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Characteristics of dairy farms with different levels of technical efficiency

Características de propriedades leiteiras com diferentes níveis de eficiência técnica

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ABSTRACT

Dairy farming is essential for Brazilian agriculture and, especially, for the Minas Gerais State. The understanding of technical efficiency and its impacts on the economic performance of dairy farms contributes to the development of the milk production chain. In the context of organizations, the Firm Theory helps in understanding how production factors affect the economic performance of these organizations, which are little studied in dairy farming. The objective of this study was to identify the main characteristics that differentiate dairy farms in the state of Minas Gerais, Brazil. For this purpose, dairy farms with different levels of efficiency (high, medium and low) were compared using data envelopment analysis (DEA), descriptive statistics and mean difference tests, analyzing socioeconomic, cost and economic performance variables. To increase the technical efficiency of dairy farms, it is important to reduce the total operating cost (TOC) and effective operating cost (EOC) by optimizing their components. However, spending on feeding (concentrated) and electricity should be increased so that the analyzed dairy farms become more efficient. In addition, the increase in the technification of dairy farms must happen, but always with caution, so that depreciation costs do not rise disproportionately. This research contributes to the advancement of scientific knowledge by applying the assumptions of the Firm Theory to dairy farming, an incipient topic in the literature. For rural producers, this research can be especially useful when presenting efficiency indicators and parameters for dairy farms, such as food costs, which must be more than 60% of the EOC.

Index terms: Firm theory; Data Envelopment Analysis (DEA); cost management; dairy cattle; milk production.

RESUMO

A pecuária leiteira é essencial para a agropecuária brasileira e, principalmente, para o estado de Minas Gerais. A eficiência técnica e seus impactos no desempenho econômico das propriedades leiteiras contribuem para o desenvolvimento da cadeia produtiva do leite. A Teoria da Firma auxilia no entendimento de como os fatores de produção afetam o desempenho econômico dessas organizações, pouco estudada na pecuária leiteira. O objetivo deste estudo foi identificar as principais características que diferenciam as propriedades leiteiras do Estado de Minas Gerais, Brasil. Para tanto, propriedades leiteiras com diferentes níveis de eficiência (alta, média e baixa) foram comparadas por meio de Análise Envoltória de Dados (DEA), estatística descritiva e testes de diferença de médias, sendo analisadas variáveis socioeconômicas, de custos e de desempenho econômico. Para aumentar a eficiência técnica de propriedades leiteiras, é importante reduzir o custo operacional total (COT) e o custo operacional efetivo (COE) otimizando seus componentes. No entanto, os gastos com alimentação (concentrada) e energia elétrica devem ser aumentados para que as propriedades leiteiras analisadas se tornem mais eficientes. Além disso, o aumento da tecnificação de propriedades leiteiras deve acontecer, mas sempre com cautela, para que os custos com depreciação não se elevem desproporcionalmente. Esta pesquisa contribui para o avanço do conhecimento científico ao aplicar os pressupostos da Teoria da Firma à pecuária leiteira, tema incipiente na literatura. Para produtores rurais, esta pesquisa pode ser especialmente útil ao apresentar indicadores e parâmetros de eficiência de propriedades leiteiras, caso dos custos com alimentação, que devem ser mais de 60% do COE.

Termos para indexação: Teoria da firma; Análise Envoltória de Dados (DEA); gestão de custos; rebanho leiteiro; produção de leite.

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INTRODUCTION

Despite the recession that has impacted and hindered national economic growth in recent years in Brazil, agriculture has been one of the main sectors of the economy that continues to grow. This is due to the high growth rates and the ability of the sector to meet the demands of the domestic market (Vilela et al., 2016). According to the Center for Advanced Studies in Applied Economics (Centro de Estudos Avançados em Economia Aplicada – CEPEA), in 2020, the gross domestic product (GDP) of agribusiness grew 24.31% compared to the previous year (Centro de Estudos Avançados em Economia Aplicada CEPEA, 2021), a rate much higher than the Brazilian GDP, which decreased by 4.1% (Instituto Brasileiro de Geografia e Estatística - IBGE, 2021). In this context, Minas Gerais stands out for being the largest milk-producing state in Brazil (Perobelli; Araújo Júnior; Castro, 2018, IBGE, 2021).

Among the production sectors making up Brazilian agriculture, the Food and Agriculture Organization (FAO) of the United Nations emphasizes that dairy farming stands out for its major contribution to the economic and social development of farmers whose income is dependent on this activity (Food and Agriculture Organization - FAO, 2020a). Studies in the literature explore issues such as production efficiency, costs and profitability in dairy farming (Lopes et al., 2004; 2011; 2021; Ferrazza et al., 2020). However, it is not clear that these studies contribute to the advancement of administrative theories, such as the Firm Theory.

The Firm Theory allows analyzing internal performance and drawing connections between market interferences and productive performance. Vasconcellos and Garcia (2009) explain that in the internal environment, this theory comprises three others: (i) Production Theory; (ii) Costs Theory; and (iii) Returns Theory. Although economic and productive efficiency is important for dairy farming (Lopes et al., 2011), the application of these concepts in the milk business has been little studied, with only one publication (Mondaini et al., 1997) addressing the topic, but superficially. Thus, the Firm Theory helps explain the efficiency and optimization of resources for production processes (Production Theory), their effects on production costs (Costs Theory) and the profitability of organizations (Returns Theory).

