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Replacement of corn with mango meal for dairy goats¤

Sustitución de maíz por harina de mango para cabras lecheras

Substituição do milho pelo farelo de manga em cabras leiteiras

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Summary

Background: the high volume of mangos harvested during the season, associated with inappropriate management of the fruit after harvesting results in increased waste of this valuable resource. Mango fruit, rich in carbohydrates, has potential use in animal feeding. **Objective:** to evaluate the effect of replacing corn with whole mango meal (0, 330, 660, and 1000 g/Kg on dry matter basis) in the diets of dairy goats on rumen fermentation kinetics, intake, milk yield and composition, and economic results. **Methods:** eight lactating Saanen crossbred goats (48.7 ± 1.99 Kg body weight) were used in the experiment, which started 48 days postpartum and lasted until completing 124 days of lactation. The experimental design consisted of a double Latin square (4×4) with four treatments, four periods and four animals per square. **Results:** a reduction ($p<0.05$) was observed in gas production from total carbohydrates and fiber carbohydrates. Replacement of corn with whole mango meal showed no effect on DM intake (1,890 g/d), crude protein (278 g/d) and neutral

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detergent fiber (959 g/d). Milk production (4% fat-corrected) and milk composition were not affected by the treatments, except for fat and myristoleic fatty acid contents. The economic evaluation showed a reduction in the total feeding cost and a better benefit:cost ratio. **Conclusion:** whole mango meal can replace corn up to 330 g/Kg in the diet of lactating goats.

Keywords: *economic evaluation, fatty acids, food waste, in vitro gas production.*

Resumen

Antecedentes: la alta producción de mango asociado con una gestión inadecuada durante la producción y pos-cosecha, resulta en un aumento de los residuos en el medio ambiente. Debido a que el mango es una fruta rica en carbohidratos (fuente de energía) es posible su utilización en la alimentación de los animales. **Objetivo:** evaluar el efecto de la sustitución de maíz con harina integral de mango (0, 330, 660 y 1000 g/Kg en base a materia seca) en las dietas de cabras lecheras sobre la cinética de fermentación ruminal, consumo, producción y composición láctea y evaluación económica de las dietas. **Métodos:** ocho cabras Saanen mestizas en lactación (48,7 ± 1,99 Kg de peso corporal) fueron utilizadas en el experimento desde el día 48 hasta el día 124 de lactancia. Se utilizó un diseño experimental doble cuadrado latino (4×4) con cuatro tratamientos, cuatro períodos y cuatro animales. **Resultados:** se observó una reducción (p<0,05) en la producción y volumen de gas de los carbohidratos totales y carbohidratos fibrosos. La sustitución de maíz con harina de mango integral no mostró ningún efecto sobre el consumo de materia seca (1890 g/d), proteína bruta (278 g/d) y fibra detergente neutra (959 g/d). La producción de leche (corregida al 4% de grasa) y su composición no fueron afectadas por los tratamientos, excepto para el contenido de grasa y ácido graso miristoleico. La evaluación económica mostró una reducción en el costo total de la alimentación y una mejor relación costo:beneficio. **Conclusión:** se recomienda sustituir el maíz por la harina de mango integral en hasta 330 g/Kg en las dietas de cabras lecheras.

Palabras clave: *ácidos grasos, desechos alimenticios, evaluación económica, producción de gas in vitro.*

