

## Metabolic profile of lactating goats fed integral mango meal

### *Perfil metabólico de cabras lactantes alimentadas com farelo de manga integral*

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### SUMMARY

The work was conducted to evaluate the metabolic profile of lactating goats fed diets containing integral mango meal as a replacement for corn. Four levels of replacement (0, 33, 66 and 100%) were evaluated in diets with forage:concentrate ratio of 60:40. Eight crossbred multiparous lactating Saanen goats ( $48.72 \pm 1.99$  kg of BW) were introduced in the experiment 48 days postpartum and maintained up to 124 days of lactation. It was used a double Latin Square (4x4) experimental design, with four treatments, four periods and four animals per square. There was no effects ( $P>0.05$ ) for the integral mango meal level on the intake of DM (1890 g/day), CP (278 g/day) and NDF (959 g/day). However, the intake of NFC and TDN decreased ( $P<0.05$ ) 27.9 g/day and 0.082 kg/day, respectively, as the dietary integral mango meal increased. The concentrations of urea, creatinine, gamma glutamyl transferase, aspartate aminotransferase, albumin, total protein, glucose, triglycerides, total cholesterol, and magnesium were not altered ( $P>0.05$ ) by replacement levels, with average values of 54.52 mg/dl, 0.71 mg/dl, 52.59 UI, 77.37 UI, 4.69 g/dl, 9.32 g/dl, 74.44 mg/dl, 40.10 mg/dl, 39.39 mg/dl, and 11.09 mg/dl, respectively. Considering the metabolic profile, mango meal whole can totally replace corn in diets of dairy goats.

**Keywords:** cholesterol, fruit wastes, GGT, glucose, triglycerides, urea

### RESUMO

O estudo foi realizado para avaliar o perfil metabólico de cabras lactantes alimentadas com dietas contendo farelo de manga integral em substituição ao milho. Foram avaliados quatro níveis de substituição (0; 33; 66 e 100%) em dietas com relação volumoso:concentrado de 60:40. Oito cabras mestiças Saanen, múltiparas e lactantes ( $48.72 \pm 1.99$  kg de peso corporal) foram introduzidas no experimento aos 48 dias pós-parto e mantidas até 124 dias de lactação. Utilizou-se como delineamento experimental dois Quadrados latinos 4x4, com quatro tratamentos, quatro períodos e quatro animais por quadrado. Não houve efeito ( $P>0,05$ ) dos níveis de farelo de manga integral sobre os consumos de matéria seca (1890 g/dia), PB (278 g/dia) e FDN (959 g/dia). Contudo, os consumos de carboidratos não fibrosos e nutrientes digestíveis totais reduziram ( $P<0,05$ ) 27,9 g/dia e 0,082 kg/dia respectivamente, à medida que aumentava o teor farelo de manga integral nas dietas. As concentrações de ureia, creatinina, gama glutamil transferase, aspartato aminotransferase, albumina, proteínas totais, glicose, triglicerídeos, colesterol total e magnésio não foram alteradas pelos níveis de substituição, com valores médios de 54,52 mg/dl, 0,71 mg/dl, 52,59 UI, 77,37 UI, 4,69 g/dl, 9,32 g/dl, 74,44 mg/dl, 40,10 mg/dl, 39,39 mg/dl e 11,09 mg/dl, respectivamente. Considerando o perfil metabólico, o farelo de manga pode substituir totalmente o milho em dietas de cabras lactantes.

**Palavras-chave:** colesterol, GGT, glicose, resíduo de frutas, ureia

## INTRODUCTION

By 2050, the requirements for meat and milk will increase by 70%, as the world will have an expected population of more than nine billion people (WADHWA & BAKSHI, 2013). However, producing the amount of animal protein that will be needed to feed the growing population and to reduce the environmental impact are the main challenges to be faced. Meanwhile, despite the fact that there is much residue available as well as discards from the fruit production in Brazil, these potentially employable byproducts are still only used at a low level. Moreover, there is the aggravating fact that the accumulation of residue in inadequate places and the contamination of water and soil resources lead to a consequent increase in disease vectors for the population, which, therefore, makes it relevant to find sustainable ways to use these residues.