In order to analyze the efficiency of dairy farms, several studies have been dedicated to studying the main characteristics that differentiate more and less efficient farms (Evink; Endres, 2017; Buss; Sabbag; Mendieta, 2020; Ferrazza et al., 2020). However, studies were not found that analyzed characteristics that differ from dairy farms with different levels of technical efficiency in the state of Minas Gerais, reason that reinforces the relevance of this study.

Given the importance of dairy farming for agriculture (FAO, 2020b), this study is justified because it establishes a relationship between the assumptions of the Firm Theory, applied to dairy farming, from the perspective of efficiency in the use of inputs for production. Thus, the following question arises: What are the characteristics that differentiate dairy farms in the state of Minas Gerais with different levels of technical efficiency? To answer this research question, the following objective was established: identify the main characteristics that differentiate dairy farms in the state of Minas Gerais.

MATERIAL AND METHODS

Data were collected monthly in 2018 by expert technicians who provided technical and managerial assistance to milk farmers participating in the Educampo Project, developed by Sebrae Minas. These data were made available with a monetary correction performed through the General Price Index - Internal Availability (IGP-DI, acronym in Portuguese), an indexer from the Getúlio Vargas Foundation (FGV, acronym in Portuguese), for February 2019. It was decided to perform a new update for June 2021 using the same index (Fundação Getúlio Vargas - FGV, 2021).

The data analysis techniques used were DEA (Data Envelopment Analysis), to define efficiency scores, and descriptive analysis with a means comparison test (Charnes; Cooper; Thrall, 1991). The first procedure was to define the DEA model and orientation. Thus, it was decided to use the CCR model oriented to inputs (Gomes et al., 2018; Buss; Sabbag; Mendieta, 2020) because in dairy farms, it is understood that it is more applicable to reduce the use of inputs (without changing production) than to increase the production scale (without changing the amount of inputs used).

Next, the efficiency scores of the analyzed farms were calculated. For this purpose, using DEA, the recommendations of Ferreira and Gomes (2020) were followed: exclude missing cases, whose variables had values equal to or less than zero. Regarding outliers, the authors recommend that they be analyzed on a case-by-case basis before their exclusion. Thus, it was decided to exclude the outliers from the sample because with them, the sample became too heterogeneous. As the literature points out, dairy farms can be very different from each other regarding the type of labor used (Ferrazza et al., 2020). Lopes et al. (2004) recommend caution when analyzing dairy farms with family, hired and mixed labor, as they tend to be farms with very different characteristics. Thus, it was decided to analyze only the properties with mixed labor, in other words, there are family members and hired employees working together in the dairy activity. Thus, from the initial sample containing 485 valid cases, 200 farms classified as family or hired labor were excluded, along with 47 others because they did not meet the aforementioned DEA criteria (outliers, missing cases and negative values), with 238 farms remaining for analysis, hereinafter also called DMUs (Dyson et al., 2001).

For the definition of input variables, the classification of inputs proposed by Lopes et al. (2004) was considered: (i) labor (people/day); (ii) health (in Brazilian Real, R$/dairy farm liter); (iii) energy (R$/dairy farm liter); (iv) milking (R$/dairy farm liter); (v) artificial insemination (R$/dairy farm liter); and (vi) maintenance of machines and equipment and improvements (R$/dairy farm liter). The authors also proposed spending on feeding, but due to its high contribution in dairy farming, it was decided to analyze its two most relevant components: (vii) spending on concentrate and (viii) production of roughage. Finally, (ix) capital invested in dairy farming was also considered because it is an important productive resource of dairy farms (Evink; Endres 2017). In this study, the data did not contain information on investment in land and animals, which is why they were not considered. As an output variable, only (x) daily milk production (liters/day) was considered. Traditionally, the Golden Rule recommends that there be at least 2 to 3 times more DMUs than variables (Banker et al., 1989). Conversely, Ferreira and Gomes (2020) recommend that the number of DMUs should be at least 4 to 5 times larger than the number of variables. In this study, both criteria were met.

After linear programming analysis, which defined the efficiency scores using DEA, the dairy farms were grouped into three levels of efficiency: high, medium and low. The definition of these clusters was based on the stratification of the DMUs at the production frontier (score equal to 1.000) and the other less efficient DMUs were grouped by hierarchical cluster analysis using Ward's method with squared Euclidean distance (Hair-Júnior et al., 2005). Next, descriptive analysis and Tukey's test were performed to compare means at a significance level of 5% (Anastasiou; Gaunt, 2020) in all variables related to production costs and economic performance. MaxDEA® software was used to define the DEA efficiency scores, and IBM SPSS® was used for cluster analysis, descriptive analysis and comparisons of means.

