Original Article

BEAN COPRODUCT AS SOURCE OF PROTEIN IN DAIRY COWS DIETS

COPRODUTO DO FEIJÃO COMO FONTE PROTEICA EM DIETAS PARA VACAS LEITEIRAS

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ABSTRACT: The objective of this study was to evaluate the supplementation of dairy cows with different protein sources in relation to intake, digestibility, production and chemical composition of milk. For this, eight crossbred cows (Hostein x Gir) were used, distributed in two simultaneous latin squares (4x4). The treatments used were: bean coproduct, soybean meal, sunflower meal and cottonseed meal. Four variance-covariance structures were tested by means of the Akaike criterion corrected to determine the best fit to the data, and afterwards they were submitted to analysis of variance, and the means of the treatments were compared by the Tukey's test, at 5% probability. Only intakes of crude protein and crude fat were influenced by the treatments, for the digestibility, regardless of the evaluated nutrient, the soybean meal was the best treatment or was among the best, a behavior also observed for milk production. Thus, it was concluded that soybean meal is the best source of protein among the supplements used, and the bean coproduct stands out as a low-cost protein source but should not fully replace soybean meal, especially in animal categories of higher nutritional requirement.

KEYWORDS: Bean coproduct. Digestibility. Intake. Milk production.

INTRODUCTION

In search of lower production costs for products of animal origin, the rational use of all available food resources has been focused. In this way, several agroindustrial residues or by-products, when employed in a rational way, can contribute to the reduction of the cost of feeding the animals (CARVALHO JÚNIOR et al., 2010).

By-products and residues resulting from grain processing are a promising alternative to the reduction of feed costs of the dairy herd. The rational use of these products depends mainly on their nutritional characteristics (PEREIRA, 2000).

Protein is an expensive nutrient and thus is the goal of several studies aimed at increasing its efficiency of use through the strategic use or replacement of traditional foods by those with better cost / benefit.

The replacement of soybean meal by alternative protein sources without compromising the performance of the animal may be a viable alternative for reducing feed costs the dairy herd. However, the potential for incorporation of these ingredients into diets for ruminant animals requires caution, planning, technical / financial assessment and market opportunity study (PINA et al., 2006).

The bean coproduct is composed of damaged or broken beans during the processing that are discarded, in some situations, the coproduct of beans represents up to 4% of the total grains harvested.

Grains of beans have the composition of 222–274g de crude protein, 161–258 of neutral detergent fiber, 1-3g of lignin and 11–24g of ether extract, per kilo of dry matter (SHARASIA et al., 2017). Goes et al. (2013) found that the addition of beans in the diet of cattle did not affect animal performance, dry matter intake and feed efficiency. However, the digestibility of dry matter, organic matter, crude protein, ether extract and total carbohydrates decreased with the inclusion of 26 percent of beans.

Nunes (1998) characterized the bean residue as a product of low palatability and digestibility that presented the following recommendations: inclusion of up to 15% in concentrates destined to cattle and of 20 to 25% for sheep in fattening, with no reports being reported indication for lactating cows. In this way the bean coproduct stands out as an alternative to supplementation.

The objective of this study was to evaluate the supplementation of dairy cows with different protein sources (bean coproduct, cottonseed meal,

Received: 20/09/17
Accepted: 20/02//18

sunflower meal, soybean meal) in relation to the intake and digestibility of nutrients, and production and chemical composition of milk.

MATERIAL AND METHODS

The experiment was conducted in the city of São João Del Rei (MG-Brazil), whose geographical coordinates are 21º 08' 00"S and 44º 15' 40"W in an altitude of 898 m. The area is located in a region where an Cwa climate (Köppen standards) predominates with an annual rainfall of 1468 mm and average annual temperature of 20.1°c.

Eight crossbred cows (¾ Holstein x ¼ Gir) were used, with an average weight of 554.59 ± 30.43 kg, average production of 14.85 ± 3.28 kg of milk / day and lactational period between 60 and 90 days of lactation. The animals were kept in pickets with Brachiaria brizanta cv. MG5, equipped with drinking fountains and salt shakers, in a rotational stocking system.

