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Article

Milk yield derived from the energy and protein of grazing cows receiving supplements under an agrosilvopastoral system

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Abstract:

Dual purpose farms southwest of the State of Mexico produce milk and calves under subtropical agrosilvopastoral systems (ASPS). During the dry season, farmers supplement their cattle due to the low availability and quality of grasses, without considering, besides grasses, the contribution of woody species to dry matter intake, metabolizable energy (ME), and crude protein (CP) requirements of cows. The aim of this study was to determine milk produced from forage energy (MFe) and protein (MFp) of grazing cow with three types of supplement. First supplement consisted of cracked maize and commercial concentrate resulting on 14 % of CP (S14). To the S14 mixture 7 % of soybean meal was added to increase CP to 16 % (S16), and commercial concentrate of 16 % CP was used as a third supplement (SC16). Six lactating cows were allocated in a 3x3 replicated Latin Square (three cows per square), three experimental periods (EP) (three weeks per EP). There were no significant effects of supplements (*P*=0.80) on performance variables. Mean milk yield was 6.8 kg/cow/d. Milk from forage energy and protein were 0.8 and 6.1 kg/cow/day, respectively. Mean milk urea nitrogen (MUN) was high regardless of supplement; but nitrogen in urine (44.1 mg/dL) and feces (1.4 mg/g) were higher for SC16 (*P*=0.001 and 0.04, respectively). Cows obtained 90 and 10 % of their CP and metabolizable energy requirements for maintenance and production from the agrosilvopastoral system.

Key words: Agrosilvopastoral, Milk from forage, Supplements, Nitrogen excretions.

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Introduction

Mexico is the eighth largest milk producer in the world (counting the European Union as a single entity) with a projected production of 12.4 million tons for 2019, but is the largest importer of dry non-fat milk with projections for 2018 equivalent to over 30 % of demand(1), with a growth rate of 1.6 % during 2018.

The national cattle herd was estimated at 33.5 million head with 51 % in the tropical and subtropical regions of the country under extensive grazing systems, where dual purpose farms are predominant and contribute to around 18 % of national milk production(2). These systems fulfil an important social role by providing vital livelihoods for families in the subtropical and tropical regions of the country(3).

Forage availability and quality during the dry season (November to May) is low; so, farmers resort to supplementation strategies aimed to maintain milk yields and body condition in cows, as well as weight gains in calves(4).

Feeding represents a large proportion of milk production cost(2), and supplements can be up to 70 % of production costs in dual-purpose subtropical farms(5). In order to reduce costs, some farmers mixed maize ears (with husks) produced in their farms, with commercial concentrate (50:50) resulting in a supplement with 14 % of crude protein (CP), while other farmers prefer more expensive commercial concentrates with a CP content that range from 16 to 18 % CP(3,5).

The amount of supplement assigned to a cow range from 5 to 9 kg/cow/d, that represents between 40 and 75 % of cow's dry matter intake (DMI). The amount assigned is firstly based on milk yield and varies over the dry season depending on forage availability (mainly grasses) on swards, without considering other resources like forbs or trees from which cows browse to complement their DMI, energy and protein requirements. This results in unbalanced diets that could lead to inadequate supply of nutrients causing low production, health problems or high production costs(6).

Tropical grasses are the main source of nutrients for cattle in traditional tropical livestock production; however, their low nutritional characteristics (i.e. low crude protein, energy and digestibility) restrict cattle productivity. The lack of technical knowledge regarding sward management, assessment of forage availability and quality along with basic animal nutritional requirements, leaves farmers with no other management tool but to use supplements based on grains as the only mean to counter the low availability and quality of grasses during the dry season(3,4).

Milk from forage intake by grazing cows can be estimated by subtracting the theoretical milk production from concentrates intake, assuming that maintenance requirements are met by forage intake(7). In order to account for the contribution of forage to energy and protein, milk from forage (MF) may be estimated following the procedure already described(8).

The objective of the study was to estimate the amount of produced milk from forage energy (MFe) and crude protein (MFp), of cows grazing on an agrosilvopastoral system, with three different types of supplement. The second objective was to estimate income over supplement cost.

