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Feed costs analysis and reduction associated with dairy production in a semi-specialized bovine system using AHP method

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Abstract

Milk production is an important line within the agricultural sector and the economy of a country. In Mexico, the contribution of the agricultural sector to the nominal Gross Domestic Product (GDP) is 4.2 %, with a 30.2 % livestock share. This type of production has several improved systems to increase the profit rate. However, it is necessary to know the production costs associated with feeding cattle in terms of dry matter consumed. In this paper, we analyzed the variable feeding costs within the milk production process for high and low producing cows in a semi-specialized bovine system. We carried out diagnosis and information gathering processes, bromatological and milk production analyses, calculation of associated costs, and finally, the evaluation of cost reduction under the multi-criteria methodology of the Analytical Hierarchy Process (AHP). Feeding costs associated with forage, silage, and concentrate feed were calculated, reaching 20.3 % and 21.9 % of the total income from milk sales for groups of cows with high and low production, respectively. We determined that the cost reduction strategy that generates better results in terms of productivity criteria, efficiency, environment, and financial factors corresponds to the elaboration of different diets according to the milk production rate. The savings associated with this strategy demonstrate the potential to lower annual feeding costs by up to USD 444 for the cows under study.

Keywords: analytic hierarchical process, bovines, dairy production, livestock feeding, production costs

Análisis y reducción de costos alimenticios asociados a la producción láctea de un sistema bovino semiespecializado, mediante el uso de la metodología AHP

Resumen

La producción de leche es un renglón importante dentro del sector agropecuario y la economía de un país. En México, el aporte del sector agropecuario al producto interno bruto (PIB) nominal es del 4,2 %, con una participación del 30,2 % de la ganadería. Este tipo de producción presenta diversos sistemas mejorados para aumentar la tasa de rendimiento. Sin embargo, es necesario conocer los costos de producción asociados a la alimentación de los bovinos en términos de materia seca consumida. En esta investigación, realizamos el análisis de los costos variables de alimentación dentro del proceso de producción de leche para vacas de alta y baja producción en un sistema bovino semiespecializado. Se desarrollaron procesos de diagnóstico y levantamiento de la información, análisis bromatológico, análisis de producción láctea, cálculo de los costos asociados y, por último, evaluación de reducción de costos bajo la metodología multicriterio de proceso de análisis jerárquico (AHP, por sus siglas en inglés). Se calcularon los costos de alimentación asociados a forraje, ensilado y concentrado, los cuales alcanzan el 20,3 % y 21,9 % de los ingresos totales por venta de leche para grupos de vacas de alta y baja producción, respectivamente. Determinamos que la estrategia de reducción de costos que genera mejores resultados, en cuanto a criterios de productividad, eficiencia, ambiente y factores financieros, corresponde a elaboración de diferentes dietas según la tasa de producción de leche. El ahorro asociado a esta estrategia demuestra un potencial de disminuir los costos anuales de alimentación hasta en USD 444 para las vacas objeto de estudio.

Palabras clave: alimentación del ganado, bovinos, costos de producción, producción lechera, proceso jerárquico analítico

Introduction

Dairy production worldwide is divided into two large groups. The first is comprised of developed countries such as the United States and those belonging to the European Union, which reflect milk production percentages of 12 % and 20 % worldwide, respectively. (Organization for Economic Cooperation and Development [OECD], 2018). In the second group, there are countries such as Australia and Argentina with low levels of dairy production associated costs due to good agroclimatic conditions and infrastructure. Mexico is ranked number eight in this category due to its production level, representing approximately 2 % of the milk production worldwide (Secretaría de Agricultura y Desarrollo Rural, 2018), which highlights the influence of the dairy sector on the economy (Montaldo et al., 2009; Oficina Económica y Comercial de España en México, 2016).

Bovine milk production ranks third in the livestock production value in Mexico, with a contribution of 17 %. This type of production is carried out in both technical and traditional production systems, which are basically focused on the production of food for human consumption (Loera & Banda, 2017). The leading producing states are Jalisco with 19.5 %, Coahuila with 11.5 %, Durango with 10.2 %, and Chihuahua with 9.3 % (Cámara Nacional de Industriales de la Leche [Canilec], 2018).

