Soybean in different forms of processing in the feeding of crossbred cows on brachiaria grass pastures

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ABSTRACT - The objective was to evaluate intake and digestibility of nutrients, as well as milk production and composition of the milk from F1 Holstein × Gyr cows kept on pasture, supplemented with sugarcane and concentrate (28% CP). Five cows with 150±14 lactation days and average milk production of 7.1±2.1 kg/day were distributed in a 5 × 5 Latin square design. The treatments were: soybean meal-based concentrate; soy bean-based concentrate; ground soybean-based concentrate; roasted soybean-based concentrate; and ground, roasted soybean-based concentrate. Dry matter (DM), organic matter, crude protein (CP), neutral detergent fiber (NDF), total carbohydrates and total digestible nutrients intakes were not affected by the diet, but ether extract intake was higher for the animals fed soy bean-based diets than those fed soybean meal. The digestibility of DM, NDF and CP did not differ. The corrected milk yield differed between treatments; animals on the treatment with soy bean-based concentrate had the lowest production in relation to the others, which did not differ from each other. There was no difference between treatments for milk composition. Thus, soybean meal can be replaced by ground soy beans or roasted soy beans (ground or whole) in diets for low-yield cows reared on *Brachiaria decumbens* pastures with no harm to milk production or composition. Therefore, the use of these alternative raw materials is recommended whenever their inclusion represents lower feeding costs.

Key Words: alternative feeds, intake, milk composition, milk yield

Introduction

Tropical forages present low digestibility and reduced protein content to meet the requirements of lactating cows, and even in the growth season, they do not provide enough nutrients for high milk yields. Hence, supplementation is an efficient alternative to improve animal performance, but the type of supplementation must be chosen based on the time of the year, production level, costs, and available feeds.

Protein is a limiting ingredient in diets for ruminants, and protein sources are the most expensive ingredients in the formulation of diets and supplements for lactating cows, due to their elevated requirement and high cost of traditional sources such as soybean meal. As an alternative, the use of soybean has increased. Because of the elevated fat content of this ingredient, about 19% of ether extract, its use as

a component in cattle diets has spread quickly. Therefore, there are several forms of processing soy to include it as an ingredient in the cattle diets, e.g., soybean meal, ground raw soybean, roasted soy beans, and ground, roasted soybeans, which were all utilized in this experiment.

Replacing soybean meal by the whole grain may provide changes in the fat content and milk production, due to the higher concentration of fat contained in the feed that can alter the metabolism of carbohydrate, also bringing economical advantages, given its lower market price.

The objective of this study was to evaluate the effect of the different forms of soy processing on the intake and digestibility of nutrients, as well as production and composition of milk from crossbred (Holstein × Gyr) cows on brachiaria grass pastures.

Material and Methods

The experiment was conducted in the county of São João Del Rei (MG/Brazil), whose geographical coordinates are 21º08'00" South latitude, 44º15'40" West longitude, and 898 m altitude, from August to November 2009, which corresponded to part of the dry period of the region in that year.

The area is located in a region where a Cwa climate (Köppen standards) predominates with an annual rainfall of 1,468 mm and annual temperature of 20.1 °C.

An experimental area of one hectare of *Brachiaria decumbens* pasture provided with masonry drinker with continuous water flow and trough for mineral supply was used.

The experiment consisted of five 14-day experimental periods each. The first nine days of the periods corresponded to the phase of acclimation, and the subsequent five days were used for sample and data collections.

The experimental design adopted was a 5 × 5 Latin square, consisting of five animals, five treatments and five experimental periods. The experimental treatments were: soybean meal-based concentrate (SM); whole raw soybean-based concentrate (SB); ground soybean-based concentrate (GSB); roasted soybean-based concentrate (RSB); and ground, roasted soybean-based concentrate (GRSB). Roasting was performed at a temperature of 100 ºC for one hour.

Five multiparous cows (Holstein × Gyr) in lactation, with an average live weight of 499±32 kg, lactating period of 150±14 days, and average production of 7.1±2.1 kg were used. These cows remained on pasture (Table 3) during the entire experimental period, under continuous grazing,

and after milking sessions, which occurred at 06.30 h and 15.30 h, they received the respective concentrates in individual troughs (Tables 1 and 2) at the ratio of 1 kg for every 3 L of milk produced. After the morning milking, only concentrate was supplied, and after the afternoon milking, the concentrate was provided with 5 kg of supplemental roughage (fresh, chopped sugarcane). The sugarcane was used so as to prevent overgrazing in the grazing area, in addition to simulating a common situation of dairy properties, which is the supply of sugarcane in the dry period for low-yield animals grazing on a low-quality pasture.

