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Effects of *Parkia platycephala* on feeding behavior, rumen health, blood markers, and physiological responses of lactating goats

Ianete Lima Batista[1], Tairon Pannunzio Dias-Silva[1], Carlo Aldrovandi Torreão Marques[2], Jacira Neves da Costa Torreão[1], Leilson Rocha Bezerra[3], Ricardo Loiola Edvan[1], Veerasamy Sejian[4], Marcos Jácome de Araújo[1*]

[1] Universidade Federal do Piauí, Programa de Pós-Graduação em Zootecnia, Campus Professora Cinobelina Elvas, Bom Jesus, PI, Brasil.
[2] Universidade Federal de Sergipe, Campus do Sertão, Nossa Senhora da Glória, SE, Brasil.
[3] Universidade Federal de Campina Grande, Centro de Saúde e Tecnologia Rural, Patos, PB, Brasil.
[4] ICAR-National Institute of Animal Nutrition and Physiology, Division of Animal Physiology, Adugodi, Bengaluru, Karnataka, India.

***Corresponding author:**
jacome@ufpi.edu.br

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ABSTRACT - The objective of this study was to evaluate the effect of *Parkia platycephala* pod meal (PP) on feeding behavior, rumen health, blood markers, and physiological responses in lactating goats. Eight apparently healthy, adult, multiparous Anglo-Nubian goats, with an average body weight of 42.06±3.5 kg and approximately 52±4 days in lactation, were randomly assigned into two Latin squares (4×4) composed of four levels of PP (0, 33.3, 66.7, and 100% of dry matter) for four periods. Daily feed intake, feeding behavior, rumen health, blood markers (hemogram and biochemical parameters), and physiological responses (rectal temperature, respiratory rate, heart rate, and sweating rate) were assessed. Intake, feeding efficiency, and rumination efficiency were not affected by the replacement of ground corn with PP. At these replacement levels, the goats significantly spent more time feeding and ruminating. There was a significant decrease in the number of chews (number/day and number/min) with an increase in PP inclusion. Rectal temperature, respiratory rate, heart rate, and sweating rate were higher in the afternoon for the three periods measured. There were no negative changes in blood markers or rumen health with the use of PP. The current findings indicate that PP can be used to replace up to 100% of the corn in the diet of lactating goats without causing significant changes in animal health, feeding behavior, or physiological parameters.

Keywords: byproducts, feed efficiency, hematology, ruminants

1. Introduction

Goat farming is a common practice in arid and semi-arid zones as they have a good adaptive capacity to the intrinsic edaphoclimatic conditions that prevail in such regions (Mdladla et al., 2017). Arid and semi-arid regions generally face an irregular rainfall, which leads to fodder scarcity for the animals. Thus, an alternative source of feed has to be determined to replace traditional ingredients (such as corn) and reduce feed costs. An ideal alternative feed should generate less heat on digestion and should meet the nutritional requirements of the animal.

Given this scenario, "faveira" (*Parkia platycephala*) is a potential alternative to reduce feed expenditure. The pods fall in the dry season when forage becomes scarce in quantity and quality. *Parkia platycephala* is a legume widely used in animal feed, but farmers are still reluctant in using it. One possible

explanation may be a lack of knowledge, especially regarding its nutritional value; therefore, scientific studies are needed to disseminate information on its potential as an alternative feed for ruminants. Other possible explanation would be the way of offering the PP, since its light or dark pods are highly acceptable to ruminants (Ramos et al., 1984; Alves et al., 2007; Magalhães et al., 2014). The seeds of *P. platycephala* are hygroscopic and contain good quantities of crude protein, but have a low digestibility when consumed unprocessed. Hence, the consumption of crushed pods after drying is advisable in ruminants (Carvalho and Ramos, 1982; Carvalho et al., 2006; Alves et al., 2007).

Research conducted by Machado et al. (1999) showed 95% of dry matter, 9.3% of crude protein, 12.8% of neutral detergent fiber, 10.4% of acid detergent fiber, 0.12% of calcium, and 0.11% of phosphorus in *P. platycephala* pods. In addition, by containing rapid ruminal fermentation carbohydrates the pods represent a potential energy source for being used in ruminant diets (Alves et al., 2007). This allows the production of propionic acid in the rumen and raises the efficiency of energy use by reducing losses through methane fermentation (Silva et al., 2012).