Resumo

Antecedentes: a elevada produção de manga associada a um manejo inadequado durante a produção e pós-colheita, resulta em aumento de resíduos no ambiente. Por ser uma fruta rica em carboidratos (fonte de energia) é possível a sua utilização na alimentação animal. **Objetivo:** avaliar o efeito da substituição do milho pelo farelo de manga integral (0, 330, 660 e 1000 g/Kg na matéria seca) na dieta de cabras leiteiras sobre a cinética de fermentação ruminal, consumo, produção e composição do leite, e também avaliação econômica das dietas. **Métodos:** oito cabras mestiças Saanen em lactação (48,7 ± 1,99 Kg de peso corporal) foram introduzidas no experimento 48 dias pós-parto e mantidas até 124 dias de lactação. Foi utilizado um delineamento em duplo quadrado Latino (4×4), com quatro tratamentos, quatro períodos e quatro animais por quadrado. **Resultados:** houve redução (p<0,05) na produção máxima de gás a partir dos carboidratos totais e o volume de gás produzido a partir de carboidratos fibrosos. A substituição do milho pelo farelo de manga integral não mostrou nenhum efeito sobre o consumo de matéria seca (1890 g/d), proteína bruta (278 g/d) e fibra em detergente neutro (959 g/d). A produção de leite corrigida para 4% de gordura e a composição do leite não foram afetadas pelos tratamentos, com exceção do teor de gordura e o ácido graxo miristoleico. A avaliação econômica mostrou uma redução no custo total da alimentação e uma melhor relação custo:benefício. **Conclusão:** recomenda-se substituir o milho pelo farelo de manga integral até 330 g/Kg na dieta de cabras leiteiras.

Palavras chave: *ácidos graxos, alimentos desperdiçados, avaliação econômica, produção de gás in vitro.*

Introduction

The world will have a population of more than nine billion people by the year 2050, which will require 70% more food in the form of meat and milk (Wadhwa and Bakshi, 2013). The greater milk intake in developed countries is a result of increased *per capita* income, urbanization growth, and changes in eating habits (Guyomard *et al*., 2013). Thus, it is estimated that animal production must increase to meet the consumer demands, which implies an increase in the price of grains since its growth in the global market cannot meet the increasing demand for animal-derived foods.

A third of all feedstuffs annually produced (1.3 billion tons) is wasted by consumers and retailers or is lost due to the lack of adequate technology during and after harvesting. Of this total, around 300 million tons per year are foods available for consumption, and according to UNEP (2013), it is enough to feed part of the global population. In Northeast Brazil, the high production of mango associated with inappropriate management during production and after harvesting results in 28% average loss index (Choudhury, 1995), which end up as residues accumulated in inappropriate places, contaminating water and soil resources.

The most adequate use of discarded feeds in animal feeding is not well known due to variations in chemical composition associated with a large number of cultivars, edaphoclimatic conditions, and industrial processing. In general, mango fruit is rich in carbohydrates and organic acids, which are important energy and flavor providers, with volatile compounds as the factors responsible for the flavor (Liu *et al*., 2013).

Aragão *et al.* (2012) evaluated corn replacement with mango meal in sheep diets and found no effects on nutrient intake, even with 100% replacement, demonstrating its acceptability. On the other hand, Cavalcante *et al.* (2006) reported that inclusion of dehydrated mango above 36.1% DM caused a decrease in nutrient intake of sheep. Negative effects on intake and nutrient digestibility were observed by Anigbogu *et al.* (2006) in sheep fed 45 and 60% mango almonds. The authors justified the results due to the toxic properties of phenolic compounds present in the fruit. Huber *et al.* (2012) reported that mango has 4.89 and 6.84% of total phenols in the skin and kernel, respectively. Depending upon the ratio of mango peels and seed kernels fed to ruminants, decreased intake and digestibility can occur due to the astringent effect of phenolic compounds, such as tannins, which interact with proteins, carbohydrates and minerals, reducing the nutritional value of the diet (Shahidi and Naczk, 1995).

Thus, we hypothesized that mango meal, which is high in carbohydrates, could replace corn used as an alternative feed in goat production systems. Therefore, the purpose of this study was to evaluate the effects of corn replacement by whole mango meal (WMM) on milk yield and composition, and rumen kinetics of lactating goats.

Materials and methods

Ethical considerations

Management and care of the animals was 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.

Location

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

Experimental diets

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-85 (*Cynodon* spp.) hay as the forage. Diets consisted of four replacement levels of corn by whole mango meal: 0, 330, 660, and 1000 g/Kg on DM basis. Chemical composition of ingredients is shown in Table 1. Proportions and chemical composition of experimental diets are shown in Table 2.

Mango meal was elaborated with the entire fresh fruit of *Mangifera indica*, "Rosa" variety. Fruit pulp, peel, and seeds were ground in a forage machine, dehydrated under the sun for 48 hours, and then ground passing through a 10 mm screen.

