Scientific Paper

Milk production and bromatological quality and costs of supplementation with *Tithonia diversifolia* (Hemsl.) A. Gray, in Jersey cows

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Abstract

In order to evaluate the milk production and bromatological quality, and the costs of supplementation with three levels of *Tithonia diversifolia* (Hemsl.) A.Gray, a trial was conducted in the Santa Lucía farm of the National University of Costa Rica. Nine Jersey cows were used in a replicated 3 x 3 Latin square. The animals were fed with a diet based on *Cynodon nlemfuensis* Vanderyst under grazing conditions and supplementation with *Cenchrus purpureus* (Schumach.) Morrone, molasses, *Digitaria decumbens* Stent hay, minerals and urea. Three treatments were evaluated: TD0, Grazing + Balanced feed (BF); TD25 (Grazing + substitution of 25 % of the BF by *T. diversifolia* forage), and TD50 (Grazing + substitution of 50 % of the BF by *T. diversifolia*). Milk production, bromatological quality and supplementation costs were evaluated. The data were analyzed through a variance analysis. In TD25 a production of 21,4 kg/animal/day was reached without significant differences with regards to TD0. In TD50 the milk production showed a decrease of 8,7 and 11,2 % compared with TD0 and TD25, respectively. The bromatological composition did not show significant differences between TD0 and TD25, while TD50 differed ($p < 0,05$) for protein (32,5 g/kg) and non-fatty solids (82,7 g/kg), compared with TD0. The use of *T. diversifolia* as supplement of dairy cows allowed to save 0,25 and 0,52 USD animal/day in treatments TD25 and TD50, respectively. It is concluded that the substitution of 25 % of the balanced feedstuff by *T. diversifolia* forage did not affect milk production and bromatological quality in Jersey cows, and it also saved 9,06 % due to the decrease of supplementation costs.

Keywords: shrubs, dairy cattle, milk production, protein

Introduction

Milk production systems in the tropics base their feeding on the utilization of pastures that show low digestible protein contents and high fiber contents, along with a reduction of biomass during the dry season (Quevedo, 2014). This situation generates a lower availability of quality feed which could affect the energy balance of high production cows, such as those of specialized dairy systems, which compels to utilize supplements elaborated with high-cost imported raw materials.

According to Madriz (2017), feeding is the highest cost in specialized dairy systems of Costa Rica, which could reach 52 % of total production costs, and from them between 40 and 45 % corresponds to the costs of the balanced feed (BF). Due to this situation the dairy sector is forced to search for feeding alternatives to decrease production costs and increase its competitiveness in national and international markets (Campos-Granados and Arce-Vega, 2016).

Cardona-Iglesias *et al*. (2016) claim that legumes, tree and shrub species have proven to be a viable nutritional strategy for the supplementation of ruminants in the tropic, because they show higher nutritional characteristics than tropical pastures and can produce high quantities of edible biomass in different seasons.

Tithonia diversifolia (Hemsl.) A. Gray was originated in Mexico and Central America. It is a tropical shrub cultivated in many countries of Africa, Asia and South America due to its multipurpose value (Heuzé *et al*., 2015). According to Crespo *et al*. (2011), its bromatological composition, on dry basis, indicates high percentages of crude protein that vary between 4,8 and 28,7 %, and shows high biomass production, because of its capacity to utilize the soil nutrients (Mustonen *et al*., 2012). In addition, it is easily established, withstands frequent cutting and is tolerant to poor soils.

Experiences with farmers reported about the viability of *T. diversifolia* in the diet of dairy cows and the interest in its use as alternative biomass source to prepare diets, without decreasing intake or production has increased (Ribeiro *et al*., 2017). Likewise, the browsing of *T. diversifolia* showed

that, with low fertilization in silvopastoral systems, milk production and quality was maintained and contributed higher net incomes per area unit when comparing it with the monocrop system (Mejía-Díaz *et al*., 2017). However, there are few studies about the utilization of this plant as feeding supplement in the diet of high-production dairy cattle, for which the objective of this research was to evaluate the milk production, bromatological quality and the costs of supplementation with three levels of *T. diversifolia* in Costa Rica.