Material and methods

Location

The study took place in a dual-purpose farm in the municipality of Zacazonapan in the south of the State of Mexico between 19º 00’ 17’’ and 19º 16’ 17’’ N and between 100º 12’ 55’’ and 100º 18’ 13’’ W, at an altitude of 1,470 m. Climate is a semi-hot of the A group, sub-humid with summer rains and a marked dry season from November to May, classified as A(C) (w2) (w), with mean temperature of 23ºC and 1,115 mm of annual rainfall. The experiment was conducted during the dry season from March 22nd to June 13th of 2010. Cattle was handled in the same way as the farmer does habitually, respecting routines and avoiding stressing the cattle.

Agrosilvopastoral system description

The farm has a land surface of 100 ha fenced in the perimeter, where cows grazed at a stocking density of 0.25 AU ha. Forage resources within the agrosilvopastoral systems have been reported previously(9), and consisted of: sward (continuous grass covered area); browse (includes leaf and twig growth of shrubs, woody vines, trees etc.); forbs (herbaceous broadleaf plant that is not a grass and is not grass-like) and crops residues(10).

Sward component consisted of Star of Africa (*Cynodon plectostachyus*) as the main grass with 44 % presence, the rest of the grasses in order of abundance were *Brachiaria plantaginea* (17 %), *Paspalum convexum* (12 %), *Cynodon dactylon* (11 %), *Eleusine indica* (5 %), *Paspalum notatum* (4 %), *Paspalum conjugatum* (4 %), *Paspalum scrobicunatum* (2 %), *Digitaria bicornis* (1 %).

The browse component included 27 woody species that are well accepted and consumed by cattle. Of these species cattle consume foliage, flowers, and fruits. Forbs consisted of 22 species and most of them are consumed by cattle. Lastly, maize (*Zea mays*) and sugar cane (*Saccharum officinarum*) are cultivated in the farm on 30 % of available land, and after harvest cattle have access to crop residues during the late dry season.

Experimental units and management

Six multiparous Brown Swiss cows were used in the experiment with an average of 4 ± 1.2 calving, 73 ± 27 d in milk, mean live weight (LW) of 491 ± 57 kg and 2.5 body condition score (BCS) on a 1 - 5 scale. Cows had a pre-experimental mean milk yield of 5.3 kg/cow/d and were hand milked once a day from 0700 to 0900 h. Before being milked, calves were allowed to suckle for few seconds the first milk from the four teats of their dams in order to stimulate milk let down; afterwards calves were tied to a pole close to their dams while they were milked.

Once the cows were milked, calves were allowed to suck residual milk and remained with their dams in grazing areas until 1400 h. Subsequently, they were separated from their mothers and were enclosed into a paddock where they grazed in a sward of characteristics above described. Calves were supplemented with 1.8 kg/day (DM basis) of cracked maize and commercial concentrate (14 % of CP) and had *ad libitum* access to water and mineral mix.

Supplements

Supplements used in this study were intended to replicate the characteristics and ingredients of those commonly used by farmers in the study region. Cracked maize ears were mixed with commercial concentrate (50:50), resulting in a supplement with 14 % of CP (S14). S14, was mixed with 7 % of soybean meal to increase CP to 16 % (S16); and commercial concentrate with 16 % of CP (SC16) was the third supplement used. Table 1 shows the chemical composition of the ingredients used.

Table 1: Chemical composition of ingredients used in supplements

Ingredients, g/kg DM	Dry matter	Crude protein	Neutral detergent fiber	Acid detergent fiber
Cracked maize ears with husks	980	83	324	120
Commercial concentrate (16 % CP)	918	161	198	103
Soybean meal	943	437	110	47

Before milking, cows received 4.5 kg/cow/d (DM basis) of the experimental supplements in a bag tied to the neck. Milking duration was enough for the cow to finish the assigned supplement; in case they did not, the bag remained tied until the cow finished the assigned amount.

Sampling and analyses

Milk yields kg/cow/d from individual cows were recorded for two consecutive days, during the last week of each experimental period (EP), using a clock spring balance with capacity for 20 kg. After recording milk yield from individual cows, two milk samples were taken. One milk sample was used to determine milk components (fat, protein, and lactose), using a portable ultrasound milk analyzer at the farm within 2 h after taking the samples. The second sample (40 ml), was preserved by adding Bromopol and transported in ice to laboratory. Samples were kept at -20°C until posterior analyses. Samples were thawed at room temperature and subjected to the enzymatic colorimetric technique(11) to determine milk urea nitrogen (MUN).

