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Multivariate analysis of characteristics associated with performance of dairy goats fed integral mango meal

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ABSTRACT

Factor analysis was used for reduction of dimensionality and to obtain latent variables, constructed from linear combinations of feeding behavior characteristics, physiological and performance, to evaluate the effects of diets containing integral mango meal (IMM) replacing corn (0, 330, 660, and 1000 g/kg) for dairy goats. Eight lactating Saanen crossbred goats (48.7 ± 1.99 kg of BW) were introduced in the experiment 48 days postpartum and maintained up to 124 days of lactation. The latent variable composed of behavioral characteristics and milk performance showed a cubic effect for the tested diets ($P < 0.05$), with a maximum point for milk performance with 78 g/kg of replacing corn with integral mango meal, and a minimum point with 763 g/kg replacing corn with integral mango meal. Similarly, there was a linear increase ($P < 0.01$) in rumination and chewing activities with replacement levels. The latent variable composed of metabolic characteristics and milk performance did not ($P > 0.05$) detect the effect of the replacement of corn with integral mango meal. From the factor analysis, it was possible to reduce the dimensionality of the set of data. Considering that the feeding behavior characterized by the amount of meals and activities of rumination interfered the performance of dairy goats, may be recommended replacing 78 g/kg of corn by integral mango meal.

1. Introduction

The dairy performance can be affected by factors related to animal (breed, age, metabolic profile, reproduction, feeding behavior), nutrition (source and composition of food) and environment (season, air temperature, installation) (Haenlein, 2007; Raynal-Ljutovac et al., 2008; Tronco, 2010). According to Coulon and Priolo (2002) the feeding, among all factors, is the one that most affects the production and composition of milk.

The metabolic activities for utilization of nutrients and milk synthesis are closely related to the physiological adaptability of goats to various edaphoclimatic conditions throughout the evolution of ruminants (Morand-Fehr et al., 2007). Thus, the combination of the animal potential for energy demand and the physical capacity of the digestive tract determines the voluntary intake of food (Resende et al., 2008), and in the case of lactating animals the energy intake is a major factor determining the synthesis and composition of milk (Seal and Reynolds, 1993). Thus, the replacement of energetic food by alternative ingredients in the diet of lactating animals can provide impacts on yield and composition of milk, which can be detected from the evaluation of feeding behavior and metabolic profile.

Therefore, a large number of variables, which quantify potential changes in production, physiological and behavioral patterns of animals can be measured and analyzed. For this reason, the use of multivariate analysis techniques, such as factor analysis, become attractive as they allow a reduction of the number of variables into a smaller number of new hypothetical variables (factors), which can be used to assess the effects of inclusion of dietary ingredient.

Thus, the aim of this study was to assess the effects of diets containing integral mango meal replacing corn (0, 330, 660, 1000 g/kg on DM basis) for lactating goats using factor analysis in order to

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reduce the dimensionality of data and obtain latent variables, built from linear combinations of feeding behavior, physiological and performance characteristics.

2. Material and methods

The experiment was conducted in the Goat Sector of the Animal Science Department of the Federal Rural University of Pernambuco (UFRPE), Recife, Brazil.

2.1. Experimental diets

The diets were formulated to meet dairy goat requirements in early lactation according to the National Research Council (NRC, 2007). The forage:concentrate ratio was 60:40 on a dry matter (DM) basis with Tifton hay as the forage. The diets consisted of four concentrate replacement levels of corn by integral mango meal, 0, 330, 660, and 1000 g/kg on a DM basis. The ingredients and chemical composition of the experimental diets are shown in Table 1.

To obtain the integral mango meal, the fresh entire fruits (pulp, peel, and seed) were ground in a forage machine, dehydrated under the sun for 48 h, and were then ground passing through a 10 mm screen.

2.2. Animals, management, and sample collection

The management and care of animals were performed in accordance with the guidelines and recommendations of the Committee of Ethics on Animal Use (CEUA) at the UFRPE, under the license number 143/2014. To determine nutrient intake and milk performance, eight crossbred Saanen goats with an average initial body weight (BW) of 48.7 ± 1.99 kg and 48.0 ± 2.0 days in lactation were distributed across a 4 × 4 double Latin square design, with four treatments, four animals and four periods. The feed was provided in two daily meals at 7h00 and 16h00 in a sufficient quantity to obtain 10% orts. The trial lasted 76 days and the four experimental periods lasted 19 days and were divided as follows: 14 days for adaptation to the diets and 5 days to collect supplied feed, and ort samples.