In this perspective, before replacing a diet with an alternate feed, it is of utmost importance to examine parameters such as feed intake, feeding behavior patterns, blood markers, rumen fermentation, and energy estimation. This would provide a better understanding on how to incorporate the feed into the new diet, understand its nutritive value, and thereby optimize animal production (Van Soest, 1994; Eustáquio Filho et al., 2014; Rodrigues et al., 2014; Mendes et al., 2015). Thus, the objective of this study was to evaluate feeding behavior; physiological, hematological, and biochemical parameters; and rumen fermentation parameters in lactating goats fed diets containing *P. platycephala* pod meal (PP).

2. Material and Methods

2.1. Study site and ethical committee

The study was conducted in Bom Jesus, Piauí, Brazil (09°04'28" S latitude and 44°2'31" W longitude, with an average altitude of 277 m). All experimental procedures and animal handling were performed in accordance with the Institutional Animal Care and Use Committee Guidelines (case no. 091/2010).

2.2. Animals and facilities

We used eight apparently healthy adult (four years old) multiparous Anglo-Nubian goats with an average body weight of 44.5±6.3 kg and 50±4 days in lactation for the current study. The goats were previously vaccinated and dewormed according to veterinary guidelines in the region and were housed in individual stalls (1.5 × 1.0 m) equipped with separate feeders and water fountains.

2.3. Treatments and experimental management

The experiment was conducted for 80 days, which consisted of four 20-day periods. During each period, 15 days were allocated for dietary adaptation, and data were collected during the last five days. The effects of dry matter replacement of ground corn with PP at four levels (0, 33.3, 66.7, and 100%) were evaluated. The PP was added manually and mixed into the concentrate according to the replacement percentage.

The diet consisted of roughage (grass hay; Colonião - *Panicum maximum*), and concentrate (ground corn, soybean meal, a mineral supplement, and PP) in the proportion of 50:50 (Table 1).

The diets (Table 1) followed the recommendations of the NRC (2007) to meet the nutrient requirements of lactating goats with a production of 1.5 kg/goat/day and 4% milk fat. Quantities were adjusted according to the intake of the previous day to provide 10% orts. The body weight of the animals was measured at the beginning and end of each experimental period. The animals were fed twice daily in individual troughs, after milking at 08.00 and 16.00 h.

Table 1 - Chemical composition and proportion of ingredients and chemical composition of experimental diets

Chemical composition (g/kg of DM)	Ground corn	Soybean meal	PP	Hay[1]
Dry matter	897.2	888.5	848.3	891.7
Crude protein	86.1	484.5	111.0	93.4
Ether extract	50.9	24.2	19.0	32.4
Mineral matter	14.8	68.6	20.4	58.9
Neutral detergent fiber	123.5	139.2	159.3	761.0
Acid detergent fiber	35.5	107.8	126.2	470.2
Non-fibrous carbohydrates	724.7	283.5	690.3	54.3
Total condensed tannins[2]	-	-	39.4	-
Soluble condensed tannins[2]	-	-	25.2	-
Condensed tannins bound to the solid residue[2]	-	-	14.2	-
	Replacement level (% dry matter)			
	0	33.3	66.7	100
Ingredient (g/kg of dry matter)				
Ground corn	385.0	256.7	128.3	000.0
Soybean meal	100.0	100.0	100.0	100.0
Mineral supplement[3]	15.00	15.00	15.00	15.00
Hay (*Panicum maximum* cv. Áries)[1]	500.0	500.0	500.0	500.0
Parkia platycephala pod meal (PP)	000.0	128.3	256.7	385.0
Chemical composition (g/kg of dry matter)				
Dry matter (g/kg as fed)	894.8	888.3	881.8	875.4
Crude protein	128.3	131.4	134.7	137.8
Neutral detergent fiber	441.9	446.5	451.2	455.7
Acid detergent fiber	259.5	271.1	282.8	294.5
Ether extract	38.2	34.1	30.0	25.9
Mineral matter	57.0	57.7	58.4	59.2
Non-fibrous carbohydrates	334.5	330.1	325.7	321.3

DM - dry matter.
[1] *Panicum maximum* cv. Áries.
[2] Equivalent to Jurema Preta tannin (*Mimosa hostilis* Benth).
[3] Guarantee levels per kg of product: Ca, 240 g; P, 71 g; K, 28.2 g; Mg, 20 g; S, 20 g; Zn, 1,700 mg; Cu, 400 mg; Fe, 250 mg; Mn, 1,350 mg; Co, 30 mg; I, 40 mg; Se, 15 mg; Cr, 10 mg; F (max.), 710 mg; vitamin A, 135 IU; vitamin D3, 68 IU; vitamin E, 450 IU.

2.4. Chemical composition

Feed and orts samples collected within five days of each experimental period were placed in labeled plastic bags and stored in a freezer at −20 °C. At the end of each experimental period, the samples were thawed, homogenized, and a composite sample corresponding to each treatment, animal, and period was formed (approximately 250 g). Samples were not pre-dried in an oven with forced ventilation (55 to 65 °C) for 72 h because it was a dry (90% dry matter [DM]) feed.

