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Research paper

The response of goats to different starch/NDF ratios of concentrates on the milk chemical composition, fatty acid profile, casein fractions and rennet clotting properties

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ABSTRACT

The partial substitution of corn grain (rich in starch) with agro-industrial by-products (rich in NDF) could be a good strategy to reduce ruminant dietary costs with no negative effects on milk properties. Thus, the present study aimed to investigate the effect of different starch/NDF ratios of concentrates, with fixed forage proportions, on the chemical composition and fatty acid profile as well as on the relative proportions of individual caseins and rennet clotting properties of goat's milk. For this purpose, sixteen crossbred dairy goats were divided into two homogeneous sub-groups based on their mean body weight and milk fat corrected yield. Each goat of each group was fed individually with alfalfa hay, wheat straw and concentrates. The two concentrates of the two dietary treatments were formulated to produce difference starch/NDF ratios, which were 1.2 and 0.3 for high starch (HS) and low starch (LS), respectively. The results showed no significant effect on milk chemical composition between the two dietary treatments. Moreover, the different starch/NDF ratios of the concentrates had no effect on the casein profile and coagulation properties of goat's milk. A significant reduction of κ- and α_{s2}-casein percentages in the milk throughout the experimental period was found. Finally, the different starch/NDF ratios of the concentrates did not reveal remarkable differences in milk fatty acids except for the individual proportions of $C_{4:0}$, $C_{6:0}$, $C_{18:0}$ and $C_{18:2n:6t}$, which were significantly higher, while those of $C_{14:1}$, $C_{15:0}$, $C_{16:1}$, $C_{17:0}$, $C_{17:1}$ and $C_{20:3n-3}$ were significantly lower, in goats that were milk fed with the HS diet compared with those who consumed the LS. In conclusion, the 4 times decrease in the starch/NDF ratio of the concentrates without changing the forage/concentrate ratio of the goat's diet could reduce the feeding cost without causing any problems in the rennet clotting properties of milk and consequently in the milk industry.

1. Introduction

Carbohydrates are the main components in ruminant nutrition providing the major source of energy for microbial growth and animal metabolism (Nocek and Russell, 1988). There are two broad classifications of carbohydrates: starch and neutral detergent fibre (NDF), which are the major components of non-structural and structural carbohydrates, respectively (National Reserch Council, 2001). The carbohydrate composition affects both milk yield and chemical composition. An increase in goat milk production occurs when the NDF content of the diet is reduced following the inclusion of cereal grains, which are rich in starch (Morand-Fehr and Sauvant, 1980; Goetsch et al., 2001; Min et al., 2005; Pullina et al., 2008; Bernard et al., 2012). The milk chemical composition is also affected by the dietary carbohydrate composition. A reduction in the milk fat content of goats fed a high concentrate diet compared with a low concentrate diet (Bernard et al., 2012) was observed, although this animal species is less sensitive in milk fat depression diets (Rapetti et al., 1997; Bailoni and Andrighetto, 1995). In contrast, milk lactose and protein content are usually increased when a high concentrate diet, rich in starch and readily fermented carbohydrates, is offered in goats (Min et al., 2005).

In all the above studies, the starch/NDF ratio was modified by changing the forage to concentrate ratio of the diets. However, the dietary starch/NDF ratio can also be modified by partial substitution of cereal grains, rich in starch, with agro-industrial by-products (e.g., sugar beet pulp, soybean hulls). These by-products, although with no

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value as edible foods for human consumption, can reduce the animal's dietary cost and can also become major sources of nutrients and energy in the support milk yield and chemical composition (Mirzaei-Aghsaghali and Maheri-Sis, 2008).

Until now, scarce information has existed regarding the impact of different starch/NDF ratios of concentrates on goat's milk yield and chemical composition (Zambom et al., 2012). However, recent studies with dairy cow diets have shown that different dietary starch/NDF ratios of concentrates with a constant forage level affects the milk yield and chemical composition (Summer et al., 2005; Pirondini et al., 2015; Cantalapiedra-Hijar et al., 2015), fatty acid profile (Pirondini et al., 2015), amino acid supply to the mammary gland (Cantalapiedra-Hijar et al., 2015), as well as the relative proportions of the individual caseins (Summer et al., 2005). From all the above, the objective of this study was to investigate the effect of different starch/NDF ratios of concentrates with fixed forage proportions on the chemical composition and fatty acid profile as well as on the relative proportions of individual caseins and rennet clotting properties of goat's milk. Thus, it was assumed that decreasing the starch/NDF ratio of concentrates without changing the forage/concentrate ratio of the goat's diet will not have negative effects on milk properties.

