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Does the use of corn and soybean hulls affect calf performance in the preweaning period?

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ABSTRACT - The objective of this study was to assess the effects of two levels of soybean hulls (0 and 400.1 g/kg) and whole or ground corn in the diet of newborn crossbred dairy male calves on intake, performance, blood indicators, and feeding cost. Twenty-eight calves with an average weight of 33.0±6.2 kg and four days of age were distributed into four treatment groups in a completely randomized design (n = 7) for 56 days. Weekly samples of feed, diets, and leftovers were collected to determine dry matter and nutrient intakes. To evaluate apparent digestibility, samples were taken using titanium dioxide as a maker. Blood samples were also collected to evaluate blood indicators. The inclusion of soybean hulls resulted in greater neutral detergent fiber intake by the calves, but reduced their non-fibrous carbohydrates intake, which was also reduced by the use of whole corn in the diet. Although the total digestible nutrients content of diets decreased with the use of whole corn and inclusion of soybean hulls, its intake did not vary (0.75 kg/d), regardless of the factors analyzed. The apparent digestibilities of dry matter (0.87 kg/kg) and crude protein (0.89 kg/kg) were similar, resulting in similar performance between the animals, regardless of the factors analyzed. In the quantities evaluated, the use of soybean hulls or whole corn did not affect blood indicators and was insufficient to reduce feed costs; the cost of daily feed was $2.06, while the cost per kilogram of gain was $3.74. The inclusion of up to 400.1 g/kg of soybean hulls or the replacement of ground corn with whole corn does not affect the performance of crossbred dairy calves during the preweaning period, demonstrating that both can be used in animal feed during this phase of production.

Keywords: byproduct, carbohydrates, digestibility, glycemia, male calves, production cost

1. Introduction

In Brazil, the number of cows milked corresponds to 17 million animals (FAO, 2019), with a birth rate of 50% males, meaning 8.5 million steers are produced annually. Although no official data exist in Brazil, their production is typically neglected, and approximately 40% of these calves are slaughtered in their first days of life. This is because producers consider that these calves will increase their production costs without generating favorable financial returns; however, these animals can yield good productive results when their requirements are met (Razook et al., 1986), mainly during the first days of life.

Because this period is the costliest in the production system, solutions are needed to balance these costs, such as using palatable solid feeds, which stimulate the animals to eat. This practice allows reducing the weaning age of animals (Baldwin et al., 2004; Heinrichs, 2005) and problems caused by early weaning (Khan et al., 2007a,b; Khan et al., 2008).

However, the use of feedstuffs such as corn and soybean meal—traditional ingredients in animal diets—in biofuel production has increased the price of these inputs (Wallington et al., 2012). Therefore, alternatives to these ingredients are needed to reduce feed costs. One of such options is soybean hulls (SH), an inexpensive, good-quality feedstuff (Ipharraguerre and Clark, 2003) that consists of the outer coating that is separated from the soybean during processing for oil extraction.

Soybean hulls have high neutral detergent fiber (NDF, 676.6 g/kg) and low lignin (31.6 g/kg) (Zhu et al., 2022) contents and a small particle size (Diao et al., 2019), which allows the establishment of a healthy rumen environment, favorable to the consumption of solid diets in the early stages of the animal's life (Mitchell et al., 2021). In addition, the degree of feed processing can be reduced by providing the corn grain whole, which reduces processing costs and allows supplying animals with solid feed with large particle sizes to induce normal chewing behavior (Beauchemin et al., 1994).

We hypothesized that soybean hulls and whole corn are good available alternative sources of energy with the potential to replace ground corn in the diet of newborn crossbred male dairy calves. Therefore, the objective of this study was to evaluate the effect of diets containing soybean hulls and whole or ground corn on the digestibility, blood parameters, performance, and cost of diets of crossbred dairy calves during the preweaning period.

2. Material and Methods

The experiment was carried out on an experimental farm located in Rio Verde, GO, Brazil (17°47'52" S latitude and 50°55'40" W longitude). The procedures involving animals were conducted according to the Institutional Committee on Animal Use (case number 23101.004142/2015-06).