Cows liveweight was recorded after milking for two consecutive days at the beginning of the experiment and on the third week of every EP using a portable electronic cattle weighbridge. Body condition score was assessed immediately after weight recording(12). Urine samples (60 ml) were collected from cows via vulva stimulations after weighing, for two consecutive days during the last week of each EP. Sample was preserved by adding 15 ml of 0.05N HSO4. Urine urea nitrogen (UUN) was analyzed using the method(11). Also, feces samples were collected in a cup and were stored at -20 °C for further analysis. Feces were dried in a forced-air oven at 60ºC for 48 h, and ground through a 1 mm screen. Nitrogen in feces was determined following standard procedures[13].

Supplements were sampled daily during the last week of each EP and composited to get a subsample for chemical analyses. Samples were subjected to dry matter determination by drying at 60 °C in a forced-air oven for 48 h, and ashes was obtained by incineration in a muffle furnace at 550 °C for 6 h. CP was estimated by the Kjeldahl method, and neutral detergent fiber (NDF) and acid detergent fiber (ADF) by the Ankom micro-bag technique[13]. The *in vitro* dry matter digestibility (IVDMD) of supplements, was determined using the in vitro gas production technique[14].

Calculations

Milk from forage based on energy and protein[8].

Energy:

$$MF\ energy\ (kg) = \text{ECM(kg)} - \frac{[NE_L \text{ supplement (Mcal)} - NE_L\ req\ BW\ change\ (Mcal)]}{0.75\ Mcal\ /\ kg\ milk}$$

where ECM (4 % fat, 3.4 % CP, kg) = milk (kg) x (0.124 % fat + 0.073 % CP + 0.256).

NE_L concentrate (Mcal) = DMI (kg) $x\ \sum_{i=1}^{n} percentage$ of DMI supplement$_i$ + NE_L of supplement$_i$ (Mcal/kg). where i = 1, 2… n, and n is the number of supplements.

NE_L req for BW change (Mcal) = BW change (kg) x NE_L req (Mcal/kg of BW change),

where NE_L (Mcal/kg of BW change) = 5.34 Mcal/kg of BW gain = -4.68 Mcal/kg of BW lost.

Protein:

$$MF\ protein\ (kg) = \text{PCM(kg)} - \frac{[\text{CP supplement } (kg) - \text{CP } req\ BW\ change\ (kg)]}{0.088\ kg\ of\ CP\ /\ kg\ milk}$$

where PCM (protein-corrected milk; 3.4% CP, kg) = milk (kg) x 0.294 % CP.

CP concentrate (kg) =

DMI (kg) x $\sum_{i=1}^{n}$[% $DMI\ of\ supplement_i\ x\ CP\ of\ supplement_i$ (%)]

where i = 1, 2…n, and n is the number of supplements.

CP req for BW change (kg) = BW change (kg) x CP req (kg of CP/kg of BW change)

where CP req (kg of CP/kg of BW change) = 0.078 kg of CP/kg of BW gain = -0.094 kg of CP/kg of BW lost.

Forage intake estimations

Forage dry matter intake (DMI) were estimated indirectly following the utilized metabolizable energy method[15], taking metabolizable energy (ME) requirements for the cows[16]. Estimated ME (eME) provided by supplements was subtracted from total ME requirements, and the result divided into eME of the forage to obtain estimated forage DMI. Total DMI was the sum of estimated forage DMI plus supplement DMI.

Cost benefit analyses

Cost benefit analysis was done by partial budgets procedure to determine the costs of supplementation and returns from milk sales[17]. Partial budgets evaluate only the changes in the expenditures and incomes derived from implementing an alternative (supplements), not taking into consideration other factors or activities that are not modified as labor, fuels, cost of grazing. Cost benefit analysis results are expressed in US dollars.

Statistical analysis

The experimental design was a replicated 3x3 Latin square design (21-d period). Supplement sequences were randomized for square one, and square two followed a mirror image in the treatment sequences to account for carry-over effects. Experimental periods lasted three weeks, the first two weeks were considered as adaptation period to the supplements and the last two days of the third week for sampling and measurements of animal response variables. Cows were assigned randomly to treatment sequence in both squares.