The cows were distributed in two simultaneous 4 × 4 latin square design. The experiment lasted 84 days, and each period had 21 days, with the first 14 days used for adaptation and the others for data collection. The treatments consisted of the protein source used to compose the concentrate supplement: coproduct bean, soybean meal, sunflower meal, cottonseed meal. concentrate supplement were formulated according to the production requirements of the animals and in accordance with the recommendations of the NRC (2001), the level of 22% of crude protein (CP) on a dry matter basis was established for the concentrates (Tables 1 and 2). The concentrate supplement was offered daily to animals after milking in the amount of five kg.

The quantities of concentrate supplied and orts left by each animal were recorded to estimate the intake. At the moment of feeding, all through the experimental periods, the diets and orts were sampled. Samples of all ingredients used and all concentrates were also collected during the preparation of the mixtures, which were conditioned in plastic bags and frozen for subsequent analyses.

For the collection of the pasture samples, the simulated-grazing method proposed by Sollenbergger and Cherney (1995) was adopted. The samples were collected by the hand-plucking method, in which the forage is collected manually after previous observation of the grazing habit of the animals.

The samples were dried in a forced-ventilation oven at 55 ºC for 72 h, and the definitive dry matter was determined in an oven at 105 ºC (DM, method 967.03; AOAC, 1990). The crude protein (CP, method 2001.11; THIEX et al., 2002), crude fat (CF, method 2003.06; THIEX et al., 2003), and ashes (Ash; method 942.05; AOAC, 1990) were performed. The neutral detergent fiber (NDF) was evaluated according to the protocols suggested by Van Soest et al. (1991). Total carbohydrates (TC) was calculated according to Sniffen et al. (1992): TC (g/kg as DM) = 1000 – (CP + CF + MM), whereas non-fibrous carbohydrate was calculated by: NFC (g/kg as DM) = 1000 – (CP + CF + MM+ NDF).

To calculate the excreted fecal matter chromic oxide (Cr_2O_3) was used as external marker. The marker was weighed (10 g), conditioned in filter paper and administered, via esophagus, in a single daily dose after the morning milking, during the ten days of experimental period (SILVA and LEÃO, 1979).

Feces were collected on the tenth, twelfth and fourteenth days of each experimental period, twice daily, at 08h00 and 16h00, directly from the rectum of the animals, according to the technique described by Leão (2002). Immediately after collection, the samples of feces were conditioned in plastic bags, labeled and frozen at –10 ºC. Subsequently, the samples were composed on the basis of the air-dry weight, per treatment and period, and analyzed for the chromium content on an atomic absorption spectrophotometer, according to the method described by Williams et al. (1962).

For fecal output determination, the following formula was utilized FO = OF/COF, where: FO = daily fecal output (g DM day^{-1}); OF = chromic oxide offered (g day^{-1}); and COF = concentration of the chromic oxide in the feces (g g^{-1} DM).

Indigestible neutral detergent fiber (iNDF) obtained after 144 h of incubation was used to determine the dry matter intake, in accordance with the technique adopted by Cochran et al. (1986). In this way, the ratio between the daily intake of the marker and its concentration in the feces was established. For the evaluation of the iNDF, the feeds and feces were ground in a 1 mm sieve mill and conditioned in non-woven textile (TNT 100) bags measuring 4 × 5 cm, following a ratio of 20 mg of DM per square centimeter of surface (NOCEK, 1997).

Table 1. Chemical composition of the feedstuffs used as inputs to optimize the treatment diets.

Nutrient	Treatment				Pasture
	Bean coproduct	Soybean meal	Sunflower meal	Cottonseed meal	
DM	939.4	958.9	950.5	959.6	239.9
OM	953.3	934.5	943.4	944.1	903.1
CP	205.4	460.9	272.5	314.4	96.8
NDF	184.0	234.5	454.7	217.9	609.2
CF	13.2	9.3	23.1	13.9	15.8
Ash	46.7	65.5	55.9	56.6	96.9
TC	734.7	464.3	648.5	615.1	790.5
NFC	575.9	251.6	236.5	413.1	25.82

DM - dry matter (g kg^{-1} as fed), OM - organic matter (g kg^{-1} as fed), CP - crude protein (g kg^{-1} of DM), NDF - neutral detergent fiber (g kg^{-1} of DM), CF - crude fat (g kg^{-1} of DM), Ash (g kg^{-1} of DM), TC - total carbohydrate (g kg^{-1} of DM), NFC - non-fibrous carbohydrate (g kg^{-1} of DM).

