 n-6 (DGLA)	0.37^{AaB}	0.24^{Aa}	0.68^{Bb}	0.32^{Aa}	0.051
20:4 n-6 (AA)	1.73^{ABa}	1.02^{Aa}	3.20^{Bb}	1.52^{Aa}	0.242
20:5 n-3 (EPA)	0.24	0.32	0.34	0.23	0.021
22:4 n-6 (Adrenic)	0.29^{ab}	0.16^{a}	0.38^{b}	0.24^{ab}	0.029
22:5 n-3	0.32^{Aa}	0.44^{AaB}	0.70^{Bb}	0.28^{Aa}	0.051
22:6 n-3	0.18	0.23	0.21	0.15	0.018
Total UFA	53.29^{AaB}	51.58^{Aa}	56.39^{Bb}	52.46^{Aa}	0.522
UFA : SFA	1.38^{Aa}	1.32^{Aa}	1.57^{Bb}	1.36^{Aa}	0.028
n-6 : n-3	9.0^{Bbc}	3.60^{Aa}	6.74^{ABb}	9.24^{Bc}	0.582
DFA[2] : OFA[3]	2.97^{A}	2.92^{A}	3.46^{B}	2.91^{A}	0.068
Cholesterol level (mg/100 g MLD)	59.53^{B}	50.05^{A}	46.45^{A}	51.98^{A}	1.281

[1] C – control; L – with linseed; RC – with rapeseed oilcake; RO – with rape seed oil

[2] desirable fatty acids – UFA + C 18:0 (dietary fatty acids having desirable neutral or hypocholesterolemic effect in human)

[3] undesirable fatty acids – C 14 + C 16 (dietary fatty acids having undesirable hypercholesterolemic effect in human)

^{a,b,c} – P≤0.05; ^{A,B,C} – P≤0.01

$$SE = \sqrt{\frac{s^2}{n}}$$

M. longissimus dorsi of bulls fed the mixture with linseeds compared with the control or RO group was similar (P>0.05) but content of C 18:3 n-3 acid was highest (P<0.01). The cholesterol level was highest in group C (P<0.01), in the remaining groups it was similar but lowest in group RC.

Data obtained for the physical and chemical properties of meat (Table 6) did not differ significantly between the groups.

TABLE 6

Chemical composition and physical and chemical properties of meat

Item	Groups C	L	RC	RO	SE
Dry matter, %	26.24	27.59	26.51	27.33	0.28
Crude protein, %	23.13	22.80	22.47	22.74	0.19
Crude fat, %	1.72[a]	3.67[b]	2.34[ab]	3.29[b]	0.26
Ash, %	1.14	1.04	1.09	1.08	0.03
pH 24 h in *M. longissimus dorsi*	5.46	5.47	5.47	5.48	0.01
Water holding capacity, %	24.83	24.65	24.10	25.02	0.19
Natural drip, %	0.68	0.91	0.43	0.69	0.09
Thermal drip loss, %	33.15	32.79	17.98	34.04	0.61
Total colouring substances, mg kg^{-1}	140.20[b]	96.73[a]	135.31[b]	125.33[ab]	6.44
Colour lightness, %	14.24[b]	14.66[b]	13.51[ab]	12.6[a]	0.28
Colour stability, %	3.66	3.46	2.80	5.39	0.58

[1]C – control; L – with ground linseed; RC – with rapeseed oil cake; RO – with rape seed oil

[a, b] – P ≤ 0.05

$SE = \sqrt{\frac{s^2}{n}}$

DISCUSSION

The high average daily body weight gains of animals in all groups obtained during the entire experimental period indicate that the feeding system used in this study resulted in the satisfactory formulation of the diets to cover the requirements of animals and rumen microorganisms. This is also corroborated by the growth rate and body size gains obtained in each particular weight compartment. The similar daily feed dry matter intake in all groups suggests that increase of fat up to 5% of dry matter in the diet in which about a half of fat was vegetable oil from ground linseed, rapeseed oil cake or rape seed oil does not alter feed intake and body gain. Rule et al. (1994) feeding bulls with diets based on maize silage with soyabean or rape seed containing from 4.7 to 11.2% fat in dry matter of ration found a slight tendency towards decreased feed intake and body weight gain only at the highest level of fat in the diet. The reason for some differences in daily intake of crude protein, PDI and energy (UFV) and efficiency of PDI and UFV kg^{-1} of body gain in the present experiment could be that the experimental diets were formulated with the intention to introduce a maximum of fat using feed ingredients of different fat and protein contents.

The higher ratio of UFA:SFA in *M. longissimus dorsi* of animals on rapeseed oil cake than on the other fat sources could be caused by limited biohydrogenation of UFA in the rumen because of the better protection of this fat from microbial activity. This suggestion is supported by the higher content of C 18:2 n-6 ($P<0.01$) in *M. longissimus dorsi* than in the remaining groups. Jilg et al. (1988), Murphy et al. (1990), Chang et al. (1991) and Rule et al. (1994) reported that the physical form of feed may influence protection of fat from biohydrogenation in the rumen. It can be presumed that rapeseed oil cake fat was better protected from biohydrogenation than that of linseed meal, leading to a decrease of C 18:2 n-6 in *M. longissimus dorsi.*

Animals on the diet with rape seed oil indeed consumed similar amounts of C 18:2 n-6 as animals in groups L and RC (37 g d^{-1}) but the concentration of this acid in *M. longissimus dorsi* was clearly lower, suggesting a higher degree of biohydrogenation in the rumen. Higher biohydrogenation of UFA in the case of feeding rape seed oil with the diet also clearly suggests a lower level of conjugated linoleic acid and linolenic (C 18:3 n-3) acid than in the group RC.

