Journal of Animal and Feed Sciences, 7, 1998, 261 – 271

Performance and body fat composition of fattening bulls fed diets with evening primrose (*Oenothera paradoxa*) oil cake

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(Received 12 March 1998; accepted 24 June 1998)

ABSTRACT

An experiment was carried out on 30 Black-and-White Lowland bulls fattened from 165 to 485 kg BW, divided into three groups fed diets without evening primrose oil cake (control group C) or with a contribution of 10 (group P1) or 30% (group P2) of evening primrose cake. Bull performance, nutrient digestibility, nitrogen balance, ammonia and volatile fatty acids in the rumen fluid, physico-chemical properties of meat and subcutaneous and kidney fat composition were estimated. Average daily body gain was 1333 g in group P1; 1235 g in P2; and 1216 g in C. The content of oleic ($C_{18:1}$) and linoleic ($C_{18:2\ n6}$) acid in subcutaneous and kidney fat was higher in bulls fed diets with evening primrose oil cake than in controls.

KEY WORDS: evening primrose cake, bull performance, fat composition, fatty acids

INTRODUCTION

The nutritive value and composition of evening primrose (*Oenothera paradoxa*) oil cake for ruminants indicates that it can be used as a supplementary feed for balancing protein and energy since it contains a relatively high level of methionine and a low level of lysine (Stasiniewicz et al., 1998). Moreover, the fat in evening primrose contains a high proportion of poly-unsaturated fatty acids, par-

ticularly of γ-linolenic ($C_{18:3\ n6}$) and linoleic ($C_{18:2\ n6}$) acids (Hudson, 1984; Lammer-Zarawska, 1992; Stasiniewicz et al., 1998) which can be absorbed from the digestive tract and deposited in animal products, favourably influencing their quality (Wright et al., 1974; Huhtanen and Poutiainen, 1985; Murphy et al., 1990; Strzetelski et al., 1992a, 1993).

The aim of the present study was to assess the effect of supplementing diets with evening primrose oil cake on fattening bull performance, meat quality and fatty acid proportions in the deposited fat.

MATERIAL AND METHODS

Experimental design

The experiment was carried out on 30.5 (±1) month old Black-and-White Lowland bulls of 165 (±25) initial to 485 (± 10) kg final body weight with an average 58% (33 to 87) HF blood share. The animals were divided into 3 groups of 10 according to an analogue method taking into account initial body weight and HF blood share. The animals were kept in individual stalls equipped with an automatic drinking bowl and a slatted floor lined with a rubber mattress. The bulls were fed different complete feed diets: group C, control, was fed a basal diet; group P1, a basal diet supplemented with 10% evening primrose oil cake, and group P2, with a 30% supplement of evening primrose oil cake (Table 1). At the end of the experiment 6 bulls from each group were slaughtered and the physico-chemical properties of meat and fat composition were determined.

Complete feed mixtures were pelleted (ϕ 8 mm) and fed *ad libitum*. From the beginning of the experiment, all of the animals additionally received 0.5 kg/day of

TABLE 1

Composition of compound feeds, %

Item	Group		
	C	P1	P2
Ground barley	10	28	35
Dehydrated whole barley crop with undersown lucerne	70	50	18
Dried sugar beet pulp	18	10	15
Evening primrose oil cake	–	10	30
Mineral mixture[1]	2	2	2

[1] composition, %: limestone 50, $CaHPO_4$ 25, commercial mineral mixture MMB 25; in 1 kg, g: Ca-267, P-83, Na-12,5, Cl-19, Mg-11,5; Cu 332,5, Mn-875, Co-5, J-5, Zn -1250

wheat chaff for 1.5 months of fattening, thereafter 1.0 kg/day of barley straw. The amount of feed given and refusals were controlled daily.

An additional 9 Black-and-White Lowland bulls (3 in each group) of average body weight 365 (±15) kg were used for nutrient digestibility and nitrogen balance determination. The animals were fed as in the fattening experiment. After a 30 day adaptation period, urine and faeces were collected for 5 days and afterwards rumen fluid samples were withdrawn with vacuum tubing at 0, 2, 4 and 7 h after feeding.