Samples of the diets and orts were ground in a Willey mill with 1-mm mesh sieves. The DM (method 934.01 - AOAC, 1990), mineral matter (method 930.05 - AOAC, 1990), crude protein (CP; method 981.10 - AOAC, 1990), and ether extract (EE; method 920.39 - AOAC, 1990) of the samples were estimated. Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were also estimated using thermostable amylase to remove starch, modified using non-woven fabric (TNT) (Van Soest et al., 1991). The non-fibrous carbohydrate content (NFC) of the sample was calculated as follows (Mertens, 1997):

$$NFC = 100 - NDF - CP - EE - Ash \quad (1)$$

2.5. Nutrient intake

Nutrient intake was determined by the difference between the total nutrients in the feed offered and the total nutrients in the orts. The samples were always weighed in the morning, of which

approximately 30% was sampled and packed in plastic bags with appropriate identification of the animals, treatments, and collection period, and then frozen at −20 °C.

2.6. Evaluation of feeding behavior

The feeding behavior of the animals was assessed on the fourth day of the experimental period, consisting of four evaluations over a period of 24 h, according to the methodology of Johnson and Combs (1991), which started at 08.00 h and ended at 08.00 h the following day. The ethnographic study was carried out by two trained observers that were strategically placed not to disturb or stress the animals. All animals were observed for the frequency of feeding, rumination, and idleness at 10 min intervals, and were observed continuously for defecation, urination, and water intake. All observations were annotated in an individual spreadsheet for each animal. The experimental site was under artificial light overnight.

The chewing time was evaluated over three rumination cycles during three different periods of the day (10.00-12.00, 14.00-16.00, and 18.00-20.00 h). During this phase, the number of ruminating chews, number of boluses ruminated per day, time spent on rumination, and number of chews for each ruminal bolus were recorded for each animal. From the sum of the time spent feeding and ruminating (FT + RT), the feeding efficiency, rumination efficiency (RE), and total chewing time (TCT, h/day) were determined according to the method reported by Bürger et al. (2000), using the following equations:

$$NRB = RT/NCt \quad (2)$$

$$NC = NRB \times NCb \quad (3)$$

$$FE_{DM} = DMI/FT;\ FE_{NDF} = NDFI/FT \quad (4)$$

$$RE_{DM} = DMI/RT;\ RE_{NDF} = NDFI/RT \quad (5)$$

$$\text{and } TCT = FT + RT \quad (6)$$

in which NRB = number of ruminal boluses, NCt = chewing time per bolus, NCb = number of chews per bolus, FE_{DM} = feed efficiency of DM (g DM intake/h), FE_{NDF} = feed efficiency of NDF (g NDF intake/h), DMI (g) = daily DM intake, NDFI (g) = daily neutral detergent fiber intake, FT = time spent feeding daily, RE_{DM} = rumination efficiency of DM (g of ruminated DM/h), RE_{NDF} = rumination efficiency of NDF (ruminated NDF/h), RT (h/day) = rumination time, and TCT = total chewing time (h/day).

2.7. Measurement of climatological and physiological data

The climate and physiological variables were recorded twice each day, in the morning (09.00 h) and afternoon (15.00 h). The climatic variables (air temperature [T, °C], and relative humidity [RH, %]) were obtained from a hygrometer installed at the study site. Additionally, the dry bulb temperature (DBT, °C), wet bulb temperature (WBT, °C), dew point temperature (DPT, °C), and black globe temperature (BGT, °C) were measured. From these data, the black globe-humidity index was calculated using the following equation, as described by Buffington et al. (1981):

$$BGHI = BGT + (0.36 \times DPT\ (DBT - (100 - RH\%)/5)) + 41.5 \quad (7)$$

Respiratory rate (RR), heart rate (HR), and rectal temperature were evaluated according to the methods of Feitosa (2014). All animals had participated in previous experiments and were adapted to human contact, such that measurement of physiological variables did not cause additional stress to these animals. Respiratory rate was measured in breaths per minute by direct observation of left flank movements. The HR, in beats per minute, was obtained using a stethoscope placed between the third and fourth intercostal space. The rectal temperature was measured using a digital thermometer (Incoterm®, Porto Alegre, Rio Grande do Sul, Brazil) inserted directly into the rectum of the animal. The clinical thermometer measured from 10 to 43.9 °C with an accuracy of 0.2 °C, with a measurement time of approximately 10 s. The sweating rate (SR) was measured using a technique developed by Berman (1957) and modified by Schleger and Turner (1965).