Twenty-eight newborn crossbred (3/4 Holstein-Zebu) male calves, with an average initial body weight of 33.0±6.2 kg, were used. After birth, the calves were separated from the cows, had their navels treated by dipping in 10% iodine solution, and were fed 4 L of colostrum on the first day and transition milk for three consecutive days divided into two daily meals. Data were collected in the subsequent 56 days. During the period of colostrum supply, the animals were treated against endo- and ectoparasites, using Abamectin 1%, and received injectable vitamins A, D, and E in variable amounts according to their weight. Calves were identified with earrings, restrained by a collar, and housed in individual shelters covered with a shaded area of 2 m^2 and equipped with individual feeders and drinking troughs. All animals had access to fresh water *ad libitum*.

The experiment was conducted in a completely randomized design with treatments distributed in a 2 × 2 factorial arrangement: without soybean hulls (NSH) or with 400.1 g/kg soybean hulls (WSH), and corn in two forms—whole (WC) or ground (GC; average particle size of 1.5 mm)—, with seven replicates. During the experimental period, the animals received diets composed of milk and concentrate feed. The diets were formulated to be isonitrogenous and contained corn, soybean hulls, soybean meal, and a commercial mineral mixture (Table 1).

After the fifth day, they also received starter concentrate (Table 2) *ad libitum*, allowing 5% leftovers. The amounts supplied and orts from each animal were recorded daily to estimate dry matter and nutrient intakes, while feed samples were collected during the preparation of diets. Whole milk was supplied in a restricted manner so that the animals consumed 4 L/d. The supply of milk was divided into two daily meals, at 07:00 and 15:00 h, at a temperature of 38 °C, in individual buckets. The milk used contained 110.7 g/kg dry matter (DM), 31.8 g/kg ether extract (EE), 29.5 g/kg crude protein (CP), 45.2 g/kg lactose, 110.7 g/kg total solids, and 79.8 g/kg solids-not-fat.

Table 1 - Estimated chemical composition of the feedstuffs used in the experimental diets

Variable	Corn	Soybean meal	Soybean hull
Dry matter (DM; g/kg NM)	850.1	830.3	889.7
Ash (g/kg DM)	17.1	65.1	45.8
Neutral detergent fiber (g/kg DM)	113.0	154.5	655.6
Hemicellulose (g/kg DM)	83.5	41.8	261.9
Acid detergent fiber (g/kg DM)	29.5	112.7	393.7
Cellulose (g/kg DM)	18.8	100.0	359.8
Lignin (g/kg DM)	10.7	12.7	33.9
Ether extract (g/kg DM)	41.5	21.3	10.5
Crude protein (g/kg DM)	81.9	474.9	146.9
NDIN (g/kg total N)	83.8	7.0	381.4
ADIN (g/kg total N)	47.9	3.8	139.0
Non-fibrous carbohydrates (g/kg DM)	746.5	284.2	141.2
Total carbohydrates (g/kg DM)	859.5	438.7	796.8

NM - natural matter; NDIN - neutral detergent insoluble nitrogen; ADIN - acid detergent insoluble nitrogen.

Table 2 - Proportion of ingredients and estimated chemical composition of the experimental diets

Item	Ground corn		Whole corn	
	NSH	WSH	NSH	WSH
Ingredients (g/kg DM)				
Whole corn	-	-	712.0	400.1
Ground corn	712.0	400.1	-	-
Soybean hull	-	400.1	-	400.1
Soybean meal	238.0	148.0	238.0	148.0
Mineral core[1]	50.0	50.0	50.0	50.0
Chemical composition				
Dry matter (DM, g/kg NM)	890.6	890.1	897.8	909.0
Ash (g/kg DM)	71.9	82.7	87.5	99.3
Neutral detergent fiber (g/kg DM)	123.0	381.5	110.2	379.8
Hemicellulose (g/kg DM)	81.3	188.1	70.8	191.9
Acid detergent fiber (g/kg DM)	41.7	193.4	39.4	187.9
Cellulose (g/kg DM)	30.9	173.6	28.5	168.1
Lignin (g/kg DM)	10.8	19.8	10.9	19.8
Ether extract (g/kg DM)	33.7	27.6	34.2	28.4
Crude protein (g/kg DM)	176.5	176.8	175.9	173.5
NDIN (g/kg total N)	89.6	87.9	84.8	86.8
ADIN (g/kg total N)	43.8	42.9	42.4	44.6
Non-fibrous carbohydrates (g/kg DM)	594.9	331.4	592.2	319.0
Total carbohydrates (g/kg DM)	717.9	712.9	702.4	698.8

