Association between technical and economic performance indexes and dairy farm profitability

Rodrigo de Andrade Ferrazza[1] (iD) **, Marcos Aurélio Lopes[2]*** (iD) **, Danielle Gonçalves de Oliveira Prado[3]** (iD) **, Renato Ribeiro de Lima[3]** (iD) **, Fabio Raphael Pascoti Bruhn[2]** (iD)

[1] Universidade Federal de Lavras, Departamento de Zootecnia, Lavras, MG, Brasil.
[2] Universidade Federal de Lavras, Departamento de Medicina Veterinária, Lavras, MG, Brasil.
[3] Universidade Federal de Lavras, Departamento de Ciências Exatas, Lavras, MG, Brasil.

*Corresponding author:
malopes@ufla.br

ABSTRACT - This study aimed to evaluate the determinant profitability indexes of typical dairy farms located in Brazil. The empirical sample included detailed technical and financial information of 61 Brazilian dairy farms across a longitudinal data set (10 years). Numerous technical and economic indexes were estimated, and Pearson's correlation coefficients were calculated to determine the relationship between each index and profitability. After selecting the significant indexes, regression equations were generated to determine the relationship between each index and profitability. The results of the analysis revealed significant interactions between different combinations of technical and financial indexes. Milk production per lactating cow and area were the indexes most positively correlated with profitability. In contrast, total unit cost in relation to the price of milk, total operating cost in relation to total revenues, and total unit operating cost in relation to the price of milk were the indexes most negatively correlated with profitability. Overall, these results indicate that profits could significantly increase if dairy farm production is conducted with more intensive use of inputs and production factors and better combinations of inputs and outputs.

Keywords: benchmark, dairy cattle, efficiency, profit, rural management

Introduction

In recent decades, there has been a structural shift in dairy farming systems worldwide towards an increase in herd size and a decrease in the number of farms (Breustedt and Glauben, 2007). In this context, researchers have suggested that improving the technical efficiency is a key factor leading to higher profitability and greater competitiveness in the dairy sector (Tauer and Belbase, 1987; Tauer, 2001; Alvarez et al., 2008; Mor and Sharma, 2012). However, an increase in annual profit achieved by maximizing only technical efficiency can hinder profitability in some cases (St-Pierre, 2001). Hence, farm efficiency should be evaluated by concurrently considering technical performance and economic outputs.

Although there is a body of evidence documenting that various production practices or technologies may affect profitability (Gloy et al., 2002; Tauer and Mishra, 2006; Cabrera et al., 2010), the current economic conditions require producers to refocus on farm efficiency. Benchmarks have emerged as important tools guiding farmers through the decision-making process and project management to ensure economic efficiency. However, identifying the most efficient benchmarks that directly or indirectly affect other factors, such as profitability, based on several partial measures of efficiency,

2

Association between technical and economic performance indexes and dairy farm profitability
Ferrazza et al.

including milk production per cow, milk sold per worker, or costs per unit of milk produced, is challenging for producers. Studies investigating farm efficiency and the indexes most correlated with profitability are important from the point of views of both practicality and policy (Solís et al., 2009). Farmers could use this information to improve their performance and prevent future mistakes that could cause great economic loss. Furthermore, policymakers could use this knowledge to identify and target public interventions to improve farm productivity and economics.

A previous study used a Monte Carlo simulation to predict the key performance indicators that were tightly related to long-term financial performance in dairy herds (Kristensen et al., 2008). However, mathematical simulation models lack the credibility of field conditions because they do not account for potential interactions or herd dynamics. Here, we hypothesized that the efficiency level of dairy farms determines profitability, which could be monitored indirectly by key performance indicators. Thus, the objective of this study was to evaluate the determinant indexes of profitability in typical dairy farms located in Brazil.

Material and Methods

We studied a sample of 61 typical Brazilian dairy farms located in the state of Minas Gerais. Non-probability sampling was conducted based on the availability and consent of producers who agreed to participate in this study without a financial incentive. The sample of farms used in the present study was characterized by significant differences in husbandry systems, herd composition, technology and production levels, area, etc. The pastured-based systems were characterized by traditional farms composed of crossbred animals (Holstein × Zebu) grazing on *Brachiaria* and/or native grass with supplementation with a commercial corn and soybean-based concentrate during the entire year. During the dry season, when the pastures were severely impaired, the cows were fed limited amounts of corn silage, chopped whole sugarcane, or chopped elephant grass. The semi-confinement systems were characterized by technologically improved systems. During the rainy season, the crossbred cows grazed on rotational pasture of more productive species of grasses, such as varieties of *Panicum maximum* (cv. Tanzânia or Mombaça) and *Cynondon dactilon* cv. Tifton 85. During winter, the forage was composed of corn silage or chopped whole sugarcane. Concentrate feed was supplied the entire year. The confinement systems were composed of pure Holstein cows stocked in free-stall structures and fed a total mixed ration based on corn silage. The daily milk production varied from approximately 48 to 12,775 L/day, and the area used varied from 0.5 to 376 ha (Table 1).