Chemical analysis and statistics

The nutrient content in feeds, faeces and urine and chemical composition of meat were determined using AOAC (1990) methods, ammonia-N in the rumen fluid according to the Conway microdiffusion method, pH was measured potentiometrically. Total and individual volatile fatty acids in the rumen liquor and fatty acids in subcutaneous and kidney fat were determined by GLC (Philips PU 4500). The pH of meat was determined using a Cnick Partamess 651-2 pH-meter in water homogenates of *M. longissimus dorsi* samples taken beyond the 11, 12 and 13 rib 45 min after slaughtering, and in 3 lateral cuts of *M. longissimus dorsi* samples 24 h after slaughtering. Meat water holding capacity was determined according to Grau and Hamm (1952), natural drip loss according to Krzywicki and Wichłacz (1974), thermal drip loss, as by Walczak (1959), content of colouring substances, colour lightness and colour stability according to Kortz et al. (1968).

Complete feed mixture composition and energetic and protein value were estimated using INWAR ver. 1.0 (1993) and INRAtion ver. 1.2.6 (1993) software according to the INRA (IZ, 1993) system. The values of protein degradability coefficients in the rumen (deg) and intestinal digestibility of feed protein undegraded in the rumen (PDIA) were obtained as in our previous experiment on the same batch of evening primrose oil cake (Stasiniewicz et al., 1998).

The results were subjected to statistical analysis using one way analysis of variance and multiple interval test according Statgraphics Plus 6.0 software (1992).

RESULTS

Rumen degradability of feed protein (deg) and intestinal digestibility of rumen undegraded feed protein (PDIA) coefficients were the same as in our previous work (Stasiniewicz et al., 1998), 0.39 and 0.65, respectively.

The ether extract content in the diets increased as the proportion of evening primrose oil cake rose (Table 2). The crude protein, PDI and feed units for meat production (UFV) levels were slightly higher, and crude fibre was lower in diet P2 than in the remaining diets.

TABLE 2

Compound feed components, chemical composition and nutritive value

Feed	Chemical composition, %					In 1 kg of DM (INRA system[1])		
	dry matter	crude protein	ether extract	crude fibre	ash	PDI, g		
						UFV	PDIN	PDIE
Ground barley	88.5	9.69	2.26	4.96	2.18	1.18	72	100
Dehydrated whole barley crop with undersown lucerne	91.20	14.91	2.60	27.75	8.00	0.51	104	90
Dried sugar beet pulp	90.39	10.37	0.89	19.21	3.48	1.11	74	117
Evening primrose oil cake	90.41	21.18	12.19	21.42	7.95	0.50	151	125
Barley straw	86.00	4.83	1.93	31.97	4.65	0.35	35	52
Wheat chaff	86.6	4.21	1.51	31.52	6.55	0.32	31	49
Compound feed								
C	90.70	13.33	2.21	23.31	4.72	0.68	93	95
P1	90.20	13.35	3.24	19.30	5.05	0.73	94	97
P2	89.70	13.99	5.05	16.06	6.91	0.82	101	105

[1] UFV – unit for meat production; PDI protein truly digested in the small intestine; PDIN – PDI dependent on ammonia-N amount; PDIE – PDI dependent on energy amount

TABLE 3

Daily feed and nutrients intake

Item	Group			SE
	C	P1	P2	
Concentrate, kg	8.76[a]	8.80[a]	8.75[a]	0.54
Dry matter, kg	8.84[a]	8.81[a]	8.69[a]	0.48
Crude protein, g	1192.8[a]	1207.8[a]	1254.1[a]	72.28
UFV1, g	5.721[a]	6.186[bc]	6.387[c]	0.37
PDI1, g	776.5[a]	774.2[a]	820.7[b]	46.01
PDI1, g	+23.7	+39.0	+47.5	4.26

a, b, c – $P<0.05$

[1] see Table 2

Daily intake of concentrate mixtures, dry matter and crude protein was similar in all groups (Table 3). The intake of energy and PDI was highest in group P2 and lowest in animals of the control group C. Daily body gain and feed efficiency were higher in animals fed the complete feed, P1, than in the remaining groups (Table 4).