Animals, management, and sample collection

To determine nutrient intake and milk parameters, eight crossbred Saanen goats with 48.7 ± 1.99 Kg average initial body weight (BW) and 48.0 ± 2.0 days in lactation were distributed across a 4×4 double Latin square design, with four treatments and four animals. Feed was offered in two daily meals at 7:00 and 16:00 h in a sufficient quantity to obtain about 10% orts. The trial lasted 76 days and each of the four experimental periods lasted 19 days, divided as follows: 14 days for adaptation to the diets and 5 days to collect supplied feed, and ort samples.

Table 1. Chemical composition of ingredients used in the diet (g/Kg DM basis).

Item	Whole mango meal (WMM)	Ground corn	Soybean meal	Tifton hay
Dry matter (g/Kg)	915	881	870	879
Organic matter	962	982	936	928
Crude protein	56	89.1	475	89
Ether extract	41.2	42	17.0	14.6
Neutral detergent fiber	284	143	155	747
Acid detergent fiber	152	41.5	95	391
Non-fibrous carbohydrates	592	710	315	117
Cellulose	67	89.5	45	303
Lignin	65	12	15	53
Total phenols	396	-	-	-
Condensed tannins	30.8	-	-	-

Table 2. Proportion of ingredients and chemical composition of the experimental diets.

Ingredient (g/Kg)	Replacement levels (WMM[1] replacing corn g/Kg)			
	0	330	660	1000
Tifton hay	600	600	600	600
Whole 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[2]	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

[1]WMM: whole mango meal.

[2]Nutrients/Kg of product: Vitamin A – 135,000 IU; Vitamin D3 – 68,000 IU; Vitamin E – 450 IU; Calcium – 240 g; Phosphorus – 71 g; Potassium – 28.2 g; Sulfur – 20 g; Magnesium – 20 g; Copper – 400 mg; Cobalt – 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.

Orts were removed each day before the morning meal and weighed, sampled, placed in plastic bags, and frozen at -18 ºC. The feed was sampled three times per week and also placed inside plastic bags and frozen at -18 ºC. At the end of each experimental period, feed samples and orts were thawed and subjected to pre-drying at 60 ºC for

72 h, then ground in a Wiley- TE-625 knife mill (Tecnal, São Paulo, SP, Brazil) passing through a 1 mm mesh. Composite samples from each animal were saved on a dry-weight basis for each time period.

Milk

Goats were hand milked twice daily at 6:00 and 15:00 h and milk yield was recorded during the five days of data collection. Milk samples were collected and pooled by proportion according to milk yield at each milking. Milk samples were analyzed for fat, protein, and lactose concentration by infrared analysis (Bentley-2000, Bentley instrument, Inc. Minnesota, USA). Total solids were determined using the oven method according to AOAC (1990).

Chemical analysis

Dry matter (DM), organic matter (OM), crude protein (CP), and ether extract (EE) analyses were performed according to the AOAC (1990), method number 934.01 for DM, 930.05 for OM, 981.10 for CP, and 920.39 for EE. The EE was analyzed by Soxhlet extraction with petroleum ether. The concentration of neutral detergent fiber (NDF) was assayed with a heat-stable amylase and corrected for ash and nitrogenous compounds using the techniques described by Mertens (2002), with corrections for protein according to Licitra *et al.* (1996) and adding thermostable alpha-amylase. Lignin 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):

$$\text{NFC (g/Kg)} = 1000-[(\text{CP–urea derived CP} + \text{urea}) + \text{NDFap} + \text{EE} + \text{ash}]$$

Where:

CP = crude protein.
NDFap = neutral detergent fiber corrected for ash and protein.
EE = ether extract.

Concentration of condensed tannins (CT) and total phenols (TP) in whole mango meal were analyzed according to Wolfe *et al.* (2008).

In vitro semi-automatic technique of gas production was used to evaluate rumen fermentation kinetics, according to Theodorou *et al.* (1994). The rumen fluid was obtained from a rumen-cannulated goat. Pressure from the accumulated gas was measured by a pressure transducer (type T443A; Bailey & Mackey, Birmingham, England).

