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Baru meal on the performance of dairy calves: an alternative to reduce costs in the breeding phase

Lucas Gomes Vieira, Luciana Castro Geraseev*, Mário Henrique França Mourthé, Felipe Gomes da Silva, Rodrigo Augusto Cortêz Passetti, Kellen Amanda Silva Borges e Maria Laura Azevedo Correia

Instituto de Ciências Agrárias, Universidade Federal de Minas Gerais, Av. Universitária, 1000, 39404-547, Montes Claros, Minas Gerais, Brazil. *Author for correspondence. E-mail: lgeraseev@gmail.com

ABSTRACT. The objective of this study was to evaluate the intake, performance, and economic viability of crossbred Holstein calves (n = 16) fed diets containg different levels of baru meal *(Dipteryx alata* . Vog) as a replacement for corn (0, 25, 50, and 72%). Total solid feed, concentrate, and forage intake, nutrient intake, weight gain, ingestive behavior, and economic viability were evaluated. Total solid feed and concentrate intake linearly increased ($p<0.05$) with the replacement of corn by baru meal, however, weight gain (13.7 Kg) was not affected ($p>0.05$). Baru meal inclusion linearly increased the intake of crude protein, minerals, ether extract, and non-fibrous carbohydrates. Concentrate feeding time exhibited a quadratic effect, with a maximum of 75.92 min. day^{-1} at 67% replacement. Economic analysis showed that the 50% replacement diet result in higher feed costs but lower cost per kilogram of gain. The inclusion of baru meal up to 72% of corn replacement increased intake without compromising the performance during preweaning phase. A 50% replacement provided the best economic return.

Keywords: animal performance, breeding phase, byproduct, *Dipteryx alata*.

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Introduction

Calf feeding during the preweaning phase is critical for the productive cycle of dairy cattle. The transition from a milk-based to a solid feed diet affects both development and health outcomes in dairy cows.

The costs attributed to the breeding phase in dairy cattle farming have a large representation in total production costs, mainly due to the expenses associated with liquid diets and starter diets. According to Hawkins et al. (2019), milk and calf starters account for more than half of the total cost of raising a calf from birth to weaning.

Calf starters are formulated with high-cost ingredients, the price of which fluctuate, directly affecting the feeding expenses during the breeding phase. Therefore, evaluating the feasibility of including agro-industrial byproducts in calf diets without compromising performance could improve production profitability (Coimbra et al., 2017).

Agro-industrial byproducts unsuitable for human consumption may provide nutritional value for ruminant diets (Vastolo et al., 2022). Baru *(Dipteryx alata*. Vog) is a fruit native to the Cerrado biome, rich in carbohydrates and energy, with high yield during periods of low forage availability (Lima et al., 2022). Baru byproduct was obtained by extracting the almonds, leaving the pulp. The pulp contained 65.01% carbohydrates (32.38% starch), 3.3% lipids, 4.39% fiber, and 4.45% protein (Alves-Santos et al., 2021).

Baru meal is a potential alternative energy source in dairy calf diets. Additionally, its utilization could also enhance the use of native fruits, contribute to livestock farming and regional economies. Therefore, this study aimed to evaluate the intake, ingestive behavior, performance, and economic viability of dairy calves fed diets with increasing levels of baru meal as a replacement for corn.

Materials and methods

This study was approved by the Animal Experimentation Ethics Committee of the Federal University of Minas Gerais, Brazil (protocol 235/2021). It was conducted at the Experimental Farm Professor Hamilton Abreu Navarro (FEHAN) of the Federal University of Minas Gerais– Institute of Agricultural Sciences (ICA), located in Montes Claros, Minas Gerais, Brazil (16°44'06” S, 43°51'42" W, altitude of 648).

Sixteen newborn male Holstein x Gir calves, with an average initial body weight of 33 ± 5,78 Kg, were utilized. After birth, calves were separated from their dams, their navels disinfected with 10% iodine solution, and fed high-quality colostrum (Brix > 21%) at 10% of weight within first 24h, followed by transition milk for three consecutive days (two daily meals/day). Blood samples were collected by jugular venipuncture within 48h of first colostrum ingestion. Total serum protein was determined using a portable digital refractometer (ITREF 200; Instrutemp, São Paulo, SP, Brazil) as an indicator of passive immunity transfer. Only calves with adequate passive immunity transfer (serum protein levels > 5.5 g dL^{-1}, Quigley et al. 2013) were included.

Animals were housed individually in $2m^2$ pens equipped with feeders and drinking troughs for 56 days. The animals were allocated in a completely randomized design with four experimental treatments, corresponding to different levels of baru meal inclusion, replacing corn, with four replicates (Table 1). The chemical-bromatological composition of corn was: 88.00% dry matter (DM), 1.57% mineral matter (MM), 9.11% crude protein (CP), 19.62% neutral detergent fiber (NDF), 6.54% acid detergent fiber (ADF), 3.15% ether extract (EE), and 66.55% non-fibrous carbohydrates (NFC).