2. Materials and methods

Sixteen 3-year-old crossbred (Alpine x native) dairy goats at 90–98 days in milk were maintained at the Agricultural University of Athens. All the animals were at the same lactation stage and at the 3rd parity. Trial animals were handled as outlined according to the Ethical Committee guidelines of the Faculty of Animal Science. The goats were divided into two homogeneous sub-groups (n = 8) based on their mean body weight (43.8 ± 2.1 kg) and milk fat corrected yield (1.73 ± 0.39 kg). Each goat of each group was fed individually with alfalfa hay, wheat straw and concentrates throughout the experimental period, which lasted 42 days. The two concentrates of the two dietary treatments were formulated to produce difference starch/NDF ratios, which were 1.2 and 0.3 for high starch (HS) and low starch (LS), respectively (Table 1). These dietary treatments were achieved by partial substitution of corn grain with sugar beet pulp and sunflower meal (Table 1). The forage/concentrate ratio was kept constant and equal to 50/50 on a DM basis between the HS and LS groups. Both dietary treatments were formulated to be iso-energetic *iso*-isoenergetic and isoprotein and to meet the individual maintenance and lactation requirements of each goat (National Academic Press, 1981). The quantities of food offered to the animals were adjusted at experimental days 0, 7, 14, 21, 28, 35 and 42, according to their individual requirements, based on their body weight and milk fat corrected yield. Diet selectivity did not occur, and no refusals of forage and/or concentrates were observed. The mineral and vitamin premix of both concentrates contained the following (per kg as mixed): 150 g Ca, 100 g P, 100 g Na, 100 mg Co, 300 mg I, 5000 mg Fe, 10,000 mg Mn, 20,000 mg Zn, 100,000 mg Se, 5,000,000 IU retinol, 500,000 IU cholecalciferol and 15,000 mg α-tocopherol. All animals had free access to fresh water.

Table 1
The chemical composition and the main fatty acids (FA) of alfalfa hay, wheat straw and concentrates [high starch (HS) vs. low starch (LS)] and the mean daily nutrients, FA from forage and concentrates.

Chemical composition (g/kg)	Alfalfa hay	Wheat straw	Concentrates	
			HS	LS
DM	93.01	94.55	91.70	92.60
OM	85.09	86.51	85.99	85.52
CP	16.58	4.05	17.04	17.43
EE	2.32	1.55	4.42	3.04
NDF	45.56	75.00	25.04	37.08
ADF	35.05	48.72	8.55	19.31

Nutrients Intake (g/animal/day)	HS	LS
DM	1930	2039
OM	1790	1872
CP	290	305
EE	70	54
NDF	880	1050
ADF	530	660
Fatty acids Intake (g/animal/day)		
$C_{16:0}$	15.31	14.00
$C_{18:0}$	4.41	3.86
cis-9$C_{18:1}$	13.84	10.97
$C_{18:2n-6c}$	25.06	17.97
$C_{18:3n-3}$	4.58	4.34

2.1. Sample collection

Animals were milked twice a day at 8 am and 6 pm by a milking machine. Individual milk samples were collected at 0, 7, 14, 21, 28, 35 and 42 days for chemical composition analysis and at 28 and 42 days from the beginning of the experiment for fatty acid analysis, after mixing two samples, each one composed of 5% of the volume of milk produced during the morning and evening milking, respectively. The milk samples were stored at −80 °C prior to analysis.

2.1.1. Sample analyses

2.1.1.1. Feed samples

Individual samples from alfalfa hay, wheat straw and concentrates were taken at the beginning of the experiment. The feed samples were analyzed for organic matter (OM; Official Method 7.009), dry matter (DM; Official Method 7.007) crude protein (CP; Official Method 7.016) and ether extract (EE; Official Method 7.060), according to the Association of Official Analytical Chemists International (1984), and for neutral detergent fibre (NDF) assayed without a heat stable amylase and acid detergent fibre (ADF) expressed exclusive of residual ash, according to Van Soest et al. (1991). Additionally, the feed samples were analyzed for the fatty acid (FA) profile according to the method of O'Fallon et al. (2007) (Table 1).

2.1.2. Milk samples

2.1.2.1. Milk chemical composition and FA analysis

Milk was analyzed for fat, protein and lactose by IR spectrometry (Milkoscan 133; Foss Electric, Hllerod, Demark), after calibration according to Gerber (British Standards Institution, 1955) and Kjeldahl (International Dairy Federation, 1993). Milk samples were also analyzed for FA according to the method of Nourooz-Zadeh and Appelqvist (1998).

2.1.3. Casein profile

Goat milk samples were analyzed by RP-HPLC according to Moatsou et al. (2006) using a Vydac C4 214 TP 5415 4.6 mm × 150 mm column (Separation group, Hesperia, CA, USA). Assessment of the casein profiles was based on the peak chromatographic area and individual caseins were expressed as the percentage of the total casein area in the respective profile.

2.1.4. Rennet clotting properties

Rennet coagulation properties of goat milk were determined by means of a Formagraph apparatus (Lattodinamographo, Foss, Italia). Ten mL of raw milk were analyzed in triplicate at 35 °C. In each sample, 200 μL of a 0.3% (w/v) calf rennet (Naturen 1125, Hansen) dilution in 10 mM acetate buffer pH 5.5 were added. The rennet clotting time