Table 2. Quantitative composition of the experimental diets.

Ingredients	Treatment			
	Bean coproduct	Soybean meal	Sunflower meal	Cottonseed meal
Bean coproduct, g kg^{-1} as fed	442.3	-	-	-
Soybean meal, g kg^{-1} as fed	-	230.8	-	-
Sunflower meal, g kg^{-1} as fed	-	-	-	269.3
Cottonseed meal, g kg^{-1} as fed	-	-	331.6	-
Corn bran, g kg^{-1} as fed	534.4	740.4	642.2	705.7
Urea, g kg^{-1} as fed	1.5	1.0	1.3	1.2
Calcium phosphate, g kg^{-1} as fed	7.8	10.6	10.3	4.6
Limestone, g kg^{-1} as fed	15.5	18.3	15.9	20.4

The apparent digestibility coefficients of dry matter and other nutrients were obtained by the ratio between the intake of these nutrients and their fecal excretions, multiplied by 1000. The excretion of nutrients was obtained by excreting fecal dry matter multiplied by the concentration of nutrients in the faeces.

The milk was weighed on the twelfth and fourteenth days of each experimental period, whereas the milk samples were collected on the fourth day of each period. Before the collection, the milk was homogenized and, immediately after it was stored in a container with preservative (Bronopol®) at the proportion of 2/3 during the morning milking and 1/3 in the afternoon milking. The morning samples were placed under refrigeration, and at the end of the day, they were mixed with the afternoon samples. After collection, milk samples were sent to the laboratory where analyzed for fat, protein, lactose, total solids, dry extract defatted, somatic cell count, urea nitrogen, casein, and protein of casein.

The milk yield was corrected for 4% of fat, using the formula described in the NRC (1989): Milk yield corrected to 4% fat = 0.4 x (kg of milk) + 15 x (kg of fat).

The following linear mixed statistical model was adopted (TEMPELMAN, 2004):

$$Y_{ikl} = \mu + \alpha_i + c_k + \beta_l + \alpha\beta_{il} + e_{ikl}.$$

in which Y_{ikl} is the observation related to the variable measured in the k-th cow fed to the i-th treatments during the l-th period. The fixed effects are the mean (μ), the treatments (α_i), the periods for the two simultaneous balanced Latin squares (β_l), and the treatment by period interaction $(\alpha\beta_{il})$. The random effects are cow (c_k) and the usual error term (e_{ikl}).

The statistical model was fitted using the PROC MIXED procedure of SAS (version 9; SAS Institute Inc., Cary, NC, USA) with restricted maximum likelihood (REML) as the estimation method. The repeated command was used with c_k as subjects.

The variance-covariance matrix was modeled as variance components, compound symmetry, first order auto-regressive correlations, and as the unrestricted variance–covariance structure (LITTELL et al., 2006). The likelihood of the different variance-covariance structures was assessed by computing Akaike information criteria (AKAIKE, 1974) as suggested by Vieira et al. (2012). The comparison between treatments was done by the Tukey test at 5% of probability.

RESULTS

The adjustment of the variables using the different variance-covariance structures showed a predominance of variance components (VC), but each structure was selected as the most probable one at least once (Table 3). The unrestricted (UN) variance-covariance structure did not fit for all nutrient digestibility variables.

The treatment means were presented followed by amplitude of 95% confidence intervals divided by 2, for the variables that had no effect was calculated the general mean. In relation to the intake, the treatments influenced only the intake of nutrients crude protein (P=0.019) and crude fat (P<0.001). Supplementation with soybean meal resulted in the highest intake of crude protein, while supplementation with bean coproduct resulted in the lowest intake of crude protein (Tables 3 and 4). Supplementation with sunflower meal caused the greatest intake of crude fat.

In relation to nutrient digestibility, treatments influenced DOM (P <0.001), DCP (P = 0.020) and, DNDF (P <0.001), cottonseed meal presented the worst digestibility in both variables (Tables 3 and 4). The interaction treatment x periods was significant for the variables DDM (P = 0.018), and DNFC (P = 0.031), in all periods the supplementation with soybean meal was presented the highest digestibility.