Coefficients of apparent digestibility of dry matter, organic matter, crude protein and crude fibre decreased, nitrogen-free extractives did not differ between the

TABLE 4

Body liveweight, daily gains and feed utilization

Item	Group C	Group P1	Group P2	SE
Initial liveweight, kg	162.3[a]	167.3[a]	164.4[a]	20.71
Final liveweight, kg	487.0[a]	481.9[a]	489.2[a]	8.42
Fattening period, days	270[a]	237[b]	267[ab]	9.52
Daily gain, g	1216[a]	1333[b]	1235[ab]	125.10
Feed utilization, per 1 kg gain				
dry matter, kg	7.27[b]	6.61[a]	7.04[ab]	0.71
crude protein, g	980.9[ab]	906.1[a]	1015.4[b]	98.32
UFV[1], g	4.70[A]	4.64 [A]	5.17[B]	0.55
PDI[1], g	630.3[AB]	580.8[A]	664.5[B]	62.57

a, b, c – $P<0.05$
[1] see Table 2

TABLE 5

Nutrients digestibility, N-retention, concentration of total VFA and their molar proportion (4 h after feeding, mean)

Item	Group C	Group P1	Group P2	SE
Nutrients digestibility, %				
dry matter	68.0[b]	68.3[b]	64.4[a]	1.95
organic matter	71.9	70.4[ab]	67.0[a]	2.15
crude protein	68.4[a]	68.2[a]	64.5[a]	2.30
ether extract	96.6[Aa]	97.1[Aab]	97.5[Bc]	0.19
crude fibre	57.4[b]	49.5[ab]	44.7[a]	4.47
N-free extractives	97.8[a]	97.7[a]	97.4[a]	0.19
N-retention, g	40.44[Aa]	50.16[Aab]	68.48[Bb]	7.33
N-retention as % of N-intake	30.7	34.8	37.1	6.05
N-retention as % of N-digested	44.9	51.0	57.5	8.28
Total VFA, mmol/l	57.28	48.52	37.10	14.76
Molar proportions of VFA, %				
C_2	62.1	59.6	57.8	2.47
C_3	16.7[a]	19.0[ab]	21.3[b]	1.72
C_4	17.7	18.6	18.3	1.32
residual	3.5	2.8	2.6	1.28
$C_2 : C_3$	3.71[b]	3.14[ab]	2.71[a]	0.42
$C_3 : C_4$	0.94	1.02	1.16	0.14