Materials and Methods

Location and climate. The study was conducted from August to October, 2017, in the experimental farm Santa Lucía belonging to the National University, located in Barva de Heredia, Costa Rica, which is found at an altitude of 1 250 m.a.s.l. The soil is predominantly of the Andisols order, moderately fertile and very stony. The climate of the zone shows annual rainfall of 2 403 mm, relative humidity of 78,0 % and mean annual temperature of 21,5 ºC (IMN, 2017).

Experimental animals. Nine multiparous cows of the Jersey breed were used, between the first and second third of lactation, which were distributed in three groups of three cows each, with a mean production of 19,6 kg/animal/day.

Experimental design. A replicated 3 x 3 Latin square experimental design was used, with three treatments; three groups of animals and three evaluation periods of 21 days each, with 15 days of adaptation to the diet and 6 days of data and sample taking. The evaluation period was 63 days.

Feeding and treatments. The cows were fed with a diet of *Cynodon nlemfuensis* Vanderyst pasture in a rotational grazing system in 3 900-m^2 paddocks as average, with occupation periods of one day and 26 days of resting and a stocking rate of 2,5 animals/ha. Besides the forage intake in the paddocks, the animals were supplemented twice a day in the squeeze chutes of the feeding facility, with *T. diversifolia* and balanced feed, and other feedstuffs, such as: *Cenchrus purpureus* (Schumach.) Morrone, molasses, bale of *Digitaria decumbens* Stent cv. Transvala, minerals and water *ad libitum* throughout the day. The bromatological composition of each one of the offered feedstuffs is described in table 1.

The experimental treatments were defined based on the fulfillment of protein and energy requirements. Three treatments were established:

1. TD0-Grazing + Balanced feed (BF)
2. TD25-Grazing + substitution of 25 % of the BF by *T. diversifolia* forage
3. TD50-Grazing + substitution of 50 % of the BF by *T. diversifolia*

The feedstuffs that integrated the treatments and the offered dry matter quantities, as well as the protein and energy contribution in each one of them, are described in table 2.

Experimental procedure. The *T. diversifolia* plants with 50 days of regrowth (only the leaves and fresh stems), without fertilization, were harvested.

Table 1. Bromatological composition of the different components of the evaluated diets.

Feedstuff	Variable, %										MJ/kg DM
	DM	CP	NDF	ADF	IVDMD	Ash	SE	Lig	Ca	P	NLE
T. diversifolia	15,0	21,5	42,5	36,8	73,5	11,5	2,4	11,5	1,4	0,3	5,0
C. purpureus	18,5	8,6	48,7	36,5	76,8	14,3	1,7	2,7	0,3	0,2	4,6
C. nlemfuensis	23,0	13,3	62,5	36,6	67,1	9,6	2,5	3,9	0,3	0,3	5,4
Molasses	81,2	5,3	-	-	100,0	8,0	0,6	-	0,8	0,05	8,0
Balanced feed	87,0	18,0	19,4	10,0	94,6	5,1	6,3	2,2	0,8	0,6	8,0
D. decumbens hay	90,3	3,4	66,1	49,0	46,8	12,1	2,0	8,0	0,2	0,2	4.2
Minerals	95,0	0,0	-	-	-	-	-	-	25,0	18,0	-
Urea	100,0	287,5	-	-	-	-	-	-	-	-	-

DM: dry matter, CP: crude protein, NDF: neutral detergent fiber, ADF: acid detergent fiber, IVDMD: *in vitro* dry matter digestibility, EE: ethereal extract, Lig: lignin, Ca: calcium, P: phosphorus, NLE: net lactation energy.

Source: Results of analyses made in the Laboratory of Animal Nutrition (UNA for its initials in Spanish) and the Animal Nutrition Research Center (CINA-UCR), 2017.

