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# Milk production and economic assessment of cassava bagasse in the feed of dairy cows

**Leandro Pereira Lima[1*], Cristina Mattos Veloso[2], Fabiano Ferreira da Silva[3], Aureliano José Vieira Pires[3], Fábio Andrade Teixeira[3], Paulo Valter Nunes Nascimento[3]**

[1]*Departamento de Zootecnia, Instituto Federal Baiano, Av. Júlio José Rodrigues, s/n, Vila Isabel, 45700-000, Itapetinga, Bahia, Brazil.* [2]*Departamento de Zootecnia, Universidade Federal de Viçosa, Viçosa, Minas Gerais, Brasil.* [3]*Departamento de Zootecnia, Universidade Estadual do Sudoeste da Bahia, Itapetinga, Bahia, Brasil. *Author for correspondence. E-mail: leandro@zootecnista.com.br*

**ABSTRACT.** The addition of 0; 5; 10 and 15% cassava bagasse, based on the dry matter of the total diet of crossbred Holstein v. Zebu cows, was evaluated on milk production and composition and on the impacts of diet costs. The animals, weighing an average of 478.5 kg, were in the middle third lactation period. Diet with 15% cassava bagasse provided a 13.2% increase in production when compared to control. Feed conversion had a quadratic effect with minimum point at 4.2% of cassava bagasse inclusion. Crude protein, the only milk component that changed, increased linearly with the inclusion of cassava bagasse levels. Treatment with 15% cassava bagasse caused a more effective operational cost (42.8% higher when compared to control) and the highest leveling point for milk production and price. The lowest leveling points were treatments with 5 and 10% inclusion of cassava bagasse, which had the best economic results. Concentrates caused cost increase, particularly when roughage : concentrate ratio decreased due to higher cassava bagasse inclusion levels.

**Keywords:** milk composition, feed conversion, costs, cow milk, income.

## Produção de leite e avaliação econômica da utilização de bagaço de mandioca na alimentação de vacas leiteiras

**RESUMO.** Estudou-se o efeito da inclusão de 0; 5; 10 e 15% de bagaço de mandioca, com base na matéria seca da dieta total de vacas mestiças Holandesas *vs.* Zebu, sobre a produção e composição do leite e sobre os impactos no custo da alimentação. Os animais estavam no terço médio de lactação e pesavam em média 478,5 kg. A dieta com 15% de bagaço de mandioca acrescentou 13,2% à produção, comparada à dieta controle. A conversão alimentar apresentou efeito quadrático com ponto mínimo em 4,2% de inclusão de bagaço de mandioca. A proteína bruta, único componente do leite que sofreu alteração, aumentou linearmente com os níveis de inclusão de bagaço de mandioca. O tratamento com 15% de bagaço de mandioca representou maior custo operacional efetivo (42,8% mais elevado em relação ao tratamento controle) e o maior ponto de nivelamento para a produção e preço do leite. Observaram-se os menores pontos de nivelamento para os tratamentos com 5 e 10% de inclusão de bagaço de mandioca, os quais apresentaram melhores resultados econômicos. O concentrado foi o principal responsável pela elevação dos custos, particularmente, quando ocorre a redução da razão volumoso : concentrado em função dos maiores teores de inclusão de bagaço de mandioca.

**Palavras-chave:** composição do leite, conversão alimentar, custo, leite de vaca, receita.

## Introduction

The low yield of dairy cattle in Brazil and low economic assets are generally related to low production and productivity indexes. Feed given to animals, either confined or bred on pastures, accounts mostly for 60 to 70% of costs (Martins et al., 2000). Cost reduction may be obtained by the rational use of available food resources with the least costs. This fact triggers research work to discover alternative sources for the reduction of feed costs for ruminants.

The breeding of dairy cows in feedlot requires diets with high energy density that permits the genetic capacity of production and the adequate composition of milk. According to Abrahão et al. (2006a), the use of a high proportion of grains in these systems implies high costs which may cause liability during periods in which the price of grain is high.

The employment of agro-industrial byproducts with low commercial value reduces feed costs and brings about the viability of the activity with an increase in profits (Abrahão et al., 2005). Cassava bagasse is one of the numberless byproducts from cassava processing (Marques et al., 2000; Prado et al., 2000). Cassava bagasse results from the manufacture of fine manioc flour. In Brazil several terms are used, such as 'grolão', 'farinha de varredura' and, especially in the state of Bahia, 'farinha lavada'. In the region of Vitória da Conquista, Bahia State, Brazil, cassava flour, produced by micro agro-industries and sold at a very low price, is normally given to cattle as feed. The use of byproducts produced by cassava processing may be an alternative for feeding dairy cattle.

