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Decreasing dietary NFC concentration during mid-lactation of dairy ewes: Does it result in higher milk production?

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ABSTRACT

The effect of the level of dietary non-fiber carbohydrates (NFC) on intake, *in vivo* digestibility, milk production and endocrine-metabolic status was studied in 20 Sarda ewes (mean ± SE, BW 42.5 ± 3.9 kg) at mid-lactation stage (89 ± 1 DIM). Ewes were divided into 2 groups and fed chopped alfalfa hay at 400 g/d and pelleted concentrates *ad libitum* in metabolic cages during 3 weeks. The concentrates differed in NFC concentration (NFC = 36% of DM: group NFC36; NFC = 23% of DM: group NFC23), due to the substitution of cereal grains with soybean hulls in the low NFC diet. Dry matter intake was higher for NFC23 than for NFC36 (2900 g/d *vs.* 2555 g/d; $P < 0.01$). Dry matter digestibility was higher in NFC36 than in NFC23 (68.4% *vs.* 62.9%, $P < 0.001$), while the contrary occurred for NDF digestibility (52.9% *vs.* 56.1%, $P < 0.015$). Energy intake did not differ between groups ($P > 0.2$). Dietary NFC concentration negatively affected milk yield (1813 ml/d *vs.* 2110 ml/d, for NFC36 and NFC23 groups, respectively, $P < 0.001$) and positively affected milk protein concentration (4.68% *vs.* 4.51%, $P < 0.05$, respectively), whereas milk fat concentration was similar between groups (5.06% *vs.* 5.19%, $P > 0.2$). Body fat increased ($P < 0.05$) without treatment-associated differences. Higher glucose ($P < 0.05$) and lower urea concentrations ($P < 0.001$) were found in blood plasma of NFC36 ewes compared to NFC23 ewes. Insulin concentration in blood plasma was higher in NFC23 than in NFC36 ($P < 0.01$), whereas GH levels were similar between groups. In conclusion, the low dietary NFC concentrate based on soybean hulls exerted positive effects on intake and milk yield in mid-lactating ewes, probably due to a higher proportion of the ingested energy being devoted to milk secretion.

1. Introduction

Non-fiber carbohydrates (NFC) constitute the most important energy-rich fraction of ruminant diets which consists mostly of starch, pectin, galactans and simple sugars (Van Soest, 1994). Non-fiber carbohydrates usually have a fast fermentation rate and stimulate the production of propionate, the most important gluconeogenetic precursor.

In sheep, milk yield is markedly affected by dietary NFC, but the knowledge on the optimal concentration of dietary NFC at different milk production levels and lactation stages is still scanty (Cannas, 2004). During the first part of lactation, high NFC concentration diets (above 30% of NFC, DM basis; Cannas, 2004) generally gave much higher milk yield than medium-low NFC diets (with less than 30% NFC, DM basis) (Susin et al., 1995; Bocquier et al., 2002; Bovera et al., 2004). Ewes in the first part of lactation usually have high energy requirements and low intake, frequently

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resulting in negative energy balance. Therefore, the utilization of these energy-rich diets (NFC higher than 30% DM) enhances energy intake, reducing the mobilization of energy from body reserves and hence favoring milk production. On the basis of the above information and direct experience, dairy sheep farmers offer high NFC concentrates based on cereal grains at high dose (400–800 g/d) to early lactating sheep (Regional Breeders Association of Sardinia, pers. com.). However the utilization of cereal-based supplements is often extended to spring (mid-lactation period) although scientific literature does not lend support to this practice.

Actually research on dairy sheep fed diets rich in sugars and starch (NFC > 30% DM) and poor in NDF (<30% DM) in mid to late stages of lactation gave different results from those observed in the first part of the lactation. For instance, when high NFC diets were offered to ewes in mid-late lactation, positive BW variations were usually observed, whereas milk yield did not change significantly or even slightly decreased (Molle et al., 1997; Bocquier et al., 2002). Furthermore, in several experiments in which dairy ewes were stall-fed diets containing different NFC concentrations, milk yield was higher for diets low in NFC and high in NDF (Cannas et al., 1998; Zervas et al., 1998; Bovera et al., 2004; Zenou and Miron, 2005, Cabiddu et al., 2006). In these experiments, the low NFC (and high NDF) diets contained fiber sources of high digestibility and limited filling effect, such as soybean hulls or beet pulps.