The economic performance of the dairy farms (DMUs) was analyzed using the operating costs method proposed by Matsunaga et al. (1976), considered by Lopes et al. (2004) as an important method to analyze the production costs of dairy farms. In this method, costs and expenses are stratified into EOC, comprising the sum of disbursements of dairy farming, and TOC, comprising the sum of EOC and nondisbursable costs (family labor and depreciation) (Matsunaga et al., 1976). The authors also present the concepts of gross margins (total revenue minus EOC) and net margins (total revenue minus TOC) to determine the results of the dairy farming activity. The parity point proposed by Schoeps (1992) in the direct costing method (this method involves allocating variable direct costs to products and services) is an indicator complementary to the operational costs method, considering that it does not allow calculating the equilibrium point of dairy farming activity because it does not stratify costs into fixed and variable costs.

RESULTS AND DISCUSSION

The discriminant cluster analysis grouped the farms with scores equal to 1.000 (72 DMUs), between 0.999 and 0.765 (112 DMUs), and less than 0.764 (54 DMUs), termed DMUs with high, medium and low efficiencies, respectively. Of the DMUs with high efficiency, 52.77% were acquired by inheritance, representing the cluster with the lowest percentage of inherited farms, followed by 54.46% and 57.40% for the DMUs with medium and low efficiency, respectively. In the clusters with high, medium and low efficiencies, 38.89%, 40.04% and 38.89% of the DMUs were purchased, respectively. It is possible that farmers who buy their farms are more motivated to produce milk due to economic and social interests, among others, explaining the lower predominance of inherited farms in the comparison among groups. Only 8.44%, 4.50% and 3.71% of the high-, medium- and low-efficiency dairy farms, respectively, were obtained through leases or partnerships.

It was found that 88.89%, 89.29% and 79.63% of farmers in DMUs with high, medium and low efficiencies, respectively, are children of farmers. In addition, 59.72%, 63.39% and 55.56% of the descendants of DMU farmers with high, medium and low efficiencies, respectively, are interested in continuing the activity. In dairy farming in Minas Gerais, family tradition and generational succession in milk production seem to be elements of great importance for the sector.

The low-efficiency cluster showed a lower number of DMUs compared to the others in which milk is the main source of family income (Table 1). In addition, low-efficiency DMUs had the greatest income diversification. Income diversification can be a strategy for farmers to remain in dairy farming (Lucca; Arend, 2019). However, the diversification of farming activities can also reduce the technical efficiency of dairy farms, considering that the most efficient farms were those with dairy farming as the main or only source of family income. One explanation for this is that farms that focus on a single activity may have larger production scales than those with multiple activities, with consequent resource optimization and higher process efficiency.

Internet access was a reality in most of the analyzed dairy farms (Table 1). Internet use is especially useful for milk farmers to search for information, keeping them informed about news and innovations for the sector (Bassotto et al., 2022). It is possible that internet access contributes to dairy farms improving their technical efficiencies by allowing searches for new information.

Most of the farmers participate in collective organizations, with production cooperatives being the most common (Table 1). In addition, approximately 50% of the farmers in the three clusters participate in associations. These results indicate that in Minas Gerais, milk farmers are likely motivated to participate in collective organizations of this nature. However, less than half of the farmers participate in trade unions, indicating that farmers possibly prefer associations and/or cooperatives to unions.

There was no large variation between the number of DMUs that had environmental, legal reserve or water regularization among those with different levels of efficiency (Table 1). However, the DMUs with medium efficiency included fewer regularized farms. In Minas Gerais, milk farmers are concerned with environmental issues because on average, more than 50% of them have these regularizations.

Only 68 (28.57%) and nine (3.78%) analyzed DMUs had environmental and social certifications, respectively. The high-efficiency cluster had the highest percentage of certified farms, with 33.33% and 6.94% of these DMUs having environmental and social certifications, respectively. Environmental certifications were more common than social certifications in Minas Gerais. Notably, no studies were found that address issues related to social certifications in Brazil. It is possible that these certifications increase the technical efficiency of dairy farms, favoring the better use of productive resources. In addition, they may also be more common among more efficient farms due to higher levels of awareness of these farmers as to the importance of sustainability-related issues. Steidle-Neto and Lopes (2020) emphasize that sustainability is a current topic of fundamental importance for the sector.

Table 1: Frequency percentage of the socioeconomic characteristics of dairy farms (DMUs).

Item	Level of efficiency		
	High[1]	Medium[1]	Low[1]
Milk is the main source of family income	76.39	63.39	59.26
The farm is the only source of income	61.11	62.50	42.59
Has internet access	79.17	79.46	90.74
Participates in a production cooperative	69.44	55.36	62.96
Participates in a trade union	48.61	43.75	50.00
Participates in a credit union	27.78	25.00	24.07
Participates in an association	51.39	50.89	50.00
Has environmental regularization	54.17	49.11	57.41
Has legal reserve regularization	72.22	56.25	64.81
Has water regularization	51.39	41.96	53.70
Has environmental certification	33.33	25.00	29.63
Has social certification	6.94	2.68	1.85

Legend: DMU: decision-making unit. [1]Values expressed in percentage (%) of each cluster.

The four most prevalent dairy breeds were (i) Holstein; (ii) dairy Gyr; (iii) Jersey; and (iv) Guzerat. However, Guzerat was the least represented among the breeds used, present only in one DMU. The most predominant breed in the three analyzed clusters was Holstein, followed by dairy Gyr. None of the analyzed farms had mixed-breed cows as the predominant breed. In the studied farms, there is little diversification of breeds used for milk production, with purebred or Holstein × dairy Gyr cows predominating, with a low incidence of mixed-breed cows.