Milk production (MY) and production corrected to 4% fat (MY4) were influenced by the treatments, for MY the soybean meal together with the sunflower meal provided the highest yields, whereas for MY4 only the soybean meal was higher. Note that for both variables the bean coproduct was the worst supplement in productive terms (Table 5).

Regarding milk composition, the only variable that presented treatment effect was TS (P = 0.025), in which supplementation with soybean meal was higher than the others. The composition of the milk predominantly was not altered by the supplement, and the only exception, total solids (TS), followed the milk yield trend (MY and MY4), where soybean meal was better (Table 5).

Table 3. *P*-values and variance-covariance matrix related to the measured variables.

Variable	P-values			Variance-covariance matrix
	Treatment	Period	Treatment*Period	
W	0.483	0.003	0.083	CS
DMI	0.791	0.962	0.749	VC
OMI	0.750	0.961	0.772	VC
AshI	0.314	0.944	0.438	VC
CPI	0.019	0.967	0.917	VC
CFI	<0.001	0.978	0.541	VC
NDFI	0.193	0.963	0.293	VC
TCI	0.841	0.961	0.750	VC
NFCI	0.700	0.913	0.976	VC
DDM	<0.001	0.883	0.018	AR(1)
DOM	<0.001	0.739	0.249	VC
DCP	0.020	0.166	0.581	VC
DNDF	<0.001	0.007	0.057	VC
DNFC	0.002	0.108	0.031	VC
MY	0.010	<0.001	0.103	VC
MY4	0.001	<0.001	0.149	CS
Fat	0.073	0.685	0.110	AR(1)
Prot	0.626	0.375	0.914	CS
Lac	0.927	0.005	0.915	CS
TS	0.025	0.330	0.317	CS
DED	0.847	0.586	0.926	CS
SCC	0.767	0.510	0.462	UN
Un	0.166	0.052	0.068	VC
Cas	0.942	0.994	0.968	CS
PCas	0.411	0.009	0.995	CS

W - live weight , DMI - dry matter intake, OMI - organic matter intake, AshI - ash intake, CPI - crude protein intake, CFI - crude fat intake , NDFI - neutral detergent fiber intake, TCI - total carbohydrates intake, NFCI - non-fibrous carbohydrates intake, DDM - digestibility of dry matter, DOM - digestibility of organic matter, DCP - digestibility of crude protein, DNDF - digestibility of neutral detergent fiber, DNFC - digestibility of non-fibrous carbohydrates, MY - milk yield, MY4 - milk yield corrected for 4% of fat, Prot - protein in milk, Lac - lactose, TS - total solids, DED - dry extract defatted, SCC - somatic cell count, Un - urea nitrogen, , Cas – casein, and PCas - protein of casein; VC - variance components, CS - compound symmetry, AR(1) - first order auto-regressive correlations, and UN - unrestricted.

Table 4. Intakes and digestibility of dry matter and nutrients in the function of the experimental diets.

Variable	Treatments				General mean
	Bean coproduct	Soybean meal	Sunflower meal	Cottonseed meal	
DMI	11.07±1.38	11.72±1.38	11.41±1.38	10.84±1.38	11.26±1.38
OMI	10.22±1.28	10.90±1.28	10.69±1.28	10.09±1.28	10.48±1.28
AshI	0.84±0.11	0.81±0.11	0.72±0.11	0.75±0.11	0.78±0.11
CPI	1.24±0.18 B	1.66±0.18 A	1.43±0.18 AB	1.44±0.18 AB	-
CFI	0.14±0.02 B	0.13±0.02 B	0.19±0.02 A	0.12±0.02 B	-
NDFI	4.45±0.59	4.31±0.59	4.42±0.59	3.67±0.59	4.21±0.59
TCI	8.85±1.09	9.11±1.09	9.07±1.09	8.52±1.09	8.89±1.09
NFCI	4.96±0.68	5.42±0.68	5.20±0.68	5.30±0.68	5.22±0.68
DDM	580.7±32.3 AB	654.4±32.3 A	570.9±32.3 B	545.1±33.3 B	-
DOM	564.4±34.7 A	566.4±34.7 A	364.0±34.7 B	234.6±38.8 C	-
DCP	621.5±50.4 AB	713.1±50.4 A	626.3±50.4 AB	596.3±56.4 B	-
DNDF	594.6±27.4 B	652.7±27.4 A	399.3±27.4 C	395.5±30.6 C	-
DNFC	672.6±27.2 B	729.9±27.2 A	730.3±27.2 A	669.7±30.4 B	-