Table 2. Feedstuffs that integrate the experimental treatments.

Feedstuff	TD0			TD25			TD50		
	DM, kg	MP, g	NLE, MJ	DM, kg	MP, g	NLE, MJ	DM, kg	MP, g	NLE,MJ
C. nlemfuensis	5,8	499	31,4	5,8	499	31,4	5,8	499	31,4
C purpureus	0,9	51	4,6	0,4	21	1,7	0,2	10	0,8
Balanced feed	5,6	641	43,5	4,2	481	32,7	2,8	321	21,8
T. diversifolia	0,0	0,0	0,0	1,4	192	7,1	2,8	385	14,7
Minerals	0,2	0,0	0,0	0,2	0,0	0,0	0,2	0,0	0,0
Molasses	0,4	15	3,3	1,2	41	9,6	1,8	61	14,2
Urea	0,2	338	0,0	0,2	311	0,0	0,1	268	0,0
D. decumbens hay	1,8	40	7,5	1,8	40	7,5	1,8	40	7,5
Total	14,9	1584	90,4	15,1	1585	90,4	15,5	1584	90,4

DM: dry matter, MP: metabolizable protein, NLE: net lactation energy.
TD0 (Grazing + Balanced feed (BF), TD25 (Grazing + substitution of 25 % of the BF by *T. diversifolia* forage) and TD50 (Grazing + substitution of 50 % of the BF by *T. diversifolia*).

The forage was carried to the dairy farm facilities, where it was chopped (particle size of 2,5 cm) and the mixtures were prepared, according to the experimental treatments.

The supplements were offered according to the treatments and the animals consumed all the supplement offered in the trough, in the morning as well as the afternoon. The animals were later transferred to the grazing system, where they remained until the next milking (milking was performed twice per day); the time dedicated to grazing was 18 hours as average in the day.

Measurement of milk production. Milk production was daily measured using an electronic measurement system coupled to an automatic milking system, which sent the data to the Gimenez Fazenda software.

Milk bromatological composition. To determine the nutritional composition (protein, fat, lactose, non-fatty solids and total solids), three samples were collected per week of approximately 25 mL, through milk collectors installed in each milking spot. These samples were sent to milk quality laboratory of the Dos Pinos RL Cooperative of milk producers, located in Alajuela, Costa Rica, where they were analyzed through infrared spectrophotometry using the MilkoScan FT1 (Foss Electric, Denmark).

Economic appraisal. The economic analysis was calculated considering only the cost of supplementation (*T. diversifolia*, BF, *C. purpureus*, molasses and urea). The price per kg of fresh *C. purpureus* matter was 0,01 USD, according to the results obtained by Villalobos *et al*. (2015).

The price per kg of dry matter of urea and molasses was 0,2 and 0,6 USD, according to references of the national market. To make this analysis the saving of BF, which was obtained with the use of *T. diversifolia* foliage as supplement in intensive cattle milk production systems, was considered as basic premise.

The price of one kg of *T. diversifolia* dry matter was 0,2 USD when considering the annual costs of labor and inputs for establishment, agronomic management, cut and carry of one hectare of *T. diversifolia*. To calculate the depreciation of the plantation a useful life of 10 years was estimated. The price per kg of dry matter of the BF was 0,45 USD, according to the purchase price in the national market.

Statistical analysis. The data were analyzed through an Anova for Latin square after testing the assumptions of variance homogeneity and normality through Levene's and Kolmogorov-Smirnov tests, respectively. The mean comparison was made through Tukey's test at 5 % of significance. The data analysis was carried out with the statistical software SAS® v 9.0 (SAS Institute Inc., 2009).

Results and Discussion

Table 3 shows the average milk production and the 4 % fat-corrected milk production, which were reached in each of the experimental treatments. The lowest production of 4 % fat-corrected milk per animal/day was obtained in treatment TD50, with significant differences from TD0 and TD25, where a value of 19,0 kg/animal/day was recorded; nevertheless, no significant differences were found between treatments TD0 and TD25, which obtained a milk production of 20,8 and 21,4 kg/animal/day, respectively.