2.8. Blood sampling and analysis

Blood samples were collected to determine biochemical (10 mL) and hematological profiles (5 mL). Samples were collected on days 1, 3, and 5 and on the last day of collection at 05.00 h, before milking and feeding. Blood samples were collected by jugular venipuncture using disposable needles (25 × 8 mm, Greinerbio-onne®, Americana, São Paulo, Brazil) and vacutainer tubes. The blood samples were transported on ice to the laboratory. The samples for biochemical profile were centrifuged at 3500 rpm for 15 min, and serum aliquots were transferred into Eppendorf tubes and stored in a freezer at −20 °C until subsequent analysis.

2.9. Measurement of hematological parameters

Red blood cell (RBC) and leukocyte counts were estimated using the Neubauer improved cell counting chamber, as recommended by Vallada (1999). The hematocrit was determined by the microhematocrit technique, and the result was expressed as a percentage (%). Plasma samples were used to measure the total protein (TP) using a refractometer with analysis based on the degree of light refraction (Thrall et al., 2015). The determination of the hemoglobin content was performed by the cyanometa-hemoglobin method with dilution in Drabkin's solution. The values obtained by counting the number of red blood cells, hematocrit, and hemoglobin content were used to establish the values of the absolute hematimetric indexes – mean corpuscular volume (MCV), and mean corpuscular hemoglobin concentration (MCHC). Two blood smears for each sample were obtained to analyze differential leukocyte counts with the use of Romanowsky-type stains (Panótico Rápido, LABORCLIN® Ltda, Pinhais, Paraná, Brazil), according to the standard technique for animals described by Viana et al. (2002). In each blood smear, 100 leukocytes were identified and classified, according to their morphological and color characteristics, into neutrophils, eosinophils, basophils, lymphocytes, and monocytes using a 1000X magnification microscope.

2.10. Measurement of biochemical parameters

The metabolites evaluated were creatinine (Labtest Diagnóstica® S.A) and urea (Urea Liquiform Labtest Diagnóstica® S.A) by the colorimetric enzymatic method; cholesterol (cholesterol Liquiform Labtest Diagnóstica® S.A), glucose (glucose Liquiform Labtest Diagnóstica® S.A), and triglycerides (triglycerides Liquiform Labtest Diagnóstica® S.A). The enzyme evaluated was aspartate aminotransferase by the UV kinetic method (AST/GOT Liquiform Labtest Diagnóstica® S.A). The biuret method was used to evaluate total proteins (Labtest Diagnóstica® S.A), and total serum proteins were estimated by the bromocresol green method. All biochemical analyses were performed using a semi-automatic biochemical analyzer (Spectrum®, São Paulo, Brazil).

2.11. Rumen fluid collection and analysis

The rumen fluid (200 mL) was collected from all goats on the fifth day of collection, 4 h after feeding in the morning. For collection, a flexible esophageal catheter was used. It was lubricated prior to use with mineral oil and washed with distilled water between collections. The esophageal catheter was connected to a vacuum pump and a manifold tube. The first aliquot was discarded to reduce contamination with saliva in the samples and to minimize interference with pH values. The pH was measured immediately after collection using a digital table pH meter.

Samples of rumen fluid were stored in thermal bottles previously heated to 39 °C and were then sent to the microbiology laboratory for the following macroscopic analyses according to the method reported by Radostits et al. (2002): coloring (olive green, dark olive green, brownish olive green, brown, brownish green, or straw yellow), consistency\viscosity (moderately viscous, slightly viscous, slightly aqueous, or aqueous), and odor (aromatic, slightly putrid, moldy, spicy acid, putrid ammonia, or odorless).

According to the methodology described by Rosenberger (1993), sedimentation and flotation times (Arcuri et al., 2006) were evaluated by assessing methylene blue reduction (Radostits et al., 2002).

The bacterial flora was analyzed in relation to the predominant type (gram-negative or gram-positive) by gram staining. Density and motility of protozoa were observed directly on a slide under an optical microscope at 100X magnification, and classified as: abundant (+++), moderate (++), reduced (+), or absent (–). The protozoal count was performed according to the method of Dehority (1984).

2.12. Statistical analysis

A Latin square (4×4) experimental design was used in the current study, which was composed of four levels of PP and four periods. Two simultaneous squares were used, in which eight animals were randomly distributed, comparing the response of the variables to the fixed effect of the treatments.

