# Physical Form of Concentrate for Lactating Murciano-Granadina Dairy Goats: Feed Intake and Sorting, Milk Production, and Blood Metabolites

Research Article

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## ABSTRACT

Global demand for goat milk and its products is increasing. Goat producers are urged to improve feed efficiency and farm economics. Physical form of concentrate was hypothesized to affect lactating dairy goats' responses in feed intake and sorting, milk production, and blood metabolites. The objective of this study was to determine effects of different physical forms of concentrate [mashed (M), pelleted (P), or textured (T)] on feed intake and sorting, milk production, and selected blood metabolites of lactating Murciano-Granadina dairy goats. Thirty Murciano-Granadina dairy goats in mid-lactation (87±6 days in milk; 2±0.04 kg/d milk yield) were used in a completely randomized design study and assigned to the three forms of concentrate (10 goats per treatment). Goats were fed the experimental diets as totally mixed rations (TMR). The data were analyzed using mixed models of SAS program. The dry matter intake (DMI) and yields of raw milk; fat-corrected milk; milk fat, protein, lactose, and solids not fat (SNF); and cheese as well as feed efficiency were improved (P<0.01) by feeding T instead of M and P. Feeding P *vs.* M improved milk production and feed efficiency (P<0.05). The milk percentages of fat, protein, lactose and blood concentrations of glucose, albumin, and non-esterified fatty acid (NEFA) were unaffected by treatments. Feed sorting occurred less for T than for the other physical forms of concentrate. Therefore, under the conditions of this experiment, feeding lactating Murciano-Granadina dairy goats TMR with textured concentrate compared to mashed and pelleted concentrates increased milk production and cheese yield estimates, and improved feed efficiency.

KEY WORDS cheese yield, concentrate, dairy goat, feed sorting, milk, physical form.

## INTRODUCTION

Human demand for goat milk and its products (e.g., cheese) has been growing mainly because of their exclusive nutritional properties (Clark and Garcia, 2017). Goat milk is rich in functional and healthy compounds such as bioactive peptides, conjugated linoleic acids and oligosaccharides (Güler *et al.* 2007; Assis *et al.* 2016; Güler *et al.* 2017). These nutritionally important compounds offer advantages for consumers of goat dairy products (Park *et al.* 2007). Altered climatic conditions and decreased precipitations in many regions have led goat farmers to intensify and industrialize their production systems. For goat nutrition under intensive production systems, physical form of ration would be of productive and economic significance (Zhong *et al.* 2018; Ebrahimi, 2020). Physical form of diet or concentrate in non-ruminants has well been studied and reviewed (Abdollahi *et al.* 2013). Simultaneous use of heat, moisture, and pressure during pelleting can alter feed nutritional characteristics and improve digestive function and growth performance of broilers (Abdollahi *et al.* 2013). Pelleting, however, requires feed ingredients to be finely ground that may result in increased ruminal fermentation rate and acidosis in beef cattle (Gimeno *et al.* 2015). In addition, pelleting may slow down oil release in the rumen and increase undegradable proteins escaping from the rumen fermentation in dairy cows (Santos *et al.* 2011).

Limited numbers of studies have previously investigated forage choices and forage physical form in lactating dairy goats (Sanz Sampelayo *et al.* 1998; Sanz Sampelayo *et al.* 2007). While it is of nutritional and economic importance, to our knowledge, no documented research has reported how different physical forms of concentrate (including pelleting, extruding, and mashing) alter production performance and metabolism of lactating dairy goats. Nudda *et al.* (2013) suggested that extruded linseed supplementation can improve milking performance of grazing Saanen goats. Our hypothesis was that physical form of concentrate (mashed, pelleted, or textured) affects dairy goats feed intake and sorting, milk production, cheese yield estimates, and blood metabolites. The objective of this study was, therefore, to determine comparative effects of feeding mashed (M), pelleted (P), or textured (T) concentrates (with the same ingredients being different only in physical form) on feed intake and sorting, milk production and composition, cheese yield estimates and feed efficiency, and selected blood metabolites in lactating Murciano-Granadina dairy goats.

## MATERIALS AND METHODS

### Animals, experimental design, and treatments

This experiment was conducted in Magsal Commercial Dairy Goat Farm (4000 dairy goats; Qazvin, Iran) from January through March 2020. Thirty heads of Murciano-Granadina goats in second-parity (87±6 days in milk; 2±0.04 kg/d milk yield) were used in a completely randomized design study with three treatments. The treatments were diets containing concentrates with different physical forms including 1) mashed (M) with mean particle size of 1 mm, 2) pelleted (P) with dimensions of 15 × 3.5 mm, or textured (T) in totally mixed rations (TMR). Each treatment was fed to 10 goats. The experimental period was 10 weeks long including 3 weeks of adaptation and 7 weeks of sampling and data collection. Reasonably adequate 3 weeks of adaptation was allowed to prevent carry-over effects. Goats were housed in fully controlled individual pens (1.5×2 m). All animals were cared for according to the guidelines of the Iranian Council on Animal Care (1995). Diets were formulated based on NRC (2007) requirements and using Small Ruminant Nutrition System (SRNS) diet formulation software program.