NM - natural matter; NSH - no soybean hull; WSH - with soybean hull; NDIN - neutral detergent insoluble nitrogen; ADIN - acid detergent insoluble nitrogen.
[1] Mineral core values: minimum calcium, 220 g/kg; phosphorus, 80 g/kg; vitamin A, 300,000 IU; vitamin E, 300 mg/kg; copper, 860 mg/kg; zinc, 3 g/kg; iodine, 120 mg/kg; iron, 2 g/kg; manganese, 1350 mg/kg; selenium, 20 mg/kg; cobalt, 80 mg/kg; monensin, 1200 mg/kg.

At the beginning (five days of age) and end of the experimental period (60 days of age), animals were weighed individually in the morning, without previous fasting, and these weights were considered the initial live weight (IW) and final live weight (FW). Animals were weighed weekly to determine average daily gain (ADG) in kilograms per day. The last weighing event took place when the animals reached 60 days of age, when the experimental period ended. Average daily gain was calculated as follows:

$$ADG = (FW - IW)/56 \text{ days} \quad (1)$$

The following morphometric measurements were recorded on the weighing events: withers height, rump height, heart girth, arm girth, and body length. These measurements were always performed on the left side of the animals in a standing position, using a horse measuring stick and a measuring tape graduated in centimeters.

Concentrate samples were collected weekly, pre-dried in a forced-air oven at 55 °C for 72 h, ground in a mill with a 1-mm mesh sieve, and stored for later analysis to determine DM (method 930.15; AOAC, 2000), CP (method 984.13; AOAC, 2000), and ash (method 942.05; AOAC, 2000). Neutral detergent fiber (NDF), acid detergent fiber (ADF), and lignin levels were determined as described previously (Van Soest et al., 1991) as adapted by Mertens (2002). Ether extract was determined by washing with petroleum ether at 90 °C for 1 h (Ankom, 2009). Non-fibrous carbohydrates (NFC) content was estimated based on the method described by Mertens (1997), whereas total carbohydrates (TC) and total digestible nutrients (TDN) values were calculated as per Sniffen et al. (1992), as follows:

$$\text{NFC} = 100 - (\text{NDF\%} + \text{EE\%} + \text{CP\%} + \text{Ash\%}) \tag{2}$$

$$\text{TC} = 100 - (\text{CP\%} + \text{EE\%} + \text{Ash\%}) \tag{3}$$

$$\text{Observed TDN} = \text{CPD} + (\text{EED} \times 2.25) + \text{TCD}, \tag{4}$$

in which CPD = apparent digestible crude protein, EED = apparent digestible ether extract, and TDC = total digestible carbohydrates.

The intakes of DM, CP, EE, NDF, NFC, and TDN, expressed in kg/day, were calculated from these analyses, considering the amount of nutrients consumed per day during the experimental evaluation.

These data were used to calculate the efficiencies of DM (kg ADG/kg DM intake), CP (kg ADG/kg CP intake), and TDN (kg ADG/kg TDN intake). Total DM intake, total CP intake, total CP efficiency, and total DM efficiency were calculated also considering the intakes of DM or CP from milk intake.

Apparent digestibility was evaluated at the end of the experimental period, when the animals reached 56 days of age. Samples of feed, leftovers, and feces were collected after 10 g of titanium dioxide (external marker) were supplied to the animals daily, for 10 days, before the beginning of collections. The fecal grab samples from each animal were collected on four consecutive days (at 08:00 h on the first day, 11:00 h on the second day, 14:00 h on the third day, and 17:00 h on the fourth day). These samples were frozen at −20 °C and subsequently transferred to the laboratory, where they were homogenized, pre-dried in a forced-air oven at 55 °C for 72 h, and ground in a mill with 2-mm screen sieves. Then, they were analyzed to determine total fecal production as per the method described in Detmann et al. (2012) and used to calculate the apparent digestibility (AD) of the DM and nutrients present in the diet. Fecal output and apparent digestibility were calculated as shown below:

$$\text{Fecal output (g/day)} = \text{Marker supplied (g/day)}/\text{Marker concentration in feces (g/g DM)} \tag{5}$$

$$\text{AD (kg/kg)} = 1 - (\text{Nutrient ingested (kg)} - \text{Nutrient excreted (kg)})/\text{Nutrient ingested (kg)} \tag{6}$$