Thus, it is important to highlight that the effects of the use of post-harvest wastes in animal feeding are not well known yet, and it is also important to recognize the impact on the metabolism of lactating animals. This indicates the need for an investigation, and in the context of evaluation, the metabolic profile becomes an adequate tool. The metabolic profile allows us to establish the nutritional status of the animals based on the blood analysis of representative groups using biochemical indexes of energy, protein, and mineral metabolism as well as the functionality of organs such as the liver, which is vital for milk production (PEIXOTO & OSÓRIO, 2007).

The present work was performed with the objective of assessing the effect on the metabolic profile of different levels

of integral mango meal as a replacement for corn in the diets of lactating goats.

## MATERIALS AND METHODS

The study was conducted in the Goat Sector of the Animal Science Department of the Universidade Federal Rural de Pernambuco (UFRPE), Recife, Brazil. The animal handling practices followed the recommendations of the National Council for the Control of Animal Experimentation of Brazil (BRASIL, 2008) under the license number 143/2014 granted by the Institutional Committee of Ethics on Animal Use (CEUA).

Four levels of replacement of corn with integral mango meal (0, 33, 66, and 100%) on a dry matter basis were utilized. The diets were adjusted to meet the requirements recommended by the NRC (2007) for lactating goats with an average production of 2.0 kg milk/d and 4.0% fat while maintaining a roughage:concentrate ratio of 60:40 (Tables 1 and 2). The feed was provided *ad libitum* as a total mixed ration twice daily at 7h00 and 16h00 after the milking.

The fruits utilized to produce mango meal were those discarded by the producer market of Petrolina city (Northeast of Brazil) due to non-acceptance by consumers; however, they were still of a good condition to use for animal feeding. The entire fresh fruits (pulp, peel, and seed) were ground in forage machines and dehydrated in the sun for 48 hours after the material was stirred every two hours until it was completely dried. Afterward, the dehydrated material was ground using a 10 mm screen.

Table 1. Chemical composition of ingredients used in the diet (g/kg of dry matter)

Nutrients	Integral mango meal	Ground corn	Soybean meal	Tifton hay
Dry matter <sup>1</sup>	915.10	880.9	870.4	879.0
Organic matter	961.8	982.2	935.8	927.6
Crude protein	56.0	89.1	475.0	89.0
Ether extract	41.2	42.0	17.0	14.6
Neutral detergent fiber	284.0	143.0	155.0	747.0
Acid detergent fiber	152.0	41.5	95.0	390.9
Non-fibrous carbohydrates	592.0	710.1	315.4	116.5
Cellulose	67.0	89.5	45.0	303.1
Lignin	65.0	12.0	15.0	53.0
Total phenols	395.7	-	-	-
Condensed tannins	30.8	-	-	-

<sup>1</sup>g/kg of natural matter.

Table 2. Ingredients proportion and chemical composition of the experimental diets

Item	Replacement levels of corn by integral mango meal (%)			
	0	33	66	100
<b>Ingredients (g/kg)</b>				
Tifton hay	600.0	600.0	600.0	600.0
Integral mango meal	0	100.0	200.0	300.0
Ground corn	300.0	200.0	100.0	0
Soybean meal	70.6	69.1	67.7	66.2
Urea	9.4	10.9	12.3	13.8
Dicalcium phosphate	7.0	7.0	7.0	7.0
Mineral mix <sup>a</sup>	13.0	13.0	13.0	13.0
<b>Diet composition (g/kg of DM)</b>				
Dry matter <sup>b</sup>	882.2	885.8	889.4	892.9
Organic matter	927.3	925.3	923.4	921.4
Crude protein	140.2	140.4	140.4	140.6
Ether extract	22.6	22.5	22.4	22.2
Non-fibrous carbohydrates	314.9	304.10	293.2	282.5
Neutral detergent fiber	502.0	515.9	529.8	543.7
Acid detergent fiber	253.7	264.6	275.5	286.4
Cellulose	218.8	209.6	206.5	205.0
Lignin	36.5	41.7	47.0	52.3
Total phenols	-	39.6	79.1	118.7
Condensed tannins	-	3.1	6.2	9.2
Total digestible nutrients	639.3	623.6	611.0	600.7

<sup>a</sup>Nutrients/kg of product: Vitamin A - 135.000,00 U.I.; Vitamin D3 - 68.000,00 U.I.; Vitamin E - 450,00 U.I.; Calcium - 240,00 g; Phosphorus - 71,00 g; Potassium - 28,20 g; Sulfur - 20,00 g; Magnesium - 20,00 g; Copper - 400,00 mg; Cobalt - 30,00 mg; Chrome - 10,00 mg; Iron - 250,00 mg; Iodine - 40,00 mg; Manganese - 1.350,00 mg; Selenium - 15,00 mg; Zinc - 1.700,00 mg; Fluorine - 710,00 mg.