Response variables were analyzed with the Proc Mixed procedure of SAS[18] using the following equation[19]:

$$Y_{ijkm} = \mu + S_m + C_{i(m)} + P_{j(m)} + Sup_k + e_{ijkm}$$

where:

μ = General mean,

S_m = fixed effect of squares (*m* = 1 and 2),

$C_{i(m)}$ = random effect of cow within square (*i* = 1, 2, 3),

P_k= fixed effect of experimental periods *j* within square *m* (*j* = 1, 2, 3),

Sup_l= fixed effect of supplement (*k* = S14, S16, and SC16)

e_{ijkm}= Residual error term.

Significant differences between means (P<0.05) were tested with the Tukey test.

Correlation analyses for milk protein, MUN, NF and UUN were performed using the Corr procedure of SAS[18]. Correlation coefficients were considered low when r ≤0.39 and moderate when r ≥0.40 and ≤0.60.

Results

Chemical composition of supplements

Table 1 shows the chemical composition of ingredients of supplements and Table 2 shows ingredient inclusion levels and chemical composition of supplements. The DM, OM, NDF, and ADF content were numerically similar between supplements. Important differences were in CP as intended with 141 for S14, 159 for S16, and 161 g/kg DM for SC16. Supplement IVDMD of S14 was 5 and 9 % higher than S16 and SC16, respectively. A similar trend was observed for estimated ME MJ/kg DM S14 (12.6) was higher than S16 (12.0) and SC16 (11.4).

Table 2: Ingredients inclusion level and chemical composition of supplements with 14 % (S14) and 16 % (S16, SC16) of crude protein, offered to Brown Swiss cows on agrosilvopastoral system during the dry season

Inclusion level (%)	**S14**	**S16**	**SC16**
Cracked maize ears with husks	50	46.5	
Commercial concentrate (16 % CP)	50	46.5	100
Soybean meal		7	
Total	100	100	100
Nutrient, g/kg DM			
Dry matter	907	889	918
Organic matter	842	846	813
Crude protein	141	159	161
Neutral detergent fiber	190	174	198
Acid detergent fiber	90	84	103
IVDMD	800	758	729
Estimated metabolizable energy, MJ/kg DM	12.6	12.0	11.4

IVDMD = *In vitro* dry matter digestibility.

Animal variables

Treatment effects on DMI, milk yield, milk composition and N excretions are shown in Table 3. There were no effects on performance variables due to supplements (P>0.05). Average milk yield was 6.8 ± 1 kg/cow/d. Fat, protein and lactose contents were 20.8 ± 7, 31.0 ± 1 and 44.6 ± 2 g/kg, respectively. Average live weight was 495 ± 53 kg, and a body condition score of 2.6 ± 0.1 points.

Table 3: Animal response variables of grazing lactating cows receiving three sources of supplements with two crude protein levels (14 *vs* 16 % CP)

Treatment	**S14**	**S16**	**SC16**	***P* =**	**SEM**
DM intake, kg/d	12.9	12.8	13.0	0.40	0.25
Milk yield, kg/d	6.7	6.7	6.9	0.80	0.70
Fat, g/kg	22.9	22.0	17.4	0.16	2.0
Protein, g/kg	31.0	30.8	31.3	0.85	1.6
Lactose, g/kg	44.9	44.1	44.9	0.79	1.6
Live weight, kg	491	491	503	0.36	25.27
Body condition score	2.5	2.7	2.5	0.20	0.02
MUN, mg/dL	23.3	22.4	29.7	0.47	2.58
UUN, mg/dL	25.7[b]	23.0[b]	44.1[a]	0.001	2.4
NF, mg/g DM	1.3[a]	1.5[b]	1.4[ab]	0.04	0.06

S14 = grounded maize ears with husks and commercial dairy concentrate (50:50); S16 = 43 % ground maize ears with husks: 50 % commercial dairy concentrate and 7 % soya bean meal; SC16 = 16 % commercial dairy concentrate. SEM = Standard error of the mean. MUN= milk urea nitrogen; UUN = urine urea nitrogen and, NF = nitrogen in feces.