The control diet contained corn, soybean meal, and minerals, whereas experimental diets contained corn partially replaced by baru meal at the specified levels. Baru meal was donated by a farmer in the city of Pintópolis, MG. Its chemical-bromatological composition was 88.68% DM, 2.88% MM, 6.51% CP, 15.07% NDF, 11.42% ADF, 2.80% EE, and 72.74% NFC.

Table 1. Percentage and chemical composition of experimental concentrates.

Ingredients	Baru Meal Replacement Levels			
	0%	25%	50%	72%
Corn (%)	65.00	47.75	31.00	17.50
Soybean meal (%)	30.00	31.00	33.00	33.00
Baru meal (%)	-	16.25	31.00	44.50
Mineral supplement[1] (%)	5.00	5.00	5.00	5.00
Mineral matter (%DM)	5.45	5.60	5.65	5.80
Crude protein (%DM)	20.32	20.01	20.06	20.00
Neutral detergent fiber (%DM)	16.54	16.18	15.99	15.58
Acid detergent fiber (%DM)	6.24	7.23	8.23	9.22
Ethereal extract (%DM)	2.09	2.08	2.07	2.05
Non-fibrous carbohydrates (%DM)	55.56	56.10	56.23	56.53

[1] Composition (per Kg): calcium (130 g), phosphorus (60 g), magnesium (10 g), sodium (185 g), sulfur (19 g), manganese (1200 mg), zinc (3200 mg), copper (1200 mg), cobalt (100 mg), iodine (140 mg), selenium (18 mg), fluoride (600 mg).

Milk was provided at 4 L $calf^{-1}$ day^{-1}, divided into two meals (08:00 and 16:00), at 38°C, in individual buckets. Milk composition was 36.88 g/kg ether extract (EE) and 32.32 g Kg^{-1} crude protein (CP). Calves had *ad libitum* access to water, Tifton 85 hay and concentrate until 60 days of age. The diets offered were weighed to allow 10% of leftovers, adjusted according to the amount of leftovers from the previous day. The leftovers were removed and weighed daily to determine the food intake.

The diet and leftover samples were collected daily. The samples were mixed weekly and stored in a freezer until subsequent analysis. The chemical compositions of the diets and leftovers (DM, MM, CP, EE, NDF, and ADF) were analyzed according to the methodology described by Detmann et al. (2012). The levels of non-fiber carbohydrates was calculated as: NFC (%) = 100 - (%PB + %EE + %MM + %NDF).

Weighing and body measurements (body length, chest diameter, and withers height) were performed weekly, always at the same time before feeding. After 60 d, the calves were weighed to obtain the average daily gain (ADG) and total weight gain (TWG).

Behavioral assessment were conducted by instantaneous scan sampling with focal observation (Araújo et al., 2021). Calves were observed weekly for 10h, at 5 min intervals. Record activities included idling, concentrate feeding, forage feeding, and rumination. Feeding time was calculated as the sum of concentrate and forage feeding times.

Economic analysis was performed to evaluate the feasibility of replacing corn with baru meal. Ingredient market price (R$ kg^{-1}) were: R$2.04, R$3.3, R$0.71, R$2.29, R$1.86, and R$2.66 for corn, soybean meal, baru meal, hay, mineral supplement, and milk, respectively. The cost per kilogram of diet, total feeding cost, and cost per kilogram of gain were calculated.

Data were analyzed using a completely randomized design. Performance, intake, and behavior data were subject to variance and regression analyses using SAS On Demand for Academics (SAS Institute Inc., 2014) with a 5% significance level. The Means procedure was used for descriptive analyses, the Robustreg procedure was used to detected outliers, the Reg procedure was used for regression analysis, and the GLM procedure was used to test the initial weight as a covariate and assess model fit.

Results and discussion

The inclusion of by-product linearly increased ($p<0.05$) solid feed intake (g DM day-1; %BW, g DM kg-1 BW 0.75) and concentrate intake (g DM day-1 and %BW) (Table 2). Dry matter intake is influenced by chemical composition of food, stage of development, and feeding conditions. The intake of concentrates may vary depending on management practices, diet composition, and acceptability of the ingredients. During the trial, calves readily accepted diets containing baru meal, which likely contributed to the linear increase in concentrate and solid feed intake.

Table 2. Means and coefficients of variation of concentrate, forage, solid feed and nutrients intake of calves fed with different levels of baru meal in the diet.