Orts were removed for each animal each day before the morning meal and were weighed, sampled, placed inside plastic bags, and frozen at −18 °C. The supplied feed was sampled three times each week and also placed inside plastic bags and frozen at −18 °C. At the end of each experimental period, the feed samples, and orts were thawed and subjected to pre-drying at 60 °C for 72 h and were then ground in a Willey-type knife mill (TE-625, TECNAL, SP, Brazil) with a 1 mm mesh. Composite samples were saved for each animal on a dry weight basis from each time period.

Table 1
Ingredients proportion and chemical composition of the experimental diets.

Items	Replacement levels (IMM[a] replacing corn g/kg)			
	0	330	660	1000
Ingredient (g/kg)				
Tifton hay	600	600	600	600
Integral mango meal	0	100	200	300
Ground corn	300	200	100	0
Soybean meal	70.6	69.1	67.7	66.2
Urea	9.4	10.9	12.3	13.8
Dicalcium phosphate	7	7	7	7
Mineral mix[b]	13	13	13	13
Diet composition (g/kg of DM)				
Dry matter (g/kg)	882	886	889	893
Organic matter	927	925	923	921
Crude protein	140	140	140	141
Ether extract	22.6	22.5	22.4	22.2
Non-fibrous carbohydrates	315	304	293	283
Neutral detergent fiber	502	516	530	544
Acid detergent fiber	254	265	276	286
Cellulose	219	210	207	205
Lignin	36.5	41.7	47.0	52.3
Total phenols	–	39.6	79.1	119
Condensed tannins	–	3.10	6.2	9.2
Total digestible nutrients	639	624	611	601

[a] Integral mango meal.
[b] Nutrients/kg of product: Vitamin A – 135,000 U.I.; Vitamin D3 – 68,000 U.I.; Vitamin E – 450 U.I.; Calcium – 240 g; Phosphorus – 71 g; Potassium – 28.2 g; Sulfur – 20 g; Magnesium – 20 g; Copper – 400 mg; Cobalt k 30 mg; Chrome – 10 mg; Iron – 250 mg; Iodine – 40 mg; Manganese – 1,350 mg; Selenium – 15 mg; Zinc – 1,700 mg; Fluorine – 710 mg.

2.3. Feeding behavior

The observations concerning the ingestive behavior of animals were performed by using the instantaneous scanning method proposed by Martin and Bateson (1986). Goats were observed every 5 min for 24 h each day starting immediately after the morning feeding, being three days of observation in each period, totalizing 72 h of observation. The activity of each goat was recorded as rumination, feeding and idling. Total chewing time was calculated as the sum of eating and ruminating time. A meal was defined as at least one observation of feeding activity occurring after at least 20 min without feeding activity, according to Wangsness et al. (1976). A period of rumination was defined as at least 5 min of rumination occurring after at least 5 min without ruminating activity.

The feed and rumination efficiencies (kg/h) of DM and NDF were calculated by dividing the intake of each of these nutrients by the total feeding time (feed efficiency) or rumination time (rumination efficiency).

2.4. Metabolic profile

Blood samples were collected four hours after the first meal on the last collection day of each period. The aliquots of serum from blood samples were obtained by centrifugation at 2500 rpm and were stored in Eppendorf's at −20 °C until performing the analyses for the biochemical doses of metabolites (glucose and total cholesterol), triglycerides, proteins (albumen and total protein), enzymes (aspartate aminotransferase – AST and gamma-glutamyl transferase – GGT), substances related to kidney functions (urea and creatinine), and minerals (calcium, phosphorus, and magnesium); this was accomplished by using the Doles® commercial kits and the colorimetric system in a semiautomatic biochemical analyzer (Doles D250, DOLES®, Brazil).

2.5. Milk performance

Goats were hand milked twice daily at 06 h00 and 15 h00 and milk yield was recorded during the 5 days of data collection. Milk samples were collected and pooled by proportion according to the milk yield at each milking. Milk samples were analyzed for fat, protein, and lactose concentration using infrared analysis (Bentley-2000, Bentley instrument, Inc. Minnesota, USA). Total solids were determined using the oven method (AOAC, 1990).