DMI - dry matter intake (kg day^{-1}), OMI - organic matter intake (kg day^{-1}), AshI - ash intake (kg day^{-1}), CPI - crude protein intake (kg day^{-1}), CFI - crude fat intake (kg day^{-1}), NDFI - neutral detergent fiber intake (kg day^{-1}), TCI - total carbohydrates intake (kg day^{-1}), NFCI - non-fibrous carbohydrates intake (kg day^{-1}), DDM - digestibility of dry matter (g kg^{-1}), DOM - digestibility of organic matter (g kg^{-1}), DCP - digestibility of crude protein (g kg^{-1}), DNDF - digestibility of neutral detergent fiber (g kg^{-1}), DNFC - digestibility of non-fibrous carbohydrates(g kg^{-1}); Means in the same row followed by different letters differ according to the Tukey test (P<0.050).

Table 5. Yield and composition of the milk in the function of the experimental diets.

Variable	Treatments				General mean
	Bean coproduct	Soybean meal	Sunflower meal	Cottonseed meal	
MY	12.1±1.56 B	15.9±1.56 A	15.3±1.56 A	15.0±1.56 AB	-
MY4	10.5±1.73 C	14.4±1.73 A	12.1±1.73 BC	12.7±1.73 AB	-
Fat	27.5±4.47	29.0±4.47	22.8±4.47	25.0±4.47	26.1±4.47
Prot	31.5±3.13	32.2±3.13	31.6±3.13	31.4±3.13	31.7±3.13
Lac	45.1±2.50	45.3±2.50	45.4±2.50	45.6±2.50	45.4±2.50
TS	113.3±7.29 AB	115.7±7.29 A	108.9±7.29 B	111.2±7.29 AB	-
DED	85.7±3.94	86.7±3.94	86.1±3.94	86.3±3.94	86.2±3.94
SCC	88.1±15.96	127.1±127.19	124.4±37.12	188.5±138.97	132.0±154.81
Un	16.8±1.72	18.5±1.72	17.6±1.72	15.9±1.72	17.2±1.72
Cas	23.94±2.80	24.30±2.80	24.1±2.80	24.2±2.80	24.1±2.80
PCas	759.5±18.30	753.98±18.30	761.51±18.30	767.81±18.30	760.70±18.30

MY - Milk yield (kg day^{-1}), MY4 - Milk yield corrected for 4% fat (kg day^{-1}), Fat (g kg^{-1} milk), Prot - Protein (g kg^{-1} milk), Lac - Lactose (g kg^{-1} milk), TS - Total solids (g kg^{-1} milk), DED - Dry extract defatted (g kg^{-1} milk), SCC - Somatic cell count (x1000 mL^{-1}), Un - Urea nitrogen (mg dL^{-1}), Cas - Casein (g kg^{-1}), Pcas - Protein of casein (g kg^{-1} of protein).
Means in the same row followed by different letters differ according to the Tukey test (P<0.050).

DISCUSSION

The investigation of better variance-covariance (Table 3) structures, based on the Akaike criterion corrected, reveals that the errors are correlated in some cases, this indicates that assuming the independence of the errors in simultaneous Latin square delineations can be incur a mistaken analysis of data (AKAIKE, 1974; JARDIM et al. 2013; VIEIRA et al. 2012).

The superiority of the soybean meal and sunflower meal for CPI and CFI, respectively (Table 4), follows the same pattern in relation to the chemical composition of these foods (table 1), but this behavior did not extend to the other variables of the intake that stood out in terms of chemical composition, as in the case of sunflower meal for NDF content and bean coproduct for NFC content (Tables 1 and 4).

