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SHORT NOTE [NOTA CORTA]

EFFECTS OF HIGH SOYBEAN OIL FOR GOATS IN LATE LACTATION ON INTAKE, MILK COMPOSITION AND FATTY ACID PROFILE

[EFECTO DE UN ALTO NIVEL DE ACEITE DE SOYA PARA CABRAS AL FINAL DE LACTACIÓN SOBRE EL CONSUMO, COMPOSICIÓN DE LECHE Y PERFIL DE ÁCIDOS GRASOS]

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SUMMARY

Animal fat and vegetable oils are generally added to livestock diets to increase energy density. Unlike other ruminants, goats can tolerate more than 6% dietary fat. Feeding a diet containing soybean oil (SO), rich in polyunsaturated fatty acids (PUFA) to goats can change the milk fat composition, thereby modifying the nutritional quality of the milk. PUFA such as linoleic acids are considered healthier fats since they have been shown to reduce the risk of cardiovascular diseases in humans. Eighteen dairy goats (3 - 4 yr.; BW = 40 kg; 9 Saanen and 9 Alpine) in late lactation were used in an experiment to determine the effect of high PUFA (12% soybean oil; 12% SO) on feed intake, milk composition and fatty acid profile. Does were group fed once a day (2 pens per treatment) a 16% CP and 3.5 Mcal DE/kg diets containing either 6 or 12% SO for 24 d. Feed intake was recorded daily during the trial and milk yield was recorded from d-10 to d-24. Milk samples were collected 3 times a week and analyzed for protein, fat, lactose, and total solids. Milk fat was extracted and prepared for fatty acid methyl esters (FAME). The FAMEs were analyzed using a gas chromatography (GC) unit, fitted with a 60 m x 0.25 mm i.d. fused silica SP 2380 (Sigma-Aldrich) capillary column. The data were analyzed using MIXED procedures in SAS as a completely randomized design with repeated measures. Dietary treatments did not affect ($P > 0.05$) pen feed intake, milk yield or milk composition (fat, protein, lactose and total solids). Diet containing 12% SO decreased ($P < 0.05$) the proportion of saturated fatty acids (SFA; C6:0, C8:0, C10:0, C12:0, C14:0, C16:0) and increased ($P < 0.01$) the proportions of monounsaturated fat (MUFA; C18:1n9; C18:1t), and the predominant PUFA, linoleic acid (C18:2n6). The results indicate that goats consuming diet with 12% SO (high PUFA) in late lactation produced milk with higher proportions of PUFA and MUFA and lower proportions of SFA compared to 6% SO.

INTRODUCTION

Dietary fat supplements generally improve efficiency of energy utilization in dairy animals, without the heat loss associated with the conversion of carbohydrates to fatty acids during lactation. However, supplemental fat above 6% decreases fiber digestion and milk fat content in cattle (Palmquist and Jenkins, 1980). Goats can withstand 10-15% fat in the diet without any of the negative effects observed in cattle (Carmichael et al., 2003). Unlike cows, goats tend to have higher milk fats with high dietary fat supplementation (Chilliard et al., 2003). Production of healthier milk through dietary manipulation is feasible with goats. Feeding a diet rich in polyunsaturated fatty acids (PUFA) to dairy goats can change the fatty acid (FA) profile and composition of milk, thereby modifying its nutritional quality. Soybean oil is rich in PUFA and can be an ideal dietary lipid supplement in dairy goat diets. Goat milk is naturally homogenized and has a higher concentration of medium-chain fatty acids. Because of these qualities, goat milk is more easily digestible than cow milk. The benefits of goat milk can be further increased by increasing its PUFA content through the inclusion of soybean oil in the diet. In humans, high levels of dietary PUFA are associated with low incidences of cardiovascular diseases. The long-range goal of this project is to make goat products healthier and more nutritious to humans. The general objective was to incorporate higher proportions of polyunsaturated fatty acids in goat milk. The specific objective of the study was to determine the effect of a higher level of dietary unsaturated fat (12% soybean oil) supplement on the composition and fatty acid profile of milk from dairy goats.