In relation to the above, the amount of product generated is associated with three factors: production costs, productivity, and sale price, where costs can be defined as all those payments that an organization makes for the acquisition and maintenance of production resources (Botero & Rodríguez, 2006). In the case of milk production, one of the most representative costs corresponds to livestock feeding (Macdonald et al., 2017).

In the literature, studies of dairy production costs have been developed and conclude the high level of incidence of variable costs influenced mainly by feeding. Gómez-Osorio et al. (2017) analyzed the profitability of milk production concerning the carbohydrate source required to supplement grazing Holstein cows. The basis established was that the high costs of food inputs become a limitation in livestock activity profitability. For their part, Shonka-Martin et al. (2019) applied statistical linear regression models to calculate measures of food efficiency, residual food intake, and income over feed cost. The latter was calculated as the income from the production of fat and protein minus the food cost. In this study, Holstein cows were compared with crossbreeds from Montbéliarde, Viking Red, and Holstein in Minnesota; crossbreeds showed lower feed costs and better income than Holstein.

On the other hand, Wu et al. (2019) developed a nutritional grouping strategy called OptiGroup that was carried out in Wisconsin to increase milk income over feeding costs. The calculation is performed through the application of an optimization algorithm based on mixed-integer nonlinear programming. The authors established a group organization by type of nutritional requirements. However, the assignment of cows to each group does not interact with the formulation of the rations to minimize costs. Therefore, they concluded that there could be a more cost-effective way to group cows nutritionally.

Ranck et al. (2020) applied a double-cropping strategy on Pennsylvania farms to minimize both food costs and the negative impact that bovine activity generates on the environment. With this approach, a reduction in leachate is achieved, and farms benefit at times of fluctuating feed costs.

In the case of Mexico, Gamboa-Mena et al. (2005) analyzed the factors that show a high incidence on the production of beef in *Bos indicus* and *B. taurus* species, identifying higher variable costs for food and labor. Likewise, Granados et al. (2011) determined the costs present in the production of one liter of milk, and the costs for obtaining meat in a dual-purpose system. In this study, fixed and variable input costs, labor, medicines, fuels, services, and maintenance are considered, concluding that the most representative costs are those of labor and fuels, with 81.36 % of the total costs.

In the study carried out by Hernández-Martínez et al. (2011), the variable costs mainly related to feeding represent approximately 90 % of the total costs in the cattle production chain. Domínguez et al. (2014) adapted a methodology that establishes the construction of individual deflators by cost item through value readjustment; the deflators were subsequently compared with the National Consumer Price Index to carry out an analysis of the 2000-2012 production periods, with variable costs being the most important.

Hernández-Martínez et al. (2016) analyzed the competitiveness and costs associated with bovine production under a political analysis matrix model. In their analysis, the authors determined the profitability of the activity with variations from 10.77 % to 15.40 %, and identified food costs of more than 80 % of the total costs.

Furthermore, Albarrán-Portillo et al. (2019) evaluated the economic and productive response of grazing dairy cows with a high animal load, and throughout the process, the profitability of using concentrate feed and high-quality forages was analyzed. The study showed no economic benefit when increasing the supplementation with concentrate feed, since the total margins on feeding costs are similar. However, forage grazing contributes to improving profitability.

Cost analyzes are generally focused on the entire production system, so the aim of this work is to analyze the production costs directly associated with feeding in a semi-specialized bovine system, allowing to measure the efficiency of the system and generate alternatives for decision-making, considering that the increase in food input costs and their high incidence in total costs can threaten the profitability of livestock productions (Martínez et al., 2015).

The central hypothesis was established by verifying that the determination of the variable feeding costs associated with milk production generates a source of information for the correct economic and productive exploitation of the economic unit. Besides, this information can be used in the development of strategies to reduce costs. Therefore, the Analytical Hierarchy Process (AHP) method was used for the design and selection of alternatives to minimize costs associated with feeding, considering that the application of multi-criteria evaluation techniques to support decision-making in the agricultural sector is still very limited.

Materials and methods

The research was developed in three phases, equivalent to six months between June and November 2019. It began with a diagnosis and daily record of the milking and feeding processes that considered the bromatological analysis of feed, a milk production analysis, and its physicochemical analysis.