The chemical composition of cassava roots and their residues are neither homogeneous nor standard as in other traditional feed given to animals (Prado et al., 1999). Besides depending on their crude matter and processing mode, the nutrition rate of the byproducts of cassava root may vary due to their starch rates. Cassava bagasse may comprise 10-20% of the roots' weight used in the production of starch, which may contain up to 60% of starch (Buitrago, 1990), with energy rate at 74.8% NDT (Abrahão et al., 2006b).

Cassava bagasse is an alternative energy source in the feed of dairy cows in feedlot due to the very high costs of intensive cattle breeding. Animal nutrition may affect costs and milk quality, or rather; diet may affect the ratios of the different components of milk, such as fat, protein and lactose. More information is required on animal performance, intake, food conversion and costs of rations in which the cassava residues are added.

Since data on the use of cassava residues as partial or total replacement of food traditional used in the feed of confined dairy cattle are still rare and non-conclusive, current analysis investigates the effect of the inclusion of cassava bagasse in the diet of crossbreed dairy cows on milk production and composition and evaluates impacts on feed costs.

## Material and methods

The experiment was conducted on the Fazenda Água Azul in Macarani, Bahia State, Brazil, between the beginning of October and the end of November 2008. Twelve crossbred Holstein v. Zebu dairy cows (racial composition varying between ¼ and ¾ H *vs.* Z) were used, mean weight 478.5 kg, and 100-150 days of lactation at the start of the experimental period. The 12 milking dairy cows were distributed into a triple 4 x 4 Latin square. The experiment consisted of four experimental periods, the first of which comprised 16 days, nine days for adaptation and seven for sample collecting. The last three periods lasted 12 days each, with the first seven days for adaptation.

Treatments comprised 0, 5, 10 and 15% inclusion of cassava bagasse based on the dry matter (DM) of total diet. Roughage consisted of elephant grass *(Pennisetum purpureum)* harvested after 70 days and pre-dried before silage. Diets were prepared for maintenance and 15 kg milk day$^{-1}$ production (NRC, 2001), based on the data of chemical analysis of elephant grass silage collected at the start of the adaptation period and with the chemical composition of concentrate ingredients (Table 1). All diets were isoproteic and isoenergetic.

The animals were housed in individual pens with manger and watering trough. Feed was provided as a complete mixture, twice a day, *ad libitum*, with 5% surplus. Amount of diet given and residues were daily registered to estimate ingestion rates. Intake of dry matter (DM), crude protein (CP), neutral detergent fiber (NDF), fibrous carbohydrates (FCH) and total digestible nutrients (TDN) in kg day$^{-1}$ (Table 2), determined according to techniques by Silva and Queiroz (2002), were evaluated to estimate food conversion (Lima et al., 2008). The animals were weighed at the start of the experiment and at every 12 days, after morning milking, to follow up changes in body weight.

The dairy cows were milked daily and by hand at 6h30 am and 4h00 pm and production was registered by a mechanical scale. Milk production was evaluated on the 8$^{th}$ and 12$^{th}$ day of each experimental period by adding the evening milking to the morning after. Milk samples of the second milking of the 9$^{th}$ day and the first of the 10$^{th}$ day of each experimental period were harvested and compounded per animal to obtain 10% of amount that the animal produced in each milking session. Samples were sent to the Milk Clinic/ESALQ-USP-Piracicaba, São Paulo State, Brazil, for analysis and determination of composition.

Data on performance, feed conversion, variation in body weight, milk production and composition were evaluated by regression analysis with SAS (2004) by orthogonal polynomials and decomposition of the sum of the squares of treatments (inclusion of cassava bagasse) in linear, quadratic and cubic effect, and parameters by test F at 1% probability.

The methodology of operational costs used by IEA (Matsunaga et al., 1976) and the criterion on profit and invested capital return for economic analysis were taken into consideration so that production costs could be evaluated. Gross revenue comprised money amounts from selling of milk whose market prices were collected in the second half of 2010 in Macarani, Bahia, Brazil. Costs comprised expenses with food, labor, depreciation of goods used in the production process and interests and bank rates. Labor costs comprised minimum wage and social benefits in the second half of 2010, amounting to BR 510.00. Expenditures and services were calculated by multiplying the amounts used by their prices.