2.6. 2.6. Chemical analysis

DM, organic matter (OM), and crude protein (CP) analysis were performed according to the AOAC (1990), method number 934.01 for DM, 930.05 for OM, and 981.10 for CP. Ether extract (EE) was analyzed by Soxhlet extraction with petroleum ether (AOAC, 1990). The concentration of neutral detergent fiber was assayed with a heat-stable amylase and corrected for ash

and nitrogenous compounds by using techniques described by Mertens (2002), with corrections for protein according to Licitra et al. (1996) and added thermostable alpha-amylase. Lignin (sa) was extracted with sulfuric acid 720 mL/L (Van Soest and Wine, 1967). Non-fibrous carbohydrates (NFC) were calculated as follows according to Hall (2000): NFC (g/kg) = 1000 – [(CP–urea derived CP + urea) + NDFap + EE + ash], where: CP = crude protein; NDFap = neutral detergent fiber corrected for ash and protein; and EE = ether extract. Total digestible nutrients (TDN) were determined according to Weiss (1999): TDN (g/kg) = $_{D}$CP + $_{D}$NDF + $_{D}$NFC + ($_{D}$EE × 2.25), in which: $_{D}$CP = digestible crude protein, $_{D}$NDF = digestible neutral detergent fiber, $_{D}$NFC = digestible non-fibrous carbohydrates, and $_{D}$EEI = digestible ether extract.

The concentration of condensed tannins (CT) and total phenols (TP) in the integral mango meal were performed according to Wolfe et al. (2008).

For evaluation of rumen fermentation kinetics, the semiautomatic in vitro technique of gas production was utilized, according to Theodorou et al. (1994). The rumen fluid was obtained from a rumen cannulated bull. The pressure from the accumulated gas was measured by a pressure transducer (type T443A, Bailey & Mackey, England).

To identify the fatty acid profile, a 200 mL composite milk sample was utilized to separate the fat, using the methodology proposed by Murphy et al. (1995). The triglycerides were submitted to transmethylation for methyl esters by using the . The methyl esters from fatty acids were analyzed by gas chromatography using Varian model 431-G ISO 5509 method (1978) C equipped with a flame ionization detector and a capillary column Zebron ZB-5MS Phenomenex (30 m × 0.25 mm × 0.25 μm). The fatty acids were quantified by area normalization of the methyl esters in percentage per area (%).

2.7. Statistical analysis

Of the different techniques for extraction of factors, the Principal Component Analysis (PCA) was used (Seal, 1964; Jeffers, 1978) through the R software (R Development Core Team, 2013), and subsequently the components that had eigenvalues greater than 1 (Kaiser, 1958) were rotated using the Varimax method. Using factor analysis, the scores of each variable were interpreted as a correlation between factors and variables. The scores were considered the values assigned to each individual from the linear combination of the scores multiplied by the latent variable (factor). Only scores with the highest values were considered for interpretation, usually those larger or equal to 0.50. In the analysis of variance, the scores of animals for each factor were used as the dependent variable according to the following model:

$$Y_{ijkl} = \mu + ql_i + P_{(i)j} + ani_{(i)k} + t_l + (ql \times t)_{il} + e_{ijkl},$$

where: Y_{ijkl} is the factor score; μ is constant inherent to all data; ql_i is the effect of Latin square i (i = 1,2); $p_{(i)j}$ is the effects of period j within Latin square i; $ani_{(i)k}$ is the effects of animal k within Latin square i; t_l is the level of replacement corn with integral mango meal; $(ql \times t)_{il}$ is the effect of the interaction between the Latin square i and replacement level l; e_{ijkl} is the residue associated with each observation, which are assumed to be independent and homocedastic.

The factor analysis and analysis of variance and regression were performed in two groups of variables (behavioral characteristics and milk performance, and metabolic characteristics and milk performance), at a significance level of 5%, using the R software (R Development Core Team, 2013).

3. Results

3.1. Behavioral characteristics and milk performance

Nine factors were important in describing the variability of the data (had eigenvalues greater than 1) and together accounted for 47% of the overall data variability (Table 2). However, only four factors (F1, F2, F4 and F6) of the model showed a significant effect (Table 3).

The first factor accounted for 16% of the data variability. The high values of factor scores indicated increases in milk production and corrected productions for fat and total solids, as well as for the production of milk constituents, as it increased the number of daily meals. There was a cubic effect (P < 0.05) for the diets tested in the Factor 1 (Table 3), with a maximum point for dairy performance with 78 g/kg replacement of corn by the integral mango meal, and a minimum point with 763 g/kg of replacement (Table 4).

Regarding the second factor (10% of the data variability) there was a linear increase (P < 0.01) (Table 5) in the rumination and chewing activities (high values of factor scores) and a decrease in idle time and rumination efficiency (negative scores) with the replacement of corn with integral mango meal. The fourth factor (5% of the data variability), in turn, showed an increase in milk constituents (positive factor scores) and reduced feed efficiency (negative scores). The high values of the scores of Factor 6 (2% of the data variability) showed an increase in the somatic cell count (SCC) of the milk.

3.2. Metabolic characteristics and milk performance

Eight factors were important in describing the variability of the data and together accounted for 28% of the overall data variability (Table 6). However, only four factors (F1, F2, F3 and F5) of the model showed a significant effect (Table 7).