Information regarding production, costs, and profit was performed monthly at the farm level. In an effort to test the robustness of the analysis across different years and milk price ranges, data were

Table 1 - Descriptive statistics of the size and animal performance indexes of 61 milk production systems

Index	Unit	Mean	Minimum	Maximum	SD
DMP	L/day	932.8	47.6	12,774.5	2,183.6
Ar	ha	65.3	0.5	375.5	72.7
HL	wd	2.8	1.0	16.0	3.0
FL	wd	0.5	0.0	2.0	0.5
DCN	head	62.9	5.7	980.0	138.8
DCSR	head/ha	1.4	0.2	11.8	1.7
AMP/DCN	L/year	4,254.9	1,500.8	10,856.2	1,764.2
DCN/L	head/wd	13.6	2.8	65.3	11.2
AMP/L	L/wd	171.1	31.5	1,039.3	195.4
AMP/Ar	L/ha/year	6,100.0	421.8	71,126.0	9,674.9

SD - standard deviation; DMP - daily milk production; Ar - area stocked with dairy cows; HL - hired labour; FL - family labour; DCN - dairy cow number; DCSR - dairy cow stocking rate; AMP/DCN - annual milk production per dairy cow; DCN/L - dairy cows per labour unit; AMP/L - annual milk production per labour unit; AMP/Ar - annual milk production per area.

collected from all dairy farms over a continuous prolonged period of 10 years (2002 to 2011). Monthly prices were deflated to August 2019 by the General Price Index of Internal Availability (IGP-DI) of the Instituto Brasileiro de Economia of the Getúlio Vargas Foundation (Portal Brasil, 2019). Several indexes were selected and estimated according to data availability and relevance (Table 2). Three farms were excluded from the initial sample due to lack of data.

The operating costs method proposed by Matsunaga et al. (1976) and total costs method proposed by Lopes et al. (2007) were applied to estimate the costs. For the calculations of the production costs, the following criteria were considered: the rate of return on capital at 6% per year, which generally corresponds to the interest rate of savings; the linear depreciation method was used to represent the cost required to replace assets that are used in milk production activity and related to physical or economic wear, which is expressed as $D = \dfrac{P_c - S_v}{U_l}$, in which D = annual depreciation value, P_c = purchase cost (new asset), S_v = salvage value, and U_l = useful life (Hoffmann, 1987); and the grouping of items that constitute the effective operating costs of milk production (labour, feed, health, breeding, milking, fixed taxes, electric power, and miscellaneous expenses). Expenses related to the use of recombinant bovine somatotropin were allocated to health, whereas expenses related to machinery rental were allocated to other expenses. The representation of these items in relation to the total cost (TC) and effective operating cost (EOC), which were expressed as percentages, was also calculated. The method proposed

Table 2- Index descriptions, abbreviations, equations, and units

Index	Abbreviation	Equation	Unit
Size indexes			
Daily milk production	DMP	-	L/day
Area stocked with dairy cows	Ar	-	ha
Hired labour	HL	-	wd
Family labour	FL	-	wd
Dairy cow number	DCN	-	head
Technical indexes			
Dairy cow stocking rate	DCSR	Number of dairy cows/Area	head/ha
Milk production per dairy cow	AMP/DCN	Annual milk production/Dairy cow number	L/year
Dairy cows per labour unit	DCN/L	Dairy cow number/Total annual labour	head/wd
Annual milk production per labour unit	AMP/L	Annual milk production/Total annual labour	L/wd
Annual milk production per area	AMP/Ar	Annual milk production/Farm area	L/ha/year
Economic indexes			
Milk gross profit (MGR) per total gross profit (TGR)	MGR/TGR	MGR/TGR × 100	%
Effective operating cost (EOC) per TGR	EOC/TGR	(EOC/TGR) × 100	%
Total operating cost (TOC) per TGR	TOC/TGR	(TOC/TGR) × 100	%
Unitary EOC per milk price (MP)	EOCun/MP	(EOCun/MP) × 100	%
Unitary TOC per milk price	TOCun/MP	(TOCun/MP) × 100	%
Total unitary cost per milk price	TCun/MP	(TCun/MP) × 100	%
Ratio of fixed cost per total cost	FC/TC	(FC/TC) × 100 (%)	%
Depreciation per TOC	D/TOC	(D/TOC) × 100	%
Profitability	PFT	(Net margin/Total gross profit) × 100	%
Representativity of items in the total cost	Feed, Labour, Health etc./TC	(Feed, Labour, Health etc./TC) × 100	%
Representativity of items in the EOC	Feed, Labour, Health etc./EOC	(Feed, Labour, Health etc./EOC) × 100	%
Labour to feed ratio	L/F	(Labour/Feed) × 100	%

4

Association between technical and economic performance indexes and dairy farm profitability
Ferrazza et al.

by Lopes et al. (2011) was used to calculate profitability and return on capital. All calculations were performed using MS Excel® spreadsheets (Microsoft Corp., Redmond, WA, USA).

Descriptive statistics (mean, minimum value, maximum value, and standard deviation) were used to describe the database. To investigate the indexes that affect the economic performance of dairy production systems, we used Pearson's correlation coefficient. A 90% confidence level was adopted. To quantify the significant indexes after selection, linear regression equations were generated for each index relative to profitability. The linear regression equation was as follows:

$$Y_i = \beta_{0i} + \beta_{1i}x,$$

in which β_0 is the intercept coefficient; β_1 is the coefficient of x, which is the value attributed to the respective indicators; and Y_i is the profitability value. All statistical analyses were performed using the functions cor and lm of the statistical software system R version 2.15.2 (The R Foundation for Statistical Computing, Vienna, Austria; http://www.r-project.org/).