The bromatological analysis was performed based on the proximal analysis methods of Weende and Van Soest (Van Soest et al., 1991). The samples were collected using the Hand Plucking technique; in the case of milk production, the laser system of the mechanical milking machine was used. The physicochemical analysis of the milk was carried out by taking samples in 100 mL plastic bottles, and examined with the Ekomilk ultrasound milk analyzer. Subsequently, the data were analyzed using the Statistical Analysis System (SAS) software to obtain the means and compare them using Tukey's test.

In the second stage, the feeding costs were identified, based on forage, silage, and concentrate feed. Finally, the AHP method was applied for the design and selection of cost reduction alternatives.

Study site

The study was carried out in the grazing module corresponding to the Animal Husbandry Department of Universidad Autónoma Chapingo, located in Texcoco, Mexico. The climate of the area is temperate subhumid with rains in summer, and an average annual temperature of 18 °C (Ramírez et al., 2011).

Sampling or experimental unit

A total of 18 Holstein cows of the New Zealand line under grazing were employed. These were divided into two groups of nine animals each, with the averages detailed in table 1. The cows were milked twice a day, called *morning milking* and *evening milking*.

Table 1. Initial average values for production, weight, age, and calvings per group

Group	1 - High producing animals	2 - Low producing animals
Days in milk (days)	238.66 ± 117.52	309.22 ± 36.35
Live weight (kg)	487.11 ± 160.94	484.77 ± 64.53
Milk production (L)	19.44 ± 2.06	13.85 ± 1.20
Age (years)	5.22 ± 1.85	6.22 ± 3.15
Number of calvings	1.88 ± 1.05	2.55 ± 1.66

Source: Elaborated by the authors

Feeding was carried out based on the supply of concentrate feed, silage, and forage rations according to milk production. The rotational grazing area consisted of 1.5 ha of mixed pastures of alfalfa *Medicago sativa* L. (Fabaceae) and orchard grass *Dactylis glomerata* L. (Poaceae), divided into three paddocks; two of these facing north and one facing south. A mobile electric fence was used to offer fresh forage gradually during the day.

For the economic analysis, the costs were established as a function of dry matter (DM), that is, the costs of forage C_f, silage C_s and concentrate feed C_c (equation 1).

$$C_{Total} = C_f + C_s + C_c \quad \textit{Equation 1}$$

For the economic analysis, the depreciation costs of livestock, equipment, wages, electricity, water, and medicines are not considered. These costs are assumed directly by the institution and are not differentiated in the module. The estimated cost for pasture forage is calculated by the relationship between the total cost per pasture establishment (*PE*) and the estimated production (*EP*) of dry matter (EP_{DM})(equation 2.)

$$\text{Forage Cost} = \frac{PE}{EP_{DM}} \quad \textit{Equation 2}$$

Likewise, to establish the daily intake of the cows in the pasture, it was necessary to determine the weight of the forage offered f_0 and residual forage f_r, taking random field samples with a 50 × 50 cm measurement box. For this, the samples are placed in an oven at 50 ° C for 24 hours to determine the DM. Furthermore, using the measurements of the area consumed A_c during a day, i.e., 1,809.58 m², the weight difference between the forage offered f_0, and the residual f_r was calculated, to later divide it by the number of cows *n* that grazed the recorded area (equation 3).

$$\text{Forage Intake} = \frac{f_0 - fr}{n} \quad \textit{Equation 3}$$

On the other hand, the cost for silage is obtained by dividing the establishment of the corn crop C_t and the total inputs for its preparation I_t, by the tons of DM/year (DM_{TN}). Subsequently, the equation is divided by the equivalence of m² (equation 4).

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$$\text{Silage cost in kg} = \frac{\frac{C_T - Ir}{DM_{TN}}}{M^2}$$ *Equation 4*

Finally, to determine the cost per kilogram, the cost of each component C_c is multiplied by its inclusion percentage per kg $\%_i$, and thus, the result per element is obtained (equation 5).

$$Concentrate\ feed\ cost\ per\ kg\ =\ Cc\ x\ \%i$$ *Equation 5*

Methodology applied for the analysis of alternatives for decision making

The Analytic Hierarchy Process (AHP) is a systematic multi-criteria tool developed in the 1980s by Thomas Saaty (Baffoe, 2019; Saaty, 1988). This method allows assessing different criteria assigned to a set of strategies to prioritize and facilitate decision-making. This makes it one of the most appropriate methods due to its efficiency in the application of problems with qualitative and quantitative factors (Sabaei et al., 2015; Wolnowska & Konicki, 2019).