Represented by 11% of the variability of the data, the first factor (F1) indicated an increase in milk production and milk constituents, feed efficiency and concentration of the enzyme gamma glutamyl transferase (high values of factor scores). The applied model explained 97.1% of the variability of the factor scores, without effect to the treatments.

At the second factor (6% of the data variability), the highest values of the factor scores indicated an increase in milk constituent levels, while Factor 3 (3% of the data variability) showed an increase in the concentration of milk SCC and the total cholesterol and calcium content. The negative factor scores showed a reduction in phosphorus levels. For the concentration of plasma urea and milk urea there were indications of increase (positive factor scores), as seen in Factor 5 (2% of the data variability), whereas the reduction of triglyceride concentration in the serum was indicated by negative scores of this factor.

4. Discussion

4.1. Behavioral characteristics and milk performance

The first factor (F1) generated indicated that the animals regulated the number of daily meals, aiming to compensate for the nutrient requirements for milk production. Thus, the higher milk production and milk components were estimated at 78 g/kg of replacing corn with integral mango meal. It can be explained by the better availability of energy in this level of inclusion. Note that higher levels of inclusion of mango meal resulted in diets with minor TDN content and more NDF. Due this, with the increase of integral mango meal in the diets was estimated lower production at the level of 763 g/kg of replacement.

Table 2
Factor analysis results.