At the end of the experimental period, during the last weighing event, blood samples were collected by jugular vein puncture, without prior fasting, one hour after feeding, using vacutainer tubes (Labtest Diagnóstica SA, Brazil). To measure blood glucose, samples were collected in tubes containing 10 μL of sodium fluoride; the other analyses involved 10 μL of EDTA as an anticoagulant. Blood samples were cooled and sent to the laboratory, where they were centrifuged at 2000 x *g* for 15 min at 37 °C to separate the plasma and serum. These aliquots were placed in Eppendorf® tubes, which were identified and frozen at −20 °C for subsequent analyses of glucose, triglycerides, total cholesterol, total protein, albumin, urea, aspartate aminotransferase (AST), alkaline phosphatase (ALT), and creatinine, performed at 37 °C, using a commercial kit (Labtest Diagnostica SA, Brazil). Readings were taken by a spectrophotometer (Bioplus® model Bio-2000 IL-A).

To evaluate the costs associated with the different diets, information was collected on the amount paid per kilogram of each feedstuff used to prepare the concentrates during the experimental evaluation period, when the value of one dollar corresponded to BRL 2.24. This information was used to calculate the cost per kilogram of diet (CKD), daily feed cost (DFC), and cost per kilogram of gain (CKG):

$$\text{DFC} = \text{CKD} \times \text{DMI/d} \tag{7}$$

$$CKG = DFC/ADG \quad (8)$$

Data were subjected to homoscedasticity and normality tests, and variance analysis was conducted using SAS software (Statistical Analysis System, version 9.1) on all continuous variables with normal distributions. Initial weight was used as the covariate and, when not significant, excluded from the model. The mathematical model used was represented by:

$$\gamma ijkl = \mu + i + £j + i*£j + \delta l + aij, \quad (9)$$

in which $\gamma ijkl$ = dependent variable, μ = overall mean, i = effect of factor i (level of inclusion of soybean hulls), $£j$ = effect of factor j (physical form of corn), $i*£j$ = interaction between factor i and factor j, δl = effect of initial weight, and aij = residual experimental error associated with the soybean hull inclusion level × corn physical form factorial. Data were analyzed using t tests at 5% significance to compare the means when the interaction of the studied factors was not significant (>5% significance).

3. Results

There was no interaction effect between the inclusion levels of SH in the diet and the physical form of corn grain for the variables related to intake (Table 3). However, when analyzed separately, the use of SH increased NDF intake (P<0.01) and reduced NFC intake (P<0.01). The use of WC in the diets also reduced NFC intake (P = 0.04). The other intakes showed similar results, regardless of the physical form of corn grain or SH inclusion level, averaging 0.39 kg/d (DM), 0.88 kg/d (total DM), 0.07 kg/d (CP), 0.20 kg/d (total CP), and 0.75 kg/d (TDN).

There was also no interaction effect between corn processing and SH inclusion for the variables related to diet digestibility (Table 4). Conversely, both the use of WC and the inclusion of SH reduced the TDN value of diets (P = 0.02 and P = 0.03, respectively), although SH inclusion increased the digestible NDF content (P<0.01). The apparent digestibility of DM, CP, and NFC, however, did not change in response to the use of WC or SH inclusion, averaging 0.87, 0.89, and 0.90, respectively.

Blood biochemical indicators (Table 5) did not differ with the use of SH or the inclusion of WC, with means of 88.57 mg/dL for glucose, 26.77 g/dL for total cholesterol, 36.82 mg/dL for triglycerides, 6.07 g/dL for total protein, 2.65 g/dL for albumin, 6.33 mg/dL for urea, 48.24 U/L for AST, 116.19 U/L for ALT, and 1.19 mg/dL for creatinine.