Variables	Baru Meal Levels				CV	P	
	0%	25%	50%	72%	(%)	Linear	Quadratic
Concentrate Intake, (g DM day^{-1})[1]	190.26	144.39	339.66	245.41	45.64	0.027	0.094
Forage Intake, (g DM day^{-1})	58.74	46.42	48.54	53.04	37.49	0.438	0.682
Solid feed intake, (g DM day^{-1})[2]	263.59	190.81	398.72	298.45	40.04	0.044	0.142
Solid feed intake (%BW)[3]	0.57	0.44	0.78	0.66	32.75	0.026	0.095
Forage intake (% BW)	0.13	0.10	0.09	0.10	34.46	0.286	0.460
CPI, (g day^{-1})[6]	47.78	37.82	82.00	58.90	35.14	0.022	0.057
NDFI, (g day^{-1})	62.46	39.56	69.56	53.14	9.64	0.068	0.090
ADFI, (g day^{-1})	26.86	15.76	25.82	20.13	18.25	0.334	0.618
NFCI, (g day^{-1})[7]	145.58	108.21	235.71	165.54	34.71	0.012	0.038
EEI, (g day^{-1})[8]	1.09	0.63	1.06	0.67	6.12	0.048	0.108
MMI, (g day^{-1})[9]	6.68	4.89	10.12	20.61	40.02	0.043	0.063

([1]) y= 131.99 + 293.31x, R^2= 0.371; ([2]) y =187.07+277.50x; R^2= 0.320; ([3]) y = 0.4110 + 0.541x; R^2= 0.328; ([4]) y = 10.66+14.48x, R^2= 0.365; ([5]) y = 0.2894+0.585x, R^2= 0.422; ([6])y= 44.49 + 33.06x, R^2= 0.551; ([7]) y =87.28+97.98x, R^2= 0,663; ([8]) y=0.9321 – 0.274x, R^2= 0.448; ([9]) y= 4,0515+13,423x, R^2= 0,464.

Forage intake averaged 51.40 g of DM and 0.11% of BW, with no treatment differences (Table 2). Forage intake was minimal during the first five weeks, but increased near weaning, reaching 229.2 g day-1. Forage provision in the preweaning phase is important for maintaining rumen pH, stimulating rumination, and supporting rumen development. Horvath and Miller-Cushon (2017) reported a mean forage intake of 25 g day^{-1} in preweaned calves, reinforcing the importance of gradual solid feed introduction.

A linear increase ($p<0.05$) in crude protein, non-fibrous carbohydrates, ether extract, and mineral matter intake was observed with increasing levels of baru meal (Table 2). However, NDF (56.18 g day-1) and ADF (22.14 g day-1) intake did not differ among treatments (Table 2). Similar results were reported by Oliveira et al. (2015) who found that inclusion of alfalfa hay or *Leucaena* in starter diets did not significantly alter fiber intake.

Acording to Khan et al. (2016), solid feed intake during the preweaning stage promotes the shift from glucose (milk-based) metabolism to volatile fatty acids (VFA) derived from starter feeds as the primary energy source. The increase in NFC intake with baru meal could favor VFA production and rumen development.

Differences in starch digestion in the small intestine of young calves may affect solid feed intake, development, and performance of calves during the preweaning and early postweaning periods (Pezhveh et al., 2014). It is likely that the availability of starch in the baru meal was high, since the inclusion of the byproduct did not affect the performance of the animals (Table 3).

No treatment effects ($p > 0.05$) were observed for total weight gain (27.1 kg) or ADG (485.3 g day^{-1}) (Table 3). The ADG results in this study were similar to those found by Poczynek et al. (2020) who obtained an average of 317.7 g day-1 for calves receiving diets with different levels of NDF and partial replacement of corn with soybean hulls. Similarly, Dondé et al. (2022) replaced ground corn from the concentrate with reconstituted corn grain silage and observed that replacement with an ingredient that presented highly digestible starch did not influence the ADG because of the calves' low rumen digestion capacity during preweaning; however, they observed improvements in feed efficiency.

Recent research has analyzed the inclusion of different byproducts and their effects on animal performance. Coimbra et al. (2017) replaced corn with citrus pulp in dairy calf diets. They observed that the replacement changed the intake of concentrate because of factors related to the palatability of the citrus pulp; however, the inclusion of the by-product did not reduce the performance of the animals or alter ruminal fermentation and plasma glucose parameters.

Body length and withers height were affected by baru meal inclusion, ranging from 65.0 to 71.5 cm and 86.0 to 90.3 cm, respectively (Table 3). Body length exhibited a quadratic response, with a minimum of 66.8 cm at 55% replacement, while withers height peaked at 88.5 cm with 21% replacement.

Table 3. Means and coefficients of variation for weight gain and body measurements of calves fed different levels of baru meal in the diet.

