Original Article
Food Science and Technology

ISSN 0101-2061 (Print)
ISSN 1678-457X (Online)

DOI: https://doi.org/10.5327/fst.00303

Chemical composition of refrigerated milk from the mesoregions of the Brazilian savanna

Rafaella Belchior BRASIL[1], Abner Alves MESQUITA[2], Ruthele Moraes do CARMO[1], Patrick Bezerra FERNANDES[2], Pamella Cristina TEIXEIRA[2], Karen Martins LEÃO[2], Clarice Gebara Muraro Serrate CORDEIRO[1], Marco Antônio Pereira da SILVA[2], Edmar Soares NICOLAU[1]

Abstract

The aim of this study was to assess the quality of milk in terms of its chemical composition in the mesoregions of the state of Goiás. Samples were collected during both the rainy and dry seasons from 2011 to 2014. A total of 17,393 data points on milk composition were extracted from the Milk Quality Laboratory's database. To determine whether the year, rainy and dry seasons, and mesoregion had an influence on milk components, we conducted a multiple linear regression analysis and used the Wald test to assess the significance of the model coefficients. Apart from fat and lactose, all the other components showed positive correlations with each other, and all these correlations were statistically significant. During the dry season, the percentages of fat, protein, non-fat dry extract, and total dry extract were more significant compared to the rainy season. Lactose exhibited antagonistic behavior compared to other milk components with respect to seasonality, as the lactose content was higher during the rainy season. The chemical composition of milk displayed both seasonal and regional variations.

Keywords: Cerrado; dairy cattle; fat; lactose; protein; seasonality.

Practical Application: The study on milk quality in Goiás revealed significant seasonal and regional variations. During the dry season, fat, protein, and other components were more pronounced, while lactose was higher in the rainy season. These findings have practical implications for adjustments in the production, processing, and marketing of dairy products to ensure consistency and quality. They also highlight seasonal quality to meet market demands.

1 INTRODUCTION

The geopolitical conflicts that have characterized recent decades, along with global health crises, have directly led to increases in inputs used in the agricultural sector (Allam et al., 2022), with a severe impact on the rise in social inequality. This situation, in turn, jeopardizes the food security of the most vulnerable populations. Since the primary source of protein is derived from animal agriculture, this sector is susceptible to the ramifications of geopolitical issues affecting agricultural commodities.

Furthermore, in tropical climate regions such as the Brazilian savanna (Cerrado), edaphoclimatic factors also act as limitations to the potential of primary production. During dry periods, due to low precipitation rates, there is a significant reduction in grain and forage production (Da Silva et al., 2015), leading to substantial increases in the cost of livestock production. This makes the activity economically burdensome for small- and medium-sized producers.

With reduced investments in proper livestock nutrition, this can compromise the quality of their respective products (e.g., milk). Therefore, it is crucial for the production sector and milk processing industries to thoroughly understand the chemical composition of milk, its degree of contamination, and its stability. These aspects play a fundamental role in choosing the most appropriate processing methods, preventing issues during industrialization and the storage of dairy products (Da Silva et al., 2012).

The state of Goiás stands out as one of the largest milk producers in Brazil. Its geography is divided into five distinct mesoregions: Northern Goiás, North-Central Goiás, Eastern Goiás, Central Goiás, and Southern Goiás, each with its own peculiarities and challenges (IMB, 2014). In 2014, the Southern Goiás mesoregion emerged as the largest milk producer, with an impressive production of 1,907,818,000 L, followed by Central Goiás (1,037,978,000 L), Eastern Goiás (309,286,000 L), Northwestern Goiás (280,134,000 L), and Northern Goiás (149,130,000 L) (IMB, 2016).