**Table 1.** Roughage:concentrate ratio, ingredients of the concentrate and chemical composition of the diets.

| Ingredients | Cassava bagasse (% DM of total diet) | | | |
|---|---|---|---|---|
| | 0 | 5 | 10 | 15 |
| Roughage:concentrate ratio | 65:35 | 62:38 | 59:41 | 55:45 |
| Cassava bagasse, g 100 $g^{-1}$ | 0.0 | 13.0 | 24.3 | 33.0 |
| Ground corn grain, g 100 $g^{-1}$ | 71.6 | 59.7 | 48.9 | 40.8 |
| Soybean flour, g 100 $g^{-1}$ | 21.8 | 21.3 | 21.3 | 20.6 |
| Urea, g 100 $g^{-1}$ | 3.1 | 2.8 | 2.6 | 2.4 |
| Calcitic limestone, g 100 $g^{-1}$ | 0.7 | 0.8 | 0.7 | 1.3 |
| Bicalcium phosphate, g 100 $g^{-1}$ | 0.2 | - | - | - |
| Mineral salt, g 100$g^{-11}$ | 2.5 | 2.3 | 2.1 | 1.9 |
| | Chemical composition | | | |
| Dry matter, g 100 $g^{-1}$ | 47.4 | 49.5 | 50.9 | 53.5 |
| Organic matter, g 100 $g^{-1}$ | 90.8 | 91.1 | 91.4 | 91.5 |
| Crude protein, g 100 $g^{-1}$ | 10.9 | 11.4 | 11.7 | 12.0 |
| Ether extract, g 100 $g^{-1}$ | 2.8 | 2.6 | 2.5 | 2.4 |
| Neutral detergent fiber, g 100 $g^{-1}$ | 51.1 | 49.3 | 48.6 | 47.0 |
| Acid detergent fiber, g 100 $g^{-1}$ | 21.5 | 20.7 | 19.7 | 19.5 |
| Total carbohydrates, g 100 $g^{-1}$ | 77.1 | 77.2 | 77.2 | 77.1 |
| Non-fiber carbohydrates, g 100 $g^{-1}$ | 26.1 | 27.9 | 28.6 | 30.0 |
| Total digestible nutrients, g 100 $g^{-1}$ | 50.8 | 51.5 | 52.2 | 52.9 |
| Mineral matter, g 100 $g^{-1}$ | 9.2 | 8.9 | 8.5 | 8.5 |

[1]Calcium 20%; phosphorus 10%; magnesium 1.5%; sulfur 1.2%; Sodium 0.68%; Selenium 32 ppm; Cobre 1650 ppm; Zinco 6285 ppm; Manganês 1960 ppm; Iodo 195 ppm; Cobalto 200 ppm.

**Table 2.** Intake of dry matter and nutrients of diet according to the increasing rates of cassava rates in cows´ diets during lactation. Regression equation, coefficient of variation (CV) and coefficient of determination ($R^2$).

| Nutrient, kg dia$^{-1}$ | Cassava bagasse (% DM)[1] | | | | CV (%) | Regression equation | $R^2$ |
|---|---|---|---|---|---|---|---|
| | 0 | 5 | 10 | 15 | | | |
| Dry matter | 13.2 | 13.4 | 13.1 | 16.6 | 8.7 | $\hat{Y}$ = 12.578 + 0.1978BM | 0.58 |
| Crude protein | 1.5 | 1.5 | 1.6 | 2.3 | 9.5 | $\hat{Y}$ = 1.3192 + 0.0526BM | 0.69 |
| Non-fibrous carbohydrates | 3.5 | 3.8 | 3.8 | 5.9 | 9.8 | $\hat{Y}$ = 3.1267 + 0.1479BM | 0.71 |
| Neutral detergent fiber | 6.7 | 6.6 | 6.3 | 6.5 | 8.9 | $\hat{Y}$ = 6.5 | - |
| Total Digestible nutrients | 6.7 | 6.9 | 6.9 | 9.3 | 8.8 | $\hat{Y}$ = 3.1267 + 0.1479BM | 0.71 |

1% DM= % DM of total diet (Data published in LIMA et al., 2008).