The data were subjected to analysis of variance using a generalized linear model. Data with measures repeated over time were analyzed using the MIXED procedure of SAS (Statistical Analysis System, version 9.1). The means were subjected to regression analysis using the REG procedure. Ruminal fluid analysis was performed using the nonparametric statistical method, NPAR1WAY, of SAS and the Kruskal-Wallis test (Statistical Analysis System, version 9.0). Results with P-value <0.05 were considered significant, and a trend was noted for P-values between 0.05 and 0.1. The statistical model was as follows:

$$Y_{ijk} = \mu + T_j + P_k + A_i(T_j) + (TP)_{jk} + e_{ijk}, \quad (8)$$

in which Y_{ijk} = observed value for each trait analyzed, μ = overall average, T_j = fixed effect of treatment (PP levels), P_k = fixed-effect collection period, A_i = random effect (animal), $(TP)_{ik}$ = fixed effect of the interaction between PP levels and collection period, and e_{ijk} = random error.

3. Results

The intake of DM, NDF, FE_{DM}, FE_{NDF}, RE_{DM}, and RE_{NDF} was not affected by the replacement of ground corn with PP. Higher RE_{DM} and RE_{NDF} was observed in animals fed 33.3 and 66.7% PP (Table 2).

The goats fed 33.3 and 66.7% PP demonstrated more feeding and ruminating (P<0.05). At the 100% substitution, the goats reduced the time spent feeding and ruminating. However, there was no difference (P<0.05) in the idle time and in the frequency of water intake, defecation, or urination (Table 2).

There was a decrease (P<0.05) in the number of chews (number/day and number/min) with an increase in the PP level. However, the number of ruminal boluses (number/day), chewing time per bolus, number of chews per bolus, and DM gain per bolus remained unchanged (Table 2).

Air temperature, WBT, THI, and BGTHI were higher in the afternoon than in the morning (Table 3). Relative humidity was higher in the morning.

There was no effect of the interaction between the treatment and period of the day or the effect of the treatment on the physiological parameters of the goats. However, there was an effect of the period of the day on all variables (rectal temperature, RR, HR, and SR) with higher values in the afternoon (Table 4).

Parkia platycephala pod meal as a substitute feed ingredient changed the MCHC, but there were no significant changes in serum hemoglobin, RBC count, MCV, leukocytes, basophils, eosinophils, lymphocytes, and monocytes (Table 5).

Regarding mineral metabolism in goats, calcium concentrations decreased linearly according to the replacement level of ground corn with PP. Serum levels of phosphorus, magnesium, TP, urea, creatinine, albumin, aspartate aminotransferase, and gamma-glutamyl transferase were not affected by PP (Table 5).

The replacement of ground corn with PP in the diet of lactating goats did not influence the color, odor, or consistency of the ruminal fluid, which was slightly viscous of straw yellow color with an aromatic odor (Table 6).

Table 2 - Intake performance and feeding behavior of lactating goats fed diets containing different levels of *Parkia platycephala* pod meal replacing ground corn

Variable	Replacement level (% dry matter)				SEM	P-value[1]	
	0	33.3	66.7	100		Linear	Quadratic
Daily intake							
Dry matter (g/day)	1450	1570	1560	1420	0.11	0.83	0.36
Neutral detergent fiber (g/day)	600	620	660	590	0.05	0.99	0.50
Feeding efficiency							
FE_{DM} (g DM ingested/h)	354.5	324.3	274.3	313.6	37.1	0.29	0.30
FE_{NDF} (g NDF ingested/h)	146.9	128.7	116.4	130.2	15.2	0.35	0.26
Rumination efficiency							
RE_{DM} (g DM ingested/h)	226.8	278.1	276.3	216.9	20.0	0.76	0.05
RE_{NDF} (g NDF ingested/h)	94.4	111.3	117.1	91.0	8.81	0.89	0.07
Number per periods (%)							
Feeding	18.70	21.68	24.25	19.15	1.81	0.51	0.04
Rumination	27.68	23.62	23.75	27.10	1.43	0.76	0.01
Idle	53.62	54.70	52.00	53.75	2.91	0.88	0.88
Time spent (min/day)							
Feeding	268.30	308.87	348.75	273.75	26.74	0.52	0.04
Rumination	401.30	339.33	343.75	390.00	20.82	0.74	0.01
Idle	770.40	791.80	747.50	776.25	44.50	0.84	0.85
Other activities							
Water intake (no./day)	4.00	3.00	4.88	5.13	0.65	0.08	0.35
Defecation (no./day)	20.38	22.38	20.88	17.12	2.40	0.30	0.25
Urination (no./day)	7.52	8.00	9.43	7.00	1.18	0.26	0.93
Chewing behavior							
NRB (no./day)	407.58	307.42	469.56	394.67	88.63	0.69	0.82
CT (sec/boli)	103.62	84.25	73.40	93.58	17.18	0.48	0.36
CT (no./day)	73405	73842	56979	52707	31.47	0.02	0.98
NC (no./day)	56.72	67.43	71.25	92.76	19.94	0.27	0.66
NC (no./min)	52.60	51.28	39.56	36.60	5.46	0.01	0.89
DMG (mg/boli)	6.25	7.54	5.96	6.55	1.3	0.80	0.79