To assess the fatty acid profile, a 200 mL composite milk sample was used to separate the fat with the methodology proposed by Murphy *et al.* (1995). Triglycerides were submitted to transmethylation for methyl esters by using the 5509 methods (ISO, 1978). Methyl esters of fatty acids were analyzed by gas chromatography using a Varian 431-GC equipment and a mass spectrophotometer Varian 220-MS in a capillary column Zebron ZB-5MS Phenomenex (30 m × 0.25 mm × 0.25 µm). Fatty acids were quantified by area normalization of the methyl esters in percentage per area (%).

Crude income (economic analysis) was estimated considering only the feeding costs, assuming that all other components, fixed and variable, would be common for all treatments. The cost of whole mango meal was calculated based on the cost of labor to prepare it. Net income was calculated by the difference between crude income (milk production × price of a milk L) and the daily cost of feeding.

Statistical analysis

Parameters for cumulative gas production kinetics were analyzed by the nonlinear regression procedure (NLIN) with SAS software (2003, SAS 9.1 Institute Inc., Cary, NC, USA).

Intake and milk performance were submitted to variance and regression analysis using the R software (R Development Core Team version 2.15.3, 2013), according to the following model:

$$Y_{ijk} = \mu + T_i + A_j + P_k + e_{ijk}$$

Where:

Y_{ijk} = dependent variable measured in animal *j* that was subjected to the *i* treatment in period *k*.

μ = general mean.
T_i = fixed effect of treatment i.
A_j = random effect of animal j.
P_k = random effect of period k.
e_{ijk} = random error.

All statistical procedures were conducted with 0.05 as the critical probability level for a type I error.

Results

Intake and milk performance

No effects were found for WMM level on the intake of DM (1890 g/d), CP (278 g/d) and NDF (959 g/d; p>0.05; Table 3). However, intake of NFC and total digestible nutrients (TDN) decreased linearly around 27.9 g/d and 0.082 Kg/d, respectively, as dietary WMM increased (p<0.05).

Milk production decreased linearly 0.04 Kg/d as WMM increased (p<0.05; Table 3). The 4% fat-corrected milk yield showed no difference between treatments (p>0.05; Table 3). WMM levels had no effect (p>0.05) on milk composition variables, with average values of 4.03% lactose, 2.40% protein, and 10.0% total solids, respectively. Milk fat content increased linearly 0.09% for every 1% increase of WMM levels (p<0.05).

Milk fatty acid profile showed no difference between treatments (p>0.05), except for myristoleic fatty acid $C_{14:1}$ *cis*-9, which decreased linearly 0.15 g/100 g of fatty acids for every 1% increase in WMM levels (p<0.05; Table 4). Saturated fatty acids (SFA), polyunsaturated fatty acids (PUFA) and desired FA content showed no difference, with mean values of 82.9, 17.1 and 25.2 g/100 g, respectively (p>0.05).

In vitro fermentation kinetics

Gas produced from total carbohydrates (V_{TC}) and fiber carbohydrates (Vf_{FC}) decreased linearly (106 and 137 mL/g of DM, respectively) as WMM increased (p<0.05; Table 5). A quadratic effect was observed for gas volume produced from non-fiber carbohydrates (Vf_{NFC}), with a value of 58 mL/g of DM estimated with 32.7% corn replacement with WMM (p<0.05). A similar effect was found for non-fiber carbohydrate fractions (Kd_{NFC}) and fiber carbohydrate (Kd_{FC}) rates, with values of 0.053 and 0.011 %/h estimated with 46.4 and 53.0% of replacement, respectively (p<0.05).

Table 3. Average daily intake, milk yield and composition for dairy goats fed whole mango meal (WMM) replacing corn.