Depreciation of improvements, machines and equipment was calculated by the linear method of fixed amounts with final result equal to zero. Interests rate at 6% a year were employed to estimate return of the capital invested. The cost of land was calculated by multiplying its price by 6% interest rate per year and costs for the formation and maintenance of grass are included in the price per kilo of dry matter of elephant grass.

## Results and discussion

Milk production was affected by added treatments due to inclusion of increasing rates of cassava bagasse. Milk production had an approximate 0.09 kg increase for every 1% inclusion of cassava bagasse in the diet (Table 3). Therefore, the diet with the greatest inclusion (15%) caused a 13.2% increase in milk production when compared to control.

Cardoso (1968) evaluated the effect of gradual replacement of corn by cassava shavings (between 0.0 and 41.5%) on milk production in cows and reported lower production rates at higher replacement levels. However, an economic evaluation showed that the byproduct was economically feasible. The effect of total replacement of de-integrated corn with straw and corncob (DCSC) by cassava shavings in the concentration on milk production was verified by Mello et al. (1976) who concluded that cassava shavings may replace DCSC up to 54.5% without any liability to milk production when prices are competitive.

As the inclusion of cassava bagasse increases, milk production also increases, probably due to a growing increase in the intake of nutrients, DM, CP and TDN. Since the inclusion of cassava bagasse in current analysis was based on totally isoenergetic and isoprotein diets, the roughage: concentrate ratio changed as the rate of cassava bagasse increased. Concentrate rose from 35% in the control volume to 45% in the treatment with 15% inclusion of cassava bagasse (Table 1). Therefore, the rise in nutrient intake (Table 2) and, consequently, milk production may be explained by high concentrate percentages in the diet with higher rates of cassava bagasse.

Costa et al. (2010) assessed concentrate rates in sugar cane-based diets for crossbreed cows during lactation and reported a linear increase of intake of all nutrients and milk production. They concluded that the inclusion of up to 30% of concentrate in the diet of crossbreed cows was biologically viable. In their evaluation of partial replacement (50%) of corn by dry starch mass for Nellore calves and crossbreeds with Angus cattle, Marques et al. (2006) did not report any difference in the intake of dry matter (9.0 kg) and food conversion (8.4 kg $kg^{-1}$ gain). However, when they evaluated total replacement of corn by dry starch mass for crossbreed calves, (Abrahão et al., 2006a) reported that the byproduct decreased the ingestion of dry matter and feed conversion.

**Table 3.** Milk production, food conversion (FC) and variation in body weight (VBW) due to increasing rates of cassava bagasse in the diet of cows during lactation. Regression equation, coefficient of variation (CV) and coefficient of determination ($R^2$).

| Item | Cassava bagasse (% DM)[1] | | | | CV (%) | Regression equation | $R^2$ |
|---|---|---|---|---|---|---|---|
| | 0 | 5 | 10 | 15 | | | |
| Milk production, kg | 11.4 | 11.8 | 11.9 | 12.9 | 4.7 | $\hat{Y} = 11.292 + 0.0931BM$ | 0.89 |
| FC, kg kg$^{-1}$ | 1.16 | 1.12 | 1.11 | 1.29 | 9.2 | $\hat{Y} = 1.1711 - 0.0264BM + 0.0023BM^2$ | 0.94 |
| VBW, kg | +0.486 | +0.125 | +0.771 | +0.715 | 179.24 | $\hat{Y} = 0.524$ | - |

[1]% DM= % DM of total diet.

Mean variation of body weight at +0.52 kg day$^{-1}$ is due to the fact that, even with high quality diet, the partition of nutrients favored body mass gain but not increase in milk production. Although all the cows had good body scores throughout the experiment, they were unable to produce 15 kg of milk day$^{-1}$, testifying to low production potential. Assis et al. (2004) and Souza et al. (2005) in their research on dairy cows fed on citric pulp and coffee husk respectively had similar results with other energetic feed.

Feed conversion had a quadratic effect (Table 3) with a minimum score of 4.2% inclusion of cassava bagasse. A better food conversion was obtained with such a level of cassava bagasse in the diet, reaching a satisfactory ingestion of DM with a satisfactory production of milk. Costa et al. (2010) calculated food efficiency and verified a quadratic effect when they compared concentrate inclusion levels in diets of dairy cows fed on sugar cane. The same authors reported that the animals did not convert feed into milk but into meat and thus increased their body weight. However, when Prado et al. (2000) replaced corn by cassava and its residues, they did not register any changes in the feed conversion of DM, even though they detected a decrease in feed intake, especially fine manioc flour. While including cassava bagasse at 0, 7, 14 and 21% levels to the diet of dairy calves, Dias et al. (2008) reported a linear increase in food conversion when the level of cassava bagasse increased in the diet, probably due to starch quality in cassava bagasse.