Although breed may affect milk composition (Ludovico; Trentin; Rêgo, 2019), this does not seem to have been decisive for discriminating DMUs with different levels of efficiency as to milk composition, as there was no significant difference ($p < 0.05$) among them (Table 2). The literature indicates that other factors influence milk composition, such as diet and herd health (Defante et al., 2019; Alves; Dantas; Gusmão, 2020). However, in this study, there seems to be no large effect of the technical efficiency of dairy farms regarding the use of inputs on milk composition in the analyzed farms, since there was no significant difference ($p < 0.05$).

According to Brazilian Normative Instruction no. 76/2018 (IN 76), the standard plate count (SPC) indicates the quality of milk in microbiological levels, and the lower is the SC, the better is the milk quality; the values should be less than 300,000 CFU/mL of milk (Brasil, 2018). The mean SPC of the DMUs with different levels of efficiency is well below the limits recommended by the current legislation (Table 2). However, as shown by the standard deviation (higher than the mean), the three analyzed clusters are very heterogeneous.

The somatic cell count (SCC) indicates the health of the mammary glands and, consequently, the milk quality (Alves; Dantas; Gusmão, 2020). To meet the current legislation, the SCC value should be below 500,000 CFU/mL of milk (Brasil, 2018). The mean of the DMUs with different levels of efficiency is below the maximum values recommended by the current legislation. In addition, in this study, farms with greater technical efficiency in the use of inputs did not tend to have better milk quality parameters because there was no significant difference ($p > 0.05$) among them.

Total revenues were composed of the sum of the sale of milk, animals, byproducts and extra income due to the quality and/or volume of production, discounting any penalties due to poor quality (Table 3). Bonuses for quality and volume are defined by the milk purchasing companies, whose farms that present values better than the pre-established levels are subsidized and those that do not are penalized.

There was no significant difference ($p > 0.05$) in revenue among DMUs with different levels of efficiency. Thus, in this study, different technical efficiency levels are not influenced by total revenues, sales of milk, animals and byproducts or bonuses and penalties for the quality/volume of milk sold.

There was a significant difference ($p < 0.05$) in the mean TOC among the three clusters analyzed (Table 3). The TOCs of the DMUs with low and medium efficiencies were 42.74% and 15.64% higher, respectively, than that of DMUs with high efficiency. In the farms analyzed, greater technical efficiencies were identified with the reduction in TOC. It is possible that increased efficiency in the use of inputs may contribute to less financial resources being allocated for this purpose, reducing production costs.

Table 2: Composition and quality of milk from dairy farms (DMUs).

Parameter	Item	Level of efficiency					
		High		Medium		Low	
		Mean	SD	Mean	SD	Mean	SD
Milk composition (%)	Nonfat dry extract	12.34	0.94	12.04	1.32	12.29	1.21
	Fat content	3.77	0.24	3.80	0.20	3.85	0.28
	Protein content	3.27	0.08	3.29	0.07	3.30	0.09
Milk quality (CFU/mL x 1,000)	Standard plate count (SPC)	37	47	32	58	28	46
	Somatic cell count (SCC)	372	195	414	278	391	156

Notes: There was no significant difference ($p > 0.05$) among the means for the three efficiency levels according to the Tukey test; DMU: decision-making unit.

Table 3: Economic performance of dairy farms (DMUs).