However, in some of these experiments milk yield at the beginning of the trial was not very high (usually below 1500 g/d). This is an important shortcoming for the application of the above results to high-yielding ewes, since it is well known that endocrine control of energy metabolism is affected by milk yield (Hart et al., 1978). Plasma insulin is regarded as an inhibiting agent of voluntary feed intake and usually favors the partitioning of metabolizable energy to fat depots rather than milk secretion (Roche et al., 2008). Responsiveness to insulin tends to increase with high NFC diet and along with lactation (Metcalf and Weekes, 1990). The effects of insulin can be counterbalanced by the enhancement of growth hormone (GH) as demonstrated in sheep by D'Urso et al. (1998). Plasma GH concentration in lactating ruminants is usually higher in high- than in low-genetic merit (Peel and Bauman, 1987) and in high- than in low-yielding animals (Hatfield et al., 1999). Since selection pressure has been lower on dairy sheep than dairy cows (Carta et al., 2009), it is probable that only high yielding sheep can respond with higher milk production to an increased allowance of energy in mid-lactation.

In dairy sheep, milk is a seasonal product and milk yield tends to decrease rapidly after the peak of lactation depending on many factors such as nutrition, breed, genetic merit, litter size, and weather (Pulina et al., 2007). Because understanding the nutritional mechanisms underlying milk persistency is of utmost importance, a feeding experiment was undertaken using Sarda dairy ewes at high milk production level during mid lactation. The main goal of the experiment was to assess the effects of different dietary NFC levels on voluntary feed intake, nutrient digestibility, milk performance and the partitioning of digested energy between milk and body tissues. In addition, the effects of the dietary treatments on metabolites and key hormones involved in energy metabolism were also evaluated. The underlying hypothesis of the study was that, even in high-yielding dairy ewes, a decrease in dietary NFC concentration during mid-lactation could result in higher milk production, through a reduction of the proportion of metabolizable energy devoted to fat depot accretion.

2. Materials and methods

The experiment was carried out at the Bonassai experimental farm (Olmedo, Sardinia, Italy) of Agris, Department of Research on Animal Production. It was conducted in compliance with the principles and specific guidelines on animal care and welfare as required by Italian law (Gazzetta Ufficiale, DL no. 116, January 27, 1992). The study lasted approximately 4 weeks, including a pre-experimental (9 days) and an experimental period (21 days).

2.1. Animals and diets

Twenty Sarda ewes in mid lactation (mean ± SE, 89 ± 1 DIM) with high milk yield (2198 ± 446 ml/d) were used. About one month before the beginning of the experiment, the ewes were selected from the farm flock to be as homogeneous as possible for age (3–5 years), lambing date and milk yield. Since then they were penned and gradually adapted to the experimental feeding regimen, being fed alfalfa hay *ad libitum* and an amount of a commercial concentrate increasing from 500 to 1100 g/head day during twenty-eight days. The ewes were then put in metabolic individual crates, where they received for nine days (pre-experimental period) diets which included chopped alfalfa hay (200 g/d as fed) and a mixture (50:50) of the two experimental pelleted concentrates. This mixture was offered at gradually increasing amounts up to the *ad libitum* level. In particular the amount of concentrates offered to each animal was adjusted each day in order to offer approximately 110% of the amount of concentrate ingested the previous day. The experimental concentrates were formulated to differ for the NFC level: low (23% DM, **NFC23**) or high (36% DM, **NFC36**). The target levels were achieved by substituting the cereal components (ground corn and wheat grain) of NFC36 with soybean hulls in NFC23 and slightly decreasing the soybean meal (Table 1). The target dietary level of crude protein (CP; 18.1% DM in both diets) was set using the Small Ruminant Nutrition System (Cannas et al., 2004; Tedeschi et al., 2010) in order to meet the requirements for a high-yielding (2.0 kg/d, 6.5% milk fat, 5% milk protein) medium-sized ewe (40 kg LW). Hay and pellets were offered in separated troughs. Water was available *ad libitum* throughout the trial. The ewes were machine-milked on the crates twice daily (7.30 and 15.30 h). At the end of the pre-experimental period, the ewes were weighed, and their milk yield was recorded. On the basis of these measurements, the ewes were randomly allocated to one of the following experimental treatment groups:

- group NFC23, receiving chopped hay of alfalfa (400 g/d as fed) and pelleted concentrate containing 23% (DM basis) of NFC supplied *ad libitum*;
- group NFC36, receiving chopped hay of alfalfa (400 g/d) and pelleted concentrate containing 36% (DM basis) of NFC supplied *ad libitum*.

The ewes were submitted to these treatments for twenty-one days (experimental period). In both pre-experimental and experimental periods, the feedstuffs were offered in two meals per day (8.00 and 16.00 h). In order to prevent acidosis, even at a sub-clinical level, 10 g/d of $NaHCO_3$ were added to all individual diets, by mixing the buffer with the concentrate in the trough. This dose was regarded as sufficient for the above purpose on the basis of the *in vitro* studies of Kohn and Dunlap (1998) and the study of Kawas et al. (2007) in growing lambs.

2.2. Measurements and samplings

The concentrates and hay offered to each ewe were weighed just before each meal. The orts were weighed daily at approximately 8.00 h. Since the ort measurements of the last experimental week were lost, the intake data of this week are not shown.

The sheep were weighed, using an electronic scale before the morning meal of the first and last days of the experimental period. Individual