With the AHP method, a hierarchy tree is built, allowing the organization of the key points of view of the problem in a staggered manner (Saaty, 1988). This methodology facilitates obtaining a single evaluation value, taking different indicators as a reference, so that the process is reduced by dividing a complex problem into a set of structured and manageable steps (Benmouss et al., 2019; Li et al. al., 2008). In this sense, the problem and the judgment options of the users are hierarchically illustrated using a numerical scale that measures qualitative performance (Saaty, 1988). This scale presents an assessment of relative dominance that ranges from equal to absolute importance (Benmouss et al., 2019), with which a matrix $A = [aij]$ is constructed at each level of the hierarchy of criteria of $n \times n$ squares, where n is the number of elements of the level (Wolnowska & Konicki, 2019) (table 2).

Table 2. Saaty's relative domination scale for paired comparisons

Comparison scale			
1	Equal importance	7	Very significant importance
3	Slight importance	9	Absolute importance
5	Significant importance	2,4,6,8	Intermediate values

Source: Elaborated by the authors

Evaluation criteria of the AHP method

The evaluation criteria in the AHP are identified and selected through a process of discussion with interested parties (Baffoe, 2019; Wolnowska & Konicki, 2019). For this work, the criteria were selected through a deliberative process with different experts and technicians in charge of the milk production grazing module of Universidad Autónoma de Chapingo and professionals from the Livestock Faculty of

Colegio de Posgraduados (Colpos). After two discussions with the participants, a consensus was reached to select the following criteria: financial factor *a1*, productivity *a2*, efficiency *a3,* and environmental factor *a4*, as development pillars associated with the aim of the research. Thus, to select the best alternative according to the established criteria, the importance of one criterion over the other was compared in pairs using the Saaty comparison scale (table 2). Once this was done, the weight per criterion was obtained, corresponding to $a_1 = 0.323$, $a_2 = 0.258$, $a_3 = 0.246$, and $a_4 = 0.173$.

Results and discussion

The cow feeding system was based on rotational grazing of mixed alfalfa and orchard grass pastures, supplemented with 10 kg of ensiled and concentrated corn depending on the group (table 3). Supplementation of 1 kg of concentrated feed was assigned for low producing cows and 2 kg for high producing cows. Additionally, silage stored in a "pile silo" was used. Then, 10 kg of wet matter was offered in two doses after each milking.

The bromatological examination of the feeds offered was carried out individually (table 4) and jointly by each experimental group (table 5), based on the proximal analysis methods of Weende and Van Soest (Van Soest et al., 1991). The animals were offered water *ad libitum.*

Table 3. Wet and dry matter intake

	Group 1 High producing animals		Group 2 Low producing animals	
Feed	**Wet matter (kg)**	**Dry matter (kg)**	**Wet matter (kg)**	**Dry matter (kg)**
Alfalfa and orchard grass	67.43	11.28	67.43	11.28
Silage	10	3.19	10	3.19
Concentrate feed	2	1.81	1	0.90
Total	79.43	16.28	78.43	15.38

Source: Elaborated by the authors

Table 4. Composition of feed offered to grazing Holstein cows

Feed	Moisture (%)	Protein (%)	Ethereal extract (%)	Ashes (%)	Organic matter (%)	NDF (%)	ADF (%)
Alfalfa and orchard grass	83.27	27.08	2.04	11.89	88.11	28.93	21.98
Silage	68.07	5.27	2.62	5.98	94.02	56.48	39.06
Feed concentrate	9.37	10.93	3.21	4.08	95.92	10.48	5.09

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Note: NDF = Neutral detergente fiber, ADF = Acid detergente fiber.
Source: Elaborated by the authors

Table 5. Diet composition per group

Total diet	Moisture (%)	Protein (%)	Ethereal extract (%)	Ashes (%)	Organic matter (%)	NDF (%)	ADF (%)
Group 1	72.06	21.00	2.28	9.89	90.10	32.19	23.44
Group 2	75.75	21.60	2.23	10.24	89.75	33.46	24.52

Note: NDF = Neutral detergente fiber, ADF = Acid detergente fiber.
Source: Elaborated by the authors

Economic analysis

The production cost analysis in an agricultural system is of vital importance to generate control of the economic and financial movements that occur in the value chain (Posadas-Domínguez et al., 2014) due to the lack of knowledge of these, generating a lack of solid sources that support the expenses over a period.