Items	Replacement levels (g/Kg)				SEM[1]	P-value	
	0	330	660	1000		Linear	Quadratic
Intake (g/d)							
Dry matter	1920	1920	1840	1870	53.63	0.17	0.63
Crude protein	282	281	271	277	7.83	0.23	0.47
Neutral detergent fiber	934	962	954	985	27.27	0.10	0.96
NFC[2]	607	581	536	529	17.27	<0.001	0.35
TDN[3] (Kg/d)	1.23	1.20	1.13	1.12	0.03	<0.01	0.60
Production (Kg/d)							
Milk	2.04	2.03	1.90	1.97	0.08	0.04	0.37
4% fat-corrected milk	1.59	1.61	1.53	1.61	0.06	0.96	0.32
Milk composition (%)							
Fat	2.54	2.58	2.69	2.79	0.06	<0.001	0.52
Lactose	4.07	4.01	4.06	3.99	0.04	0.33	0.87
Protein	2.43	2.40	2.37	2.38	0.06	0.44	0.74
Total solids	9.96	9.92	10.1	10.1	0.13	0.32	0.73

[1] Standard error of the mean.
[2] Non-fiber carbohydrates.
[3] Total digestible nutrients.

Table 4. Milk fatty acid profile in dairy goats fed whole mango meal (WMM) replacing corn.

Items	Replacement levels (g/Kg)				SEM[1]	Effect (P-value)	
	0	330	660	1000		Linear	Quadratic
Fatty acid (g/100 g of total FA)							
Caprylic $C_{8:0}$	0.47	0.45	0.25	0.39	0.05	0.25	0.35
Capric $C_{10:0}$	11.6	10.2	11.7	13.0	0.49	0.12	0.11
Undecanoic $C_{11:0}$	0.99	1.14	0.72	0.27	0.14	0.08	0.34
Lauric $C_{12:0}$	6.22	6.13	5.04	5.59	0.24	0.07	0.35
Tridecanoic $C_{13:0}$	0.55	0.54	0.27	0.32	0.06	0.09	0.79
Myristic $C_{14:0}$	17.9	15.3	18.7	16.5	0.70	0.87	0.88
Myristoleic $C_{14:1}$ *cis*-9	0.87	0.63	0.35	0.32	0.07	0.002	0.15
Pentadecanoic $C_{15:0}$	0.42	0.86	0.23	0.33	0.08	0.06	0.11
Palmitic $C_{16:0}$	37.6	37.6	38.5	37.8	0.77	0.78	0.80
Palmitoleic $C_{16:1}$	0.33	0.81	0.44	0.76	0.08	0.11	0.50
Heptadecanoic $C_{17:0}$	0.32	0.55	0.38	0.39	0.03	0.89	0.11
Heptadecenoic $C_{17:1}$ *cis*-10	0.09	0.21	0.13	0.11	0.08	0.78	0.06
Stearic $C_{18:0}$	7.75	8.22	8.26	7.93	0.39	0.86	0.59
Oleic $C_{18:1}$ *cis*-9	13.7	15.4	13.7	14.8	0.59	0.79	0.85
Linoleic $C_{18:2}$ *cis*-9, *cis*-12	1.42	1.71	1.28	1.40	0.25	0.75	0.81
Saturated Fatty Acids	83.8	81.0	84.1	82.6	0.55	0.92	0.63
UFA[2]	16.2	18.9	15.9	17.40	0.56	0.92	0.63
Desirable Fatty Acids[3]	23.9	27.2	24.2	25.3	0.83	0.89	0.59

[1] Standard error of the mean.
[2] Unsaturated fatty acids.
[3] DFA = (UFA + C18:0).

Table 5. *In vitro* fermentation kinetics of diets replacing corn with whole mango meal (WMM).

Items	Replacement levels (g/Kg)				SEM [1]	P-value	
	0	330	660	1000		Linear	Quadratic
Volume of gas produced (mL/g DM)							
Total carbohydrates	256	231	189	153	10.26	<0.001	<0.001
NFC[2]	67.0	59.9	66.5	99.4	4.06	0.011	<0.001
Fiber carbohydrates	189	171	122	53.1	13.63	<0.001	<0.001
Degradation rate (%/h)							
NFC[2]	0.067	0.064	0.047	0.079	0.003	0.580	0.032
Fiber carbohydrates	0.017	0.012	0.011	0.016	0.001	0.489	<0.001
Lag time (h)	11.5	10.8	9.42	6.54	0.49	<0.001	<0.001

[1] Standard error of the mean.
[2] Non-fiber carbohydrates.