The physical form of corn and inclusion level of SH did not influence animal performance-related variables (Table 6). The means were 64.3 kg for final weight, 31.3 kg for total weight gain, 0.56 kg/d for ADG, 1.64 kg gain/kg DM for DM efficiency, 0.62 kg gain/kg DM for total DM efficiency, 8.69 kg gain/kg CP for CP efficiency, 2.76 kg gain/kg CP for total CP efficiency, and 0.75 kg gain/kg TDN for TDN efficiency.

Table 3 - Intake of chemical components of the experimental diets

Variable (kg/d)	Ground corn		Whole corn		CV (%)	P-value		
	NSH	WSH	NSH	WSH		PF	SH	PF × SH
DMI	0.47	0.43	0.28	0.39	45.83	0.11	0.58	0.24
TDMI	0.96	0.92	0.77	0.89	20.22	0.12	0.56	0.25
CPI	0.09	0.07	0.06	0.08	49.06	0.38	0.87	0.23
TCPI	0.21	0.20	0.18	0.20	18.39	0.37	0.86	0.24
NDFI	0.05b	0.21a	0.02b	0.20a	55.93	0.50	<0.01	0.76
NFCI	0.27Aa	0.09Ab	0.16Ba	0.08Bb	50.01	0.04	<0.01	0.07
TDNI	0.82A	0.78A	0.65B	0.73B	21.4	0.08	0.73	0.29

NSH - no soybean hull; WSH - with soybean hull; DMI - dry matter intake; TDMI - total dry matter intake; CPI - crude protein intake; TCPI - total crude protein intake; NDFI - neutral detergent fiber intake; NFCI - non-fibrous carbohydrates intake; TDNI - total digestible nutrients intake; CV - coefficient of variation; PF - physical form; SH - soybean hull.
Means followed by different letters in the same factor differ by t test (P<0.05), being capital letters for physical form and lowercase letters for soybean hull.

Table 4 - Apparent digestibility coefficients and total digestible nutrient values of experimental diets

Variable (kg/kg)	Ground corn		Whole corn		CV (%)	P-value		
	NSH	WSH	NSH	WSH		PF	SH	PF × SH
DMAD	0.87	0.86	0.86	0.87	1.26	0.92	0.66	0.53
NDFD	0.40b	0.52a	0.41b	0.52a	5.94	0.54	0.01	0.74
CPAD	0.89	0.90	0.90	0.90	1.87	0.69	0.59	0.62
NFCD	0.90	0.90	0.90	0.91	1.94	0.75	0.97	0.86
TDN (g/kg)	849.4Aa	839.0Ab	837.6Ba	823.1Bb	1.77	0.02	0.03	0.72

NSH - no soybean hull; WSH - with soybean hull; DMAD - dry matter apparent digestibility; NDFD - neutral detergent fiber digestibility; CPAD - crude protein apparent digestibility; NFCD - non-fibrous carbohydrates digestibility; TDN - total digestible nutrients; CV - coefficient of variation; PF - physical form; SH - soybean hull.
Means followed by different letters in the same factor differ by t test ($P<0.05$), being capital letters for physical form and lowercase letters for soybean hull.

Table 5 - Biochemical indicators in the blood of crossbred dairy male calves

Variable	Ground corn		Whole corn		CV (%)	P-value		
	NSH	WSH	NSH	WSH		PF	SH	PF × SH
GL (mg/dL)	83.71	90.29	89.64	90.67	15.85	0.55	0.48	0.60
TCL (mg/dL)	25.79	28.36	24.79	28.17	55.84	0.92	0.60	0.94
TG (mg/dL)	28.93	40.00	42.36	36.00	33.43	0.32	0.62	0.07
TP (g/dL)	5.70	6.13	6.49	5.98	11.57	0.23	0.88	0.09
ALB (g/dL)	2.71	2.80	2.46	2.64	12.04	0.10	0.27	0.73
UR (mg/dL)	6.57	5.86	8.07	4.83	42.07	0.81	0.06	0.22
AST (U/mL)	46.03	47.14	44.17	46.13	24.18	0.42	0.99	0.69
ALP (U/mL)	148.00	108.57	104.29	103.92	59.72	0.37	0.45	0.46
CRT (mg/dL)	1.25	1.04	1.26	1.21	26.9	0.46	0.28	0.50

NSH - no soybean hull; WSH - with soybean hull; GL - glucose; TCL - total cholesterol; TG - triglycerides; TP - total protein; ALB - albumin; UR - urea; AST - aspartate aminotransferase; ALP - alkaline phosphatase; CRT - creatinine; CV - coefficient of variation; PF - physical form; SH - soybean hull.