Variables	Baru Meal Levels				CV	P	
	0%	25%	50%	72%	(%)	Linear	Quadratic
Total body weight gain, (Kg)	27.55	22.73	30.93	27.15	23.25	0.834	0.979
Average daily gain, (Kg)	0.50	0.38	0.51	0.46	21.64	0.958	0.991
Body length, (cm) (1)	71.50	65.00	70.00	66.00	4.62	0.004	0.016
Thoracic diameter, (cm)	86.00	88.00	92.50	88.75	4.83	0.056	0.135
Withers height, (cm) (2)	88.75	86.00	90.25	86.50	2.63	0.0003	0.001

(1) $y= 70.54 - 13.43x +12.13x^2$, $R^2= 0.590$; (2) $y= 88.04 +1.372x -3.213x^2$; $R^2= 0.754$

Concentrate feeding time increased ($p < 0.05$) with baru meal inclusion, ranging from 35.3 to 86.3 min day^{-1}, with a maximum of 75.9 min day^{-1} at 67% replacement (Table 4). The inclusion of the byproduct probably altered the palatability of the diet, as observed by the increase in the time of concentrated intake, indicating a preference for consuming the byproduct. High acceptability of baru meal indicates its potential as a regional feed alternative, particularly in semi-arid regions where feed costs are high.

No differences ($p > 0.05$) were observed in forage feeding, rumination, or idling times, averaging 101.6, 148.4, and 1120.8 min day^{-1}, respectively (Table 4).. Rumination time is influenced by particle size and fiber content (Oliveira et al., 2016). The NDF content was similar among the diets, explaining the lack of differences in rumination time.

Table 4. Average time values in minutes of behavioral activities of calves fed with different levels of baru meal in the diet.

Variables	Baru Meal Levels				CV	P	
	0%	25%	50%	72%	(%)	Linear	Quadratic
Feeding Forage, min. day^{-1}	134.77	95.15	130.10	46.34	46.61	0.117	0.248
Feeding Concentrate, min. day^{-1} (1)	45.79	50.88	86.27	71.10	35.32	0.001	0.006
Ruminating, min. day^{-1}	134.18	140.63	178.91	140.00	37.17	0.625	0.666
Idle, min. day^{-1}	1119.46	1146.94	1039.46	1177.37	7.46	0.842	0.480

(1) $y = 41.965 + 101.50x – 75.848x^2$, $R^2= 0.6886$.

Economic analysis showed that replacing corn with baru meal reduced diet cost from R$2.52 to R$1.97 per kg DM (Table 5), representing a 22% decrease. Typically, the inclusion of byproducts reduces the cost per kilogram of diet, as more expensive ingredients, such as corn, are replaced. Ezequiel et al. (2006) also observed a reduction in the costs of diets for fedlot Nellore cattle fed with sugarcane bagasse, citrus pulp, corn germ bran and soybean hulls replacing corn without changes in dry matter intake similar to the results found. Santana et al. (2023) did not observe a reduction in production costs when corn was replaced with soy hulls in the diets of dairy calves during the preweaning period because of the purchase price of the byproduct.

Table 5. Average values for the costs of complete diets, feed costs and cost per kilo of gain (R$ Kg^{-1}) of calves fed with different levels of baru meal.

Variables	Baru Meal Levels			
	0%	25%	50%	72%
Diet cost (R$ Kg^{-1})	2.52	2.32	2.15	1.97
Cost of solid feed (R$)	39.85	26.56	52.72	35.28
Cost of liquid feed (R$)	638.40	638.40	638.40	638.40
Total feed cost (R$)	678.25	664.96	691.12	673.68
Cost kg of gain (R$ Kg^{-1} of gain)	24.62	29.25	22.34	24.81

The economic viability of using by-products such as baru meal depends on the prices of the by-product and the food to be replaced (corn) as well as on animal intake. In the present study, total feed costs ranged from R$664.96 to R$691.12, with cost per kilogram of gain between R$22.34 and R$29.25. The 50% replacement diet yielded the lowest cost per kilogram of gain (R$22.34), while the 25% replacement diet, despite the lowest feed cost, had the highest cost per gain (R$29.25).

Approximately 65% of total variable costs are feeding costs, so a small difference in relative prices and substitution rates can have a substantial effect on profitability (Hawkins et al., 2019). Baru meal therefore represents a promising ingredient for calf starter diets, particularly in regions where it is locally available and competitively priced.

Conclusion

The inclusion of baru meal to replace corn in the diet of calves in the preweaning phase increased their intake and resulted in similar performance. It is recommended to replace 50% of corn with baru meal, as it is the most economically viable diet.

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Data availability

Data generated or analyzed during this study are available from the corresponding author upon reasonable request.

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