The diets were formulated according to the production requirements of the animals and in accordance with the recommendations of the NRC (2001); the level of 28% of crude protein (CP) on a dry matter basis was established for the concentrates. For the collection of the pasture samples, the simulated-grazing method proposed by Sollenbergger and Cherney (1995) was adopted. According to those authors, this would be the best way of performing collection as close as possible to the feed the animals would be consuming. 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.

Table 1 - Proportion of ingredients utilized in the experimental concentrates, expressed on a fresh-matter basis

Ingredient (g/kg)	Concentrate				
	SM	SB	GSB	RSB	GRSB
Corn	414.3	314.3	314.3	314.3	314.3
Soybean meal	557.1				
Raw soybeans		657.1			
Roasted soybeans				657.1	
Ground raw soybeans			657.1		
Ground roasted soybeans					657.1
Mineral	28.6	28.6	28.6	28.6	28.6

SM - soybean meal-based concentrate; SB - raw soybean-based concentrate; GSB - ground soybean-based concentrate; RSB - roasted soybean-based concentrate; GRSB - ground, roasted soybean-based concentrate.

Table 2 - Chemical composition (g/kg) of the concentrates utilized in the experimental diets and sugarcane, on a dry matter basis

Component	Concentrate					Sugarcane
	SM	SB	GSB	RSB	GRSB	
Dry matter	897.5	879.9	879.9	881.2	881.2	295.2
Organic matter	911.7	927.7	927.7	922.6	922.6	964.3
Crude protein	281.8	288.1	288.1	279.9	279.9	27.2
Neutral detergent fiber	197.1	314.9	314.9	316.9	316.9	464.5
NDFap	167.0	267.0	267.0	270.2	270.2	385.0
Acid detergent fiber	75.2	232.4	232.4	198.1	198.1	271.2
Ether extract	23.7	145.2	145.2	128.4	128.4	5.9
Non-fibrous carbohydrates	439.3	227.4	227.4	244.2	244.2	546.2
Total carbohydrates	606.3	494.5	494.5	514.4	514.4	931.2

SM - soybean meal-based concentrate; SB - raw soybean-based concentrate; GSB - ground soybean-based concentrate; RSB - roasted soybean-based concentrate; GRSB - ground, roasted soybean-based concentrate.
NDFap - neutral detergent fiber corrected for the residual ash and protein.

Table 3 - Chemical composition (g/kg) of the pasture during the experimental periods

Nutrient	Pasture				
	P1	P2	P3	P4	P5
Organic matter	917.7	921.2	931.2	931.0	935.3
Crude protein	60.4	67.6	8.40	69.7	67.6
Neutral detergent fiber	725.9	728.7	71.80	714.4	718.1
NDFap	683.6	682.1	68.30	664.6	670.3
Acid detergent fiber	420.0	448.4	433.1	424.3	426.3
Ether extract	11.2	20.9	20.2	21.2	14.6
Non-fibrous carbohydrates	162.5	150.7	144.1	175.5	182.8
Total carbohydrates	846.1	832.7	827.1	840.1	853.1

P1, P2, P3, P4 and P5 - 1st, 2nd, 3rd, 4th and 5th experimental periods, respectively.
NDFap - neutral detergent fiber corrected for the residual ash and protein.

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

The samples were dried in a forced-ventilation oven set at 55 ºC for 72 h, and the definitive dry matter was determined in an oven at 105 ºC (DM, method 967.03; AOAC, 1998); crude protein (CP, method 2001.11; Thiex et al., 2002), crude fat (CF, method 2,003.06; Thiex et al., 2003), ash (method 942.05; AOAC, 1998), and lignin (H2SO4 72% p/p) were analyzed according to the techniques described by method 973.18 of the AOAC (1998). Neutral detergent fiber was evaluated according to the protocols suggested by Mertens (2002). Total carbohydrates were calculated according to Sniffen et al. (1992), by the formula: TC (%DM) = 100 – [CP (%DM) + EE (%DM) + MM (%DM)].