Concentrations of fat, lactose and total solids of milk were not modified ($p > 0.01$) by inclusion rates of cassava bagasse, and mean rates 3.6, 4.6 and 12.3% were respectively reported (Table 4), probably due to the intake of NDF which was similar to all treatments (Table 2). Regardless of the diet, NDF level was therefore sufficient to avoid any possible reduction in milk fat rate, which has a positive co-relationship with NDF rates in the diet causing an increase in the concentration of acetic acid in the rumen, the main precursor of the milk's fat synthesis. Costa et al. (2010) evaluated the different roughage: concentrate ratios and did not report any difference in mean rates of fat and total solids.

**Table 4.** Fat, protein, lactose and total solids percentage according to increasing rates of cassava bagasse in the diet of cows during lactation. Regression equation, coefficient of variation (CV) and coefficient of determination ($R^2$).

| Component, % | Cassava bagasse (% MS)[1] | | | | CV (%) | Regression equation | $R^2$ |
|---|---|---|---|---|---|---|---|
| | 0 | 5 | 10 | 15 | | | |
| Fat | 3.5 | 3.6 | 3.6 | 3.6 | 20.1 | $\hat{Y} = 3.55$ | - |
| Protein | 3.0 | 3.2 | 3.2 | 3.3 | 3.4 | $\hat{Y} = 3.0598 + 0.164BM$ | 0.99 |
| Lactose | 4.5 | 4.6 | 4.5 | 4.6 | 3.1 | $\hat{Y} = 4.55$ | - |
| Total solids | 12.1 | 12.3 | 12.2 | 12.5 | 5.5 | $\hat{Y} = 12.28$ | - |

[1]% DM= % DM of total diet.

Similar results were obtained by Souza et al. (2005) who evaluated intake and milk production and composition of cows fed on diets with different levels of coffee husks inclusion replacing corn from concentrated diet. These authors concluded that, although coffee husk reduced the digestibility of diet nutrients, the changes were not able to decrease milk production and composition. Mean rates comprised 4.0% fat, 3.1% CP and 12.2% total solids.

There was a linear rise in milk protein rates according to the inclusion levels of cassava bagasse, probably caused by an increasing rise in the ingestion of diet protein and a greater NFC ingestion (Table 2) which may have stimulated bacterial growth. Costa et al. (2010) also registered increase in concentrate rates on protein rates in the milk of dairy cows fed on increasing concentrate rates. However, the same authors reported a quadratic effect for protein mean rates.

The physical-chemical results on milk in current experiment (Table 4) fit the rates recommended by the Regulation of Industrial and Sanitary Inspection of Animal-derived Products. This fact reveals that milk from dairy cows supplemented with cassava bagasse does not have any change in its characteristics. It is a type of milk complying with the legislation and may be used in the milk industry.

All treatments had positive economic results (Table 5). If the price of milk is BR 0.70, a greater gross income occurs for treatment with 15% of cassava bagasse and, therefore, 13.9% higher than the income of control treatment, due to the great quantity of milk available for commercialization in the treatment.