<sup>b</sup>g/kg as-fed basis.

Eight crossbred lactating multiparous Saanen goats with an average body weight of  $48.72 \pm 1.99$  kg were utilized; they were introduced to the experiment at 48 days after parturition until 124 days into lactation. The acclimation

period to the diets, installations and handling was 38 days, followed by 76 days for the experimental period. The goats were distributed randomly in two simultaneous Latin square (4x4) designs and were housed in individual wood

pens of 6.25 m<sup>2</sup>, with a feeder and drinker. Before the beginning of the experiment, the goats were identified, treated for endoparasites, and vaccinated against *Clostridium*. The shed was kept under permanent artificial lighting during all experimental periods (76 days).

The trial lasted 76 days and the five experimental periods lasted 19 days and were divided as follows: 14 days for adaptation to the diets and five days to data and samples collect. During all the experiment, the offering and leftovers of feeds were weighed daily to calculate the voluntary intake and to adjust the offered feed to guarantee 15% of leftovers. Water was provided *ad libitum*.

The biochemical doses were performed 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 2,500rpm and were stored in Eppendorf at -20°C until performing the analysis. The biochemical metabolites analyzed were: glucose, total cholesterol, triglycerides, proteins (albumin 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). Doles® commercial kits and the colorimetric system in a semiautomatic biochemical analyzer, D-250 Doles® were used for biochemical analysis.

Data were submitted for variance and regression analyzes at a 5% significance level by using the software R (R Core Team, 2013).

## RESULTS AND DISCUSSION

There was no effects ( $P>0.05$ ) for the integral mango meal level on the intake of DM (1890 g/day), CP (278 g/day) and NDF (959 g/day) (Table 3). However, the intake of NFC and TDN decreased ( $P<0.05$ ) 27.9 g/day and 0.082 kg/day, respectively, as the dietary integral mango meal increased. The lack of effects on DM intake shows that the animals accepted the tested ingredient. Besides, the animals were fed a total mixed ration that minimized the selectivity. Since the diets were isonitrogenous (Table 2) and mango meal did not lead to any effect on DMI, naturally the CP intake by the goats also was no different.

Table 3. Intake of nutrients (g/day) of goats fed diets containing different replacement levels of corn by integral mango meal

Item	Replacement levels (%)				SEM <sup>a</sup>	<i>P</i> -value	
	0	33	66	100		L <sup>b</sup>	Q <sup>c</sup>
Dry matter	1918	1915	1844	1871	53.63	0.17	0.63
Organic matter	1775	1769	1701	1721	49.47	0.12	0.66
Crude protein	282	281	271	277	7.83	0.23	0.47
Ether extract	44.56	44.49	42.59	43.41	1.22	0.06	0.44
Neutral detergent fiber	934	962.1	954.3	984	27.27	0.10	0.96
Non-fiber carbohydrates	607	581	536	529	17.27	<0.001	0.35
Total digestible nutrients (kg/day)	1.23	1.20	1.13	1.12	0.03	<0.01	0.60

<sup>a</sup>SEM = standard error of the mean; <sup>b</sup>L = linear effect; <sup>c</sup>Q = quadratic effect.

For small ruminants, in the case of dairy goats, the maximum and minimum amounts of fiber in the diet, providing higher intake and production efficiency are not well defined, especially when working with alternative feeds such as fruit wastes. Importantly, the average fiber intake (NDF) registered in this study suggests that goats tolerate the relatively high amount of NDF in the diets, coming to represent approximately 50% of the DM intake and 1.97% of body weight (BW), without, however, significantly limit intake.