In this sense, for the analysis of feeding costs in terms of DM, equation 2 was initially applied to determine the estimated cost for pasture forage that amounts to USD 0.04 per kg of DM. This figure is derived from the total cost for establishing the pastures, equivalent to USD 570, and for the estimated production of dry matter in four years corresponding to USD 16,240 kg of DM, an approximate time that the pasture persists. The establishment cost comprises the costs of preparing the land, purchasing seeds, and fertilizing. Each of these components represents 36 %, 54 %, and 10 %, respectively, of the total forage costs.

The cost for silage is obtained employing equation 4, equivalent to USD 0.05 per kg of DM. Cultivation (61 %) and silage (49 %) costs are considered. The cultivation costs correspond to land preparation, seed purchase, fertilization, irrigation, and harvest, with participation percentages of 16.4 %, 24.6 %, 24.6 %, 8.2 %, and 26.2 %, respectively. Similarly, silage costs correspond to 53.06 % of the preparation of the silo, and the rest, is derived from other expenses.

On the other hand, applying equation 5, the estimated cost per kilogram of concentrate feed was determined, being equivalent to USD 0.39. This cost may fluctuate depending on the treatment provided to high- and low-producing cows. Likewise, the cost per kilogram for each element was calculated (table 6). The cost of the concentrate feed rises as DM intake increases with respect to the treatment of high and low producing animals. Similarly, forage intakes were calculated using equation 3 (table 7).

Table 6. Ingredients that comprise the concentrate with their inclusion percentage

Concentrate feed	Cost (USD)	Inclusion percentage per kg
Gluten	0.64	14.9
Bypass fat	1.18	2.3
Rolled corn	0.31	53.3
Molasses	0.32	4.0
Ground sorghum	0.32	24.0
Minerals	1.07	1.5

Source: Elaborated by the authors

Table 7. Cost (USD) per hectare, milk production, and intake data

Variable	High producing animals	Low producing animals
Feed concentrate cost, kg	0.39	0.39
Feed concentrate intake, kg cow day	2	1
Silage cost, kg	0.05	0.05
Silage intake, kg cow day	10	10
Pasture forage cost, kg of dry matter (DM)	0.035	0.035
Pasture forage intake, kg of DM cow day	11.28	11.28
Feed concentrate intake cost, cow day	0.79	0.39
Silage intake cost, cow day	0.51	0.51
Pasture forage intake cost, cow day	0.40	0.40
Total intake cost, cow day	1.69	1.30
Liters of milk, cow day	19.44	13.85
Price per liter of milk	0.43	0.43
Income for selling milk, hectare day	8.3	5.9
Net income, hectare	6.6	4.6

Source: Elaborated by the authors

Average milk production for cows in groups 1 and 2 corresponds to 19.44 L/day and 13.85 L/day, respectively. Additionally, the income generated by the sale of milk equivalent to USD 8.33 for group 1 and USD 5.94 for group 2 were recorded. If the feeding costs per cattle head are deducted from the income, the net income is recorded in USD 6.64 for high producing animals, and USD 4.64 for low producing animals. Feed costs represent 20.3 % for group 1, while for group 2, they represent 21.9 %.

The feed of high producing cows is higher due to the change in the kilograms of concentrate feed in the diet. It is expected that when more concentrate feed is offered, the cows have more energy to produce milk. The data analyzed per group of cows assessed in the experiment show that the net income per day is USD 60 for group 1 and USD 42 for group 2 (table 8).

Table 8. Costs and income (USD) per hectare, due to feeding and milk production

Variable	High producing animals	Low producing animals
Intake cost day (silage, feed concentrate, and forage)	15.24	11.69
Milk liters, cow day	174.96	124.65
Income from milk sale, day	75	53
Net income, hectare	60	42

Source: Elaborated by the authors

Milk production was measured using a laser system in the milking machine and recorded in a database for control and monitoring. The composition of the milk was analyzed in the Ekomilk equipment, generating data of protein, non-fat solids, and fat percentages, and milk density. In the same way, data on dry matter intake and feed conversion were analyzed. After obtaining the data, the SAS statistical program was used to obtain the means and compare them using Tukey's test (table 9).