There were no differences on milk urea nitrogen (MUN) due to supplements (*P*=0.47). Urine urea nitrogen (UUN) mg/dL was higher (P<0.01) for SC16 (44.1) than S14 (25.7) and S16 (23.0) supplements (Table 3). Also, differences were detected for nitrogen in feces (NF) (P=0.04), where S16 and SC16 were similar, but S16 was different from S14. There were significant effects of experimental periods on some variables. Dry matter intake decreased from 13.0 to 12.6 (3 %) from EP1 to EP3 (P=0.04). Milk protein decreased 6 % and lactose 7 %. The greatest reduction was on MUN concentration which decreased from 32.9 to 15.7 mg/dL, that is a 52 % reduction from EP1 to EP3. There was a trend (*P*=0.08) for fat to decrease as EP progressed (from 25.0 to 18.9). The rest of the performance variables and nitrogen excretions in urine and feces remained constant from the beginning to the end of the trial.

Table 4 shows the correlation coefficients between MY, milk protein, MUN, UUN and NF. A moderate but significant correlation was detected between MPr and MUN (r=0.49). A negative correlation between MPr and NF (r=-0.58, *P*<0.01), and NF with MUN (r=-0.48). The remaining correlations were low and not significant (*P*>0.05).

Table 4: Correlation coefficients between milk yield kg/day, milk protein g/kg, milk urea nitrogen (MUN) mg/dL, Nitrogen in feces (NF) mg/g and urine urea nitrogen (UUN) mg/dL

	M. Protein	**MUN**	**NF**	**UUN**
Milk yield	-0.32	-0.35	0.09	-0.12
M. Protein		0.49*	-0.58**	0.36
MUN			-0.48*	0.37
NF				-0.39

* *P*<0.05, ** *P*<0.01.

Calculations

Milk yield from grazing

Table 5 shows the calculations of milk allowed from forage according to contributions of ME and CP to cow requirements. Milk allowed from ME of forage was not greater than 1.0 kg/d, with a trend for higher MFe when cows received supplements S14 (0.9) and SC16 (1.0), than when on S16 (0.5 kg/d). Milk allowed from forage CP were on average 6.1 kg/cow/d, with no effect due to supplement (*P*=0.74). Allowable milk from forage ME was on average 0.8 kg/d. Average milk from forage (MFe + MFp / 2) was 3.3 kg/d indicating that 49 % of milk yields were due to forage contributions.

Table 5: Milk allowance from energy and protein from forage by cow grazing on agrosilvopastoral system, with three sources of supplements and two crude protein levels (14 *vs* 16 %)

Treatment	S14	S16	SC16	***P* =**	SEM
MF energy, kg/d	0.9	0.5	1.0	0.06	0.32
MF protein, kg/d	6.0	6.0	6.3	0.74	0.57
MF average, kg/d	3.1	3.3	3.6	0.13	0.39

MF energy = milk from forage on an energy basis; MF protein = milk from forage on protein basis; and MF average = average milk from forage.

Cost benefit analyses

Table 6 shows benefit over supplementation costs in US dollars ($) for the use of supplements to grazing dual purpose cows. The SC16 supplement had the highest cost 0.34 followed by S16 0.29, and the lowest was S14 0.28 $/kg, which was 3 and 18 % cheaper than S16 and SC16, respectively. Total MY differences among S14 and SC16 was only 3 %, having the same difference in total returns. The highest profit margin was obtained with S14 0.22 that was 19 % higher compared with the lowest obtained with SC16 of 0.18 $/kg.

Table 6: Supplementation costs and returns ($ USD) for milk production from three types of supplements

Treatment	S14	S16	SC16
Supplement cost, $/kg	0.28	0.29	0.34
Total supplement cost	516	546	634
Milk yield/treatment, kg	2,523	2,514	2,596
Total returns	1,058	1,054	1,088
Gross margin	544	509	455
Cost / returns ratio	0.49	0.52	0.58
Milk production cost, $/kg	0.20	0.22	0.24
Milk selling price , $/kg	0.42	0.42	0.42
Profit margin, $/kg	0.22	0.20	0.18

S14 = grounded maize ears with husks and commercial dairy concentrate (50:50); S16 = 43 % cracked maize ears with husks: 50 % and commercial dairy concentrate: 7 % soya bean meal; SC16 = 16 % commercial dairy concentrate.

Discussion

Supplementation in this study contributed to sustain dry matter and energy intake of cows avoiding milk yields and body weight losses, regardless of supplement type. Supplements have advantages and disadvantages to farmers. Supplements mixed in the farm (S14) using local resources like cracked maize ears, proved to be of higher nutritional quality, that was more digestible and with higher energy density than the other supplements, and at a lower cost. The disadvantages of this strategy according to farmers is that it requires more labor and time to make the mixture, but most importantly is the lack of technical advice or knowledge in order to balance rations according to cow requirements(4,6).