	Level of efficiency								
	High			Medium			Low		
Item	Mean	%[1]	SD	Mean	%[1]	SD	Mean	%[1]	SD
Total revenue[2]	216.12[a]	100.0	18.98	221.2[a]	100.0	24.59	217.67[a]	100.0	28.17
Milk[2]	181.98[a]	84.53	19.85	183.83[a]	83.67	17.66	180.27[a]	83.50	16.75
Additional income from quality/ volume[2]	17.08[a]	7.79	13.57	19.07[a]	8.63	13.61	18.37[a]	8.50	10.58
Bonuses[2]	17.86[a]	8.17	13.76	20.08[a]	9.09	13.80	19.84[a]	9.18	11.00
Penalties[2]	-0.78[a]	0.37	1.67	-1.01[a]	0.47	1.58	-1.48[a]	0.68	2.24
Animals[2]	15.16[a]	6.82	15.74	14.96[a]	6.32	19.15	17.18[a]	7.16	23.56
Other[2]	1.91[a]	0.86	6.01	3.34[a]	1.38	10.11	1.85[a]	0.84	3.34
Total operating cost (TOC)[2]	178.96[a]	83.15	19.80	206.94[b]	94.19	30.86	255.45[c]	118.93	42.06
Family labor[2]	9.73[a]	4.54	6.44	9.61[a]	4.44	5.75	10.68[a]	5.01	5.91
Depreciation[2]	20.03[a]	9.40	10.56	23.71[a]	10.90	11.63	32.84[b]	15.24	14.49
Effective operating cost (EOC)[2]	149.20[a]	69.21	19.58	173.62[b]	78.85	28.22	211.94[c]	98.68	35.77
Feeding[2]	94.64[a]	43.78	17.64	107.37[b]	48.87	13.56	124.21[c]	57.81	24.44
Concentrate[2]	67.41[a]	31.22	14.82	72.42[a]	32.90	12.23	81.02[b]	37.74	26.98
Forage[2]	21.02[a]	9.68	10.68	26.61[b]	12.21	9.94	33.85[c]	15.76	8.20
Minerals[2]	5.36[a]	2.48	3.63	6.98[b]	3.14	4.31	7.94[b]	3.66	4.97
Other[2]	0.85[a]	0.39	1.18	1.36[a]	0.61	1.58	1.41[a]	0.66	1.48
Hired labor[2]	20.68[a]	9.72	9.10	24.48[a]	11.17	11.46	32.46[b]	15.18	14.18
Wages[2]	16.02[a]	7.52	8.06	18.36[a]	8.41	9.33	23.74[b]	11.10	10.29
Social security[2]	2.00[a]	0.95	1.88	2.82[a]	1.27	2.36	3.86[b]	1.81	2.92
Technical assistance[2]	2.01[a]	0.95	1.27	2.63[b]	1.19	1.30	3.39[c]	1.60	2.21
Other[2]	0.65[a]	0.30	1.37	0.64[a]	0.28	1.63	1.47[b]	0.66	2.14
Energy[2]	8.50[a]	3.97	3.46	10.82[b]	4.94	4.00	13.29[c]	6.17	3.79
Electricity[2]	4.96[a]	2.31	2.28	6.20[b]	2.83	2.70	6.82[b]	3.17	2.11
Fuels[2]	3.54[a]	1.66	2.22	4.62[b]	2.11	2.53	6.47[c]	3.00	2.37
Maintenance[2]	4.89[a]	2.30	4.28	6.08[ab]	2.70	4.57	6.69[b]	3.11	4.11
Health[2]	6.78[a]	3.14	3.17	8.71[b]	3.97	3.22	10.69[c]	5.01	3.96
Preventive[2]	2.31[a]	1.08	1.63	2.38[a]	1.10	1.63	2.59[a]	1.23	1.67
Healing[2]	4.35[a]	2.01	2.34	6.13[b]	2.79	2.55	7.91[c]	3.69	3.68
Other[2]	0.12[a]	0.06	0.26	0.20[a]	0.09	0.37	0.19[a]	0.09	0.34
Milking[2]	2.66[a]	1.23	1.70	3.59[b]	1.64	1.55	4.61[c]	2.16	1.93
Fees and taxes[2]	0.34[a]	0.16	0.49	0.24[a]	0.11	0.28	0.33[a]	0.16	0.37
Artificial insemination[2]	1.65[a]	0.76	1.44	2.60[b]	1.17	1.60	3.8[c]	1.77	1.86
Other expenditure[2]	5.43[a]	2.46	7.46	4.57[a]	2.01	7.73	11.44[a]	5.30	19.76
Gross margin[2]	66.92[a]	30.79	20.18	47.57[b]	21.15	26.92	5.73[c]	1.32	45.01
Net margin[2]	37.16[a]	16.85	22.04	14.26[b]	5.81	31.36	-37.79[c]	-18.93	49.74

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Table 3: Continuation.

	Level of efficiency								
	High			Medium			Low		
Item	Mean	%[1]	SD	Mean	%[1]	SD	Mean	%[1]	SD
Profitability (%)	16.85[a]	-	9.43	5.81[b]	-	14.46	-18.93[c]	-	24.05
Labor (Number of people)	3.9[a]	-	2.14	4.6[a]	-	3.51	4.1[a]	-	2.60
Hired (Number of people)	2.8[a]	-	2.20	3.5[a]	-	3.24	3.2[a]	-	2.57
Family (Number of people)	1.2[a]	-	0.9	1.1[a]	-	0.8	0.9[a]	-	0.6
Productivity (liters/person/day)	448[a]	-	191.9	427[a]	-	153	319[b]	-	108
Production (liters/day)	1.900[ab]	-	1.752.1	2.066[a]	-	1.762	1.331[b]	-	1.059
Parity point - PP (liters/day)	1.566[a]	-	1.500	1922[a]	-	1.663	1.512[a]	-	1.070
Production – PP difference (liters)[3]	334[a]	-	312	145[b]	-	345	-182[c]	-	268

Notes: Different letters in the same row indicate significant differences between the means ($p < 0.05$) according to the Tukey test; DMU: decision-making unit; [1]Percentage of total revenue; [2]Indices expressed in R$/100 liter; [3]Daily milk production subtracted from the production at the parity point.

Among the components of TOC, there was a significant difference ($p < 0.05$) in depreciation between DMUs with low efficiency and those with high and medium efficiencies, which were similar to each other (Table 3). The DMUs with low efficiency had 63.95% higher depreciation than those with high efficiency (with $p < 0.05$). It is possible that in low-efficiency DMUs, there is greater capital invested in dairy farming activities, a condition that would explain such an increase, indicating that these farms need to have larger production scales so that the share of depreciation is minimized because, according to Ferrazza et al. (2020), depreciation is considered a fixed cost of dairy farming.