The average intake of 1.17 kg/day of TDN is slightly lower of recommendation by the NRC (2007), of 1.43 kg/day for lactating goats with 50kg of BW and milk production of 2.0kg/day. This result can be explained

by the reduction of 639.3 to 600.7 g of TDN/kg DM in the experimental diets (Table 2) and due to the quality of the fiber used in the diet, reducing thereby the supply of energy to the animals. These facts are related to the increase in indigestible fractions, represented by phenolic compounds in the diet (tannin and lignin), compromising the microbial action on the substrate.

The concentrations of urea, creatinine, gamma glutamyl transferase, aspartate aminotransferase, albumin, total protein, glucose, triglycerides, total cholesterol, and magnesium were not altered by replacement levels; with average values of 54.52mg/dl, 0.71mg/dl, 52.59 UI, 77.37 UI, 4.69g/dl, 9.32g/dl, 74.44mg/dl, 40.10mg/dl, 39.39mg/dl, and 11.09mg/dl, respectively (Table 4).

Table 4. Metabolic profile of goats fed diets containing different replacement levels of corn by integral mango meal

Item	Reference value <sup>s</sup>		Replacement levels (%)				SEM <sup>f</sup>	P - value	
	Min. <sup>b</sup>	Max. <sup>c</sup>	0	33	66	100		L <sup>g</sup>	Q <sup>h</sup>
Urea (mg/dl)	21.4	42.8	54.92	52.25	57.81	53.12	1.60	0.99	0.68
Creatinine (mg/dl)	1.0	1.8	0.76	0.61	0.69	0.79	0.03	0.51	0.08
GGT (UI) <sup>d</sup>	20.0	56.0	50.76	54.80	52.04	52.79	1.77	0.46	0.12
AST (UI) <sup>e</sup>	43.0	132.0	75.00	83.66	77.40	73.42	2.61	0.51	0.12
Albumin (g/dl)	2.7	3.9	4.59	4.57	4.53	5.10	0.09	0.06	0.09
Total protein (g/dl)	6.2 <sup>b</sup>	7.9 <sup>b</sup>	9.00	9.28	9.89	9.09	0.17	0.55	0.10
Glucose (mg/dl)	50.0	75.0	76.97	73.85	73.52	73.44	1.66	0.48	0.65
Triglycerides (mg/dl)	21.4	42.8	38.95	42.95	38.09	40.40	1.58	0.96	0.72
Total cholesterol (mg/dl)	80.0	130.0	41.10	43.33	42.18	30.97	2.52	0.09	0.10
Calcium (mg/dl)	8.9	11.7	9.13	9.01	9.16	9.51	0.10	0.03	0.08
Phosphorus (mg/dl)	4.2	9.1	9.26	8.94	8.63	8.27	0.27	0.03	0.95
Magnesium (mg/dl)	2.8	3.6	11.15	10.97	11.26	10.99	0.07	0.81	0.80

<sup>a</sup>Kaneko et al. (2008); <sup>b</sup>Minimum; <sup>c</sup>Maximum; <sup>d</sup>GGT - Gamma glutamyl transferase; <sup>e</sup>AST - Aspartate aminotransferase; <sup>f</sup>SEM – standard error of mean. <sup>g</sup>L – linear effect; <sup>h</sup>Q – quadratic effect.

The concentrations of urea, albumin, and glucose (Table 4) in goats fed a control diet (0%) presented with greater values than those considered reference to goats, as mentioned by Kaneko et al.

(2008). The urea and albumin determination in blood serum shows protein metabolic activity of the animal. The urea is a product of nitrogen metabolism excretion, and the albumin

is the main plasma protein synthesized in the liver, representing 50 to 65% of total blood protein (WITTWER, 2000). Despite the increase in urea concentration in the diets (Table 2), the diets were balanced and isonitrogenous, thus was not expected increase in the concentrations of urea and albumin. However, there was a reduction in the energy input from the total digestible nutrients when the corn was replaced by integral mango meal, which was verified in the decrease of TDN intake (Table 3). According to Wittwer (2000) high values of urea in the blood may occur when a low energy diet is provided, which causes a contrary action in the concentration of rumen ammonia. This is caused by the reduction in microbial protein synthesis, which leads to a consequent increase in urea concentration in the blood.