Table 6 - Performance of crossbred dairy male calves fed experimental diets

Variable	Ground corn		Whole corn		CV (%)	P-value		
	NSH	WSH	NSH	WSH		PF	SH	PF × SH
IW (kg)	32.93	32.00	32.43	34.67	18.75	0.65	0.78	0.51
FW (kg)	69.43	63.64	58.00	66.08	18.79	0.33	0.80	0.14
TWG (kg)	36.50	31.64	25.57	31.42	27.44	0.10	0.88	0.11
ADG (kg/d)	0.65	0.57	0.46	0.56	27.54	0.09	0.87	0.10
DME (kg/kg)	1.51	1.52	2.00	1.54	38.11	0.29	0.35	0.32
TDME (kg/kg)	0.68	0.61	0.58	0.63	19.92	0.48	0.85	0.20
CPE (kg/kg)	8.00	9.79	9.27	7.73	43.60	0.79	0.93	0.26
TCPE (kg/kg)	3.03	2.85	2.42	2.75	22.96	0.15	0.76	0.30
TDNE (kg/kg)	0.80	0.72	0.69	0.77	20.00	0.62	0.99	0.18

NSH - no soybean hull; WSH - with soybean hull; IW - initial live weight; FW - final live weight; TWG - total weight gain; ADG - average daily gain; DME - dry matter efficiency; TDME - total dry matter efficiency; CPE - crude protein efficiency; TCPE - total crude protein efficiency; TDNE - total digestible nutrients efficiency; CV - coefficient of variation; PF - physical form; SH - soybean hull.

Morphometric measurements were similar, independently of the physical form of corn and SH inclusion level (Table 7), both in the evaluation of the final results and in the respective gains obtained during the experimental evaluation.

Considering the cost of ingredients during the evaluation period, the use of SH and WC was insufficient to reduce feed costs (Table 8). The DFC was \$2.06, while the CKG was \$3.74.

Table 7 - Morphometric measurements of crossbred dairy male calves fed experimental diets

Variable (cm)	Ground corn		Whole corn		CV (%)	P-value		
	NSH	WSH	NSH	WSH		PF	SH	PF × SH
IWH	72.86	70.21	70.36	72.25	5.02	0.86	0.78	0.11
IRH	76.57	75.29	74.14	76.67	5.68	0.75	0.71	0.25
IAG	11.36	11.33	10.93	11.17	8.08	0.39	0.76	0.69
IBL	61.79	59.00	60.93	62.22	9.25	0.58	0.73	0.35
IHG	75.86	75.07	71.21	77.00	7.59	0.53	0.25	0.14
WHG	10.36	12.28	11.07	9.50	33.42	0.49	0.84	0.23
RHG	11.07	11.86	10.78	11.66	31.19	0.84	0.54	0.99
AGG	1.00	1.24	0.93	1.00	46.78	0.41	0.38	0.70
BLG	12.36	11.71	10.65	8.95	47.50	0.29	0.60	0.74
HGG	20.07	19.86	15.28	18.25	39.39	0.71	0.61	0.60
FWH	83.21	82.50	81.43	81.75	5.45	0.46	0.91	0.76
FRH	87.64	87.14	82.36	88.33	7.11	0.38	0.25	0.18
FAG	12.36	12.57	11.86	12.17	6.83	0.16	0.42	0.88
FBL	74.14	70.71	67.43	71.17	7.37	0.13	0.94	0.08
FHG	95.93	93.50	86.50	95.25	9.01	0.71	0.56	0.73

NSH - no soybean hull; WSH - with soybean hull; IWH - initial withers height; IRH - initial rump height; IAG - initial arm girth; IBL - initial body length; IHG - initial heart girth; WHG - withers height gain; RHG - rump height gain; AGG - arm girth gain; BLG - body length gain; HGG - heart girth gain; FWH - final withers height; FRH - final rump height; FAG - final arm girth; FBL - final body length; FHG - final heart girth; CV - coefficient of variation; PF - physical form; SH - soybean hull.