a, b – $P \leq 0.05$; A, B – $P \leq 0.01$
without letters – $P > 0.05$

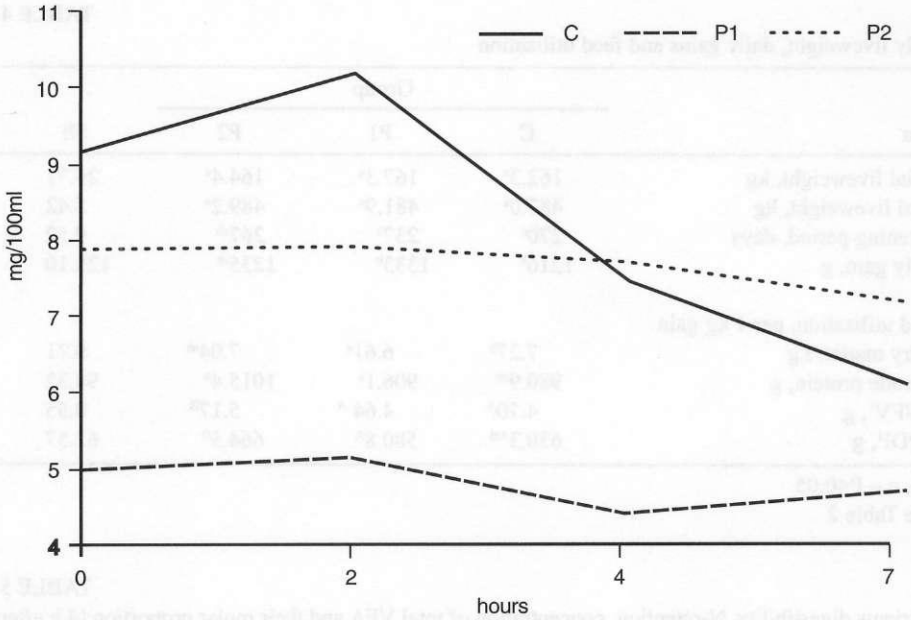

Figure 1. NH_3-N level in the rumen fluid; groups: ___ C ----- P1 _ _ _ P2

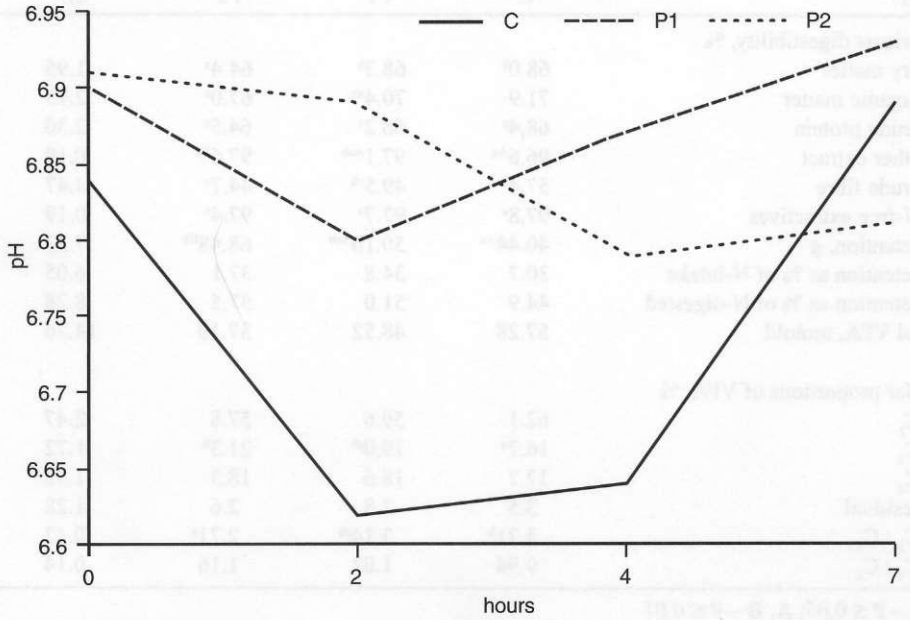

Figure 2. pH of the rumen fluid; groups: ___ C ----- P1 _ _ _ P2

TABLE 6

Fatty acid composition of subcutaneus and kidney fat, %

Acid	Perinephric fat groups				Subcutaneous fat groups			
	C	P1	P2	SE	C	P1	P2	SE
C_{12}	0.057^{ab}	0.065^{a}	0.043^{b}	0.002	0.053	0.057	0.053	0.003
C_{14}	2.048	2.032	1.698	0.050	2.25	2.63	2.15	0.084
$C_{14:1}$	0.710^{aA}	0.553^{aB}	0.520^{bB}	0.013	1.190	1.116	1.095	0.052
C_{15}	0.902^{aA}	0.630^{bB}	0.485^{bB}	0.025	0.660	0.657	0.552	0.028
izo-C_{16}	0.475^{aA}	0.295^{bB}	0.188^{cB}	0.014	0.345^{aA}	0.212^{bB}	0.160^{bB}	0.011
C_{16}	21.40^{aA}	21.03^{aAB}	17.69^{bB}	0.330	24.96^{a}	23.14^{ab}	21.67^{b}	0.336
$C_{16:1}$	2.27	1.87	1.87	0.073	5.71^{a}	4.94^{ab}	4.17^{b}	0.155
C_{17}	2.43^{aA}	1.83^{bB}	1.38^{cC}	0.035	1.52	1.45	1.30	0.033
izo C_{18}	0.96^{aA}	0.66^{bB}	0.48^{cC}	0.018	1.45^{aA}	1.14^{bB}	0.89^{cB}	0.028
C_{18}	31.57^{a}	32.84^{a}	25.56^{b}	0.757	13.40	13.62	12.30	0.440
$C_{18:1}$	28.43^{aA}	29.68^{aA}	39.84^{bB}	0.609	41.522	43.22^{ab}	45.92^{b}	0.451
C_{20}	1.30	1.28	1.40	0.046	0.93	1.15	1.20	0.037
$C_{18:2\ n6}$	3.76^{aA}	4.60^{aA}	6.83^{bB}	0.157	2.83^{aA}	3.99^{bA}	5.83^{cB}	0.154
$C_{18:3\ n6}$	0.34	0.34	0.35	0.018	0.16	0.25	0.26	0.018
$C_{18:3\ n3}$	2.65^{aA}	1.64^{bA}	1.19^{cB}	0.059	2.22a	1.71b	1.66b	0.061
C_{21}	0.365	0.380	0.422	0.018	0.487	0.457	0.452	0.030
$C_{20:2}$	0.188	0.165	0.177	0.013	0.162	0.178	0.167	0.013
C_{22}	0.113	0.118	0.175	0.011	0.111^{a}	0.112^{a}	0.198^{b}	0.011