Commercial concentrate spares them from the extra labor, it however comes at a higher cost reducing profitability(20), and the quality of ingredients is not ideal judging by the lower IVDMD, high ADF and lower ME content. The lower ME density of supplements S16 and SC16 could be due to the higher CP content that reduced ME. A strategy to reduce the unbalance between CP and energy in supplements would be the use of high energy ingredients like molasses, starch or fat, when cows graze on low quality forage(21,22).

Average milk yields were lower than those reported from crossbreed cows of 13.5 kg/cow/d grazing *Cynodon nlemfuensis* swards, supplemented with 5.1 kg/cow/d of concentrate and also lower than 14.5 kg/cow/d from same type of cows grazing on an intensive silvopastoral system composed of Leucaena and *C. nlemfuensis* receiving 5.5 kg/cow/d of concentrate. These results were obtained from a study carried out with cows and sward under intensive management in a tropical region(23), whereas this study was carried out under extensive conditions on a commercial farm, where weaned calf production is also important. In order to achieve maximum weight gains calves remained with their mothers five hours during the day, suckling continuously which is a factor that reduces next day milk yields. Similar milk yields (7.0 kg/cow/d) and milk protein (32.3 g/kg) were reported from cows under extensive grazing on swards of native and introduced tropical grasses, receiving similar amounts of supplements as the present study(24).

Fat concentration was lower than normal values reported in the literature but are in line with a report that found low fat concentration (2 %) from dual purpose farms in the same region of this study and, under similar management conditions(25). One possible explanation of the low milk fat concentration is fiber quality, it is well known that tropical grasses are of low quality containing high NDF fractions and low digestibility(22). Low fat concentration in milk have an economic implication, since fat along with protein concentration in milk are the most important components considered for milk payments to farmers, in regions of the country where milk production is linked with the dairy industry; however, this is not the case in the region where this study was performed, and milk price is establish regardless components. In this case, low fat concentration in milk is a temporary effect[25], due to forages diminished quality and low restricted availability because of the dry season.

The correlation between MUN and milk protein in our study indicate a linear relationship. Both variables had a higher concentration at the beginning of the experiment and as it progressed values of both variables decreased. Milk protein and MUN were negatively correlated with nitrogen in feces, which indicates that as the first two decreased from EP1 to EP3, nitrogen in feces tended to increase.

These results evidence the importance of trees and forbs most of them legumes present in the agrosilvopastoral system[9] as CP sources for the lactating cows. Forages provided 62, 11 and 89 % of DMI, ME and CP, respectively for maintenance and production. These results show the evident importance of supplements sustain milk yields and bodyweight. Average MUN was above benchmark values of 12 mg/dL[26], which indicates that cows consumed CP in excess of their requirements. Based on this, supplements should be of lower CP and higher in energy density using readily available energy sources (like molasses) and non-protein nitrogen (urea) in order to optimize microbial ammonia capture[27].

Crude protein reduction in supplements not only will allow reductions of milk production costs, since protein is the most expensive ingredient in cow diets[22], but also will increase forage CP utilization efficiency, reducing fecal and urinary nitrogen excretions to the environment[27]. But, in order to determine the appropriate CP levels in supplements, MUN must be constantly monitored in order to make appropriate adjustments[28].

The reduction of MUN concentrations (52 %) in the last experimental period (advanced dry season), indicated that forage availability and nutritional value decreased, having a reduction on DMI of cows, but without effect on in cow performance. In a different study in the same farm[5], a 34 % reduction of CP and a 12 and 15 % increase of NDF and ADF respectively and a 14 % reduction of IVDMD of grasses from early to late dry season was documented.

Decreasing levels of MUN will decrease N excretions in urine. However, there is evidence that under silvopastoral systems emissions of N_2O from UUN are lower than those from cattle grazing on monoculture pastures[29].

This agrees with a comprehensive literature review paper[30], which shows that fodder from woody legumes (that contain condensed tannins) enhance N recycling, reducing nitrogen volatilization and lowering the risk of N_2O emissions and N losses.