Table 8 - Costs associated with feeding crossbred dairy male calves

Variable	Ground corn		Whole corn		CV (%)	P-value		
	NSH	WSH	NSH	WSH		PF	SH	PF × SH
CKD ($/kg DM)[1]	0.28	0.25	0.27	0.24	-	-	-	-
DCM ($/d)	1.95	1.95	1.95	1.95	-	-	-	-
DFC ($/d)	2.10	2.07	2.04	2.06	2.53	0.06	0.89	0.21
CKG ($/kg)	3.23	3.63	4.43	3.67	50.35	0.44	0.81	0.15

NSH - no soybean hull; WSH - with soybean hull; CKD - cost per kilogram of diet; DCM - daily cost with milk (0.488 US $/L of milk); DFC - daily feed cost (price/4 L of milk + price/kg feed × DMI); CKG - cost per kilogram of gain (DFC/ADG); CV - coefficient of variation; PF - physical form; SH - soybean hull.
[1] Price quotation (in American dollar) performed during the experimental phase: ground corn, $0.185/kg; whole corn, $0.172/kg; soybean hull, $0.16/kg; soybean meal, $0.432/kg; and mineral core, $0.894/kg.

4. Discussion

Soybean hulls have lower NFC contents than corn, as well as high NDF levels (Table 1), and are constituted basically by structural carbohydrates. This caused their inclusion in the diet to also contribute to the reduced NFC intake, resulting in an increased NDF intake. The literature features similar reports of SH inclusion in high-energy diets (Cannas et al., 2013; Freitas et al., 2013). This occurs because SH inclusion usually reduces the proportion of other feedstuffs, e.g., corn and sorghum, which have high NFC and low NDF contents.

The fact that the corn grain used in this study was the hard type (flint), associated with the use of non-pelleted feed, such as soybean meal and the mineral mixture, may have contributed to the reduced NFC intake with the use of WC. This is because, by being fed whole grains, the animals selected what they ate from their diets, preferring to feed on components that were easier to chew, to the detriment of corn grain intake. This selection favored the decreased NFC intake, since other components of the diet preferred by the animals, such as soybean meal, have a much lower NFC content than that found in corn (184 and 754 g/kg, respectively; NRC, 2001).

Although the animals expressed a preference for certain feedstuffs in the diet, the similar DM and total DM (concentrate + milk) intakes between the treatment groups indicated that the diets were well accepted by the animals. This result is very important at this stage of production, since ingesting solid feed reduces the dependence of animals on liquid diets (Hodgson, 1971), thereby allowing a reduction in weaning age (NRC, 2001) and accelerating the return on the capital invested in animal production.

In addition, the DM and total DM intakes were 0.39 and 0.89 kg/d, respectively, lower than those observed by Gomes et al. (2012), who evaluated the inclusion of soybean hulls in the diet of male calves during the preweaning period and found a mean DM intake from concentrate feed of 0.49 kg/d. However, despite the lower intakes, the feed conversion results were better, and the animals needed to consume 1.70 kg of total DM to gain one kilogram of live weight, whereas in the study by Gomes et al. (2012), the animals needed 1.91 kg/d. This shows that the animals were highly efficient, which impacted their weight gain as evidenced by their ADG of 0.56 kg/d.

By comparing the results of weight gained using the WSH diets with the results of other studies in the literature, we found that SH has superior performance during the preweaning period [ADG of 0.35 (Pedrico et al., 2011) and 0.45 kg/d (Schalch et al., 2001)] of dairy calves compared with byproducts similar to SH with high fiber content and low particle size, such as babassu mesocarp meal (Pedrico et al., 2011) and citrus pulp (Schalch et al., 2001). Thus, SH is a good option to be used on farms that produce this type of animal, since it allows the animals to be weaned at a high weight.

The observed high digestibility of DM and evaluated nutrients indicates that, although the animals were young, using solid feeds resulted in high digestibility of the diet nutrients, e.g., CP, which is highly required by animals during the initial production phase (NRC, 2001) and whose apparent digestibility was high (0.89 kg/kg).