When substituting 25 % of the BF by fresh *T. diversifolia* forage no significant differences were found in milk production with regards to the treatment TD0. This result could be associated to a similar dry matter, protein and energy intake in these two treatments.

Table 3. Real milk production and 4 % fat-corrected milk production according to the treatments.

Treatment	Milk production, kg/animal/day	
	Real	4 % fat-adjusted
TD0	19,1[a]	20,8[a]
TD25	19,3[a]	21,4[a]
TD50	17,2[b]	19,0[b]
SEM ±	1,04	1,06
P-value	< 0,01	< 0,01

P-value: probability value, SEM: standard error of the mean.
a, b: Different letters in the same column indicate significant differences among the data ($p \leq 0,05$).
TD0 (Grazing + Balanced feed (BF), TD25 (Grazing + substitution of 25 % of the BF by *T. diversifolia* forage) and TD50 (Grazing + substitution of 50 % of the BF by *T. diversifolia*).

The results in this study were similar to the ones reported by Gallego-Castro *et al*. (2017), who evaluated the inclusion of *T. diversifolia* as supplement in the diet of F1 cows, where they substituted up to 25 % of the diet by forage from this species and the milk production and quality of the animals was not affected. According to López *et al*. (2015), the contribution of nitrogen to the rumen made by *T. diversifolia*, along with an adequate energy level in the diet, allows a contribution of microbial protein to the small intestine capable of maintaining and increasing milk production in medium-potential cows. This could have been related with the results that were obtained when including the fresh *T. diversifolia* forage in the diets of the animals in this study.

Due to the nutritional composition and the high digestibility shown by the plant it could be inferred that its inclusion in the diet of dairy cows improved the synchronization between the energy and protein contribution which entered the rumen, and this benefitted the efficiency in rumen fermentation (Gallego-Castro, 2016).

The milk production values obtained in the treatments coincide with the ones reported for this breed by Larsen *et al*. (2016), who evaluated the effect of silage of spring and autumn grasses on the milk production and quality of Jersey cows. The values were 20 to 22 kg/animal/day.

When analyzing the milk production with the substitution of 50 % of the BF by *T. diversifolia* forage (TD50), a decrease was observed in milk production of 8,2 and 10,8 % with regards to treatments TD0 and TD25, respectively. This difference in milk production could be related with the DM intake of the animals that were supplemented with more quantity of *T. diversifolia* forage, because it was harvested during the rainy season, and showed an average dry matter content of 15 %, which possibly caused an effect of physical fill and a decrease of *C. nlemfuensis* intake under grazing conditions.

The average values of fat, protein, lactose, non-fatty acids and total solids in the milk, are shown in table 4.

The average fat values in milk did not show significant differences among treatments and 43,6; 44,4 and 44,5 g/kg were obtained for treatmentsTD0, TD25 and TD50, respectively. These results were higher than the ones reported by Gallego-Castro *et al*. (2017), when they evaluated the effect of the

Table 4. Milk quality according to the treatments, g/kg.

Indicator	TD0	TD25	TD50	SEM	P-value
Fat	43,6	44,4	44,5	0,13	0,3
Protein	33,9[a]	33,3[ab]	32,5[b]	0,08	<0,01
Lactose	45,2	44,9	44,8	0,1	0,53
Total solids	127,4	127,2	126,6	0,25	0,64
Non-fatty solids	85,4[a]	84,1[ab]	82,7[b]	0,18	<0,01

P-value: probability value, SEM: standard error of the mean.
a, b: Different letters between the rows show a significant difference among the data ($p < 0,05$).
TD0 (Grazing + Balanced feed (BF), TD25 (Grazing + substitution of 25 % of the BF by *T. diversifolia* forage) and TD50 (Grazing + substitution of 50 % of the BF by *T. diversifolia*).

inclusion of *T. diversifolia* in Holstein cows and the values varied between 34,4 and 36,8 g/kg, with a milk production of 24-25 kg/animal (corrected at 4 %). In turn, they were lower than those found by Brosillon *et al*. (2017), when evaluating the effect of ground or cracked corn, with or without linseed oil, on the yield and composition of milk fatty acids with Jersey cows (from 5,07 to 5,30 with milk production that varied from 17,0 to 18,3 kg/cow).