**Table 5.** Gross income, effective and total operational costs, total cost per animal day$^{-1}$ and per kg of milk.

| Item | Cassava bagasse (% DM)[1] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0% | | 5% | | 10% | | 15% | |
| | Quant. | BR | Quant. | BR | Quant. | BR | Quant. | BR |
| Gross income | | | | | | | | |
| Milk, kg | 11.35 | 7.95 | 11.98 | 8.39 | 11.92 | 8.34 | 12.88 | 9.02 |
| Costs[2] | | | | | | | | |
| Effective operational costs | | | | | | | | |
| Labor, day $h^{-1}$ | 0.025 | 0.54 | 0.025 | 0.54 | 0.025 | 0.54 | 0.025 | 0.54 |
| Concentrate, kg DM[3] | 4.72 | 2.92 | 5.26 | 3.13 | 5.50 | 3.21 | 9.57 | 5.44 |
| Silage, kg DM[4] | 8.48 | 1.70 | 8.09 | 1.62 | 7.63 | 1.53 | 6.99 | 1.40 |
| Medicine, BR | | 0.04 | | 0.04 | | 0.04 | | 0.04 |
| Electricity, KW $h^{-1}$ [5] | 0.013 | 0.003 | 0.013 | 0.003 | 0.013 | 0.003 | 0.013 | 0.003 |
| Sub-total | | 5.19 | | 5.33 | | 5.32 | | 7.41 |
| Total operational costs | | | | | | | | |
| Depreciations of improvements | | 0.171 | | 0.171 | | 0.171 | | 0.171 |
| Depreciation of machinery and equipments | | 0.095 | | 0.095 | | 0.095 | | 0.095 |
| Sub-total | | 5.46 | | 5.60 | | 5.58 | | 7.68 |
| Stock return from improvements | | 0.21 | | 0.21 | | 0.21 | | 0.21 |
| Stock return machinery & equipments | | 0.06 | | 0.06 | | 0.06 | | 0.06 |
| Stock return from animals | | 0.33 | | 0.33 | | 0.33 | | 0.33 |
| Return of floating stock | | 0.31 | | 0.32 | | 0.32 | | 0.44 |
| Return of bare land | | 0.05 | | 0.05 | | 0.05 | | 0.05 |
| Total/animal costs | | 6.41 | | 6.55 | | 6.54 | | 8.76 |
| Costs $kg^{-1}$ milk | | 0.56 | | 0.55 | | 0.55 | | 0.68 |

[1]% DM= % DM of total diet; [2] updated rates on 17/9/2010; [3]BR $kg^{-1}$ DM 0.62 (0%); 0.60 (5%); 0.58 (10%), 0.57 (15%); [4]BR 0.20 $kg^{-1}$ DM; [5]BR 0.27 kw $h^{-1}$.

Although there was a greater gross income, the treatment with the addition of 15% of cassava bagasse had the highest operational costs, or rather, 42.8% higher than control. Rates may be due to a greater expenditure with feed in the treatment, since the other costs remained constant for all treatments. Consequently, control treatment had the lowest operational cost due to low costs in feed, with 89.01% of total costs, when compared to 89.11, 89.08 and 92.31% respectively for treatments with 5, 10 and 15% cassava bagasse. When total cost per kg of milk produced is calculated, the highest rates occurred for the treatment with 15% inclusion of cassava bagasse, or rather, a 21.4% increase over control treatment. Ramalho et al. (2006) evaluated the effects of replacement levels of ground corn by cassava shavings on the production costs of dairy cows' diet and registered the feasibility of partial replacement. In fact, cassava shavings are cheaper and may be a regional alternative.

According to Silva et al. (2008), the activity's economic analysis by production costs and economic efficiency index, such as gross and net rates, is an aid in decision-taking within the agricultural enterprise. Gross (gross income minus effective operational costs) and net (gross income minus total operational costs) indexes demonstrate that results were positive and reveal that all treatments were viable respectively in the short and medium terms.

The best results with regard to gross income (Figure 1) occurred in treatments with the addition of 5 and 10% cassava bagasse. Net income had a similar behavior, or rather; the activity is stable and may be expanded. It may be maintained at medium term since income is over total operational costs and, depending on feed costs or income from milk, the producer may intensity profits by seeking better economic results for a determined period or conjuncture. Treatment with 15% cassava bagasse provided the lowest rates in gross and net profits due to the high rates of effective operational costs, mainly caused by expenditures on the concentrate.

When profit was analyzed as an index of economic efficiency, results were satisfactory and showed that treatments produced stock return. Profits per animal and kg of milk also demonstrated the same trend, with best results for treatments with 5 and 10% inclusion of cassava bagasse. Profit indicates stable activity with relevant growth possibility. Results suggest that, although milk production is lower in 0, 5 and 10% treatments, they may be competitive when compared to profits with 15% treatment, due to low costs in feed and higher profits.