MATERIALS AND METHODS

Animals and Treatments

Eighteen dairy goats grouped in pens (2 pens of 5 goats each; 2 pens of 4 goats each) were used in this experiment. Each pen had an indoor part (6 x 6 m)

and an outdoor part (6 x 6 m). In late lactation (approximately 180 days in milk), the does were stratified by previous milk yield and lactation number and then randomly assigned to two dietary treatments. The experimental diets contained 30% roughage and 70% concentrate with either 6% (control) or 12% soybean oil (Table 1). The diets were isocaloric and isonitrogenous. The animals were fed the experimental diets every day, and water was available at all times. Two pens were assigned to each dietary treatment. The experiment lasted 24 days. The protocol for this experiment was approved by the Institutional Animal Care and Use Committee (IACUC) at Fort Valley State University (FVSU).

Table 1. Feed composition and analysis.

Ingredient, % DM	6% SO	12% SO
Alfalfa meal	33.0	35.0
Yellow corn, ground	35.0	20.0
Soybean hulls	8.0	13.5
Soybean meal, 44%	16.0	16.0
Soybean oil	6.0	12.0
Trace mineral salt[a]	0.5	0.5
Limestone	0.5	0.5
Dicalcium Phosphate	0.5	2.0
Vitamin premix[b]	0.5	0.5
Analysis		
CP	16.98	16.40
NDF	28.49	24.80
ADF	17.40	15.55
Ether extract	7.33	12.13
DE, Mcal/kg (Calculated)	3.5	3.6
Ca:P	2.4	2.5

[a] Contained 95 to 98% NaCl and at least 0.05% Mg, 0.032% Cu, 0.005% Zn, 0.24% Fe, 0.011%, Co, 0.007% I and 0.24% Mn.
[b] Contained at least 2,200 IU vitamin A, 1,200 IU vitamin D_3 and 2.2 IU vitamin E per gram.

Sampling and analysis
Feed intake was recorded daily during the trial and milk yield was monitored for two weeks after the diets had been fed for 10 days. Feed samples were collected, ground, and analyzed for composition using AOAC (1984) procedures.

Milk samples were collected every 4 days and analyzed for protein, fat, lactose, and solid non fat using a MilkoScan S 50B unit (Foss Electric A/S, Eden Prairie, MN, USA). The MilkoScan S 50B is an automatic, microprocessor-controlled infrared instrument for the determination of nutritive constituents in milk. Milk fat was extracted and prepared for fatty acid methyl esters (FAME). The FAMEs were analyzed using a gas chromatography (GC) Unit (Thermo Electron Corporation, Louisville, CO, USA), equipped with a flame ionization detector, an autosampler AS 3000, and a 60 m x 0.25 mm i.d. fused silica SP 2380 capillary column (Sigma-Aldrich, Supelco, Inc., PA, USA). The column temperature was programmed from 50 °C (2 min) to 250 °C at 4 °C/min. The individual FAMEs were expressed as relative weight percentage.

Blood samples were collected every 4 d by jugular venipuncture into Vacutainer tubes containing 81 µl of 15% K_2EDTA solution, and stored on ice. Blood samples were centrifuged at 1,000 x g for 20 min and the plasma samples were stored at -20 º C. A month after the end of the experiment, plasma samples were analyzed for urea N (PUN), glucose using commercial clinical chemistry kits from Thermo Electron Corporation (Thermo Electron, Louisville, CO, USA) and non-esterified fatty acids (NEFA) using the NEFA-HR(2) microtiter procedure from Wako Chemicals (NEFA-HR(2), Code No. 999-34691; Wako Chemicals, Richmond, VA, USA) at 550 nm. The absorbance values for the metabolites were read using a µQuant Microplate Reader (Bio-Tek, Winooski, VT, USA).