FE_{DM} - feed efficiency of dry matter; FE_{NDF} - feed efficiency of neutral detergent fiber; RE_{DM} - rumination efficiency of dry matter; RE_{NDF} - rumination efficiency of neutral detergent fiber; NRB - number of ruminal boli; CT - chewing time; NC - number of chews; DMG - dry matter gain per boli; SEM - standard error of the mean.
[1] Significant at P<0.05 by regression analysis.

Table 3 - Climatic data during the experimental period

Climatic variable	Period of the day		
	Morning	Afternoon	Average
Air temperature (°C)	28.3	34.3	31.3
Relative humidity (%)	62.6	43.8	53.2
Maximum temperature (°C)	28.7	34.7	31.7
Minimum temperature (°C)	26.9	31.6	29.2
Dry bulb temperature (°C)	27.5	34.9	31.2
Wet bulb temperature (°C)	24.9	28.2	26.5
Dew point temperature (°C)	20.0	18.6	19.3
Black globe temperature (°C)	28.5	34.2	31.3
Black globe humidity index	77.2	82.3	79.7

The density of protozoa was influenced by diet (P<0.05). However, motility of protozoa and the predominant type of bacteria (gram-positive or gram-negative) did not differ between the diets (Table 6).

As more PP was used, there was intensification in the reduction of methylene blue (P<0.05). However, the replacement did not promote a significant difference in pH, sedimentation, or flotation time, or in the relative percentages of small, medium, and large protozoa (Table 7).

Table 4 - Physiological variables (morning and afternoon) of lactating goats fed diets containing different levels of *Parkia platycephala* pod meal replacing ground corn

Response	Replacement level (% dry matter)				Period of the day (P)		P-value		
	0	33.3	66.7	100	Morning	Afternoon	Treatment (T)	P	T × P
RTe	38.7	38.7	38.7	38.7	38.3b	38.9a	0.3029	0.0001	0.8614
RR	31.0	31.0	30.0	31.0	28.3b	34.2a	0.9946	0.0001	0.1126
HR	124.0	137.0	145.0	127.0	99.0b	168.0a	0.5364	0.0001	0.9461
SR	124.8	137.2	145.2	127.3	99.1b	168.2a	0.5364	0.0001	0.9461

RTe - rectal temperature (°C); RR - respiratory rate (breaths/min); HR - heart rate (beats/min); SR - sweating rate (g/m^2 min); T × P - treatment × period of the day interaction.

Table 5 - Hematological and biochemical parameters of lactating goats fed diets containing different levels of *Parkia platycephala* pod meal replacing ground corn

Cell	Replacement level (% dry matter)				SEM	P-value		Reference[1]
	0	33.3	66.7	100		Linear	Quadratic	
Erythrogram								
Ht (%)	25	23	24	25	0.51	0.85	0.12	22-38
Hgb (g/dL)	9.01	9.09	9.2	9.09	0.18	0.88	0.79	8-12
RBC (× 10^6/µL)	14.50	14.30	14.57	14.67	438	0.72	0.75	8-18
MCV (fl)	17.37	17.33	16.83	17.24	0.47	0.67	0.65	15-25
MCHC (%)	36.60	37.69	37.48	37.10	0.23	0.23	0.005	30-36
Leucogram								
Leu (× 10^3/µL)	10833	10811	10613	10700	314.16	0.67	0.86	4000-13000
Bas (/mm^3)	59860	59806	61263	60641	315.22	0.80	0.93	370-11552
Eos (/mm^3)	254	262	276	232	42.25	0.80	0.58	50-650
Lin (/mm^3)	4452	4740	3830	3862	362.23	0.14	0.74	2000-9000
Mon (/mm^3)	181	172	193	176	31.38	0.96	0.90	0-550
Mineral metabolism								
Ca+ (mg/dL)	9.75	10.00	9.94	10.57	0.20	0.01	0.35	
P (mg/dL)	6.76	5.52	6.05	6.35	0.36	0.66	0.04	
Mg (mg/dL)	2.56	2.78	2.75	2.77	0.14	0.33	0.48	
Protein metabolism								
TP (g/dL)	7.52	7.52	7.6	7.5	0.15	0.98	0.46	
Urea (mg/dL)	38.70	40.06	38.35	43.03	2.13	0.25	0.45	
Creatinine (mg/dL)	1.11	1.00	1.05	1.07	0.06	0.87	0.29	
Albumin (g/dL)	2.74	2.76	2.81	2.7	0.09	0.80	0.43	
Enzymatic metabolism								
AST (U/L)	85.34	82.65	83.69	83.09	5.67	0.82	0.85	
GGT (U/L)	53.67	53.49	55.05	53.83	3.28	0.89	0.87	