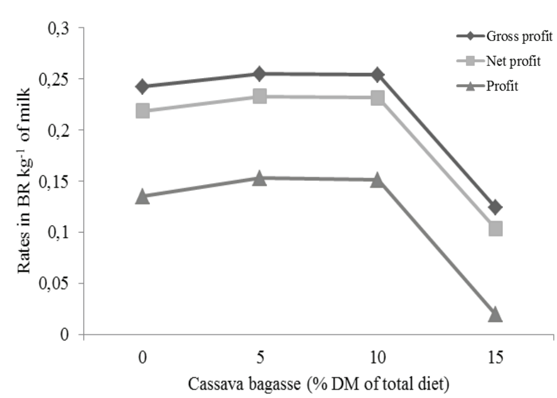


**Figure 1.** Gross and net profit per kg of milk.

A lower profit and stock return were reported in the case of treatment with 15% cassava bagasse inclusion rate, with higher rates for 5 and 10% treatments. The participation of effective operational costs within total costs was higher in the treatment with 15% cassava bagasse inclusion probably due to higher expenditure in feed which was 48% higher when compared to that of control. The inclusion of 15% cassava bagasse caused a decrease in roughage: concentrate ratio (Table 2) for diet balance. Since all diets were isoprotein and isoenergetic, costs of concentrate increased and directly affected economic results.

Stock returns and profit were positive for all treatments (Table 6). In fact, results foregrounded the comparison of treatments, with special emphasis for treatments with 5 and 10% cassava bagasse providing the best results, or rather, respectively BR 0.16 and BR 0.15 returns for each BR 1.00 invested. Treatment with 15% cassava bagasse had the lowest profit (2.81%) due to higher total operational costs, mainly on feed.

**Table 6.** Economic analysis of stock returns, profit, participation of costs in total costs and leveling point.

| Item | Cassava bagasse (% DM)[1] | | | |
|---|---|---|---|---|
| | 0% | 5% | 10% | 15% |
| Stock return, % | 13.01 | 15.54 | 15.30 | 2.15 |
| Profit, % | 19.31 | 21.85 | 21.62 | 2.81 |
| Participation of costs in total costs, % | | | | |
| Participation of effective operational cost, % | 81.00 | 81.30 | 81.30 | 84.6 |
| Feed | 45.53 | 47.80 | 49.10 | 62.03 |
| Labor | 8.43 | 8.24 | 8.26 | 6.17 |
| Medicines | 0.55 | 0.54 | 0.54 | 0.40 |
| Depreciation | 4.15 | 4.06 | 4.07 | 3.04 |
| Stock profits | 8.95 | 8.88 | 8.89 | 8.07 |
| Leveling point | | | | |
| Milk production, kg | 5.02 | 4.80 | 4.82 | 10.84 |
| Price of milk, R$ | 0.31 | 0.28 | 0.28 | 0.59 |

[1]% DM= % DM of total diet.

The equilibrium point is the instance in which costs are equaled and profit is available. The four systems under analysis have positive net profit, with good sustainability at the activity's equilibrium point. Treatment with 15% cassava bagasse was only slightly flexible, with the equilibrium point close to production. This fact revealed that the production factors were not being employed adequately.

The lowest leveling points for production and milk prices occurred for treatments with 5 and 10%, underscoring higher rates when 15% of cassava bagasse was included in the diet. Or rather, in the case of treatments with 5 and 10% cassava bagasse inclusion, the production of milk per cow day$^{-1}$ over 4.80 and 4.82 kg were profitable, whereas production over 10.84 kg of milk cow$^{-1}$ day$^{-1}$ was required for treatment with 15% cassava bagasse. Further, milk sold above BR 0.28 for treatments with 5 and 15% were profitable, whereas the profit price had to be higher than BR 0.59 for treatment with 15% of cassava bagasse inclusion.

When results of technical efficiency (Table 3) are compared with economic efficiency results (Table 6) between the treatments, the best technical performance of the animals with treatment featuring 15% cassava bagasse inclusion failed to comply with the highest economic efficiency reported in the treatments with 5 and 10% of cassava bagasse.

Economy of diets should be evaluated within the total context of production costs: the most viable diet is that with the highest yield. Therefore, inclusion of 5% and 10% of cassava bagasse provides the best technological alternative for the exploitation of dairy cows since results show the best cost-benefit results when compared to the other treatments. It should also be underscored that these two treatments also provided the best feed conversions (Table 3).

## Conclusion

The inclusion of up to 15% of cassava bagasse in total diet of dairy cows linearly increases milk production, whereas the best feed conversion occurs at 4.2% inclusion of cassava bagasse in the diet. However, inclusion of these rates does not alter concentrations of fat, lactose and total solids of milk.

The 5 and 10% inclusion of cassava demonstrated better feed rates and higher cost-benefits with regard to those of the other treatments. Consequently, in the conditions of current experiment, these inclusion levels were the best alternatives.

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