Economic evaluation

The mango used in the study was discarded fruit (mango wastes) from municipal markets, and the cost involved in its acquisition and transportation was R$0.33/Kg DM. The lowest total cost of feeding (Table 6) was found at a replacement level of 1000 g/Kg (BRL, R$1.17; where BRL = code for Brazilian currency in "Real" = R$). For each R$1.00 invested, R$2.52 was returned.

Table 6. Economic evaluation of the experimental diets.

Item	Replacement levels (g/Kg)			
	0	330	660	1000
Feeding costs[1] (BRL, R$/Kg)	1.53	1.42	1.26	1.17
Price of milk[2] (BRL, R$/Kg)	1.50	1.50	1.50	1.50
Milk yield (Kg/d)	2.04	2.03	1.90	1.97
Crude income (BRL, R$/d)	3.06	3.05	2.85	2.96
Net income (BRL, R$/Kg)	1.53	1.63	1.59	1.79
Benefit:cost ratio	2.00	2.14	2.26	2.52

BRL – code for Brazilian currency, real (R$); USD$1.00 = BRL, R$2.24.

[1]Ingredient costs (R$/Kg DM): Whole mango meal: 0.33; Ground corn: 0.80; Soybean meal: 0.95; Urea: 1.80; Dicalcium phosphate: 1.35; Mineral mix: 1.50; Tifton hay: 0.59.

[2] Price of a liter of milk in the region of the study: R$1.50.

Discussion

The absence of effects on milk yield (4% fat-corrected) and total milk solids suggests that goats have adapted to variations in diet quality, characterized by increasing levels of indigestible nutrients such as lignin and phenolic compounds. This result is in agreement with Hofmann (1989) that reported high selectivity in goats, and ability to adapt to seasonal variations in the quality of fodder.

Seventy-five percent of the milk fatty acid (FA) profile of goats is composed of capric ($C_{10:0}$), myristic ($C_{14:0}$), palmitic ($C_{16:0}$), stearic ($C_{18:0}$), and oleic ($C_{18:1}$) acids, according to Park *et al.* (2007). In the present study, these FAs totalized 89.1% of the total FA in milk fat (Table 4), which probably was influenced by the source of the tested feed, as the kernel of mango seed is basically composed of C16:0, C18:0, and C18:1, which together represent 91% of the total FA (Rukmini and Vijayaraghavan, 1984). An average concentration of stearic acid C18:0 of 8.04 g/100 g FA was observed in this study, which is within the range suggested (from 6 to 11%) by Chilliard *et al.* (2001). This is a positive result, since stearic acid is not involved in the increase of cholesterol levels. Thus, as soon as stearic acid is ingested, it is metabolized to oleic acid C18:1.

The reduction in concentration of myristoleic acid C14:1 cis-9 per 100 g FA could be related to the presence of tannins in mango meal. A similar result was recorded by Toral *et al.* (2011), when tannins with sunflower oil were added to the diets of Assaf sheep, observing a reduction in C14:1 cis-9 in comparison to a diet without tannins. Literature results referring to the impact of tannin intake on milk fatty acid profile is still inconsistent. Reductions in 18-carbon FA contents can occur in the presence of tannins for grazing cows or sheep, or it may increase due to biohydrogenation of dietary PUFA, which depends on tannin type or dose (Cabiddu *et al.*, 2009).

The lowest gas production obtained from total and fiber carbohydrates can be attributed to the greatest percentage of lignin in the fiber fraction and the presence of tannins in the WMM (Table 1). Digestion (gas production) is assessed by the ratio between soluble and insoluble fractions. Thus the higher concentration of the fraction for low digestibility observed in the diets where corn was totally replaced (1000 g/Kg) with WMM (Table 5) contributed to the lower gas production.