Ht - hematocrit; Hgb - hemoglobin; RBC - red blood cells; MCV - mean corpuscular volume; MCHC - mean corpuscular hemoglobin concentration; Leu - leukocytes; Bas - basophils; Eos - eosinophils; Lin - lymphocytes; Mon - monocytes; TP - total protein; AST - aspartate aminotransferase; GGT - gamma glutamyl transferase; SEM - standard error of the mean.
[1] Kramer (2000).

Table 6 - Physical aspects and microbiological parameters of rumen fluid of lactating goats fed diets containing different levels of *Parkia platycephala* pod meal replacing ground corn

Variable	Replacement level (% dry matter)				P-value[1]
	0	33.3	66.7	100	
Color	Straw yellow (50%)	Straw yellow (50%)	Straw yellow (50%)	Straw yellow (87.5%)	0.59
	Brownish green (12.5%)	Brownish green (25%)	Brownish green (25%)	Brownish green (12.5%)	
	Olive green (37.5%)	Olive green (25%)	Olive green (25%)	Olive green (0%)	
Odor	Ammoniac putrid (37.5%)	Ammoniac putrid (12.5%)	Ammoniac putrid (12.5%)	Ammoniac putrid (12.5%)	0.42
	Aromatic (37.5%)	Aromatic (75%)	Aromatic (50%)	Aromatic (50%)	
	Slightly putrid (37.5%)	Slightly putrid (12.5%)	Slightly putrid (37.5%)	Slightly putrid (37.5%)	
Consistency	Moderately viscous (50%)	Moderately viscous (25%)	Moderately viscous (37.5%)	Moderately viscous (50%)	0.99
	Slightly viscous (37.5%)	Slightly viscous (62.5%)	Slightly viscous (62.5%)	Slightly viscous (25%)	
	Slightly aqueous (12.5%)	Slightly aqueous (12.5%)	Slightly aqueous (0%)	Slightly aqueous (25%)	
Motility of protozoa	+++ (25%)	+++ (37.5%)	+++ (37.5%)	+++ (12.5%)	0.14
	++ (62.5%)	++ (50%)	++ (50%)	++ (25%)	
	+ (12.5%)	+ (12.5%)	+ (12.5%)	+ (62.5%)	
Density of protozoa	+++ (50%)	+++ (37%)	+++ (0%)	+++ (12.5%)	0.02
	++ (25%)	++ (50%)	++ (37.5%)	++ (12.5%)	
	+ (25%)	+ (12.5%)	+ (62.5%)	+ (75%)	
Bacteria in predominance	Gram – (62.5%)	Gram – (62.5%)	Gram – (62.5%)	Gram – (50.0%)	1.00
	Gram+ (37.5%)	Gram+ (37.5%)	Gram+ (37.5%)	Gram – (50.0%)	

[1] Kruskal-Wallis Test.
+++ = abundant; ++ = moderate; + = reduced; – = absent.

Table 7 - Biochemical and microbial aspects of rumen fluid of lactating goats fed diets containing different levels of *Parkia platycephala* pod meal replacing ground corn

Variable	Replacement level (% dry matter)				SEM	P-value	
	0	33.3	66.7	100		Linear	Quadratic
pH	6.3	6.4	6.3	6.4	0.08	0.86	0.98
RMB (min)	2.15	3.52	2.27	4.27	0.34	0.003	0.40
SFT (min)	2.61	3.61	3.50	3.70	0.45	0.14	0.39
Protozoa (number of cells/mL)							
Small	7.12×10^5	7.4×10^5	7.5×10^5	7.8×10^5	3.01	0.09	0.92
Medium	2.1×10^5	1.8×10^5	1.7×10^5	1.5×10^5	2.09	0.06	0.77
Large	7.7×10^4	8.0×10^4	7.5×10^4	6.0×10^4	1.30	0.36	0.50

RMB - reduction of methylene blue; SFT - Sedimentation and flotation time; SEM - standard error of mean.