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 right after the morning milking, during ten days per period (Silva and Leão, 1979).

Feces were collected on the tenth, twelfth and fourteenth days of each experimental period, twice daily, at 08.00 h and 16.00 h, 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 = COS/COF, in which: FO = daily fecal output (g DM/day); COS = chromic oxide supplied (g/day); and COF = concentration of the chromic oxide in the feces (g/g DM).

Indigestible neutral detergent fiber (iNDF) 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 fabric (TNT 100) bags measuring 4 × 5 cm, following a ratio of 20 mg of DM per square centimeter of surface (Nocek, 1997).

Afterwards, the bags were incubated for 240 h (Casali et al., 2008) in the rumen of a crossbred cow (Holstein × Gyr) fed a diet containing, on a DM basis, 70% of corn silage and 30% concentrate (composed of cornmeal, soybean meal and a mineral mixture). After the incubation period, the bags were removed and washed in running water until complete clearing. Next, they were subjected to extraction with neutral detergent (Mertens, 2002), in a fiber analyzer (Ankom200®) and washed with warm water and acetone. After this treatment, the bags were dried in a forced-ventilation oven (60 ºC/72 h) and in a non-ventilated oven (105 ºC/45 min), conditioned in desiccators (20 bags per desiccator) and weighed (Detmann et al., 2001).

Prior to the incubation process, the bags were washed in neutral detergent according Mertens (2002) and dried similarly to the procedure described previously to obtain the tares.

Total intake was estimated by internal marker iNDF using the following formula: DMI = [(FO × MF) − ((SPI × MSP) + (SCI × IPC))/MFR] + MSC + SCI, in which: DMI = DM intake (kg/day); FO = fecal output (kg/day); MF = concentration of the marker in the feces; SPI = supplement DM intake (kg/day); MSP = concentration of the marker in the supplement; SCI = sugarcane intake; MSC = marker in the sugarcane; and MFR = concentration of the marker in the forage.

The digestibility of the nutrients was calculated by subtracting the ingested DM by the excreted DM, divided by the ingested DM.

The non-fibrous carbohydrates (NFC) of the supplements were estimated according to Hall (2000): NFC 100 – [(% total CP) + (% NDFap) + % EE + % Ash].

The total digestible nutrient (TDN) contents were calculated according to the NRC (2001): TDN: DCP + (2.25 × DEE) + DNDF + DNFC – 7, in which DCP = digestible crude protein; DEE = digestible ether extract; DNDF = digestible neutral detergent fiber; and DNFC = digestible non-fibrous carbohydrates.

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. Right after collection, milk samples were sent to the laboratory, where the milk solids were analyzed

The milk yield was corrected for 4% of fat, using the formula described in the NRC (1989): kg of 4% fat-corrected milk yield = 0.4 (kg milk) + 15 (kg milk 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 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 × 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. Treatments were compared by Tukey's test at 5% of probability.

Results

The intakes of dry matter, organic matter, neutral detergent fiber, total carbohydrates and total digestible nutrients were not affected (P>0.05) by the different processing forms of soybean in the diets (Table 4). In the average of all treatments, dry matter intake was 9.43 kg or 1.90% LW, and NDF intake was 5.03 kg or 1.02% LW.

The animals subjected to the treatments based on soybean (SB, GSB, RSB and GRSB) showed higher EE intake (P<0.05) in relation to the soybean meal-based diet, averaging intakes of 0.50 and 0.19, respectively (Table 4).

The apparent digestibility coefficients of dry matter, crude protein, and neutral detergent fiber were not affected by the different soy processing forms (P>0.05), averaging 521.9, 602.6, and 360.9 g/kg, respectively (Table 5).

In relation to milk yield, the animals fed diets containing GRSB and SM had higher values than SB, while the other treatments had an intermediate response. The same trend was also was observed for fat-corrected milk yield, except for SM (Table 6).

Milk composition was not affected by the diets (P>0.05; Table 6). The mean contents of protein, fat, lactose, TS and SNF were 27.5, 31.4, 45.3, 113.2, and 82.0 g/kg, respectively.