The higher contents of dihomo-γ-linoleic acid 20:3 n-6, arachidonoic acid 20:4 n-6, adrenic acid 22:4 n-6 and docosapentaenoic acid 22:5 n-3 in *M. longissimus dorsi* of animals in group RC than in remaining groups ($P<0.01$ or 0.05) could be a result of desaturation and elongation occurring in the tissue (Jenkins and Kramer, 1990; Nettleton, 1991; Chang et al., 1992). Significantly higher concentration of C 18:3 n-3 in *M. longissimus dorsi* of animals fed the diet with ground linseed, compared with the remaining groups, could be explained by higher intake of this acid in this group (106 g day^{-1}) than in groups L and RO (17 g day^{-1}). However, it can not be excluded that C 18:3 n-3 acid of linseed origin enriched the conjugated C 18:2 (CLA) pool in lipids of *M. longissimus dorsi*. Indeed, processes of hydrogenation do not cover CLA (Harfoot and Hazlewood, 1988), however during hydrogenation of linolenic acid in the rumen C 18:1 trans-11 acid is produced which can be transformed into CLA endogenously involving Δ-9desaturase (Griinari et al., 1997). The significantly higher content of conjugated C 18:2 (CLA) in the *M. longissimus dorsi* in group RC than in groups C and RO could probably be explained by slower biohydrogenation of isomer C 18:2 n-6 in the rumen. However it can not be excluded that the proportion of fatty acids in the fat of *M. longissimus dorsi* in respective groups was affected by different proportion of maize silage fat, which amounted to about 60% in the control group but only 30-36% of total dietary fat in experimental diets. These processes could be the reason that differences between the groups in the concentration of majority of fatty acids did not reach statistical significance, however, individual fatty acid contents in maize silage fat in this experiment were not measured.

The ratio of n-6:n-3 in fat of *M. longissimus dorsi* was in the range from 3.6:1 to 9.2:1 and was close to values from 3:1 to 9:1 in majority of body tissues reported by Horrobin (1990). A marked decrease of the n-6:n-3 ratio in meat of bulls fed linseed suggests that it has a higher dietetic value because of the beneficial anti-sclerotic properties of n-3 family acids (Brisson, 1986). They could also cause a decrease the level of total cholesterol in *M. longissimus dorsi* animals of this (L) group compared with the control group. On the other hand, the lower content of cholesterol in the meat of RC group animals than in the control group could probably be related to the higher content of unsaturated fatty acids and higher ratio of hypocholesterolemic to hypercholesterolemic acids.

CONCLUSIONS

Summarizing the results of the experiment, it can be concluded that fattening bulls from 184 to 530 kg body weight fed rations formulated according to IZ-INRA standards (1997) consisting of (DM basis) 56% maize silage and 44% concentrate supplemented with vegetable oils, provided an average daily body weight gain of about 1.35 kg. The fat content increased to about 5% in dry matter of the diet with about 50% fat of linseed or rapeseed oil cake, enriched the lipids of meat in essential, unsaturated fatty acids and conjugated linoleic acid and decreased cholesterol level, which was particularly marked when feeding the diet supplemented with rapeseed oil cake.

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STRESZCZENIE

Opas buhajków żywionych kiszonką z kukurydzy i mieszankami pasz treściwych z dodatkiem tłuszczów roślinnych

W doświadczeniu przeprowadzonym na 44 buhajkach rasy cb (4 grupy po 11), od średniej masy ciała 184 kg do 530 kg, badano efektywność opasu i jakość mięsa. Po sześć buhajków z każdej grupy ubito na zakończenie doświadczenia. Dawkę podstawową dla grupy kontrolnej stanowiła kiszonka z kukurydzy oraz granulowana mieszanka treściwa. W grupach doświadczalnych do mieszanki treściwej dodawano śrutowane nasiona lnu, makuch rzepakowy lub olej rzepakowy, jako źródło tłuszczu. Skarmiane dawki były zbilansowane pod względem energetyczno:białkowym według norm IZ INRA. Uzyskane dzienne przyrosty masy ciała buhajków wynoszące średnio 1,35±0,14 kg, wykorzystanie suchej masy skarmianych pasz, 5,4±0,07 kg/kg przyrostu, oraz właściwości fizyko-chemiczne mięsa nie różniły się istotnie pomiędzy grupami. W tłuszczu mięśnia najdłuższego grzbietu buhajków karmionych dawką z dodatkiem makuchu rzepakowego stwierdzono większą zawartość nienasyconych kwasów tłuszczowych o liczbie 18, 20 i 22 atomów węgla w cząsteczce oraz wyższy stosunek kwasów hipo- do hipercholesteromicznych niż w pozostałych grupach. Mięso buhajków z grup otrzymujących pasze z dodatkiem tłuszczów roślinnych, a szczególnie makuchu rzepakowego, zawierało mniej cholesterolu w tłuszczu mięsa niż w grupie kontrolnej.