Results

The economic indexes analysed showed large variation among the sampled farms (Table 3). Feeding, followed by labour, was the most significant component of EOC and TC. On average, feeding represented 58.8±11.0 and 37.5±10.7% of EOC and TC, respectively, while labour represented 15.0±10.9 and 9.7±6.8% of EOC and TC, respectively (Table 3). We observed that the indexes that were most negatively correlated with profitability were total unitary cost by milk price (TCun/MP), total operating cost by total gross profit (TOC/TGR), and unitary total operating cost by milk price (TOCun/MP; Table 4). The production per lactating cow (AMP/DCN) was more closely correlated with profitability (r = 0.30) than land (AMP/Ar; r = 0.25) and labour (AMP/L; r = 0.19) productivity (Table 4). No significant correlation (P>0.10) was identified between the number of lactating cows in the herd (DCN) and profitability (Table 4). The impact of the intensification on farm efficiency is better illustrated in Figure 1. The difference among the farms reflects disparities across farms in milk production per cow. Profitability increased as the milk production per cow increased. The mathematical equations indicated the magnitude of the increase in profitability based on the substitution of values corresponding to the predictor variable in the regression function (Table 5). The high dispersion in the regression represented the effect of the variability in managerial decisions and practices among the farms.

Discussion

In this study, the data were collected from typical farms in the state of Minas Gerais, Brazil, which has traditionally been the top state in terms of milk production and dairy farming in Brazil. Recent data show that the 216,419 dairy farms located in the state of Minas Gerais produce approximately 8.9 billion litres of milk per year from milking approximately 3.4 million cows (IBGE, 2017). The average daily milk production of the sampled production systems (932.8±2,183.6 L/day; Table 1) was greater than that of all systems in the state of Minas Gerais (184.8 L/day; FAEMG, 2006). The studied production systems used on average 2.8±3.0 hired workers and 0.5±0.5 family workers, while the mean number of lactating cows in the sample herd was 62.9±138.8 heads, which was approximately 3.6 times greater than the value assessed in all farms in the state of Minas Gerais (FAEMG, 2006). Similar to our results, another study reported an average daily milk production of 769.6 L, employment of 2.6 hired workers, and 58.7 lactating cows in a set of 159 farms located in the Triângulo Mineiro – Alto Paranaíba mesoregion in the state of Minas Gerais (Pereira et al., 2016). This disparity may be explained by the sample containing a non-random selection of milk producers in the region under study. Therefore, while these farms are not necessarily representative of the entire dairy industry or specific dairy regions in Brazil, they provide information regarding the identification of appropriate benchmarks in heterogeneous areas that can explain differences in efficiency among farms and can be applied to other areas (Fassio et al., 2006; Oliveira et al., 2016; Pereira et al., 2016).

As expected, profitability figures varied among sampled farms (Table 3). On average, over the 10-year period, 30 (49.2%) farms presented negative profitability, while 31 (50.8%) farms had positive profitability. Our previous data demonstrated that profitability was unaffected by production scale (Ferrazza et al., 2018), suggesting there is great variation in net returns within each production strata. Thus, although a greater production scale is a desirable condition, it fails to ensure better economic results in the herds studied. Other studies have reported that the increase in milk production was the most important factor influencing the variation of economic performance among farms (Nehring et al., 2009; Wilson, 2011). The herd profile and technological differences among the systems are possible explanations for this discrepancy. Furthermore, it has also been previously reported that variability of milk price has greatest influence on profitability (Ruelle et al., 2018). Hence, in an era of increased levels of milk price volatility (Hemme et al., 2014), producers require to maximize production efficiencies and, in particular, business resilience (Shadbolt, 2012).

Table 3 - Descriptive statistics of the economic indexes of 61 milk production systems, expressed as %

Index	Mean	Minimum	Maximum	SD
MGR/TGR	87.2	53.8	100.0	11.7
EOC/TGR	64.5	37.5	125.5	19.0
TOC/TGR	79.8	52.1	133.3	18.6
EOCun/MP	74.4	46.7	137.9	20.5
TOCun/MP	92.2	60.1	151.1	20.9
TCun/MP	19.1	71.8	281.8	32.4
FC/TC	28.7	58.3	4.5	12.8
D/TOC	11.5	0.0	30.8	6.1
PFT	−1.0	−56.5	35.7	22.1
F/TC	37.5	12.9	63.8	10.7
L/TC	9.7	0.0	24.4	6.8
H/TC	3.5	0.4	14.0	2.2
B/TC	0.6	0.0	5.1	1.1
M/TC	0.8	0.0	3.7	0.9
FT/TC	0.4	0.0	7.9	1.1
E/TC	4.0	0.5	10.0	2.3
ME/TC	7.4	0.0	21.4	4.5
F/EOC	58.8	32.2	84.0	11.0
L/EOC	15.0	0.0	45.3	10.9
H/EOC	5.3	1.0	15.3	2.6
B/EOC	0.8	0.0	6.0	1.4
M/EOC	1.1	0.0	4.3	1.1
FT/EOC	0.6	0.0	9.3	1.3
E/EOC	6.8	0.9	21.9	4.3
ME/EOC	11.6	0.0	28.7	6.4
L/F	30.0	0.0	127.5	28.3