The EOC of DMUs with low and medium efficiencies was, on average, 42.05% and 15.37% higher than that of DMUs with high efficiency ($p < 0.05$; Table 3). These results suggest that more efficient dairy farms have a lower EOC than others and are less efficient due to, among other factors, the better use of inputs. Among the components of EOC, feeding costs are considered the most significant, equivalent to approximately 60% of the EOC (Lopes et al., 2004). In this study, feeding represented 63.43%, 61.84% and 58.61% of the EOC in the clusters with high, medium and low efficiencies, respectively ($p < 0.05$). Feeding costs should only be reduced if doing so does not negatively affect the nutrition of the herd. Similarly, it is possible that more efficient farms are those that have lower EOCs but a higher concentration of expenditure on animal feeding (greater than 60% of the EOC).

Feeding costs were stratified into roughage, concentrate, minerals and other (Table 3). Roughage feeding was significantly different ($p < 0.05$) among the three clusters analyzed, with a reduction in its use as the efficiency level of the DMUs increased. Spending on roughage represented 14.09%, 15.33% and 15.97% of feeding costs in the DMUs with high, medium and low efficiencies, respectively ($p<0.05$). For better technical efficiencies, it is possible that dairy farms have to dedicate approximately 14% of the total amount spent on feeding to the production of roughage to ensure high quantity and quality in the production of feeds of this nature. These results were higher than those found by Santos and Lopes et al. (2012), who identified a share of 11.48% for this feeding component.

The DMUs with low efficiency had 11.88% and 20.19% higher consumption of concentrated feed than those with medium and high efficiencies ($p < 0.05$). It is possible that in these farms, there was a waste of concentrates caused by issues such as misuse, storage, poor roughage quality or overfeeding, among others. Lazarini, Lopes and Cardoso (2017) emphasize that improperly used concentrate supplementation (without a balanced diet) increases costs via the use of excess inputs (overfeeding) or by reducing milk production due to nutritional problems (underfeeding). However, in this study, concentrates represented 38.23%, 41.71% and 45.18% of feeding costs in DMUs with low, medium and high efficiencies, respectively. Although the most efficient DMUs spent less on concentrate (Table 3), the share of this input in feeding was higher, suggesting that in these farms, there was a greater balance between the amount of resources intended for feeding that should be used in conjunction with concentrates.

Hired labor differed significantly ($p<0.05$) only between the DMUs with low efficiency and the others

(Table 3). The amount spent on hired labor is usually the second most important item in the EOC, varying according to the type of labor on a farm, which can be family, hired or mixed labor (Lopes et al., 2006; Ferrazza et al., 2020). In this study, only farms with mixed labor were considered; therefore, it is possible that the significant difference ($p < 0.05$) is linked to issues such as the efficiency of the labor used, the number of family members working or the level of technification of the analyzed farms.

In this study, there was not a fewer number of people working in the activity on the most efficient farms ($p > 0.05$; Table 3). However, because only the farms with low efficiency were significantly different ($p < 0.05$) from the others, it is possible that in these cases, the increase in the workforce used is linked to a greater number of registered employees, considering that there was a significant difference ($p < 0.05$) in wages and social security payments only between the cluster with low efficiency and the others.

Farms with high efficiency, on average, spent less on technical assistance than those with medium and low efficiencies ($p < 0.05$; Table 3). Technical assistance is essential for the development of dairy farms, contributing to increased production scale (Gomes et al. 2018) and productivity. Thus, higher expenditure on quality technical assistance contributes to increased process efficiency and production scale. As a consequence, unit costs can be reduced.

Energy costs include expenditures on electricity and fuels (Table 3). In DMUs with medium and low efficiencies, these expenditures were, on average, 27.29% and 56.35% higher, respectively, than those of DMUs with high efficiency ($p < 0.05$). The higher is the efficiency of DMUs, the greater is the share of electricity in total energy (51.33%, low efficiency; 57.28%, medium efficiency; and 58.36%, high efficiency). Likewise, proportionally, fuel consumption decreased with the percentage increase in energy consumption and, consequently, in the efficiency level of DMUs.

The results for energy and its components (Table 3) suggest that for there to be an increase in the technical efficiency of dairy farms, two conditions, among others, are necessary: reduction in energy costs and greater use of electricity than fuels. The high use of fuels can indicate a greater number of machines invested in dairy farming and, in turn, contribute to the increased maintenance of machines, equipment and implements. Such maintenance was significantly different ($p < 0.05$) only between DMUs with high and low efficiencies, reinforcing this understanding. Managers should be concerned with these costs because they are linked to farms with high invested capital, impacting production costs.

The health group comprises costs related to the health of the animals, whether preventive or curative. There was a significant difference ($p < 0.05$; Table 3) among the three clusters, indicating that the most efficient DMUs spent more on health, especially on curative health. It is possible that on more efficient farms, the animals present lower risks of diseases, explaining the low use of inputs for curative health. According to Lopes et al. (2011), this is associated with the efficiency of the production process.

Milking costs were significantly different ($p < 0.05$) among the three clusters analyzed (Table 3); the DMUs with high efficiency were those that spent less on these inputs. Milking processes are especially important because they contribute to the income generation of dairy farms, resulting from the additional income from milk quality (Alves; Dantas; Gusmão, 2020). That is, the most efficient DMUs with better performance in milking processes may have used inputs associated with milking processes with greater efficiency. However, because there was no significant difference ($p > 0.05$) in milk quality (Table 2), it is possible that the reduction in spending on milking materials in this study did not have a significant impact on milk quality and, consequently, on revenue from bonuses, provided that the ideal conditions for the milk to be considered good quality were appropriately met.