Statistical Analysis
The data were analyzed using MIXED procedures in SAS as a completely randomized design with repeated measures. When significant by ANOVA ($P < 0.05$), the means were separated using the LSD test.

RESULTS AND DISCUSSION

Feed intake
Pen intakes were similar ($P > 0.05$) with an average of 7401 ± 275 g for the high SO diet compared to 7615 ± 344 g the 6% SO fed does. The diets being isocaloric and isonitrogenous, and the goats having a high tolerance for dietary fat, we did not expect to see any differences in intake. However, there was a trend ($P = 0.06$) for higher intakes for the 6% SO diets during the first (8544 ± 429 g vs 7383 ± 384 g) and a significant difference during the second (8839 ± 404 g vs 7311 ± 362 g) sampling compared to those fed the high SO diet. This may be due to the short adaptation period.

Blood Metabolites
Plasma glucose (81.8 ± 1.70 mg/dl) and urea nitrogen (6.75 ± 0.453 mg/dl) concentrations were not affected ($P > 0.05$) by dietary treatments (Table 2). Plasma NEFA was significantly higher ($P < 0.001$) in goats fed the 12% soybean oil (0.363 ± 0.028 mmol/l) compared to the 6% soybean oil group (0.218 ± 0.032 mmol/l). Higher plasma NEFA for the 12% SO group, may relate to higher dietary intake of fat rather than body fat mobilization. It has been reported that goats output more of their dietary fat into milk fat (Chilliard et al., 2003). But during late lactation, it is not clear if the lower ability to produce milk will influence the transfer or conversion of plasma NEFA into milk fat.

Milk yield, Composition and Fatty acid Profile
Dietary treatment also did not affect ($P > 0.05$) milk yield and composition in goats (Table 2). Percentages

of fat, protein, lactose, and total solids were not significantly different between the treatment groups. Results on milk yield are similar to the findings of Chillard et al. (2001) and that of milk fat contents are in agreement with reports from Bauman and Griimari (2001).

The proportions of saturated fatty acids were higher ($P < 0.001$) in the control group (6% soybean oil) compared to the 12% soybean oil group (Table 2). The control group had higher ($P < 0.05$) percentages of caproic (C6:0), caprylic (C8:0), capric (C10:0), lauric (C12:0), myristic (C14:0), and palmitic (C16:0) acids compared to the 12% SO-treated group. The predominant saturated fatty acid in goat milk was palmitic acid.

The predominant monounsaturated fatty acid (MUFA) in goat milk was oleic acid (C18:1n9). The proportions of oleic acid and elaidic acid (C18:1t) were significantly higher ($P < 0.001$) in the 12% SO group compared to the control group (Table 2). The proportions of PUFA were higher ($P < 0.05$) in milk from the 12% SO-fed goats compared to the 6% SO group. Linoleic (C18:2n6) and linolenic (C18:3n3) acids were the predominant PUFA in goat milk. The concentration of linoleic acid was significantly higher in the 12% fat supplement group compared to the control group (Table 2). Soybean oil, rich in C18:2, was added as free oil during mixing of the diet. Chillard et al. (2003) reported that as little as 3-4% of dietary DM as free oil may be sufficient to inhibit ruminal biohydrogenation resulting into incorporation of more dietary PUFA into milk fat. The levels of fatty acids in the milk usually indicate the extent of ruminal biohydrogenation of the dietary unsaturated fatty acids. The results of this study indicated that a significant proportion of dietary unsaturated fat escaped rumen bio-hydrogenation. Feeding 12% SO was sufficient to overwhelm microbial hydrogenation and increase the concentration of milk PUFA. Since soybean oil is rich in PUFA, particularly linoleic acid (C18:2n6), the treated group had significantly higher linoleic acid content in milk compared to the control group.