Although cattle digest fibrous feeds efficiently only from the moment the rumen is functional, the high digestibility of NDF in the WSH diets demonstrated that although this feedstuff is high in fiber (Table 1), the fiber has high quality because of the high pectin (NRC, 2001) and low lignin (Miron et al., 2001; NRC, 2001) contents. This allowed the animals to make great utilization of the fiber present in this feedstuff despite their young age.

Although NDF digestibility was favored, SH have lower energy content than corn [3.4 and 3.9 Mcal/kg, respectively (NRC, 2001)], causing it to reduce the TDN value of the diet. This result is common when SH is used instead of high-energy concentrates, such as corn, in bovine diets (Löest et al., 2001; Mueller and Boggs, 2011). Additionally, the literature shows that as the SH inclusion level is increased, the TDN value of the diet varies considerably (Ipharraguerre and Clark, 2003), as also observed in this study.

This reduction in the amount of digestible nutrients available to the animals also occurred with the use of WC grain, although the whole and ground grain diets showed the same chemical compositions (Table 2). However, this variation between the TDN level of the diets with WC and GC was only 1.64%, representing minimal change. Thus, the proximity between the TDN value of the diets with WC and GC allowed the animals that fed these diets to revert this difference in TDN value, since they achieved TDN intake results similar to those of the animals fed GC.

This similarity was evidenced in the blood data of animals, since the glycemic levels remained within the range considered normal for the animal category (Pogliani and Birgel Junior, 2007), indicating that, although glucose metabolism in ruminants is highly complex, the animals received sufficient nutrients to meet their needs. In addition, the creatinine, AST, and ALP results indicated that the experimental diets did not alter the hepatic (AST and ALP) (Franzese et al., 1997; Stojevic et al., 2005) or renal (creatinine) functions of the animals (Finco, 1989; Thrall, 2012). That is, the diets did not impose great metabolic challenge to the suckling calves, as the levels of these indices remained within the normal ranges for suckling Holstein calves according to Fagliari et al. (1998) (creatinine between 0.98 and 1.56 mg/dL, AST between 27.6 and 46.3 U/mL, and APL between 67.71 and 141.33 U/mL).

The animals fed the experimental diets developed well, based on the data from the morphometric measurements performed on them during the preweaning period. During the evaluation period, the animals exhibited significant gains for these measurements, and these gains were similar between diet groups, which reflected the similarity in weight gain and TDN intake between the calves. This was also highlighted in the study of Bartlett et al. (2006), who obtained similar metabolizable energy intakes in Holstein calves, thus resulting in similar morphometric measurements for these animals.

Despite the favorable results regarding animal performance, the use of SH or the reduction in processing by using WC did not reduce feed costs, even when the costs were analyzed as a function of weight gain. These results demonstrate the need for a greater difference in the market value between GC and WC and between GC and SH to significantly reduce production costs by using WC or SH in calf diets during the suckling period.

Katsuki (2009) reported reduced diet costs with the use of SH, describing a 20% decrease in costs per kilogram of weight gain with the inclusion of up to 30% SH in the diet of Nellore steers. However, in the study by Katsuki (2009), the difference between the prices of GC and SH was of 25%, whereas in the present study, the variation was only of 14%.

Nonetheless, it is important to consider that even without reducing feed costs, the use of SH can still be advantageous due to its chemical characteristics, as it reduces the incidence of common digestive disorders when high-starch diets are supplied (Santos et al., 2008). Further research on this topic is warranted to establish the extent to which its inclusion benefits the animal in terms of feed costs.

5. Conclusions

The use of soybean hulls or whole corn in the diet of crossbred dairy male calves can alter their digestibility without impairing animal performance or changing their blood parameters. However, for production costs to be reduced, there must be a greater difference in price between these products and ground corn.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Conceptualization: J.N.M. Neiva. Funding acquisition: J.N.M. Neiva. Investigation: A.E.M. Santana and V.L.A. Bozorg. Project administration: A.E.M. Santana, V.L.A. Bozorg and J.N.M. Neiva. Resources: U.O. Bilego. Supervision: V.L.A. Bozorg. Validation: A.E.M. Santana and W.F. Augusto. Visualization: A.E.M. Santana. Writing – original draft: A.E.M. Santana. Writing – review & editing: A.E.M. Santana, J. Restle and J.N.M. Neiva.

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