Table 9. Milk production and composition per group

Treatment	Milk liters	Protein (%)	Fat (%)	Non-fatty solids (%)	Density	DMI (kg)	FC
Group 1	19.44[a]	3.49[a]	4.04[a]	8.82[a]	1.32[a]	16.28[a]	0.84[a]
Group 2	13.85[b]	3.44[a]	3.34[b]	8.74[a]	1.32[a]	15.38[b]	1.11[b]
SEM	1.688	0.110	0.615	0.306	0.008	0.000	0.092
p	< 0.001	0.4045	0.0291	0.5899	0.0686	< 0.001	< 0.001

Note: [ab] Values with a different letter in the same row are statistically different ($p \leq 0.05$). SEM = Standard error of the mean; DMI = Dry matter intake; FC = Feed conversion.

Source: Elaborated by the authors

In group 1 cows, the percentage of fat in milk was 4.04 and, in group 2 cows, it was 3.34 with an SEM of 0.615. This shows a higher fat content in high-production cows, a situation that could be related to the feeding process associated with the intake of concentrate feed. Feed intake was established in an average of 16.28 kg of DM for high producing cows and 15.38 kg of DM for low producing cows, showing a direct relationship between production and feeding.

On the other hand, according to the National Research Council (2001), dairy cows with an average live weight of 454 kg have a consumption of 16 kg of DM and need a diet with 15.1 % crude protein. For this study, the dry matter intake was similar, but the percentage of protein in the diet of group 1 was 21 %, while in group 2, it was 21.6 %. This shows an excess of crude protein in both groups and, most likely, an excess of energy in the cows of group 2, because their milk production is lower, and they demand a lower level of energy.

One possible cause is the use of corn as the base for the concentrate feed. Mosavi et al. (2012) found that, by resorting to different types of starches in the diet of dairy cattle with the use of corn, an increase in fat levels was obtained. By relying on the data obtained by Mosavi et al. (2012) and Castro-Hernández et al. (2014), we could assume that the increase in fat levels in group 1 is due to the excess energy provided in the diet and the type of starch used.

Application of the AHP multi-criteria method

A set of strategies was designed to minimize the costs related with the production system, considering the main problems associated with feeding costs disaggregated from the milk production process in a semi-specialized bovine system. The detail of the strategies is as follows:

i. *First strategy*. Implement a registration system for economic control and milk production to guarantee the efficient management of resources and the optimization in all farm areas (x_1).
ii. *Second strategy*. Reduction of silage to increase forages among other foods produced in the field, without generating imbalances in the diet in terms of energy, fiber, and protein at the rumen level (x_2).
iii. *Third strategy*. Design different diets considering different groups of cows, in such a way that the cheapest rations are offered to the cows with the lowest production (x_3).
iv. *Fourth strategy*. Reduction in the use of chemical fertilizers to enrich the soil, through the production of organic fertilizers with natural resources to obtain forage (x_4).

Description of the strategies

First strategy

The application of accounting tools in the management of dairy production systems allows the construction of profitability measurement indicators and generates a financial picture that facilitates control and decision-making (Posadas-Domínguez et al., 2014). The objectives that every organization wishes to achieve are based on development, stability, and obtaining profits. For the achievement of each of the established points, it is necessary to make an adequate distribution of both financial and human resources based on the information generated on the costs, which must contain each of the concepts incurred in the development of the activity, since they are a fundamental part of the economic planning and control.

Second strategy

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Reducing the use of silage is a resource of great importance that can be used to minimize the costs associated with bovine feeding. This process must be carried out, ensuring access to forages during the afternoon hours and even at night (Kismul et al., 2019). Access to pastures can be done in restricted hours, thus, delimiting this process and supplying the concentrate feed the rest of the time; this can also increase grazing efficiency (Kennedy et al., 2009). In this sense, the grazing process can be beneficial during the day (Spörndly et al., 2015); however, it is even more beneficial during the evening hours (Charlton et al., 2013). The proposal is to reduce by 50 % the silage supplied to the animals (going from 10 kg to 5 kg), and this proportion of feed is increased in forage intake, obtaining a 29 % decrease in costs per day in the reference groups.