SD - standard deviation; MGR/TGR - milk gross profit per total gross profit; EOC/TGR - effective operating cost per total gross profit; TOC/TGR - total operating cost per total gross profit; EOCun/MP - unitary effective operating cost per milk price; TOCun/MP - unitary total operating cost per milk price; TCun/MP - total unitary cost per milk price; FC/TC - fixed cost to total cost ratio; D/TOC - depreciation per total operating cost; PFT - profitability; F/TC - representativity of feed in the total cost; L/TC - representativity of labour in the total cost; H/TC - representativity of health in the total cost; B/TC - representativity of breeding in the total cost; M/TC - representativity of milking in the total cost; FT/TC - representativity of fixed taxes in the total cost; E/TC - representativity of electric power in the total cost; ME/TC - representativity of miscellaneous expenses in the total cost; F/EOC - representativity of feed in the effective operating cost; L/EOC - representativity of labour in the effective operating cost; H/EOC - representativity of health in the effective operating cost; B/EOC - representativity of breeding in the effective operating cost; M/EOC - representativity of milking in the effective operating cost; FT/EOC - representativity of fixed taxes in the effective operating cost; E/EOC - representativity of electric power in the effective operating cost; ME/EOC - representativity of miscellaneous expenses in the effective operating cost; L/F - labour to feed ratio.

6

Association between technical and economic performance indexes and dairy farm profitability
Ferrazza et al.

Table 4 - Pearson's product-moment correlation coefficient (CC) and descriptive level of probability (P-value) of the indexes evaluated for profitability

Index	Unit	CC	P-value
DMP	L/day	0.15	0.256
Ar	ha	−0.05	0.678
HL	wd	0.08	0.534
FL	wd	0.02	0.859
DCN	head	0.15	0.240
DCSR	head/ha	0.23	0.071*
AMP/DCN	L/year	0.30	0.017*
DCN/L	head/wd	0.20	0.125
AMP/L	L/wd	0.19	0.142
AMP/Ar	L/ha/year	0.26	0.047*
MGR/TGR	%	−0.24	0.061*
EOC/TGR	%	−0.51	<0.001*
TOC/TGR	%	−0.79	<0.001*
EOCun/MP	%	−0.42	<0.001*
TOCun/MP	%	−0.67	<0.001*
TCun/MP	%	−0.86	<0.001*
FC/TC	%	−0.37	0.003*
F/TC	%	0.36	0.004*
L/CT	%	−0.09	0.484
H/TC	%	0.15	0.262
B/TC	%	0.05	0.707
M/TC	%	0.08	0.538
FT/TC	%	−0.19	0.151
E/TC	%	0.11	0.405
ME/TC	%	0.26	0.042*
F/EOC	%	0.22	0.096*
L/EOC	%	−0.25	0.056*
H/EOC	%	0.03	0.812
B/EOC	%	0.04	0.740
M/EOC	%	0.08	0.533
FT/EOC	%	−0.23	0.073*
E/EOC	%	−0.07	0.571
ME/EOC	%	0.11	0.390
D/TOC	%	−0.32	0.012*
L/F	%	−0.32	0.014*

DMP - daily milk production; Ar - area stocked with dairy cows; HL - hired labour; FL - family labour; DCN - dairy cow number; DCSR - dairy cow stocking rate; AMP/DCN - annual milk production per dairy cow; DCN/L - dairy cows per labour unit; AMP/L - annual milk production per labour unit; AMP/Ar - annual milk production per area; MGR/TGR - milk gross profit per total gross profit; EOC/TGR - effective operating cost per total gross profit; TOC/TGR - total operating cost per total gross profit; EOCun/MP - unitary EOC per milk price; TOCun/MP - unitary TOC per milk price; TCun/MP - total unitary cost per milk price; FC/TC - fixed cost to total cost ratio; F/TC - representativity of feed in the total cost; L/CT - representativity of labour in the total cost; H/TC - representativity of health in the total cost; B/TC - representativity of breeding in the total cost; M/TC - representativity of milking in the total cost; FT/TC - representativity of fixed taxes in the total cost; E/TC - representativity of electric power in the total cost; ME/TC - representativity of miscellaneous expenses in the total cost; F/EOC - representativity of feed in the effective operating cost; L/EOC - representativity of labour in the effective operating cost; H/EOC - representativity of health in the effective operating cost; B/EOC - representativity of breeding in the effective operating cost; M/EOC - representativity of milking in the effective operating cost; FT/EOC - representativity of fixed taxes in the effective operating cost; E/EOC - representativity of electric power in the effective operating cost; ME/EOC - representativity of miscellaneous expenses in the effective operating cost; D/TOC - depreciation per total operating cost; L/F - labour to feed ratio.
*Significant difference (P<0.10).

7

Association between technical and economic performance indexes and dairy farm profitability
Ferrazza et al.

The contribution of gross milk revenue to the total gross revenue (MGR/TGR) was 87.2±11.7% (Table 3). The negative Pearson's correlation coefficient value between MGR/TGR and profitability (Table 4) indicated that herds with greater milk contributions to the revenue composition generally had
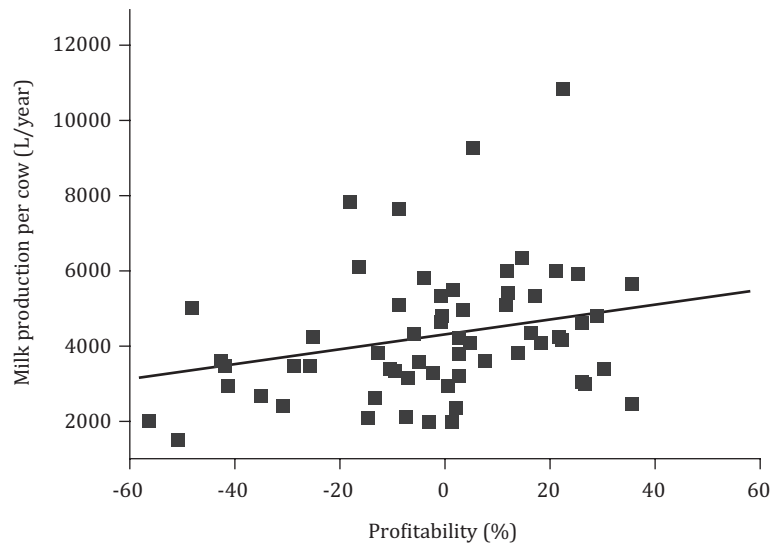
The dots represent individual farms and the line represents the regression equation.