a, b, c – $P \leq 0.05$; A, B – $P \leq 0.01$
without letters – $P > 0.05$

TABLE 7

Chemical composition and physico-chemical properties of meat

Item	Group C	P1	P2	SE
Dry matter, %	26.12	25.71	26.46	0.75
Crude protein, %	21.94	21.91	21.50	0.51
Crude fat, %	2.37	2.85	3.47	1.27
$pH_{45\ min}$ in *M. longisimus dorsi* at 11, 12 and 13 rib, av.	6.59	6.54	6.60	0.03
$pH_{24\ h}$ – in *M. longisimus* dorsi slaughter on section	5.59	5.58	5.64	0.03
Water holding capacity, %	28.96	29.22	28.83	0.52
Natural drip, %	0.84	0.61	1.30	0.14
Thermal drip loss, %	29.67	29.19	28.08	0.58
Total colouring substances content, mg/kg	131.39	123.16	137.07	6.60
Colour lightness, %	13.47	13.40	12.11	0.27
Colour stability, %	6.50	6.23	7.91	0.53

$P > 0.05$

groups but ether extract digestibility coefficients, nitrogen retention and utilization increased with increasing evening primrose oil cake content in diets (Table 5). The molar proportions of C_2 and C_2:C_3 in the rumen liquor were lower, but the proportion of C_3 and C_3:C_4 increased when the amount of evening primrose oil cake in the diet increased (Table 5). The pH values were higher (Figure 1) and the level of ammonia-N in the rumen liquor were lower (Figure 2) in the groups fed diets with evening primrose oil cake.

The proportions of γ-linolenic ($C_{18:3\ n6}$) acid (GLA) in subcutaneous and kidney fat were similar in all groups, but of oleic acid $C_{18:1}$ and linoleic $C_{18:2\ n6}$ acid were significantly higher in animals fed diets with evening primrose oil cake (Table 6). The type of diets did not affect the composition of meat or its physico-chemical properties (Table 7).

DISCUSSION

The highest daily body gains and significantly better nutrient efficiency in the group of bulls fed the complete feed containing 10% evening primrose oil cake suggest that the cake may favourably influence animal performance. However, the worse performance results in group P2 which was fed the complete feed with 30% of oil cake suggest that an excessively high proportion of cake in the diet should not be recommended for fattening bulls. The probable reason for worse performance in group P2 could be the lower nutrient digestibility of this diet resulting from the depressing effect of tannins. Evening primrose oil cake contains a relatively high level of tannins that form complexes with protein. These complexes are indigestible in the rumen and small intestine (Hanczakowski and Szymczyk, 1993).

The lower level of ammonia-N in the rumen of bulls fed diet P2 could result from the lower degradability of protein of this diet. Taking into consideration lower volatile fatty acid concentration in the rumen in this group and, in turn, the reduced supply of energy needed for microbial protein synthesis, it should not be presumed that microbial protein synthesis in this group was higher than in the remaining groups, causing the ammonia level in the rumen to decrease.

The lack of significant differences between the groups in N-free extractive digestibility could be explained by their similar dietary starch contents, which are not affected by tannins. The decrease in crude fibre digestibility of diets containing cake, particularly of diet P2, could be caused by an increased level of fat introduced with the cake into these diets (Kowalczyk et al., 1977). It could be also presumed that poly-unsaturated fatty acids of evening primrose oil were biohydrogenated in the rumen and the trans-acids that were so formed inhibiting fermentation and cellulolytic activity in the rumen (Banks et al., 1990). Inhibition of cellulolytic activity could in turn have consequences in lowering total volatile fatty

acids and acetic acid as well as its proportion to propionic acid in the rumen fluid. Similar changes and consequences were found in other experiments (Sutton et al., 1983; Jenkins and Jenny, 1989; Strzetelski et al., 1992b).