Table 4 - Average daily intakes and variations in the live weight (LW) of animals according to experimental diets and their respective coefficients of variation (CV)

Variable	Concentrate					CV (%)
	SM	SB	GSB	RSB	GRSB	
	Intake (kg/day)					
Dry matter	10.11	9.05	8.93	9.30	9.75	10.91
Organic matter	9.36	8.45	8.33	8.66	9.08	10.75
Total digestible nutrients	6.68	6.14	6.06	6.17	6.49	11.44
Neutral detergent fiber	4.71	5.00	4.89	5.15	5.40	8.37
Total carbohydrates	7.62	6.72	6.61	6.96	7.29	9.59
Crude protein	1.55	1.21	1.21	1.22	1.29	21.16
Ether extract	0.18b	0.51a	0.51a	0.47a	0.50a	12.78
	Intake (g/kg of LW)					
Dry matter	20.4	18.3	18.0	18.8	19.7	110.1
Neutral detergent fiber	9.5	10.1	9.9	10.4	10.9	83.9

SM - soybean meal-based concentrate; SB - raw soybean-based concentrate; GSB - ground soybean-based concentrate; RSB - roasted soybean-based concentrate; GRSB - ground, roasted soybean-based concentrate.
Means in the row followed by different letters differ according to the Tukey test (P<0.05).

Table 5 - Digestibility coefficients (g/kg) and their respective coefficients of variation (CV) obtained for the experimental diet

Digestibility coefficient	Diet					CV (%)
	SM	SB	GSB	RSB	GRSB	
Dry matter	560.2	514.4	500.6	508.2	525.9	13.50
Neutral detergent fiber	358.7	348.9	344.9	378.4	373.8	18.58
Crude protein	663.6	556.9	603.8	560.1	628.8	10.76

SM - soybean meal-based concentrate; SB - raw soybean-based concentrate; GSB - ground soybean-based concentrate; RSB - roasted soybean-based concentrate; GRSB - ground, roasted soybean-based concentrate.

Table 6 - Production and composition of the milk from Holstein × Gyr cows fed different experimental diets

Variable	Diet					CV (%)
	SM	SB	GSB	RSB	GRSB	
Milk yield (kg/day)	7.79a	6.07b	6.70ab	6.98ab	7.98a	10.75
4% fat-corrected milk yield (kg/day)	6.72ab	5.32b	6.00ab	6.35ab	7.08a	12.23
Fat (g/kg)	31.0	32.0	31.5	32.4	31.6	15.72
Protein (g/kg)	27.9	28.0	27.2	26.9	27.3	4.90
Lactose (g/kg)	45.5	44.9	45.1	45.5	45.4	1.61
Total solid (g/kg)	113.7	111.3	113.5	114.2	113.1	4.29
Solids nonfat (g/kg)	82.7	82.0	81.4	81.7	82.1	1.83

SM - soybean meal-based concentrate; SB - raw soybean-based concentrate; GSB - ground soybean-based concentrate; RSB - roasted soybean-based concentrate; GRSB - ground, roasted soybean-based concentrate; CV - coefficient of variation.
Means in the row followed by different letters differ according to the Tukey test (P<0.05).

Discussion

Soy beans have approximately 39% and soybean meal approximately 2% EE, which favored the elevation of the lipid content of diets composed of soy beans with different treatments.

The NDF intake in the present study was below the 1.2% LW reported by Mertens (1994) as the ideal to obtain optimal DM intake. Some factors may have influenced these low intakes, such as the animals used, which were of low production and in the last third of lactation; the roughage utilized, which was brachiaria grass pasture at an advanced maturity stage; and the supplemental roughage, low-quality sugarcane. Both roughages had a high NDF content, which, coupled with the fiber digestibility of these feeds, might have negatively affected the dry matter intake because of its slow release from the rumen and slow passage through the digestive tract.

According to Oba and Allen (2003), the high fiber content determines the rumen fill, which limits dry matter intake, and consequently milk production. In the equations proposed by Mertens (1994) to estimate intake, they used animals of high production and the diets were based on ingredients containing good-quality fibers, which provided higher values than those found in the present study.

Similar results were reported by Carvalho (2001) and Corrêa (2007), who evaluated different forms of supply of soybean in a diet for high-yield cows in the first third of lactation, using the silage as roughage. Those authors did not observe differences in DM intake, although they obtained higher values: 3.03 and 3.33% LW, respectively.

Evaluating the inclusion of different fat sources in the diet of cows at the peak of lactation with production above 20 kg/day, Costa (2008) and Vargas et al. (2002) observed a decrease in DM intake when replacing diets based on soybean meal by soy beans.