Diets differed only in the physical form of concentrate (Table 1).

**Table 1** Ingredients and chemical composition (DM-based) of the experimental diet fed to lactating Murciano-Granadina dairy goats

| Ingredient | % of diet DM |
|---|---|
| Corn silage | 40.27 |
| Barley grain | 6.28 |
| Corn grain | 18.56 |
| Beet pulp-dehydrated pellet | 2.86 |
| Soybean meal | 12.61 |
| Soybean-whole roasted | 1.81 |
| Canola meal | 2.43 |
| Wheat bran | 10.76 |
| Calcium carbonate | 1.67 |
| Magnesium oxide | 0.19 |
| Salt | 0.33 |
| Mineral supplement[1] | 0.75 |
| Sodium bicarbonate | 0.67 |
| Bentonite | 0.67 |
| Toxin binder | 0.14 |
| **Chemical composition** | |
| Neutral detergent fiber (NDF) | 37.13 |
| Crude protein (CP) | 15.08 |
| Fat | 3.31 |
| Ash | 11.5 |
| Calcium | 1.06 |
| Phosphorus | 0.54 |
| Metabolizable energy (ME), Mcal/kg | 2.33 |

[1] Provided per kg of supplement: vitamin A: 750000 IU; vitamin D: 204000 IU; vitamin E: 5400 IU; Monensin: 2000 mg; Ca: 250 g; Mg: 35700 mg; Co:17 mg; Cu:1650 mg; I: 52 mg; Mn: 3200 mg; Se: 45 mg and Zn: 9350 mg.

Diets were prepared and offered as TMR and delivered 6 times daily. Diets were fed *ad libitum* for 5-10% daily orts. Goats had free access to fresh water all the time. Goats were milked twice daily at 07:00 and 19:00 h in a milking parlor (Westfalia Dema Tron 70).

### Feed and milk sampling and analysis

Feed and milk samples (from a.m. and p.m. milkings) were collected weekly for later analytical measurements. Feed was analyzed for neutral detergent fiber (NDF) (Van Soest *et al.* 1991), crude protein, ether extract, and ash (AOAC, 2002). Goats were weighed weekly just before the morning feeding. The amounts of TMR delivered and orts remained were recorded daily to calculate daily dry matter intake (DMI) by subtracting the DM content of orts from that of TMRs. An observational scoring system was developed for quantifying feed sorting. Feed sorting was determined by three individuals by observing and scoring the physical form of orts with scores 1, 2, and 3 representing very coarse (i.e., forage-like), medium, and very fine (i.e., concentrate-like) forms, respectively. Milk samples were analyzed for fat, protein, lactose, total solids, solids-nonfat, urea nitrogen, and total fatty acids using an analytical machine (CombiScope FTIR 600, Delta Instruments, Drachten, The

Netherlands). The fat-corrected milk yield (3.5% fat) was also calculated: FCM= milk yield × (0.634+0.1046×fat) (Curro *et al.* 2019). Cheese yield was estimated according to Zeng *et al.* (2007).

### Blood sampling and analysis

Blood samples (20 cc) were taken from all animals at 08:00 h on d 1, 30, and 56 using vacuum tubes to obtain serum. Blood tubes were then centrifuged at 3000 rpm for 15 min at room temperature. Serum was transferred to 1.5 mL tubes and stored at -20 ˚C for later analysis of circulating metabolites. Serum was analyzed for non-esterified fatty acids (NEFA) (Rendox, UK), glucose, albumin, and total proteins (Pars Azmoon, Iran) by using commercial kits.

### Statistical analysis

The data were analyzed with Mixed Models Procedures of SAS (2004) program. Treatment effect was considered fixed while animal (within treatment) and residuals were considered random. Model for repeated measures of blood metabolites consisted of treatment, week, and their interaction (treatment×week) as fixed effects and animal within treatment plus residuals as random effects. Initial measurements for feed intake, milk production and blood metabolites were modeled as covariate. Least square means were estimated using Maximum Likelihood method and compared using multiple-range Tukey test. Significant treatment effects were declared at $P < 0.05$. Trends for significance were declared at $P < 0.10$.