Sustainability of dual-purpose farms in the study region was evaluated considering agroecological, socio-territorial and economic scales. In the first two scales sustainability scores were high (87 and 73 out of 100 points, respectively), but the economic scale had the lowest scores (56 out of 100 points), becoming the limiting factor for the whole system. Dependency on external inputs such as commercial concentrates, and the low or nil added value to milk were the items that limited sustainability within the economic scale[20].

Therefore, the development of feeding strategies based on the efficient use of local resources like woody species as fodder banks during the dry season, as well as, supplements formulation using local resources such as maize and molasses, as readily available sources of energy in supplements, will increase the efficiency of use of low quality forage during the dry season at a lower cost.

Conclusions and implications

Under the conditions of this study, it is possible to reduce milk production costs by using a 14 % or even lower CP supplement made with homegrown maize ears with husks, without affecting cow performance, bodyweight or body condition score. Cows on an agrosilvopastoral system obtained 50 % of their energy and crude protein requirements for maintenance and milk production from grazing. The high levels of milk urea nitrogen indicated that cows grazing on the agrosilvopastoral system consumed fodder rich in crude protein. In order to maximize the used of these forage resources, readily sources energy should be included to properly balanced energy and crude protein in the diets of the cows. Therefore, it is important to monitor MUN as a tool to determine CP levels in supplements, avoiding over feeding of crude protein in cow diets.

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Literature cited:

1. IndexMundi. Agricultural production, supply and distribution. www.indexmundi.com/agriculture/. Accessed July 15, 2019.

2. Lactodata Información sobre el sector lechero. Reporte 11 www.lactodata.info/produccion-de-leche-de-vaca. 2017. Consultado julio 2, 2018.

3. Albarrán-Portillo B, Rebollar-Rebollar S, García-Martínez A, Rojo-Rubio R, Avilés-Nova F, Arriaga-Jordán CM. Socioeconomic and productive characterization of dual purpose farms oriented to milk production in a subtropical region of Mexico. Trop Anim Health Prod 2015;47:519-523.

4. Absalón-Medina VA, Blake RW, Gene Fox D, Juárez-Lagunes EG, Nicholson FC, Canudas-Lara EG. Limitations and potentials of dual-purpose cow's herds in central coastal Veracruz, Mexico. Trop Anim Health Prod 2011;44:1131-1142. https://doi.org/10.1007/s11250-011-0049-1.

5. Salas-Reyes IG, Arriaga-Jordán CM, Estrada-Flores JG, García-Martínez A, Rojo-Rubio R, Vázquez-Armijo JF, *et al*. Productive and economic response to partial replacement of cracked maize ears with ground maize or molasses in supplements for dual-purpose cows. Rev Mex Cienc Pecu 2019;10(2):335-352. https://doi.org/10.22319/rmcp.v10i2.4569.

6. Deen AU, Tyagi N, Yadav RD, Kumar S, Tyagi AK, Kumar Singh, S. Feeding balanced rations can improve the productivity and economics of milk production in dairy cattle: a comprehensive field study. Trop Anim Health Prod 2019;51:737-744 https://doi.org/10.1007/s11250-018-1747-8.

7. Charbonneau E, Chouinard PY, Allard G, Lapierre H, Pellerin D. Milk from forage as affected by carbohydrates source and degradability with alfalfa silage-based diets. J Dairy Sci 2006;89:283-293.

8. Charbonneau E, Bregard A, Allard G, Lefebvre D, Pellerin D. Revisiting the prediction of milk from forage according to NRC 2001 [abstract]. Can J Anim Sci 2003; 83:647.

9. Albarrán-Portillo B, García-Martínez A, Ortiz-Rodea A, Rojo-Rubio R, Vázquez-Armijo JF, Arriaga-Jordán CM. Socioeconomic and productive characteristics of dual purpose farms based on agrosilvopastoral systems in subtropical highlands of central Mexico. Agroforest Syst 2018;93:1939-1947. doi: 10.1007/s10457-018-0299-2.

10. Grazing terminology. Terminology for grazing lands grazing animals. Forage information system. Oregon State University. Accessed April 2nd 2020. https://forages.oregonstate.edu/fi/topics/pasturesandgrazing/grazingsystemdesign/grazingterminology.

11. Broderick GA, and Clayton MK. A statistical evaluation of animal and nutritional factors influencing concentrations of milk urea nitrogen. J Dairy Sci 1997;80:2964–2971. doi:10.3168/jds.S0022-0302(97)76262-3.