CONCLUSION

Feeding a diet with 12% soybean oil did not affect feed intake and milk yield in goats in this experiment. Monounsaturated fatty acid and PUFA contents in milk fat were higher in the 12% soybean oil group compared to the control group. Goats fed a higher level of dietary unsaturated fat (12% soybean oil) produced milk with higher proportions PUFA and MUFA, and lower proportions of SFA (lauric, myristic, and palmitic acids) compared to the controls. The results of this experiment showed that feeding dairy goats in late lactation a diet containing 12% soybean oil is an effective dietary manipulation method to produce healthier goat milk for human consumption.

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Table 2. Blood metabolites, milk yield, composition and milk fatty acid profile from dairy goats fed high levels of dietary soybean oil.

Items	6% SO	12% SO
Blood metabolites		
Glucose, mg/dl	82.0 ± 1.8	81.5 ± 1.6
PUN, mg/dl	7.07 ± 0.48	6.42 ± 0.43
NEFA, mmol/l	0.22[b] ± 0.032	0.36[a] ± 0.029
Milk Yield, kg	1.08 ± 0.16	1.17 ± 0.14
Protein , %	4.14 ± 0.12	4.01 ± 0.11
Fat, %	4.61 ± 0.24	4.69 ± 0.24
Lactose, %	4.24 ± 0.07	4.31 ± 0.06
Total Solids, %	13.79 ± 0.34	13.81 ± 0.32
Fatty acids, %		
Saturated (SFA)	57.44[a] ± 1.07	48.18 [b] ± 0.93
Monounsaturated (MUFA)	30.00[b] ± 1.08	37.10 [a] ± 0.96
Polyunsaturated (PUFA)	8.12[b] ± 0.34	9.01[a] ± 0.30
Individual Fatty acids, % Wt		
C4:0	1.27 ± 0.038	1.20 ± 0.033
C6:0	1.64[a] ± 0.058	1.14 [b] ± 0.050
C8:0	2.12 [a] ± 0.089	1.28 [b] ± 0.077
C10:0	7.89 [a] ± 0.346	4.35 [b] ± 0.300
C11:0	0.09 ± 0.009	0.06 ± 0.014
C12:0	3.38 [a] ± 0.275	2.26 [b] ± 0.238
C13:0	0.06 ± 0.006	0.05 ± 0.006
C14:0	8.32 [a] ± 0.343	5.52 [b] ± 0.298
C14:1n5	0.22 ± 0.014	0.20 ± 0.012
C15:0	0.53 [a] ± 0.023	0.41 [b] ± 0.020
C16:0	22.56 [a] ± 0.572	18.32 [b] ± 0.496
C16:1t	0.19 [b] ± 0.042	0.35 [a] ± 0.037
C16:1n7	0.51 ± 0.047	0.57 ± 0.041
C17:0	0.37 ± 0.017	0.40 ± 0.015
C18:0	10.33 ± 0.649	11.67 ± 0.563
C18:1t	0.87 [b] ± 0.119	1.27 [a] ± 0.105
C18:1n9	26.77 [b] ± 1.550	35.82 [a] ± 1.344
C18:2n6t	0.41 ± 0.023	0.45 ± 0.020
C18:2n6	4.38 [b] ± 0.386	6.31 [a] ± 0.334
C18:3n6	0.16 ± 0.008	0.16 ± 0.007
C18:3n3	2.90 ± 0.265	3.10 ± 0.230
C20:0	0.06 [b] ± 0.015	0.12 [a] ± 0.013
C20:1n9	0.31 [b] ± 0.019	0.42 [a] ± 0.017
C21:0	0.09 ± 0.012	0.09 ± 0.008
C20:4n6	0.21 ± 0.015	0.18 ± 0.013
C24:1	0.10 ± 0.007	0.11 ± 0.006

[ab]Means ± SE in the same row with similar letters are not significantly different ($P > 0.05$).

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