## RESULTS AND DISCUSSION

The current study provides new information on how the physical form of concentrate in TMR affects feed intake and feed sorting, milk production and composition, cheese yield estimates, and blood metabolites concentrations in lactating Murciano-Granadina dairy goats. The data for feed intake and sorting, and body weight changes are presented in Table 2. Body weight and its changes during the experimental period were not significantly affected by treatments ($P>0.10$). However, the T-fed goats had numerically higher body weight (BW) compared to other goats, which might suggest that more nutrients were available for body tissue accretion in goats fed T than in goats fed other treatments. This data is supported by increased DMI of T-fed goats ($P<0.01$). Goats in T-group consumed 58 and 57 g greater DMI than goats on M and P groups, respectively (Table 2). The increased DMI of the T-fed goats suggests that textured concentrate may have increased diet palatability compared to mashed and pelleted concentrates. In a study by Raghuvansi *et al.* (2007), lambs fed pelleted feed had greater DMI than peers fed mashed feed. In another study (Karimizadeh *et al.* 2017), finishing lambs fed pelleted feed had greater DMI and weight gain than those fed mashed feed. The present study is the first to report comparisons among different forms of concentrates on feed intake and sorting for lactating dairy goats.

Scoring the coarseness of orts revealed that orts for M-fed goats were significantly finer and had more concentrate ($P<0.05$) than orts for goats fed P and T, suggesting that M-fed goats sorted against finer concentrate particles, compared to T- and P-fed goats. In other words, more concentrate was present in orts when M *vs.* T and P was fed. Hence, it seems that goats consume TMR more uniformly and sort less against particular particles when offered T and P concentrates instead of M concentrate. Goats did not show as much appetite towards M as did they towards T and P. This finding confirms that feeding T and P concentrates minimizes feed sorting, when compared to the M concentrate.

As presented in Table 3, raw and 3.5% fat-corrected milk yields were greater ($P<0.01$) for T (1653 and 2074 g/d) than for P (1372 and 1752 g/d) and M (1089 and 1439 g/d), respectively. Because of unchanged milk composition ($P>0.10$), daily yields of milk fat, protein, lactose, solids nonfat (SNF) and total solids were also greater ($P<0.01$) for T than for other treatments (Table 3). As a result of increased total milk fat, protein, and solids yields, cheese yield estimates were greater ($P<0.01$) for T than for other forms of concentrate (Table 3). For example, milk fat yield was 17% and 36% greater for T than for P and M, respectively. These results demonstrated that goats fed T had better energy and nutrient balance than goats fed other treatments (Sanz Sampelayo *et al.* 1998). Nudda *et al.* (2013) reported that extruded linseed supplementation improved milk performance of Saanen goats. The milk production data alongside feed sorting results suggest that feeding M (and likely P) might have adversely affected rumen conditions. Pelleting concentrate may increase the likelihood of subacute ruminal acidosis (Ebrahimi, 2020), and thus reduce nutrient intake and microbial protein synthesis. The present data reports for the first time that physical form of concentrate affects milk production of lactating dairy goats and that textured concentrate is superior to both pelleted and mashed concentrates.

Feeding P instead of M improved yields of fat-corrected milk and milk protein, lactose, and total solids as well as feed efficiency (Table 3, $P<0.05$). In addition, orts were finer containing more concentrate for M than for P (Table 2, $P<0.05$). These data suggest that feeding P instead of M concentrate resulted in decreased feed sorting and improved nutrient assimilation by lactating dairy goats.

**Table 2** Body weight, DMI, and orts coarseness score for lactating dairy goats fed the experimental diets

| Parameter | Concentrate physical form | | | SEM | P-value |
|---|---|---|---|---|---|
| | Mashed | Pelleted | Textured | | |
| Body weight (kg) | 35.46 | 35.72 | 36.01 | 0.176 | 0.109 |
| Weight gain (g/day) | -6.10 | -7.67 | 4.08 | 4.45 | 0.148 |
| Dry matter intake (g/day) | 1620[b] | 1621[b] | 1678[a] | 12.703 | 0.005 |
| Orts coarseness score[1] | 2.23[a] | 1.32[b] | 1.26[b] | 0.093 | < 0.001 |

[1] Scores 1, 2, and 3 being very coarse (i.e., forage-like), medium, and very fine (i.e., concentrate-like) orts particles.
The means within the same row with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