Figure 1 - Linear model showing the relationship between milk production per cow (L/year) and profitability (%).

Table 5 - Regression, descriptive levels of probability (P-value), and coefficient of determination (R^2) of indexes that are significant in relation to profitability (P)

Independent variable	Unit	Regression	P-value	R^2
DCSR	head/ha	Y = 1.3962 + 1.4953 P	0.071	3.81
AMP/DCN	L/year	Y = 4,314.9 + 19.93 P	0.017	7.65
AMP/Ar	L/ha/year	Y = 6,375 + 9,156 P	0.048	4.88
MGR/TGR	%	Y = 0.8690 – 0.1049 P	0.061	4.24
EOC/TGR	%	Y = 0.6341 – 0.3582 P	<0.001	24.42
TOC/TGR	%	Y = 0.7811 – 0.5475 P	<0.001	62.01
EOCun/MP	%	Y = 0.7343 – 0.3189 P	<0.001	16.06
TOCun/MP	%	Y = 0.9068 – 0.5217 P	<0.001	44.02
TCun/MP	%	Y = 1.1617 – 1.0366 P	<0.001	73.59
FC/TC	%	Y = 0.28193 – 0.1779 P	0.003	12.53
F/TC	%	Y = 0.3789 + 0.1442 P	0.004	11.61
ME/TC	%	Y = 0.0753 + 0.0442 P	0.042	5.24
F/EOC	%	Y = 0.59032 + 0.08794 P	0.095	3.04
L/EOC	%	Y = 0.1472 – 0.1004 P	0.056	4.48
FT/EOC	%	Y = 0.1472 – 0.1004 P	0.072	3.78
D/TOC	%	Y = 0.1125 – 0.0727 P	0.012	8.77
L/F	%	Y = 0.2899 – 0.3311 P	0.014	8.34

DCSR - dairy cow stocking rate; AMP/DCN - annual milk production per dairy cow; AMP/Ar - annual milk production per area; MGR/TGR - milk gross profit per total gross profit; EOC/TGR - effective operating cost per total gross profit; TOC/TGR - total operating cost per total gross profit; EOCun/MP - unitary effective operating cost per milk price; TOCun/MP - unitary total operating cost per milk price; TCun/MP - total unitary cost per milk price; FC/TC - fixed cost to total cost ratio; F/TC - representativity of feed in the total cost; ME/TC - representativity of miscellaneous expenses in the total cost; F/EOC - representativity of feed in the effective operating cost; L/EOC - representativity of labour in the effective operating cost; FT/EOC - representativity of fixed taxes in the effective operating cost; D/TOC - depreciation per total operating cost; L/F - labour to feed ratio.
Y - dependent variable (index).

lower profitability, thus highlighting the importance of the sale of animals and derivatives. However, notably, the sample mostly consisted of medium- (45.9%) and small-scale (39.3%) production systems characterized by a low MGR/TGR ratio. A similar result is not expected in specialized herds with more than 90% of the output derived from dairy sales (Alvarez et al., 2008).

The excessively high mean TCun/MP value observed (Table 3) suggests that the total unit cost was 19.1±32.4% greater than the value of milk in the market, indicating the low average economic efficiency achieved by the producers in the sample studied. The TCun/MP was strongly negatively correlated with profitability (Table 4). In addition to the price of milk, the comparison of the price of inputs and production factors (exchange ratio) showed that the profitability of dairy farming depends on the volume produced relative to the amount of production factors used (Oliveira et al., 2001). Factors, such as market, milk production seasonality, volume, composition, and quality, are associated with subsidies or penalties and may be strategically used by producers. Understanding the market-driven milk price is an important planning tool. Farmers have minimal influence on the price of milk because they are price takers. However, farmers may concentrate managerial and/or technological efforts, including efforts aiming to train people and improve the productive and allocative efficiency of production factors. Thus, when the price of milk is low, farmers might need to adjust their management strategies and farming system to remain in the dairy business (Hemme et al., 2014).

Despite the high representativeness of food in the composition of costs, our results showed that, on average, herds associated with higher food expenditures were more profitable, implying that the increased intensification of a farm with greater food-related expenditures and, consequently, higher production per cow could lead to greater profitability. These results are consistent with those previously presented by Kompas and Che (2006) and Cabrera et al. (2010) in dairy farms in Australia and Wisconsin (USA), respectively. An explanation for these results may be that milk production from supplemented cows in a pasture or feedlot is curvilinear as a function of the increase in the supply of concentrate (Bargo et al., 2002; Sairanen et al., 2006), which induces gains in efficiency by "diluting" the nutritional maintenance demands related to higher production per cow (Gibson, 1986), although it has been shown that this response to concentrate supplementation is highly dependent on the type of cow (Fulkerson et al., 2008).