Regarding the protein percentage in milk (table 4), treatment TD50 showed significant difference (32,5 g/kg) with regards to TD0 (33,9), which indicates that the substitution of 50 % of the BF by *T. diversifolia* forage in the diet significantly decreased ($p < 0,05$) the milk protein content.

The fibrous compounds contained in *T. diversifolia* could have had incidence on the efficiency with which the rumen ammonia is utilized for the synthesis of microbial protein, because when the retention time of the feedstuff is higher in the rumen, protein can increase its degradability with the subsequent loss of ammonia nitrogen. In addition, effects have been reported on the concentration of protein with regards to the dry matter intake (Gallego-Castro *et al*., 2017).

In the lactose content no significant differences appeared among the treatments. These values were similar to the ones reported by Larsen *et al*. (2016) in Jersey cows (47,7 and 48,1 g/kg for spring and autumn, respectively). They were also similar to the ones reported for this breed by Brossillon *et al*. (2017).

The lactose content in milk in the treatments of this study was similar, because the offered diets were balanced, from the isoprotein as well as the isoenergy point of view, for which the animals consumed similar levels of energy, which is closely related to the lactose percentages in milk.

When analyzing the content of total solids no significant differences were found among the experimental treatments (table 4). The non-fatty solids of treatment TD25 did not differ significantly from the control; however, treatment TD50 statistically differed ($p < 0,05$) from TD0. These results were possibly related to a lower protein content in milk in TD50 (32,5 g/kg), which influences the content of non-fatty solids.

The bromatological quality of the milk of Jersey cows that was found in this study was similar to the one reported by Vargas *et al*. (2012), who conducted bioeconomic studies in Costa Rica of Holstein, Jersey breeds and their crossings, and found values of 42,7; 34,8; 125,3 and 82,6 g/kg of fat, protein, total solids and non-fatty solids, respectively.

The costs per animal per day of supplementation for each experimental treatment are shown in table 5. In TD25 a saving of 9,06 % appeared in the supplementation costs with regards to treatment TD0, and in TD50 18,8 % could be saved. In treatment TD25 0,25 USD animal/day were saved with regards to TD0.

The cost of supplementation was lower as the inclusion of *T. diversifolia* in the experimental treatments increased. These results were similar to the ones obtained by Gallego-Castro (2016), who by increasing the *T. diversifolia* meal in the diet of

Table 5. Supplementation cost according to experimental treatments.

Treatment	Supplement type	Quantity, kg	Cost, $ USD animal/day	Saving, % With regards to TD0
TD0	Balanced feed	6,40	2,77	
	Molasses	0,60		
	Urea	0,18		
	C. purpureus	5,00		
TD25	Balanced feed	4,80	2,52	9,06
	T. diversifolia	9,28		
	Molasses	1,50		
	Urea	0,17		
	C. purpureus	2,00		
TD50	Balanced feed	3,20	2,25	18,8
	T. diversifolia	18,65		
	Molasses	2,20		
	Urea	0,15		
	C. purpureus	1, 00		

TD0 (Grazing + Balanced feed (BF), TD25 (Grazing + substitution of 25 % of the BF by *T. diversifolia* forage) and TD50 (Grazing + substitution of 50 % of the BF by *T. diversifolia*).

dairy cows could decrease significantly the value of the kilogram of supplement offered to the animals.

Conclusions

It is concluded that the substitution of 25 % of the balanced feed with *T. diversifolia* forage did not affect the milk production and bromatological quality in Jersey cows, and also generated a saving of 9,06 % due to the decrease of supplementation costs.

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