Item	F1[a]	F2[b]	F3[c]	F4[d]	F5[e]	F6[f]	F7[g]	F8[h]	F9[i]
Milk production	**0.964**	0.001	−0.053	−0.219	0.082	−0.018	−0.040	0.040	0.028
3,5% fat-corrected milk	**0.976**	0.048	−0.123	0.010	0.088	−0.013	−0.011	0.107	0.080
4% fat-corrected milk	**0.976**	0.047	−0.122	0.007	0.088	−0.013	−0.011	0.106	0.079
Total solids corrected milk	**0.975**	0.008	−0.121	0.122	0.085	−0.018	0.006	0.079	0.042
%Fat	0.337	0.116	−0.276	**0.734**	0.001	0.122	0.099	0.278	0.189
%Protein	−0.001	0.013	−0.028	**0.933**	−0.047	0.198	−0.160	−0.133	−0.096
%Casein	−0.058	−0.015	−0.016	**0.927**	−0.048	0.239	−0.151	−0.131	−0.114
%Lactose	0.474	−0.442	−0.070	0.348	−0.003	−0.194	0.488	0.172	−0.091
%Total solids	0.286	−0.077	−0.160	**0.901**	−0.029	0.091	0.142	0.111	0.001
%Non-fat solids	0.216	−0.208	−0.058	**0.919**	−0.048	0.058	0.157	−0.020	-0.133
Urea concentration	0.051	0.441	0.089	**0.500**	−0.033	0.023	0.186	0.246	0.408
Somatic cell count	−0.019	0.010	0.172	0.285	−0.207	**0.871**	-0.088	−0.117	0.027
Total bacterial count	−0.023	0.029	0.141	0.359	−0.003	**0.857**	0.097	0.087	-0.024
Fat yield	**0.932**	0.083	−0.171	0.192	0.089	−0.009	0.012	0.154	0.117
Protein yield	**0.854**	0.009	−0.087	0.438	0.045	0.076	−0.145	−0.064	-0.039
Casein yield	**0.816**	−0.010	−0.081	0.492	0.041	0.118	−0.151	−0.071	-0.060
Lactose yield	**0.969**	−0.100	−0.070	−0.097	0.096	−0.089	0.085	0.060	-0.011
Total solids yield	**0.981**	−0.010	−0.107	0.102	0.083	−0.021	0.004	0.059	0.022
Non-fat solids yield	**0.986**	−0.050	−0.078	0.062	0.080	−0.025	0.001	0.017	-0.017
Feeding efficiency	0.579	−0.029	0.120	**-0.622**	0.202	0.147	0.349	0.194	0.063
Feeding time/day	0.247	0.185	**0.898**	0.081	−0.003	0.073	−0.265	0.041	-0.067
Rumination time/day	0.165	**0.952**	−0.009	0.079	−0.132	-0.083	−0.122	−0.084	-0.013
Idle time/day	−0.253	**−0.784**	−0.483	−0.101	0.097	0.019	0.233	0.037	0.046
Total chewing time	0.253	**0.784**	0.483	0.101	−0.097	−0.019	−0.233	−0.037	-0.046
Feeding efficiency of DM	0.293	−0.181	**-0.893**	0.100	−0.108	−0.118	−0.063	−0.094	-0.006
Feeding efficiency of NDF	0.301	−0.142	**-0.903**	0.097	−0.124	−0.092	−0.050	−0.051	0.030
Rumination efficiency of DM	0.390	**−0.805**	−0.151	0.213	−0.007	−0.068	−0.312	0.024	-0.017
Rumination efficiency of NDF	0.426	**−0.787**	−0.177	0.209	−0.024	−0.023	−0.302	0.075	0.022
Total chewing/kg DM	−0.458	**0.567**	0.550	−0.251	0.086	0.045	0.268	0.043	-0.026
Total chewing/kg NDF	−0.501	0.525	**0.571**	−0.236	0.107	−0.015	0.245	−0.009	-0.084
DM intake min/kg	−0.269	0.139	**0.902**	−0.172	0.103	0.109	0.130	0.114	-0.032
NDF intake min/kg	−0.299	0.095	**0.911**	−0.153	0.114	0.056	0.104	0.076	-0.073
No. of rumination/day	−0.163	0.402	−0.138	0.185	−0.236	−0.332	0.044	**-0.621**	0.097
Total rumination	0.281	**0.858**	0.075	−0.041	−0.014	0.114	−0.118	0.247	-0.076
Rumination time/kg DM	−0.485	**0.741**	0.168	−0.248	0.053	−0.012	0.305	−0.018	-0.016
Rumination time/kg NDF	−0.527	**0.713**	0.182	−0.239	0.075	−0.064	0.289	−0.070	-0.072
Rumination g DM/bolus	0.549	−0.352	0.018	0.123	**0.676**	−0.186	−0.212	−0.076	-0.022
Rumination g NDF/bolus	0.573	−0.315	0.011	0.110	**0.677**	−0.148	-0.206	-0.041	0.012
No. of idle/day	0.054	−0.327	−0.444	−0.051	−0.058	−0.390	0.214	0.363	-0.100
Total idle	−0.320	**-0.747**	−0.339	−0.087	0.152	0.197	0.191	−0.122	0.118
Remastication time/bolus	0.238	0.299	0.115	−0.085	**0.883**	−0.130	−0.029	−0.043	0.010
No. of bolus/day	−0.057	0.393	−0.112	0.160	**−0.872**	0.053	−0.091	−0.097	-0.016
Remastication time/day	−0.137	0.052	−0.150	0.153	**−0.923**	0.091	−0.068	−0.106	-0.004
No. of remastication/bolus	0.040	0.156	0.034	0.031	**0.942**	0.167	0.065	0.052	0.028
No. of remastication/day	−0.062	**0.785**	−0.070	0.233	0.291	0.341	0.048	−0.007	-0.001
No. of meals/day	**0.615**	0.020	0.581	0.065	0.237	−0.254	−0.019	-0.076	0.241
Meals time	−0.513	0.102	0.117	0.008	−0.259	0.399	−0.227	0.112	**-0.527**
Defecation frequency/day	0.153	−0.257	−0.124	−0.382	−0.086	0.080	−0.224	−0.088	**0.778**
Urinary frequency/day	0.099	−0.289	−0.206	−0.068	**−0.548**	0.018	−0.514	0.059	0.265
Drink water/day	0.242	0.207	0.239	0.052	0.037	-0.155	0.014	**0.724**	-0.006
Variance explained (%)	15.98	9.58	6.96	4.73	3.52	2.00	1.92	1.24	1.06

Coefficients in bold were used for interpretation.
[a] Milk production and composition as function of amount meals.
[b] Rumination activities.
[c] Feeding activities.
[d] Composition of milk and feeding efficiency.
[e] Chewing activities and urinary frequency.
[f] Milk quality.
[g] No variable present any association greater than 0.50.
[h] Rumination activities and drink water frequency.
[i] Meal frequency and defecation.

The differences in the behavioral patterns of animals of the same species may be related to the mechanism psychogenic (Mertens, 1985), wherein each animal interacts differently with the received food, and flavor characteristics inform the feed characteristics and show an important biological role in the animal-environment interaction, collaborating in the intake regulation. The high values of the factor scores of Factor 3 (Table 2) indicated that animals have increased the feeding time and chewing time to better food processing, characterized by low digestibility with higher fiber content, which explains the decrease in feeding efficiency. In addition, increases in the chewing activity (Factor 5) and rumination (Factor 2) were due to higher lignin and tannin with replacing corn with integral mango meal. According to Cao et al. (2013), the higher the lignin content in the NDF fraction, the higher the time spent in rumination and chewing in minutes/kg of DM. This is due to the barrier created by lignin to access of cellulolytic enzymes (McSweeney et al., 2001).