Labour productivity was positively correlated with profitability. However, herds associated with greater labour costs were less profitable. Thus, inefficient dairy producers are characterised by too much labour use and too little milk production. The explanation relies on the "dilution" of labour costs, indicating that producers with lower labour costs conduct their activities with greater professionalism and are more competitive. Accordingly, training programmes (Stup et al., 2006) and adoption of labour-saving technology (Kompas and Che, 2006) could be necessary to obtain better and greater labour efficiency. Another possible strategy involves increasing animal production to replace production factors associated with rising prices (i.e., labour) with capital items whose relative prices are lower. Thus, each farmer must consider whether the adoption of this managerial practice could affect the farm level efficiency based on limiting factors and economic scenarios.

In the current study, production per lactating cow was more closely correlated with profitability than land productivity. These results corroborate those reported by Resende et al. (2016) in Minas Gerais state. However, these results differ from those reported by Oliveira et al. (2007) in Bahia state, where land productivity was the key variable explaining the efficiency in generating profit. Several factors, including inferior genetics, low quality feed, disease incidence (Tauer and Mishra, 2006), and reproductive performance (Giordano et al., 2012), could explain why production per cow is limited and thus should be considered.

The relationship between farm size and efficiency is a more persistent puzzle in development economics (Mburu et al., 2014). Our results suggest that intensification rather than size of the production system positively affects profit. These results corroborate the findings reported by Cabrera et al. (2010) and Camilo Neto et al. (2012), who found no significant correlation between number of cows in a herd and economic sustainability; however, these findings contradict the

report published by Wronski et al. (2007), who showed that larger farms were more profitable and competitive than smaller farms. Furthermore, consistent with our findings, another recent study associated a reduction in profitability of pasture-based systems as dairy farm size increased, which could possibly be as a result of an increase in the proportion of employed labour within the overall system (Hanrahan et al., 2018).

The total operating cost (TOC) involves costs that are essential for conducting operations and production processes, including feeding, labour, health, milking, and breeding, which constitute the EOC, as well as the depreciation of improvements, machinery and equipment, and family labour. Thus, a factor responsible for the economic inefficiency of dairy farms is high TOC. Indeed, considering the economic inputs and outputs, the overuse of debt capital was identified as a possible factor explaining the inefficiency of dairy farms (Mor and Sharma, 2012). Such results show that both managerial and technological effort should be undertaken to minimize production costs primarily by correcting inefficiencies and weaknesses in the production process and maximizing technical efficiency. Alves et al. (2001) confirmed this hypothesis in a study analysing 963 establishments distributed throughout Brazil and concluded that resource misallocation significantly contributed to negative net income in most samples (74%). Similarly, Cabrera et al. (2010) reported low technical efficiency (88%) in dairy farms located in Wisconsin and suggested improvements by using the current level of inputs and technologies already available in the area.

The dispersed nature of the relationship between the indexes, which is evidenced by the low assessments of the coefficient of determination (R^2) values (Table 5), suggests that a range of variables, including amount of purchased feed, pasture allowance and quality, stocking rate, labour cost, milk constituents, dairy cow genetics, reproductive performance, replacement cost, investment in depreciating assets, and other that are under the farmer's control to a lesser extent (i.e., year, region, weather conditions, soil fertility status, and environmental constraints), determine the economic performance of the herds studied, which is very understandable because of the complex and multifactorial nature of dairy activity (Juszczyk, 2005), making it challenging. This implies that differences in input combinations and adequate technical strategies may change farm efficiency. Accordingly, it has been well known that profitable and sustainable dairy farming depends significantly on farm management capabilities (Solano et al., 2006), mainly in extensive production systems that have large technical challenges rather than intensive ones (Alvarez et al., 2008).

Conclusions

Among the many variables related to the success of dairy farmers, this study shows that the farm intensification is the main determinant of economic results. Specifically, because milk production per lactating cow and area were the indexes most positively correlated with profitability, we suggest that the pursuit of efficiency is necessary for the success of dairy farmers. Moreover, we found that the profitability of dairy farming critically depends on the price of milk compared to input prices and production factors. Hence, efficiently allocating inputs is a desirable goal for farmers to become and remain profitable and sustainable in the dairy industry. Altogether, these results contribute to an improved understanding of the efficiency level and the indexes most correlated with profitability and may support decision making regarding the economic sustainability of dairy farms.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Conceptualization: R.A. Ferrazza. Formal analysis: D.G.O. Prado and R.R. Lima. Funding acquisition: R.A. Ferrazza and M.A. Lopes. Investigation: R.A. Ferrazza. Methodology: R.A. Ferrazza and D.G.O. Prado.

10

Association between technical and economic performance indexes and dairy farm profitability
Ferrazza et al.

References

Alvarez, A.; del Corral, J.; Solís, D. and Pérez, J. A. 2008. Does intensification improve the economic efficiency of dairy farms? Journal of Dairy Science 91:3693-3698. https://doi.org/10.3168/jds.2008-1123

Alves, E.; Souza, G. S. and Brandão, A. S. P. 2001. A situação do produtor que tem menos de 100 hectares. Revista de Política Agrícola 10:27-36.