Pina et al. (2006) evaluated nutrient intake by cows fed diets containing different protein sources, including soybean meal and cottonseed meal, and did not observe differences in dry matter and organic matter intake, a behavior observed in the present study. Already Magalhães et al. (2008) reported that beans have a high time of colonization of their fibrous portion (lag time) which delays fiber degradation, resulting in a lower flow in the gastrointestinal tract of the animals, which may affect intake. This behavior may be barely perceptible due to the low fiber content of the treatment with bean coproduct, but in this case the fiber quality is as important as the quantity.

The absence of a significant effect for most intake variables, especially dry matter, organic matter and fiber (Table 4) indicates the possibility of using any of the feeds with the objective of supplementation, but the superiority of soybean meal in relation to to crude protein intake (CPI), which is a nutrient deficient in pastures mainly in the winter, and its superior performance in terms of digestibility makes it the most suitable for supplementation.

Conrad et al. (1964) have shown that the physical and physiological factors that regulate food intake are altered by the increased dry matter digestibility of the diet and that for diets below 660 g/kg of apparent digestibility, physical factors are determinant of intake. This report may explain the lack of effect for most of the intake variables evaluated in the present study, since they presented dry matter digestibility values lower than the reference cited above (Table 4).

The performance obtained by the bean coproduct for DDM, DOM and DCP credence as a potential low cost alternative to soybean meal, mainly in animal categories of lower nutritional requirement and because it is an abundant residue in regions producing this food. The cottonseed meal was the supplement that presented the worst results in terms of digestibility, a behavior also observed by Pina et al. (2006), and since the main intake variables did not present a significant effect, it can be inferred that among the supplements evaluated, this was the one least able to replace soybean meal (Table 4). Soybean meal was the one that presented the best results in terms of digestibility, regardless of the evaluated nutrient.

Regarding milk production, the same soybean meal superiority trend was observed for both MY and MY4. On the other hand, the bean coproduct showed good results in terms of intake and digestibility, as previously discussed, showing the worst values for yield variables (Table 5), which may be due to poor protein quality and the presence of anti-nutritional factors of the bean coproduct, demonstrating that caution should be exercised in the use of this supplement, mainly in category more demanding animals such as dairy cows.

Contradictory results are reported in the literature regarding the production of dairy cows supplemented with different protein sources such studies reveal since no significant effect (BERNARD, 1997; PINA et al, 2006; MENA et al, 2001; MENA et al, 2004.) to the linear decrease of milk production with the inclusion of bean residues (MAGALHÃES et al., 2008).

CONCLUSIONS

The soybean meal and the cotton meal stood out in allowing better milk yields with good composition.

The bean coproduct stands out as a low-cost protein source but should not fully replace soybean meal, especially in animal categories of higher nutritional requirement.

ACKNOWLEDGEMENTS

R. P. Araujo thanks the Instituto Federal do Tocantins (IFTO) for the support to carry out the experimente. R. S. Gomes thanks the post-doctoral fellowships provided by Fundação de Amparo à Pesquisa do Estado do Rio de Janeiro (FAPERJ) and Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES).

RESUMO: Objetivou-se com este estudo avaliar a suplementação de vacas leiteiras com diferentes fontes proteicas em relação ao consumo, digestibilidade, produção e composição química do leite. Para tanto, utilizou-se oito vacas mestiças (Holandês x Gir), distribuídas em dois quadrados latinos (4x4) simultâneos. Os tratamentos utilizados foram: coproduto do feijão, farelo de soja, farelo de girassol e farelo de algodão. Foram testadas quatro estruturas de variância-covariância por meio do critério de Akaike corrigido para determinar o melhor ajuste aos dados, e posteriormente foram submetidas à análise de variância, sendo as médias dos tratamentos comparadas pelo teste de Tukey, a 5% de probabilidade. Apenas os consumos de proteína bruta e gordura bruta foram influenciados pelos tratamentos, já em relação a digestibilidade, independente do nutriente avaliado o farelo de soja foi o melhor tratamento ou esteve entre os melhores, comportamento este observado também para a produção de leite. Com isso, concluiu-se que dentre os suplementos utilizados o farelo de soja é a melhor fonte proteica, e o coproduto de feijão se destaca como uma fonte proteica de baixo custo, mas que deve substituir integralmente o farelo de soja, principalmente em categorias animais com alta exigência nutricional.

PALAVRAS-CHAVE: Consumo. Coproduto do feijão. Digestibilidade. Produção de leite.

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