12. Wildman EE, Jones GM, Wagner PE. A dairy cow body condition scoring system and its relationship to select production characteristics. J Dairy Sci 1982;265:495-501.

13. AOAC. Official Methods of Analysis. 15th ed. AOAC International, Arlington, VA, USA. 2000.

14. Mauricio MR, Mould FL, Dhanoa MS, Owen E, Channa K, Theodorou MK. A semi-automated *in vitro* gas production technique for ruminant feedstuff evaluation. Anim Feed Sci Technol 1999;79(4):321-330.

15. Baker RD. Estimating herbage intake from animal performance. In: Leaver JD editor. Herbage Intake Handbook. Hurley: British Grassland Society. UK. 1982:77-93.

16. AFRC. Agricultural and Food Research Council. An advisory manual prepared by the AFRC Technical Committee on Responses to Nutrients. Wallingford: CAB International. 1993.

17. Harper JK, Cornelisse S, Kime LF, Hyde J. Budgeting for agricultural decision making. Pennsylvania State University. College of Agricultural Sciences. 2013. https://extension.psu.edu/budgeting-for-agricultural-decision-making. Accessed November 19, 2018.

18. SAS. SAS/STAT User's guide. (Version 9 ed.). Cary, NC, USA. 1989.

19. Kononoff PJ, Handford KJ. Technical Note: Estimating statistical power of mixed models used in dairy nutrition experiments. Faculty Papers and Publications in Animal Science. Paper 725. 2006 http://digitalcommons.unl.edu/animalscifacpub/725.

20. Salas-Reyes IG, Arriaga-Jordán CM, Rebollar-Rebollar S, García-Martínez A, Albarrán-Portillo B. Assessment of the sustainability of dual-purpose farms by the IDEA method in the subtropical area of central Mexico. Trop Anim Health Prod 2015;47:1187-1194.

21. Gehman AM, Bertrand JA, Jenkins TC, Pinkerton BW. The effect of carbohydrate source on nitrogen capture in dairy cows on pasture. J Dairy Sci 2006;89(7):2659-2667.

22. Granzin BC, Dryden G McL. Monensin supplementation of lactating cows fed tropical grasses and cane molasses or grain. Anim Feed Sci Technol 2005;120:1-16.

23. Bottini-Luzardo MB, Aguilar-Pérez CF, Centurión-Castro FG, Solorio-Sánchez FJ, Ku-Vera JC. Milk yield and blood urea nitrogen in crossbred cows grazing *Leucaena leucocephala* in a silvopastoral system in the Mexican tropics. Trop Grasslands-Forrajes Trop 2016; 4:159–167. doi:10.17138/TGFT(4)159-167.

24. Salvador-Loreto I, Arriaga-Jordán CM, Estrada-Flores JG, Vicente-Mainar F, García-Martínez A, Albarrán-Portillo B. Molasses supplementation for dual-purpose cows during the dry season in subtropical Mexico. Trop Anim Health Prod 2016;48(3):643-648. doi:10.1007/s11250-016-1012-y.

25. Morales CH, Montes AH, Villegas De Gante AZ, Mandujano EA. El proceso socio-técnico de producción de Queso Añejo de Zacazonapan, Estado de México. Rev Mex Cienc Pecu 2011;2:161–176.

26. Kohn RA, Kalscheur KF, Russek-Cohen E. Evaluation of models to estimate urinary nitrogen and expected milk urea nitrogen. J Dairy Sci 2002;85:227-233.

27. Tamminga S. Nutrition management of dairy cows as a contribution of pollution control. J Dairy Sci 1992;75:345-357.

28. Jonker JS, Kohn RA, High J. Use of milk urea nitrogen to improve dairy cow diets. J Dairy Sci 2002;85:939-946.

29. Rivera JL, Chára J, Barahona R. CH4, CO2, and N2O emissions from grasslands and bovine excreta in two intensive tropical dairy production system. Agroforest Syst 2019;93:915-928. https://doi.org/10.1007/s10457-018-0187-9.

30. Vandermeulen S, Ramírez-Restrepo CA, Beckers Y, Claessens H, Bindelle,J. Agroforestry for ruminants: a review of trees and shrubs as fodder in silvopastoral temperate and tropical production systems. Anim Prod Sci 2018;58:767-777. https://doi.org/10.1071/AN16434.