The levels of glucose in the lactating goats fed 33, 66, and 100% of integral mango meal as a replacement for corn remained within the normal range for goats (KANEKO et al., 2008). It was expected the reducing of the serum glucose concentrations in the lactating goats, since the NFC content of diets reduced with the inclusion of the integral mango meal. According to Mundim et al. (2007) in goats of second and third lactation typically occur lower serum glucose concentrations, resulting from higher demand of this metabolite by the mammary gland, especially in animals with higher milk production. The crossbred Saanen goats used in this study presented low milk production (ranging from 2.04 to 1.97kg/day). Therefore, this can probably explain the lack of effect on serum glucose concentration. In the case of ruminants, glucose is insensitive to variations in energy input associated with the diet, as even its blood concentration is regulated by an efficient hormonal mechanism,

with few alterations. Thus, decreases in blood concentration should be associated with a high-energy deficit (ROWLANDS, 1980), which was not the case for this study.

The concentrations of creatinine remained lower (Table 4) compared to reference values (KANEKO et al., 2008). However, Sodré et al. (2007) reported that the amount of formed creatinine is relatively constant for a determined subject and is barely affected by feeding with regards to protein intake.

Except total cholesterol, which maintained its levels below the reference values (KANEKO et al., 2008), the triglycerides presented within the normal range (Table 4). The levels of cholesterol are good indexes of adequate concentrations of lipids in the plasma, as they represent approximately 30% of the total lipids. As previously mentioned, the average NDF intake (Table 3) suggests that the goats tolerate high amount of fiber in the diet, coming to represent approximately 50% of the dry matter intake. Probably the higher fiber intake contributed to the reduction in the serum levels of total cholesterol. This result corroborates with Ajila & Prasada Rao (2013), as ingredients containing fiber and bioactive compounds such as polyphenols and carotenoids are important constituents of fruits that affect the reduction of blood cholesterol.

The concentrations of gamma-glutamyl transferase (GGT) and aspartate aminotransferase (AST) were maintained within the normal range (KANEKO et al., 2008; Table 4). We can infer that the tested diets did not promote damage to the liver of the animals, even though these enzymes work as blood biomarkers for the evaluation of metabolic disturbances and hepatic operations (GONZÁLEZ &

SILVA, 2003). This result also justifies the absence of an effect on the albumin concentrations that, according to Rowlands (1980), can be altered by hepatic operations, amino acid availability, and diseases involving mainly gastrointestinal parasites.

The serum levels of the minerals, except magnesium (Mg), were altered by the replacement of corn with integral mango meal (Table 4). There was an increase of 0.12 mg calcium (Ca), and reduction of 0.32 mg phosphorus (P) per dl of serum for each 1% level of replacement. However, the levels of Ca and P were maintained within the normal range described by Kaneko et al. (2008) and González (2000), except magnesium (Mg) as it was greater (Table 4).

The reduction in the levels of P were related to an unbalance between Ca and P in the diet, which was in turn promoted by the addition of integral mango meal and the removal of corn, even though they were formulated with the same inclusion of dicalcium phosphate. The relation between Ca and P was maintained closely to 1:1 (Table 4). According to Underwood (1981), in livestock diets is recommended Ca:P ratio of almost 1:1 to 2:1. McDowell (1992) reported that this ratio (1:1 to 2:1) is suggested to be the physiological serum ratio to meet the growth requirements, bone formation and maintaining milk production. However, this unbalances need to be corrected in the diet, since the balance of minerals to lactating goats is important to subsequent lactation.

González (2000) reported that the most common deficiency observed is in phosphorus, and the levels of Ca are relatively constant. The endocrine system and vitamin D, parathyroid hormone (PTH), and calcitonin are responsible for the adjustment of the

current amount of Ca; indicating that there should be a low variation in the level of Ca ( $\pm 17\%$ ) when compared to P ( $\pm 40\%$ ) and Mg ( $\pm 57\%$ ). Only P and Mg are good indexes of nutritional status compared to mineral balance. Regarding Mg, according to González (2000), homeostatic control did not exist; thus, its blood concentration reflects the levels of minerals in the diet. After its absorption in the intestine by the active transport system, the factors that could interfere with this event is the Na:K ratio, the concentration of Ca and P, and the amount of energy in the diet.

Therefore, integral mango meal can replace up to 100% of corn without altering the main indexes of energy and protein metabolism. As a result, making a decision regarding the use of integral mango meal depends on factors related to the product availability and the costs associated with acquiring the mango meal.

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