**Table 3** Milk production and composition for lactating dairy goats fed the experimental diets

| Parameter | Concentrate physical form | | | SEM | P-value |
|---|---|---|---|---|---|
| | Mashed | Pelleted | Textured | | |
| Raw milk, g/day | 1089[c] | 1372[b] | 1653[a] | 74.05 | < 0.001 |
| 3.5% Fat corrected milk, g/day | 1439[c] | 1752[b] | 2074[a] | 92.27 | < 0.001 |
| Fat, g/day | 72[b] | 84[b] | 98[a] | 4.70 | 0.002 |
| Protein, g/day | 37.4[c] | 46.0[b] | 54.2[a] | 2.05 | < 0.001 |
| Lactose, g/day | 47.59[c] | 61.15[b] | 73.31[a] | 3.39 | < 0.001 |
| Total solids , g/day | 171.24[c] | 209.31[b] | 246.24[a] | 10.38 | < 0.001 |
| Solids nonfat (SNF), g/day | 95.20[c] | 120.37[b] | 142.98[a] | 5.99 | < 0.001 |
| Fat (%) | 6.59 | 6.41 | 6.08 | 0.22 | 0.294 |
| Protein (%) | 3.55 | 3.44 | 3.35 | 0.09 | 0.335 |
| Lactose (%) | 4.37 | 4.41 | 4.40 | 0.02 | 0.448 |
| Total solids (%) | 15.74 | 15.49 | 15.02 | 0.29 | 0.224 |
| SNF (%) | 8.85 | 8.78 | 8.67 | 0.09 | 0.418 |
| Urea N (mg/dL) | 17.45 | 18.15 | 17.67 | 0.55 | 0.661 |
| Denovo fatty acids (%) | 2.45 | 2.35 | 2.24 | 0.09 | 0.290 |
| Fatty acids (%) | 2.23 | 2.16 | 2.05 | 0.08 | 0.321 |
| 3.5% fat-corrected milk/dry matter intake | 0.895[b] | 1.086[a] | 1.241[a] | 0.054 | < 0.001 |
| Cheese yield estimate (g) | 427.19[b] | 499.80[b] | 583.50[a] | 27.94 | 0.002 |

The means within the same row with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

**Table 4** Blood metabolites for lactating dairy goats fed the experimental diets

| Parameter | Concentrate physical form | | | SEM | P-value |
|---|---|---|---|---|---|
| | Mashed | Pelleted | Textured | | |
| Glucose (mg/dL) | 59 | 59 | 61 | 1.87 | 0.711 |
| NEFA (mmol/L) | 0.326 | 0.304 | 0.263 | 0.044 | 0.599 |
| Total protein (g/dL) | 7.88 | 10.90 | 8.19 | 1.48 | 0.306 |
| Albumin (g/dL) | 3.64 | 3.60 | 3.69 | 0.071 | 0.657 |

SEM: standard error of the means.

Notable, dry matter intake was similar between M and P (Table 2, P>0.10), emphasizing the increased orts fineness and improved feed efficiency for P *vs.* M. It is obvious that because of more sorting, less concentrate (than predicted) was consumed for M than for P. It is also likely that M was degraded more rapidly in the rumen, suggesting induced ruminal acidosis. This cascade could reduce nutrient efficiency in M-fed goats than in other goats.

In dairy cows, feeding steam-flaked corn grains instead of ground or dry-rolled grains have improved (Yu *et al.* 1998; Cooke *et al.* 2008), tended to improve (Zhong *et al.* 2008), or not affected (Dhiman *et al.* 2002; Shen *et al.* 2015) milk production. Steam-flaking and texturizing are to some extent similar, as they both produce feeds with larger and more uniform particles, when compared to grinding or dry-rolling. The improved milk production of goats fed T in the current study is consistent with the above-mentioned increases in milk production of cows fed steam-flaked corn grains. Feed efficiency or FCM to DMI ratio was improved by feeding T and P instead of M, which was due to the much improved milk yield in the T and P groups than in the M group.

Milk urea N was similar among the treatments, probably suggesting that rumen ammonia and splanchnic urea outputs were not significantly affected by the treatments. Findings provided new evidence that feeding lactating Murciano-Granadina dairy goats textured concentrate instead of pelleted and mashed concentrates minimized feed sorting, increased dry matter intake and milk production, and improved cheese yield estimates and feed efficiency.

Feeding pelleted *vs.* mashed concentrate improved milk production and feed efficiency.

Blood metabolites are usually monitored to compare nutritional treatment effects on energy and nitrogen metabolism, and health status of ruminant animals (Desnatie *et al.* 2020). In the present study, blood concentrations of glucose, NEFA, albumin and total protein were not affected by treatments (P>0.10; Table 4). These data suggest that treatments did not have any significant effects on overall health and tissue mobilization of the experimental lactating dairy goats (Ye *et al.* 2009; Kholif *et al.* 2018). No significant effects on blood NEFA may suggest that goats were not under significant negative energy balance. The lack of any treatment effects on blood albumin and total protein could suggest that immune and liver functions were not affected by dietary treatments, as well.

## CONCLUSION

Findings provided new information that feeding lactating Murciano-Granadina dairy goats TMR with textured concentrate instead of pelleted and mashed concentrates minimized feed sorting, increased dry matter intake and milk production, and improved cheese yield estimates and feed efficiency. Feeding pelleted *vs.* mashed concentrate improved milk production and feed efficiency. Blood concentrations of glucose, NEFA, albumin and total protein were not affected by the physical form of concentrate. Future studies on optimizing physical form of concentrate in relation to dietary forage source are warranted.

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