Third strategy

The quality of the diet that constitutes the best use of feed suggests an increase in the superiority of cows and also in milk production (O'Sullivan et al., 2019). For this reason, this strategy proposes the elaboration of different diets that include silage, concentrate feed, and forages supplied according to a previous classification of cattle and depending on their current milk production rate. Thus, it is possible to reduce silage to 5 kg per group and increase the forage supply per cow by 30 %. With this, a minimization of feeding costs is achieved by USD 1.56 and USD 1.16 for groups 1 and 2, respectively. This means saving 8 % in each group.

Forth strategy

The use of fertilizers suggests a rise in gross farm income by increasing pasture yield per hectare (Macdonald et al., 2017). However, forage production represents costs associated with using fertilizers for soil enrichment that positively influence the increase in the costs of obtaining milk in bovine systems. In this sense, the use of organic fertilizer is proposed that, in addition to minimizing the costs of using fertilizers, proposes the sustainable use of field resources, so that environmental degradation is minimized. This is one of the approaches that should be used to support the transition to sustainability through the good management of natural resources (Gavito et al., 2017). Cost savings with the use of organic fertilizers can approximate up to 60 % of fertilization costs. This suggests that feeding costs are reduced by up to 20 %.

The methodology step by step

Steps one and two

Once the alternatives and the evaluation criteria have been defined, the hierarchy tree is built (figure 1), with the corresponding objective to minimize food costs associated with milk production processes.

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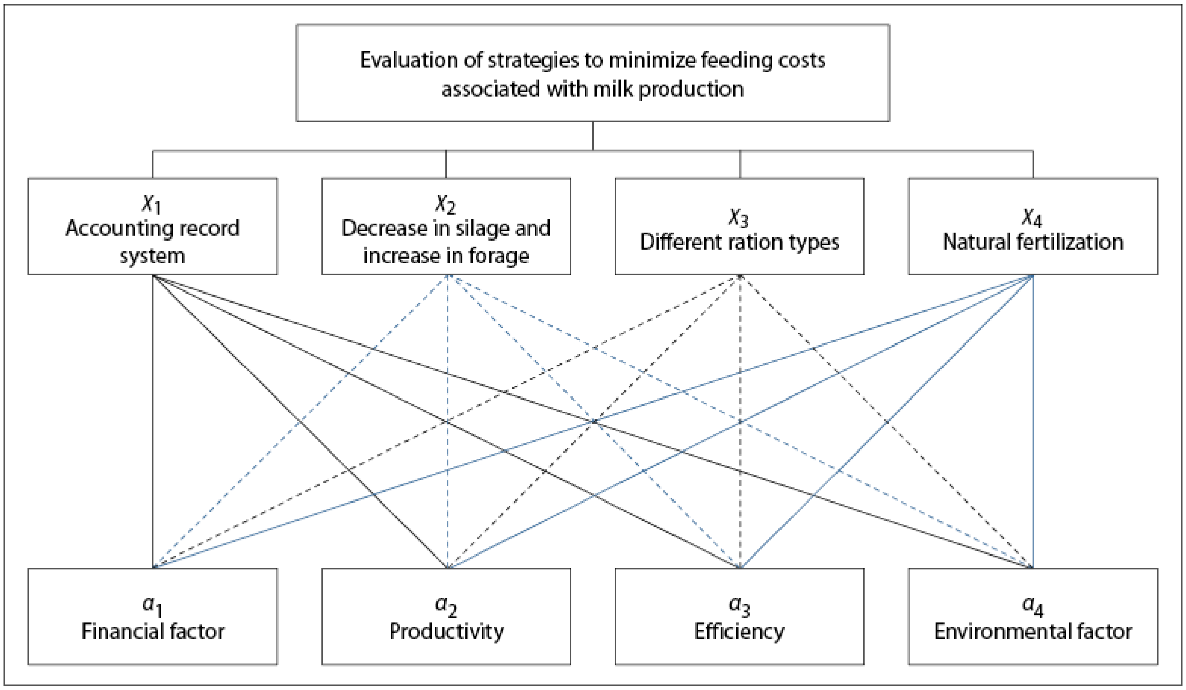

Figure 1. Tree of hierarchies to minimize feeding costs associated with milk production.