Considering the principle that rate of digestion is essentially a physicochemical function of the diet (Van Soest, 1994), we can say that lignin content, physicochemical interaction between NDF and the other dietary compounds, and the presence of tannins affected the degradation dynamics. The presence of seeds in the WMM contributed to the increased contents of lignin (Table 2), which explains the reduction in rumen fermentation due to inhibition of microbial adhesions and, consequently, the degradation process.

The results related to rumen degradation kinetics were correlated with those of ingestion behavior. When the goats were fed 1000 g/Kg WMM, there was a daily rumination time (554 minutes) close to the physiologic time (600 min/d) cited by Welch (1982), a fact that may be attributed to a greater proportion of fractions of low digestibility carbohydrates and phenolic compounds that block the access of cellulolytic enzymes. As a result, there was an increase in the time required to process the forage into small particles, which reduces rumination efficiency.

Knowing that the mango origin was from discarded food at municipal markets, the cost involved in its acquisition and transportation represented only R$0.33/Kg of DM (Table 6). The low cost of discarded mango resulted in 23.5% economy of the diet when

1000 g/Kg of corn was replaced by WMM. Despite the decrease of crude income with the replacement of corn by WMM, the control diet (R$3.06/d) and the diet with 330 g/Kg replacement (R$3.05/d) were similar. This decrease can be explained by the fact that crude income takes into account only the gain from milk produced. However, an opposite behavior was observed for net income, since diets with higher WMM were more profitable due to a lower cost of the feed. The costs reduction of the diet represents a 17% increase in net income for the diet with 1000 g/Kg replacement when compared to the control diet. This suggests a better benefit:cost ratio and indicates a higher economic return. Besides being economically viable, replacement of corn with WMM becomes interesting from the standpoint of environmental preservation, since discarded mango fruit -unacceptable for human consumption- can be used in a sustainable way as animal feed instead of being improperly discarded.

We recommend replacing corn with whole mango meal up to 330 g/Kg DM of diet, because of the better fermentation of fiber carbohydrates, it does not compromise milk yield of lactating goats, and it also reduces feeding costs.

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Conflicts of interest

The authors declare they have no conflicts of interest with regard to the work presented in this report.

References

AOAC. Association of Official Analytical Chemist. Official Methods of Analysis. 15th ed. Arlington (VA): Inc; 1990.

Anigbogu NM, Bienstman P, Van Damme B, Ezeokoli CD. Incorporation of dry *Mangifera indica* kernel in the concentrate ration of growing lambs. Rev Elev Med Vet Pay 2006; 59:39-42.

Aragão ASL, Pereira LGR, Chizzotti ML, Voltolini TV, Azevêdo JAG, Barbosa LD, Santos RD, Araújo GGL, Brandão LGN. Farelo de manga na dieta de cordeiros em confinamento. Arq Bras Med Vet Zoo 2012; 64:967-973.

Cabiddu A, Molle G, Decandia M, Spada S, Fiori M, Piredda G, Addis M. Responses to condensed tannins of flowering sulla (*Hedysarum coronarium* L.) grazed by dairy sheep. Part 2: Effects on milk fatty acid profile. Livest Sci 2009; 123:230–240.

Cavalcante MA, Clementino RH, Neiva JN. Consumo e digestibilidade da matéria seca de dietas contendo diferentes níveis de subproduto da manga. Proceedings of the 43rd Annual Meeting of the Brazilian Society of Animal Science; 2006 Jul 24-27; João Pessoa, Brazil. João Pessoa: Brazilian Society of Animal Science; 2006.

Chilliard Y, Ferlay A, Doreau M. Effect of different types of forages, animal fat or marine oils in cow's diet on milk fat secretion and composition, especially conjugated linoleic acid (CLA) and polyunsaturated fatty acids. Livest Prod Sci 2001; 70:31-48.

Choudhury MM. Perdas de frutas e hortaliças na pós-colheita. Petrolina: Informe CPATSA; 1995.

Guyomard H, Manceron S, Peyraud JL. Trade in feed grains, animals and animal products: current trends, future prospects and main issues. Anim Frontiers 2013; 3:14-18.