The DMUs with medium and low efficiencies spent, on average, 57.58% and 130.30% more, respectively, on artificial insemination than did those with high efficiency (Table 3). The lower costs of artificial insemination are related to more efficient herd health and nutrition. Morais et al. (2020) corroborate this interpretation and add that this occurs due to higher pregnancy rates of cows, indicating higher efficiency.

The gross margin is the difference between total revenues and the EOC (Ferrazza et al., 2020). In DMUs with high efficiency, the gross margin was, on average, 40.68% and 1,067.89% higher than that of DMUs with medium and low efficiencies, respectively ($p<0.05$; Table 3). This implies that the maximization of inputs was essential for this indicator to increase, allowing the conclusion that the greater is the technical efficiency of dairy farms, the greater the gross margin of the activity will be.

The net margin is the difference between the total revenues and the TOC (Ferrazza et al., 2020), differing significantly ($p < 0.05$) among the three clusters analyzed, with the DMUs with low efficiency being the only ones with a negative net margin (Table 3). The DMUs with high efficiency had a 162.43% higher net margin than those with medium efficiency. These results indicate that efficiency in the use of inputs is essential for dairy farms to have high net margins. Similarly, it is possible that net margin can be considered an indicator of the technical efficiency of dairy farms.

The profitability of DMUs with high, medium and low efficiencies was 16.85%, 14.46% and -18.93%, respectively ($p < 0.05$; Table 3). These results reinforce the understanding that the efficiency of the production process of dairy farms is essential for better economic/financial performance, corroborating Lopes et al. (2021), who show the importance of this indicator for dairy activity. The farms with the highest profitability were the most technically efficient.

There was a significant difference ($p < 0.05$) in labor productivity (liters/person/day) only between the DMUs with low efficiency and the others (Table 3). This indicator is essential for analyzing the efficiency of the labor used in dairy farming (Lopes et al., 2004). Farms with low efficiency may have used more workers to perform milk production activities. The most technically efficient dairy farms were those that presented higher profitability.

One of the limitations of the operating costs method is that it does not stratify costs into fixed and variable costs, preventing a break-even point from being calculated. In his article published on the direct costing method, Schoeps (1992) proposed the parity point indicator, which allows portraying production at the time when total revenue and total cost are equal, a concept equivalent to the break-even point. This indicator can be expressed in production units, in monetary units or as a percentage (Schoeps, 1992). In dairy farming, the parity point allows analyzing the moment when revenues will be equal to the TOC, giving a net margin equal to zero, which is why it was adopted in this study. In addition, for farms whose variable costs are greater than the revenue from milk sales (negative contribution margin), a break-even point cannot be calculated, a condition that does not occur with the parity point, whose results will never be negative. To calculate the parity point, in this study, the following Equation 1 was used (result expressed in liters):

$$PP = \frac{TOC}{MR} \quad (1)$$

where,
PP is the parity point (liters);
TOC is the total operating cost (R$); and
MR is the total revenue per liter of milk (R$/liter).

In this study, there was no significant difference ($p > 0.05$) in the parity point among the DMUs with different levels of efficiency (Table 3). However, more efficient farms may reduce the TOC, contributing to the aforementioned indicator being lower. In this regard, because more efficient farms tend to have lower TOCs, it is possible that this indicator is lower in scenarios of higher technical efficiency. Only in the DMUs with low efficiency was the parity point higher than the average milk production/day (Table 3), indicating that on average, these farms could not reach the minimum amount of milk necessary to have a net margin equal to zero.

The production – PP difference is the daily milk production subtracted from the production at the parity point. There was a significant difference ($p < 0.05$) in this indicator among the three clusters analyzed (Table 3). Only the farms with low efficiency showed a negative production – PP difference, indicating that milk production is below the parity point. This may be an indication of risk for these farms because the actual production is lower than that required to cover the expenditures. The farms with high efficiency were the ones that showed the largest production – PP difference. This greater difference suggests that these farms are less likely to have losses.

The correct technification of dairy farming contributes to an increase in invested capital and subsequent improvements in efficiency (Evink; Endres, 2017). Given this, it is possible that DMUs with low efficiency invest their capital inappropriately, not favoring an increase in the efficiency of production. It is essential that decision-makers analyze the economic and financial viability of investments to be made before their implementation to increase the possibilities of return on invested capital without unnecessarily burdening production costs.

With the results of this study, it was possible to identify the main factors that affect the technical efficiency of dairy farms from the perspective of inputs (Figure 1). The arrows inside the boxes indicate the ideal behavior of the resource for dairy farms to become more efficient, and the arrows outside the boxes indicate the flow of resources for greater technical efficiency. For the technical efficiency of DMUs to increase, there must be a reduction in the TOC, which, according to Ferrazza et al. (2020), is composed of family labor, depreciation and EOC. Because there was no significant difference ($p < 0.05$) in family labor among the three analyzed clusters (Table 3), for there to be a reduction in TOC (to increase technical efficiency), it is necessary to reduce depreciation and the EOC without compromising revenue.