Source: Elaborated by the authors

Step three

Once the alternatives and the criteria have been defined, we order and weigh the interest of each criterion in the selection of the alternatives. The objective at this point is to measure the importance assigned by the decision-makers to each of the criteria by comparing each criterion or alternative *i* with each criterion or alternative *j*, for which the Saaty scale defined in table 2 is used. This is done to qualify the relative preferences of the elements. Each number represents the proportion of the dominance of an element with respect to a criterion, where the smallest element has the inverse value concerning the largest, which means that, if x corresponds to the number of times that an element has dominance over another element, then this last element is dominated x^{-1} times, in such a way that $x^{-1} \cdot x = x \cdot x^{-1} = 1$ (Benmouss et al., 2019).

Forth step

The weighting of the criteria allows the evaluation of the alternatives for the calculation of priorities. Subsequently, the multiplication of both matrices is carried out, in which the matrix represents the weighting of the criteria, and the 4 × 4 matrix, the weighting of the alternatives based on the criteria, resulting in the 4 × 1 matrix. This indicates which is the best alternative sequence related to the criteria.

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According to the evaluation made to the different alternatives, the most important based on the four criteria evaluated was alternative *x3* (different types of diets), with a weighting of 0.286. Alternative *x2* (reduction of concentrate feed and increasing pastures) was found in second place, with a weighting of 0.27. Alternative *x1* (registration system) is in third place with a weight of 0.258. Finally, alternative *x4* (natural fertilization) is in fourth place with a weighting of 0.231 (table 10).

Table 10. General importance position of the alternatives evaluated for cost reduction

	Alternatives				Criteria	Results
X_3	0.590	0.118	0.201	0.090	0.246	0.286
X_2	0.504	0.126	0.151	0.219	0.258	0.270
X_1	0.319	0.167	0.311	0.202	0.323	0.258
X_4	0.106	0.306	0.222	0.367	0.173	0.231

Source: Elaborated by the authors

Conclusions

The analysis of bovine systems costs facilitates control and administration for efficient decision making at an economical and productive level. Within the production costs of this type of system, the variable costs associated with food inputs represent a high percentage. In this study, feed costs based on forage, silage, and concentrate feed corresponded to 20.3 % and 21.9 % of the total income from the milk sale obtained from high and low production cows, respectively.

In the economic analysis of the variables, the participation of each of the elements that comprise it, and their impact on total costs is evidenced. Forage costs include 36 % for land preparation, 54 % for seed acquisition (alfalfa and orchard grass), and, finally, 10 % for fertilization. The costs for the production of silage are composed of 10 % for land preparation, 15 % for seed purchase (inoculant corn), 15 % for fertilization, 5 % for irrigation, 16 % for harvest, 26 % for repairing the silo, and other expenses that complete 100 %. Finally, the costs of the concentrate feed are established based on the components that are part of its production and the percentage of participation: 42 % in rolled corn, 24 % in gluten, 20 % in ground sorghum, 7 % in excess fat, 4 % in minerals, and 3 % in molasses. In this sense, the feed costs per kilogram, in terms of forage, silage, and concentrate feed, participate in 8.33 %, 12.82 %, and 81.25 %, respectively.

On the other hand, consumption and feed conversion are related to dairy production. A higher intake of dry matter allows a higher production, since the energy requirements of the cows are covered. For this case, the group of high producing animals with a production of 19.44 L/day per cow consumed 16.28 kg of DM on average, while the group of low producing animals with a production of 13.85 L/day consumed 15.38 kg DM on average. Feed conversion is affected by milk production and the kilograms of DM ingested. High producing cows need less feed intake to produce 1 L of milk, making them more profitable on the farm compared to low producing cows. The conversion was recorded at 0.84 for high producing cows and 1.11 for low producing cows.

As a result of the application of the AHP method for the design of strategies that allow the reduction of food costs, it has been found that the highest general priority has been reached by the alternative x3, called *different types of diets*. This means that this alternative is the most efficient of the four proposals with reference to the evaluated criteria when reducing feeding costs. The savings that can be achieved with the implementation of this strategy reach up to USD 444 per year under the conditions of this study.

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