4. Discussion

In this research, *Parkia platycephala* was readily accepted by lactating goats, as observed in previous studies (Alves et al., 2007; Silva et al., 2012; Araújo et al., 2019). Incorporation of this ingredient led to higher rumination efficiency (RE_{DM} and RE_{NDF}), which could be due to its particle size and high fiber content. From these results, it can be inferred that the replacement of ground corn with PP maintains nutrient availability in the rumen for microbial protein synthesis (Visoná-Oliveira et al., 2015), that is, *P. platycephala* was comparatively more degradable in the rumen, not altering rumen fermentation patterns, as highlighted by Araújo et al. (2019). Feeding and rumination efficiencies are mainly affected by particle size, which has implications for time spent feeding, ruminating, and being idle (Carvalho et al., 2008). The intake of small particles reduces the time spent on rumination, possibly increasing the amount of feed consumed and improving the productive performance (Zhao et al., 2011). In this study, the goats tended to be more efficient in the rumination of diets containing 33.3 and 66.7% PP. Reducing particle size is more difficult in diets with a higher fiber content (as in the diet with 100% PP) (Silva et al., 2005). Thus, the significant difference in chewing time (per minute, and per day) is attributed to the time spent ruminating.

The search for drinking water, followed by water intake, showed a proportional increase with increasing levels of ground corn replacement and NDF in the diet.

Nutritional management is an important practice in tropical and subtropical regions to ameliorate the detrimental effects of heat stress on animal production and welfare (Buffington et al., 1981). In this context, further research must be developed to evaluate the impact of PP on endogenous heat production under hot environmental conditions. In the present study, lactating animals were under metabolic stress because of milk production (Linhares et al., 2015). However, the goats in this study exhibited normal physiological parameters, indicating that they were well adapted to the hot environmental conditions prevailing in the region.

Replacement of ground corn with PP did not affect the health status of the goats, as all the blood parameters were within the normal range (Kramer, 2000), and according to similar findings verified by Araújo et al. (2019). A significant increase in serum calcium was observed in animals supplemented with PP, which was within the physiological limits (8.9 to 11.7 mg/dL; Kaneko et al., 2008). This is an important finding as the goats were lactating and had a high calcium requirement. Serum phosphorus and magnesium and protein metabolism were not affected by the introduction of PP in the diets. The similarity in serum blood components among the female goats in different treatments may be related to the formulation of the diets, which were determined to meet the requirements of the animals, regardless of the replacement level, ensuring that up to the 100% replacement level, there were no changes in the biochemical parameters.

The pH values were similar among treatments, ranging from 6.3 to 6.4. It should be noted that, for effective rumen microbial activity, it is important to maintain the normal pH (6.2 to 6.7), which promotes an effective multiplication of the microbiota, maximization of the time for cell wall colonization, and rate of fiber degradation. In this case, the methylene blue test showed a medium level of microbial activity, indicating an average digestion rate. According to Dirksen (1993), when the microbiota is highly active, the reduction of methylene blue occurs within 3 min, or even less for concentrate-rich feed. However, if the reduction occurs in 3-6 min, it indicates an average microbial activity. Above 6 min, it indicates that the feed is difficult to digest (Dirksen et al., 1993).

Rumen health was also evaluated by examining ruminal fluid. The PP maintained a normal ruminal environment, as indicated by yellow color rumen liquor with aromatic odor, and a slightly viscous consistency (Rosenberger, 1993). *Parkia platycephala* pod meal could be used as a raw material substitute that does not cause physicochemical or homeostatic changes in the goat.

The bacterial population remained unaffected, with gram-negative predominance in goats fed 0, 33.3, and 66.7% PP. Similarly, the replacement did not affect the number (normal range of 10^4 to 10^6) (Kamra, 2005) or size of rumen protozoa, but there was a predominance of small protozoa.

Based on these results, there is potential for the use of *P. platycephala* as an alternative feed ingredient for goats during periods of feed shortage, or to reduce costs by replacing conventional feed ingredients.

5. Conclusions

It is recommended to replace up to 100% of ground corn with *Parkia platycephala* in the diet of lactating goats without causing significant changes to the health, feeding behavior, or physiological parameters of the animals. This suggests that *Parkia platycephala* pod meal can potentially be an alternative feed ingredient in the diet of lactating goats.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Conceptualization: I.L. Batista, T.P. Dias-Silva, L.R. Bezerra and M.J. Araújo. Data curation: C.A.T. Marques. Formal analysis: R.L. Edvan. Investigation: I.L. Batista and T.P. Dias-Silva. Methodology: J.N.C. Torreão and L.R. Bezerra. Project administration: M.J. Araújo. Supervision: C.A.T. Marques and V. Sejian. Validation: R.L. Edvan. Visualization: R.L. Edvan. Writing-original draft: I.L. Batista and J.N.C. Torreão. Writing-review & editing: V. Sejian and M.J. Araújo.

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