Diets based on soybean (SB, GSB, RSB, and GRSB) showed an average content of 4.62% EE, whereas the diet with soybean meal showed 1.99% EE, which explains the higher ether extract intake of the animals fed the diets based on soy beans, although the dry matter intake did not vary between treatments.

The lipid content of the diet may affect the digestibility, creating a physical barrier that surrounds the fiber and hindering the attack of the rumen microflora to the particles. Besides, when supplied at high amounts, usually above 7%, fat may be toxic to the rumen microorganisms, especially when supplied at a large proportion of unsaturated fatty acids, sometimes being toxic to the ruminal microorganisms (Kozloski et al., 2002).

The observed digestibility values for all variables (Table 5) are below those reported in the literature (Guidi et al., 2007; Silva et al., 2009), which is explained by the use of brachiaria grass as roughage source at an advanced maturity stage, associated with the sugarcane, which are two roughage feeds of low quality, with elevated iNDF content. Moreover, the low amount of NFC decreased the digestibility of nutrients (Table 5). Another factor that could

cause reduced digestibility is inclusion of fats; however, the EE levels remained within the recommended range in the literature, and therefore do not affect the fiber digestibility.

The others similar results, although higher, were observed by Corrêa (2007), who did not report difference between the digestibility of DM, CP, and NDF when replacing soybean meal by soy in different forms of processing in diets for high-yield cows fed corn silage as roughage feed, with mean values of 67.16, 71.15, and 53.40%, respectively.

Supplying soy beans in diets for lactating cows may affect both production and composition of the milk due to the elevated fat content of this ingredient. The diets used in this study presented a lower EE content than the maximum inclusion level suggested by Palmquist and Mattos (2006) (5 to 7% of EE in the diet, depending on the animal category and production), without impairing the use of the feeds by cattle, since the diets composed of soy beans showed a higher EE (4.62%) than the diet containing soybean meal (1.99%).

It can be assumed that the degradability of the crude protein from the different sources caused differences in milk yield, with GRSB better in relation to SB, with different uptakes and amino acid profiles that reached the mammary gland. Similar results were observed by Mora et al. (1996), who found a 17.7% decrease in 4% fat-corrected milk from cows fed a diet containing 45% soy beans in the concentrate as compared with a diet with soybean meal. Rabelo et al. (1996) also reported reduction in 4% fat-corrected milk yield when they added soy beans to the diet.

Regarding milk yield, Carvalho (2001) worked with replacement of raw and roasted soy beans in a commercial concentrate and a soybean meal-based concentrate and did not observe differences in corrected milk yield. Likewise, working with replacement of soybean meal by raw soy beans, roasted soy beans and soybean meal + 5% urea in the diet of high-yield cows, Corrêa (2007) also did not observe differences in milk production. Working with inclusion of fats (soy beans and soybean oil) replacing soybean meal in diets for lactating cows, Vargas et al. (2002) did not observe differences in corrected milk yield.

A possible explanation for this absence of effect on the composition of the milk would be the similarity of the composition of experimental diets associated with the low production and the advanced lactation period of the animals utilized.

Among the milk components, the fat content is the easiest to be altered through the diet. The milk solids nonfat, however, are the least likely to change according to the feeding management. Lactose practically does not change according to the diet, because it is osmotically active, so the quantity of milk will be higher as the lactose content in the secreting epithelial cells is increased (Nunes, 2004).

The results obtained in the present study regarding the composition of milk agree with those observed by Santos et al. (2001), Barnabé et al. (2007), and Corrêa (2007), who evaluated soy in different forms in diets for lactating cows and also did not obtain significant effects. On the other hand, Vilela et al. (2003) observed an increase in the milk fat content when they replaced soybean meal by roasted soy beans in diets for high-yield cows. According to these authors, this accrual is because the process of roasting whole soy beans increases the digestibility of the fatty acids in the gastrointestinal tract of lactating cows and the use of roasted whole soybean elevated the polyunsaturated fatty acid content of the milk fat as compared with the animals which received soybean meal.

Conclusions

Soybean meal can be replaced by ground soy bean or roasted soy bean – ground or whole – in diets for low-yield cows on a *Brachiaria decumbens* pasture with no detrimental effects on the production and composition of milk. Thus, these alternative raw materials can be chosen whenever their inclusion results in lower feeding costs.

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