The process of rumination (chewing activities) in the buccal cavity is important to reduce feed particles and moisturize the bolus with saliva, which facilitate the degradation in the rumen

Table 3
ANOVA of factors generated from the multivariate analysis of behavioral characteristics and milk performance.

Factors:	F1		F2		F3		F4		F5		F6		F7		F8		F9	
ANOVA models																		
Significance	***		*		NS		**		NS		**		NS		NS		NS	
Coeff. determination (r^2)	0.97		0.85		0.54		0.89		0.73		0.89		0.79		0.69		0.71	
Variance source	Sign.	%SS	Sign.	%SS	Sign.	%SS	Sign.	%SS	Sign.	%SS	Sign.	%SS	Sign.	%SS	Sign.	%SS	Sign.	%SS
Diets (Linear effect)	NS	0.4	**	15.2	NS	3.1	NS	0	NS	3.9	NS	0	NS	0.1	NS	5.7	NS	4.2
Diets (Quadratic effect)	NS	0.2	NS	1.9	NS	0.9	NS	0.3	NS	0.6	NS	1.6	NS	0.6	NS	0.4	NS	0.2
Diets (Cubic effect)	*	1.4	NS	0.1	NS	0.1	NS	0.6	NS	0	NS	1.1	NS	0	NS	11.4	NS	0.2
Latin square (LS)	**	3.3	**	13.4	NS	0.9	NS	0.2	*	18.8	NS	0.1	NS	6.5	NS	3.4	NS	2.0
Diets × (LS)	NS	0.9	NS	0.3	NS	11.2	NS	1.1	NS	9.3	NS	6.1	NS	11.6	NS	3.4	NS	7.0
Animal (LS)	***	69.1	**	41.8	NS	24.8	***	74.8	NS	37.1	***	75.1	NS	29.0	NS	21.8	NS	19.7
Period (LS)	***	22.0	NS	12.8	NS	12.8	NS	12.1	NS	3.7	NS	4.9	NS	30.7	NS	22.8	NS	37.7
Regression equation																		
Diets	1		2		NS		NS		NS		NS		NS		NS		NS	

Sign., significance level; NS, not significant; %SS, percentage of total sum of squares.
[1] $\hat{Y} = 0.245122765 + 0.007106151X - 0.000481204X^2 + \mathbf{0.000004036X}^3$.
[2] $\hat{Y} = 0.458678569 - \mathbf{0.003192783X} + 0.000196011X^2 - 0.000000601X^3$.
* Significant at the 0.05 level.
** Significant at the 0.01 level.
*** Significant at the 0.001 level.

Table 4
Mean values for the variables of the Factor 1 obtained from the multivariate analysis of behavior characteristics and dairy performance.

Diets (g/kg)	Ingestive behavior	Milk performance									
	Meals (n°/d)	MP (kg/d)	3.5% FCM (kg/d)	4% FCM (kg/d)	TSCM (kg/d)	Fat (g/d)	Protein (g/d)	Casein (g/d)	Lactose (g/d)	TS (g/d)	NFS (g/d)
0	11.3	2.04	1.72	1.59	1.64	51.9	49.8	39.1	83.4	204	152
333	11.1	2.03	1.74	1.61	1.64	53.2	48.6	37.9	82.7	203	150
666	9.88	1.90	1.66	1.53	1.55	51.7	44.9	35.2	77.5	191	140
1000	10.8	1.97	1.75	1.61	1.62	55.3	46.5	36.2	78.9	199	144
Regression equation											
Diets*	$\hat{Y} = 0.245122765 + 0.007106151X - 0.000481204X^2 + \mathbf{0.000004036X}^3$										

MP – milk production; 3,5%FCM – 3.5% fat-corrected milk; 4%FCM – 4% fat-corrected milk; TSCM – total solids corrected milk; TS – total solids; NFS – non-fat solids. X – level of integral mango meal.
* Significant at the 0.05 level.

Table 5
Mean values for the variables of the Factor 2 obtained from the multivariate analysis of behavior characteristics.