Bargo, F.; Muller, L. D.; Delahoy, J. E. and Cassidy, T. W. 2002. Performance of high producing dairy cows with three different feeding systems combining pasture and total mixed rations. Journal of Dairy Science 85:2948-2963. https://doi.org/10.3168/jds.S0022-0302(02)74381-6

Breustedt, G. and Glauben, T. 2007. Driving forces behind exiting from farming in Western Europe. Journal of Agricultural Economics 58:115-127. https://doi.org/10.1111/j.1477-9552.2007.00082.x

Cabrera, V. E.; Solís, D. and del Corral, J. 2010. Determinants of technical efficiency among dairy farms in Wisconsin. Journal of Dairy Science 93:387-393. https://doi.org/10.3168/jds.2009-2307

Camilo Neto, M.; Campos, J. M. S.; Oliveira, A. S. and Gomes, S. T. 2012. Identification and quantification of benchmarks of milk production systems in Minas Gerais. Revista Brasileira de Zootecnia 41:2279-2288. https://doi.org/10.1590/S1516-35982012001000020

Fassio, L. H.; Reis, R. P. and Geraldo, L. G. 2006. Desempenho técnico e econômico da atividade leiteira em Minas Gerais. Ciência e Agrotecnologia 30:1154-1161. https://doi.org/10.1590/S1413-70542006000600018

FAEMG - Federação de Agricultura do Estado de Minas Gerais. 2006. Diagnóstico da pecuária leiteira do estado de Minas Gerais em 2005: relatório de pesquisa. FAEMG, Belo Horizonte.

Ferrazza, R. A.; Lopes, M. A.; Bruhn, F. R. P. and Moraes, F. 2018. Zootechnical and economic performance indexes of dairy herds with different production scales. Semina: Ciências Agrárias 39:287-298. https://doi.org/10.5433/1679-0359.2018v39n1p287

Fulkerson, W. J.; Davison, T. M.; Garcia, S. C.; Hough, G.; Goddard, M. E.; Dobos, R. and Blockey, M. 2008. Holstein-Friesian dairy cows under a predominantly grazing system: Interaction between genotype and environment. Journal of Dairy Science 91:826-839. https://doi.org/10.3168/jds.2007-0147

Gibson, J. P. 1986. Efficiency and performance of genetically high and low milk-producing British Friesian and Jersey cattle. Animal Production 42:161-182. https://doi.org/10.1017/S0003356100017888

Giordano, J. O.; Kalantari, A. S.; Fricke, P. M.; Wiltbank, M. C. and Cabrera, V. E. 2012. A daily herd Markov-chain model to study the reproductive and economic impact of reproductive programs combining timed artificial insemination and estrus detection. Journal of Dairy Science 95:5442-5460. https://doi.org/10.3168/jds.2011-4972

Gloy, B. A.; Hyde, J. and LaDue E. L. 2002. Dairy farm management and long-term farm financial performance. Agricultural and Resource Economics Review 31:233-247.

Hanrahan, L.; McHugh, N.; Hennessy, T.; Moran, B.; Kearney, R.; Wallace, M. and Shalloo, L. 2018. Factors associated with profitability in pasture-based systems of milk production. Journal of Dairy Science 101:5474-5485. https://doi.org/10.3168/jds.2017-13223

Hemme, T.; Uddin, M. M. and Ndambi, O. A. 2014. Benchmarking cost of milk production in 46 countries. Journal of Reviews on Global Economics 3:254-270. https://doi.org/10.6000/1929-7092.2014.03.20

Hoffmann, R. 1987. Administração da empresa agrícola. Pioneira, São Paulo.

IBGE - Instituto Brasileiro de Geografia e Estatística. 2017. Censo agropecuário 2017. Rio de Janeiro. v.7, p.1-108. Available at: <http://www.ibge.gov.br>. Accessed on: Mar. 26, 2019.

Juszczyk, S. 2005. Milk production profitability: multiple regression analysis. Electronic Journal of Polish Agricultural Universities 8:46. Available at: <http://www.ejpau.media.pl/volume8/issue4/art-46.html>. Accessed on: Nov. 25, 2017.

11

Association between technical and economic performance indexes and dairy farm profitability
Ferrazza et al.

Kompas T. and Che, T. N. 2006. Technology choice and efficiency on Australian dairy farms. Australian Journal of Agricultural and Resource Economics 50:65-83. https://doi.org/10.1111/j.1467-8489.2006.00314.x

Kristensen, E.; Ostergaard, S.; Krogh, M. A. and Enevoldsen, C. 2008. Technical indicators of financial performance in the dairy herd. Journal of Dairy Science 91:620-631. https://doi.org/10.3168/jds.2007-0201

Lopes, M. A.; Cardoso, M. G.; Carvalho, F. M.; Lima, A. L. R.; Dias, A. S. and Carmo, E. A. 2007. Efeito do tipo de sistema de criação nos resultados econômicos de sistemas de produção de leite na região de Lavras (MG) nos anos 2004 e 2005. Ciência Animal Brasileira 8:359-371.

Lopes, M. A.; Santos, G.; Resende, M. C.; Carvalho, F. M. and Cardoso, M. G. 2011. Estudo da rentabilidade de sistemas de produção de leite no município de Nazareno, MG. Ciência Animal Brasileira 12:58-69. https://doi.org/10.5216/cab.v12i1.7725

Matsunaga, M.; Bemelmans, P. F.; Toledo, P. E. N.; Dulley, R. D.; Okawa, H. and Pedroso, I. A. 1976. Metodologia de custo de produção utilizado pelo IEA. Agricultura em São Paulo 23:123-139.