Depreciation is influenced by the level of technological development and capital invested in dairy farming (Figure 1). Thus, it is suggested that reducing invested capital or increasing the scale of production to levels higher than the increase in the investment level is important for dairy farms to work with minimal investments without compromising production efficiency. However, according to Evink and Endres (2017), there must be an increase in the technological development of production processes, which is mainly occur through increased investments. To solve this dilemma, it is important for decision-makers to evaluate whether making new investments will contribute to an increase in the production scale.

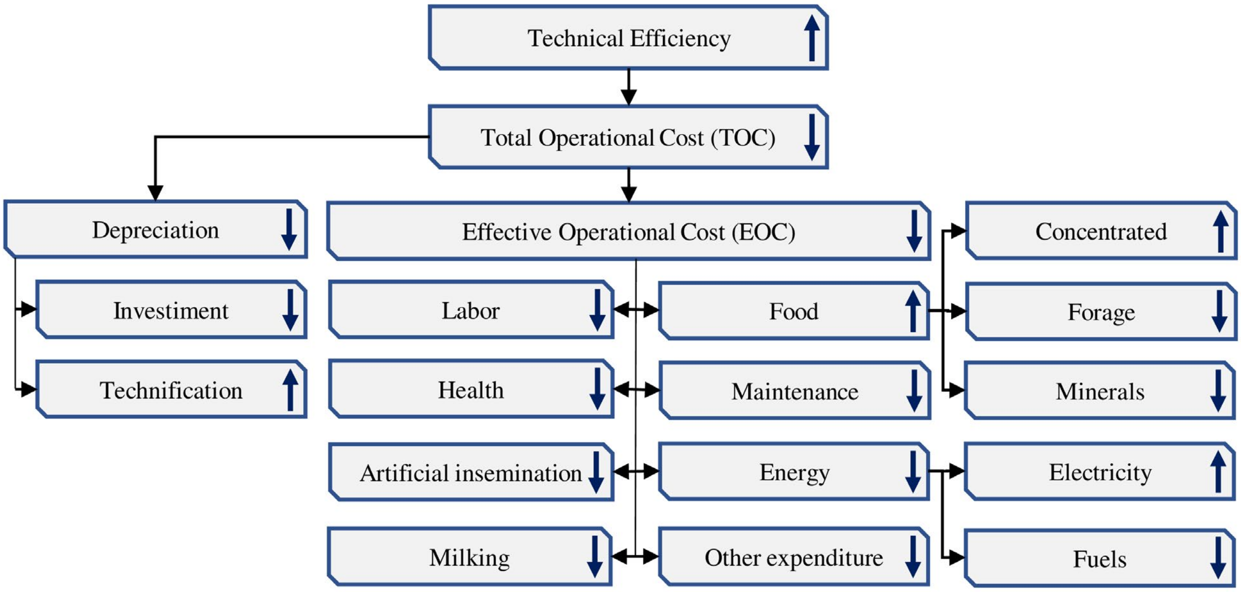

Figure 1: Behavior of different inputs as a function of increased technical efficiency of dairy farms in the state of Minas Gerais

Note: The direction of the arrows inside the boxes indicates the ideal behavior of the input to contribute to an increase in the efficiency of dairy farms.

For the EOC to decrease, it is necessary to improve the use of resources, thus reducing the total amount spent (Figure 1). However, it is necessary for there to be variation in the share of each EOC component in the total value. In this context, the absolute and percentage values of the EOC components (except feeding) over the EOC must be reduced so that EOC can decrease. Although it is important to reduce spending on feeding (without compromising the nutritional quality of the herd), it is possible that to increase the technical efficiency of dairy farms, the percentage of expenses with feeding (over the EOC) should be reduced to amounts lower than the other components of the referred cost indicator, a condition that would cause its share of the EOC to increase. In addition, the results suggest that farms that use more electricity have better technical efficiencies than do those that use more fuels.

Among the main components of feeding, the results also suggest that the share of spending on concentrate feed should be increased and that the share of the other components (roughage and minerals) in the EOC should be reduced (Figure 1), considering that the DMUs with high efficiency spent 45.18% of the EOC on concentrate. However, an increase in concentrate feeding should only be done if the amount and quality of roughage is sufficient. Thus, it is understood that such analyses are only possible on farms that do not have nutritional problems within the herd.

CONCLUSIONS

Dairy farms with different levels of efficiency had characteristics that differentiated them and that there were main aspects that influenced the technical efficiency of these farms. Further studies should be conducted mainly focused on measuring how these indicators behave between farms with family and mixed labor.

AUTHOR CONTRIBUTIONS

Conceptual Idea: Bassotto, L. C.; Lima, A. L. R.; Data collection: Bassotto, L.C.; Lima, A. L. R.; Data analysis and interpretation: Bassotto, L.C.; Nascimento, E.F.R., Writing and editing: Bassotto, L.C.; Nascimento, E.F.R.; Reviewer: Bassotto, L.C.; Lopes, M. A.; Carvalho, F. M.; Lima, A. L. R.; Lima Netto, E. P.

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