	Behavioral characteristics										
Diets (g/kg)	RT (min)	IT (min)	TCT (min)	RE (g DM/h)	RE (g NDF/h)	TC (min/kgDM)	R (min)	R (min/kg DM)	R (min/kg NDF)	Idle (min)	Rem (n°/d)
0	468	659	782	216	123	416	27.1	250	513	29.9	20841
333	485	656	785	245	121	416	27.5	258	512	30.8	20735
666	496	657	783	228	118	433	28.9	273	528	28.8	21595
1000	554	588	852	203	107	462	30.4	299	571	26.3	22517
Regression equation											
Diets**	$\hat{Y} = 0.458678569 - \mathbf{0.003192783X}$										

RT – rumination time; IT – idle time; TCT – total chewing time; RE – rumination efficiency; TC – total chewing; R – rumination; Rem – remastication. X – level of integral mango meal.
** Significant at the 0.01 level.

by exposing degradable fiber surface (Weimer, 2015). It is can be explained because the chewing activities can facilitate microbial attack (particularly fibrous components) permitting the access to reserve tissues. Humidification, according to Van Soest (1981), helps the digestion of feed from microbial attack, which occurs by means of water-soluble enzymes. These processes play an essential role in the establishment of bacteria and fungi fibrolytic species adhering to the cell wall (De Boever, 1990).

4.2. Metabolic characteristics and milk performance

The relationship between hepatic metabolism and dairy performance was verified in the first factor (F1) through the record of high factor scores of the plasma concentration of GGT and milk production. With the exception of muscle cells, the GGT enzyme is present in all cells of the organism and its most pronounced activity in the kidneys and liver (Santos et al., 2007). It can be inferred that in this study there were no liver disorders throughout the experiment, as the GGT and AST enzymes remained within the normal range. However, Factor 3 indicated an increase in somatic cell count (SCC), total cholesterol, which could be interpreted as an inflammatory response to a future bacterial infection.

Health status of animal may contribute to the higher incidence of infections and metabolic diseases, as in the stage of lactation the animal are more required for the maintenance of homeostasis and milk production. Thus, analysis of the lipid metabolites can be used

Table 6
Factor analysis results.

Item	F1[a]	F2[b]	F3[c]	F4[d]	F5[e]	F6[f]	F7[g]	F8[h]
Milk production	**0.974**	−0.194	−0.001	0.035	−0.046	−0.025	−0.003	−0.026
3,5% fat-corrected milk	**0.991**	0.032	−0.037	0.008	0.028	−0.034	0.062	−0.003
4% fat-corrected milk	**0.991**	0.029	−0.036	0.009	0.027	−0.033	0.061	−0.004
Total solids corrected milk	**0.985**	0.147	−0.042	−0.003	0.005	−0.023	0.034	−0.008
%Fat	0.357	**0.755**	−0.058	90.108	0.226	−0.059	0.292	0.096
%Protein	−0.025	**0.926**	0.197	0.220	0.036	0.064	−0.105	0.113
%Casein	−0.085	**0.926**	0.226	0.188	0.006	0.065	−0.084	0.117
%Lactose	0.463	0.410	−0.297	**−0.572**	−0.157	0.020	0.083	90.165
%Total solids	0.278	**0.926**	−0.028	−0.143	0.085	0.001	0.105	0.039
%Non-fat solids	0.190	**0.944**	−0.003	−0.151	−0.025	0.045	−0.041	90.005
Urea concentration	0.085	0.385	0.081	0.029	**0.731**	−0.005	0.017	90.030
Somatic cell count	−0.075	0.340	**0.806**	−0.003	0.004	0.028	0.261	0.111
Total bacterial count	−0.050	0.400	**0.773**	−0.086	0.011	−0.122	0.367	0.169
Fat yield	**0.950**	0.211	−0.063	−0.013	0.086	−0.039	0.111	0.014
Protein yield	**0.846**	0.458	0.082	0.190	−0.038	0.019	−0.074	0.049
Casein yield	**0.805**	0.517	0.117	0.184	−0.063	0.026	−0.069	0.063
Lactose yield	**0.976**	−0.064	−0.092	−0.105	−0.082	−0.016	−0.001	−0.064
Total solids yield	**0.989**	0.129	−0.036	−0.001	−0.015	−0.019	0.014	−0.014
Non-fat solids yield	**0.989**	0.092	−0.024	0.003	−0.058	−0.010	−0.026	−0.026
Feed efficiency	**0.609**	-0.602	0.104	−0.240	−0.075	−0.122	0.166	0.018
Plasma urea	-0.054	0.279	−0.061	−0.022	**0.722**	0.142	−0.430	−0.200
Creatinine	0.165	−0.063	0.267	0.115	-0.016	0.177	**0.757**	0.028
Gamma glutamyl transferase	**0.689**	−0.299	−0.268	−0.272	0.255	0.005	−0.007	−0.082
Aspartate aminotransferase	0.300	−0.371	−0.033	0.067	0.305	−0.375	−0.453	0.323
Albumin	-0.005	0.018	0.068	0.087	0.185	**0.711**	0.254	0.072
Total proteins	-0.070	0.212	−0.008	0.041	−0.001	0.099	0.023	**0.886**
Glucose	0.081	0.215	−0.056	**0.878**	−0.057	0.019	0.062	0.001
Triglycerides	0.098	0.335	0.053	0.038	**−0.746**	−0.082	−0.127	−0.186
Total cholesterol	0.211	−0.149	**0.608**	−0.070	−0.208	−0.364	−0.155	−0.304
Calcium	0.082	−0.179	**0.594**	0.455	−0.111	0.401	−0.015	0.188
Phosphorus	0.288	0.044	**−0.740**	−0.051	−0.107	−0.179	0.004	0.178
Magnesium	−0.063	0.173	−0.015	−0.567	−0.083	**0.648**	−0.226	0.044
Variance explained (%)	10.7	6.21	2.92	2.03	2.00	1.52	1.51	1.26