Mburu, S.; Ackello-Ogutu, C. and Mulwa, R. 2014. Analysis of economic efficiency and farm size: A case study of wheat farmers in Nakuru District, Kenya. Economics Research International, Article ID 802706. https://doi.org/10.1155/2014/802706

Mor, S. and Sharma, S. 2012. Technical efficiency and supply chain practices in dairying: The case of India. Agricultural Economics – Czech 58:85-91. https://doi.org/10.17221/11/2011-AGRICECON

Nehring, R.; Gillespie, J.; Sandretto, C. and Hallahan, C. 2009. Small U.S. dairy farms: can they compete? Agricultural Economics 40:817-825. https://doi.org/10.1111/j.1574-0862.2009.00418.x

Oliveira, T. B. A.; Figueiredo, R. S.; Oliveira, M. W. and Nascif, C. 2001. Índices técnicos e rentabilidade na pecuária leiteira. Scientia Agricola 58:687-692. https://doi.org/10.1590/S0103-90162001000400006

Oliveira, A. S.; Cunha, D. N. F. V.; Campos, J. M. S.; Vale, S. M. L. R. and Assis, A. J. 2007. Identificação e quantificação de indicadores-referência de sistemas de produção de leite. Revista Brasileira de Zootecnia 36:507-516. https://doi.org/10.1590/S1516-35982007000200030

Oliveira, M. C.; Campos, J. M. S.; Oliveira, A. S.; Ferreira, M. A. and Melo, A. A. S. 2016. Benchmarks for milk production systems in the Pernambuco Agreste region, Northeastern Brazil. Revista Caatinga 29:725-734. https://doi.org/10.1590/1983-21252016v29n324rc

Pereira, M. N.; Resende, J. C.; Pereira, R. A. N. and Silva, H. C. M. 2016. Indicadores de desempenho de fazendas leiteiras de Minas Gerais. Arquivos Brasileiros de Medicina Veterinária e Zootecnia 68:1033-1042. https://doi.org/10.1590/1678-4162-8218

Portal Brasil. 2019. Índice geral de preços – IGP-DI. Available at: <http://www.portalbrasil.net/igp.htm>. Accessed on: Sep. 19, 2019.

Resende, J. C.; Freitas, A. F.; Pereira, R. A. N.; Silva, H. C. M. and Pereira, M. N. 2016. Determinantes de lucratividade em fazendas leiteiras de Minas Gerais. Arquivo Brasileiro de Medicina Veterinária e Zootecnia 68:1053-1061. https://doi.org/10.1590/1678-4162-8220

Ruelle, E.; Delaby, L.; Wallace, M. and Shalloo, L. 2018. Using models to establish the financially optimum strategy for Irish dairy farms. Journal of Dairy Science 101:614-623. https://doi.org/10.3168/jds.2017-12948

Sairanen, A.; Khalili, H. and Virkajarvi, P. 2006. Concentrate supplementation responses of the pasture-fed dairy cow. Livestock Science 104:292-302. https://doi.org/10.1016/j.livsci.2006.04.009

Shadbolt, N. M. 2012. Competitive strategy analysis of New Zealand pastoral dairy farming systems. International Journal of Agricultural Management 1:19-27.

Solano, C.; León H.; Pérez E.; Tole, L.; Fawcett, R. H. and Herrero, M. 2006. Using farmer decision-making profiles and managerial capacity as predictors of farm management and performance in Costa Rican dairy farms. Agricultural Systems 88:395-428. https://doi.org/10.1016/j.agsy.2005.07.003

Solís, D.; Bravo-Ureta, B. E. and Quiroga, R. E. 2009. Technical efficiency among peasant farmers participating in natural resource management programmes in Central America. Journal of Agricultural Economics 60:202-219. https://doi.org/10.1111/j.1477-9552.2008.00173.x

St-Pierre, N. 2001. Economic factors affecting nutrient balance on dairy farms. Advanced Dairy Science and Technology 13:263-281.

Stup, R. E.; Hyde J. and Holden L. A. 2006. Relationships between selected human resource management practices and dairy farm performance. Journal of Dairy Science 89:1116-1120. https://doi.org/10.3168/jds.S0022-0302(06)72180-4

Tauer, L. W. and Belbase, K. P. 1987. Technical efficiency of New York dairy farms. Northeastern Journal of Agricultural and Resource Economics 16:10-16. https://doi.org/10.1017/S0899367X00000313

Tauer, L. W. 2001. Efficiency and competitiveness of the small New York dairy farm. Journal of Dairy Science 84:2573-2576. https://doi.org/10.3168/jds.S0022-0302(01)74710-8

12

Association between technical and economic performance indexes and dairy farm profitability
Ferrazza et al.

Tauer, L. W. and Mishra, A. K. 2006. Dairy farm cost efficiency. Journal of Dairy Science 89:4937-4943. https://doi.org/10.3168/jds.S0022-0302(06)72544-9

Wilson, P. 2011. Decomposing variation in dairy profitability: The impact of output, inputs, prices, labour and management. Journal of Agricultural Science 149:507-517. https://doi.org/10.1017/S0021859610001176

Wronski, M.; Cichocki, M.; Borkowska, K. and Redmer, J. 2007. Milk production efficiency as dependent on scale of production and cow management systems on dairy farms. Polish Journal of Natural Science 22:50-60.