Daily body weight gain in animals of group P2 receiving more cake with their diet was not worse than in the control group, despite the negative effect of a higher proportion of evening primrose oil cake on digestive processes and fermentation in the rumen. One could suppose that γ-linolenic ($C_{18:3\ n6}$) acid, a component of evening primrose oil and an important factor regulating tissue metabolic rate, reduced the negative effect of antinutritive factors of evening primrose on nutrient efficiency (Horrobin, 1990). It is difficult to explain the higher nitrogen retention than in the remaining groups which did not reflect of higher body gain.

An increase of oleic and linoleic acid proportions in subcutaneous and kidney fat could reflect higher intake of evening primrose oil. Dinius et al. (1974) found an increased proportion of these acids in subcutaneous and kidney fat in bulls when the safflower oil intake was higher. Other authors reported an increased content of C_{18} acids in milk fat after feeding cows diets with oil seeds (Stasiniewicz, 1982; Murphy et al., 1990; Strzetelski et al., 1993).

Higher proportions of oleic ($C_{18:1}$) and linoleic acids ($C_{18:2}$) in the fat of bulls fed diets with 30% evening primrose oil cake could suggest transformation of acids with three double bonds by biohydrogenation or be a result of their higher intake, however, the relatively low proportion of stearic acid ($C_{18:0}$) does not indicate that this acid was the end product of biohydrogenation of unsaturated acids, nevertheless, it is worth mentioning that Banks (1987) reported partial dehydrogenation of stearic acid in the wall of the small intestine and its lower deposition in fat. The lack of differences between the groups in chemical composition, physicochemical properties of meat and low proportion of α-linolenic ($C_{18:3\ n3}$) and γ-linolenic ($C_{18:3\ n6}$) acids did not point to improvements of meat quality, however there was a significant increase in the proportion of oleic ($C_{18:1}$) and linoleic ($C_{18:2}$) acids in fat deposited in the body owing to feeding bulls a diet containing evening primrose oil cake.

It can be concluded that supplementing the complete feed mixture for fattening bulls with 10% evening primrose oil cake favourably influenced animal performance suggesting a stimulating effect of γ-linolenic ($C_{18:3\ n6}$) acid, a component of evening primrose oil, on nutrient efficiency. However, the effect of greater amounts (30%) of evening primrose oil cake in the diet did not improve animal performance compared with animals fed the control diet without oil cake, may be because of the decreased nutrient digestibility of such a diet. Feeding diets with evening primrose oil cake increased the proportion of oleic and linoleic acids in fat deposited in the body but the deposited fat was not enriched in γ-linolenic ($C_{18:3\ n6}$) acid compared with animals fed the control diet.

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STRESZCZENIE

Wpływ skarmiania makuchu z wiesiołka (*Oenothera paradoxa*) na wyniki produkcyjne i skład tłuszczu intensywnie opasanych buhajków

Prowadzono badania na 30 buhajkach rasy nizinnej czarno-białej opasanych od 165 do 485 kg masy ciała, podzielonych na trzy grupy i żywionych mieszanką pasz bez dodatku (grupa C) lub z dodatkiem 10% (grupa P1) bądź 30% (grupa P2) makuchu z wiesiołka. Oznaczono strawność składników pokarmowych, bilans azotu, stężenie azotu amonowego i lotnych kwasów tłuszczowych w treści żwacza, fizyko-chemiczne właściwości mięsa oraz skład tłuszczu podskórnrgo i okołonerkowego. Średnie dzienne przyrosty masy ciała wynosiły w grupie P1 – 1333 g; P2 – 1235 g, w grupie C – 1216 g. Zawartość kwasu oleinowego ($C_{18:1}$) i linolowego ($C_{18:2\ n6}$) w tłuszczu podskórnym i okołonerkowym była większa u zwierząt żywionych dawkami z makuchem z wiesiołka niż w grupie kontrolnej.