Coefficients in bold were used for interpretation.
[a] Milk performance and hepatic metabolism.
[b] Milk composition.
[c] Milk quality, energetic and mineral metabolism.
[d] Glucose and lactose content.
[e] Milk urea, plasma urea and triglycerides.
[f] Albumin and magnesium concentrations.
[g] Creatinine.
[h] Total proteins.

Table 7
ANOVA of factors generated from the multivariate analysis of behavioral characteristics and milk performance.

Factors	F1		F2		F3		F4		F5		F6		F7		F8	
ANOVA models																
Significance	***		***		***		NS		*		NS		NS		NS	
Coeff. determination (r^2)	0.97		0.93		0.96		0.73		0.83		0.66		0.62		0.54	
Variance source	Sign.	%SS	Sign.	%SS	Sign.	%SS	Sign.	%SS	Sign.	%SS	Sign.	%SS	Sign.	%SS	Sign.	%SS
Diets (L)	NS	0.3	NS	0.1	NS	0.5	NS	0	NS	3.3	NS	5.2	NS	7.2	NS	0.9
Diets (Q)	NS	0.2	NS	0.0	NS	0.6	NS	4.5	NS	0.7	NS	8.7	NS	10.7	NS	6.9
Diets (C)	NS	0.6	NS	0.3	NS	0.1	NS	1.2	NS	3.3	NS	0.9	NS	0	NS	0.2
Latin square (LS)	***	5.1	NS	0.5	NS	9.6	NS	0.1	**	14.2	NS	0.6	NS	2.8	NS	6.2
Diets × LS	NS	1.2	NS	1.7	NS	5.4	NS	7.0	NS	3.6	NS	13.0	NS	2.7	NS	6.5
Animal (LS)	***	65.5	***	78.2	***	77.8	NS	28.5	NS	8.6	NS	28.2	NS	33.8	NS	15.0
Period (LS)	***	24.2	*	12.4	NS	2.5	NS	31.4	**	49.3	NS	9.6	NS	5.1	NS	18.8

Sign., significance level; NS, not significant; %SS, percentage of total sum of squares.
* Significant at the 0.05 level.
** Significant at the 0.01 level.
*** Significant at the 0.001 level.

in the diagnosis of metabolic and nutritional diseases in ruminants. In this study, the concentration of total cholesterol maintained their levels below the reference values (Kaneko et al., 2008), which probably was related to the replacement of corn (more energetic) by integral mango meal. Nevertheless, the results corroborate with those reported by Santos et al. (2007), that cholesterol concentration in the herbivores is usually lower. The plasma levels of calcium and phosphorus remained within normal levels as reported by Kaneko et al. (2008) and González (2000).

The inverse relationship between plasma glucose and lactose content of milk was verified by Factor 4. According to Hurley (2009), in lactating animals the mammary gland uses about 60–85% of the

total glucose in the body, with a correlation 93% between milk production and glucose uptake by the mammary gland. However, ruminants have insignificant amounts of glucose in the small intestine because most of the soluble sugars are completely fermented in the rumen, which explains the need for biosynthesis.

Factor 5 indicated a high correlation between the plasma urea concentration and milk urea. This is because of the low molecular weight of plasma urea crossing alveolar epithelium of the mammary gland spreading in the milk (Wittwer, 2000). Thus, when there is a reduction of energy in the diet, a reverse action takes place in the ruminal ammonia concentration, with a reduction in microbial protein synthesis and consequent increase in plasma urea concentration (Wittwer, 2000).

5. Conclusions

From the factor analysis, it was possible to reduce the dimensionality of the set of data. Considering that the feeding behavior characterized by the amount of meals and activities of rumination interfered the performance of dairy goats, may be recommended replacing 78 g/kg of corn by integral mango meal.

Conflict of interest

The authors wish to confirm that there are no known conflicts of interest associated with this publication.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.smallrumres.2015.10.023.

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