Hall MB. Calculation of non-structural carbohydrate content of feeds that contain non-protein nitrogen. Florida: Bull. Tech. University of Florida; 2000.

Hofmann RR. Evolutionary steps of ecophysiological adaptation and diversification of ruminants: a comparative view of their digestive system. Oecologia 1989; 78:443-457.

Huber K, Queiroz JH, Moreira AVB, Ribeiro SMR. Caracterização química do resíduo agroindustrial da manga Ubá (*Mangifera indica* L.): uma perspectiva para a obtenção de antioxidantes naturais. Rev Bras Tecnol Agroind 2012; 6:640-654.

ISO. Animal and Vegetable Fats and Oils - Preparation of Methyl Esters of Fatty Acids (method ISO 5509). Geneva: International Organization for Standardization; 1978.

Licitra G, Hernandez TM, Van Soest PJ. Standardization of procedures for nitrogen fractionation of ruminant feeds. Anim Feed Sci Technol 1996; 57:347–358.

Liu FX, Fu SF, Bi XF, Chen F, Liao XJ, Hu XS, Wu JH. Physico-chemical and antioxidant properties of four mango (*Mangifera indica* L.) cultivars in China. Food Chem 2013; 138:396-405.

Mertens DR. Gravimetric determination of amylase-treated neutral detergent fiber in feeds with refluxing in beakers or crucibles: collaborative study. J AOAC Int 2002; 85:1217-1240.

Murphy JJ, Connolly JF, Mcneill GP. Effects on cow performance and milk fat composition of feeding full fat soybeans and rapeseeds to dairy cows at pasture. Livest Prod Sci 1995; 44:13-25.

NRC, National Research Council. Nutrient requirements of small ruminants. Washington (DC): National Academy Press; 2007.

Park YW, Juarez M, Ramos M, Haenlein GFW. Physicochemical characteristics of goat and sheep milk. Small Ruminant Res 2007; 68:88-113.

R Development Core Team. R: a language and environment for statistical computing. Vienna, Austria, the R Foundation for Statistical Computing; 2013.

Rukmini C, Vijayaraghavan M. Nutritional and toxicological evaluation of mango kernel oil. J Am Oil Chem Soc 1984; 61: 789-792.

SAS. Statistical Analysis System. User's guide., Version 9.1, Ed. Cary (NC): USA. SAS Institute Inc. 2003.

Shahidi F, Naczk MF. Food phenolcs: sources, chemitrys, effects and applications. Lancaster (PA): Technomic Publishing Co. Inc; 1995.

Theodorou MK, Williams BA, Dhanoa MS, McAllan AB, France J. A simple gas production method using a pressure transducer to determine the fermentation kinetic of ruminant feeds. Anim Feed Sci Technol 1994; 48:185-197.

Toral PG, Hervás G, Bichi E, Belenguer A, Frutos P. Tannins as feed additives to modulate ruminal biohydrogenation: Effects on animal performance, milk fatty acid composition and ruminal fermentation in dairy ewes fed a diet containing sunflower oil. Anim Feed Sci Tech 2011; 164:199-206.

UNEP. United Nations Environment Programme, New effort launched to measure and monitor global food loss and waste. UNEP News Centre; 2013.

Van Soest PJ, Wine RH. Use of detergents in analysis of fibrous feeds. IV. Determinations of plant cell-wall constituents. J AOAC Int 1967; 50:50-55.

Van Soest PJ. Nutritional ecology of the ruminant. 2nd ed. Ithaca (NY): Cornell University; 1994.

Wadhwa M, Bakshi MPS. Utilization of fruit and vegetable wastes as livestock feed and as substrates for generation of other value-added products. FAO Publications 2013. [Access date: November 20, 2013]. URL: http://www.fao.org/docrep/018/i3273e/i3273e00.htm

Welch JG. Rumination, particle size and passage from the rumen. J Anim Sci 1982; 54:885-894.

Wolfe MR, Terrill TH, Muir JP. Drying method and origin of standard affect condensed tannin (CT) concentrations in perennial herbaceous legumes using simplified butanol-HCl CT analysis. J Sci Food Agr 2008; 88:1060-1067.