In this context, the primary objective of this study is to evaluate the quality of milk in terms of its chemical composition, addressing parameters such as fat, protein, lactose, non-fat dry extract, and total dry extract in the mesoregions of the state of Goiás. This study encompasses both rainy and dry seasons, allowing for a comprehensive understanding of variations over

Received: 8 Mar, 2024.
Accepted: 7 Apr., 2024.
[1] *Universidade Federal de Goiás, Programa de Pós-Graduação em Ciência Animal, Goiânia, Goiás, Brazil.*
[2] *Instituto Federal de Educação, Ciência e Tecnologia Goiano, Rio Verde, Goiás, Brazil.*
Conflict of interest: nothing to declare.
Funding: Coordenação de Aperfeiçoamento de Pessoal de Nível Superior—Brasil (CAPES)—Finance Code 001; Fundação de Amparo à Pesquisa do Estado de Goiás, Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), and Instituto Federal de Educação, Ciência e Tecnologia Goiano (IF Goiano—19/2022).

the years from 2011 to 2014. Therefore, the factors that influence milk quality in this region are investigated, providing valuable information for the industry, producers, and policymakers.

2 MATERIALS AND METHODS

2.1 Ethics statement

The data related to milk collection were obtained during the collection phase at refrigeration facilities on dairy farms located in the different mesoregions of the state of Goiás, Brazil, which are part of the savanna biome. Since no invasive procedures and animal handling were conducted, it was not necessary to submit the research project for ethical committee evaluation. Therefore, the research in question is in accordance with the guidelines established by the academic faculties of the Universidade Federal de Goiás and the Instituto Federal Goiano.

2.2 Study area coverage

The location where the study was conducted experiences a predominantly tropical semi-humid climate with two well-defined seasons: a dry winter and a very hot and rainy summer. Temperatures vary considerably, ranging from around 40°C in the hottest months to 15°C in the coldest months. Data collection for the chemical composition of milk (fat, protein, lactose, non-fat dry extract, and total dry extract) was carried out during the rainy period (October to April) and the dry period (May to September) from 2011 to 2014.

The distribution of data comprising the sample universe was conducted according to the regional division of Brazil into mesoregions. The state of Goiás is divided into five mesoregions, and those evaluated in this research were Northern, Northwestern, Central, and Southern Goiás. The Eastern Goiás mesoregion was not assessed due to its inability to relate geographic points to producers in the region.

2.3 Description of the study subject

The study was conducted by analyzing data extracted from the database of the Milk Quality Laboratory at the Food Research Centre of the School of Veterinary Medicine and Animal Science at the Universidade Federal de Goiás (16°35'57.3" S and 49°16'36.6" W). Data regarding the chemical composition of milk for database structuring were obtained from the results of milk analyses from rural properties that supply raw materials to dairy industries in the state of Goiás, under Federal Inspection by the Ministry of Agriculture, Livestock, and Supply (MAPA).

A total of 17,393 data points on the chemical composition of refrigerated milk were evaluated for the years 2011 (4,250 data points), 2012 (4,591 data points), 2013 (4,364 data points), and 2014 (4,188 data points) from 401 rural properties located in 27 municipalities in Goiás over the 4 years analyzed.

2.4 Collection of milk samples

The procedures for collecting milk samples that comprised the sample universe of this study were conducted following the descriptions provided by the Brazilian Agricultural Research Corporation (EMBRAPA 2001).

After collection, in accordance with Normative Instruction nº 76 of 2018 from MAPA (Brasil, 2018), the milk samples were placed in isothermal boxes with recyclable ice packs, with temperatures between 1.0°C and 10.0°C, and transported to the laboratory. Subsequently, the samples were selected based on the acceptance or rejection criteria, which included the appropriate transportation temperature, the presence of preservatives, and their physical state (Neves et al., 2015). Producer data were recorded using self-adhesive labels with a barcode to identify the milk samples.

2.5 Electronic analysis of milk samples

The determination of the chemical composition of milk (fat, protein, lactose, and total dry extract) was carried out using Milkoscan 4000 (FOSS) and Lactoscope (Delta) equipment through near-infrared spectroscopy, following ISO standards (ISO-2013). The determination of non-fat dry extract was calculated differentially. The results were expressed as percentage (%).

2.6 Statistical analysis of the data

The analysis excluded the transition periods of April and October. To describe the milk components stratified by year, season, and mesoregion, the mean and standard deviations were calculated. To assess the association between milk components, a Pearson correlation matrix was generated. To visualize the correlations between the components and potential associations with year, season, and mesoregion, a perceptual map was constructed using principal component analysis (Hair et al., 2009).

To determine whether year, season, and mesoregion had an influence on milk components, a multiple linear regression was performed, and the Wald test was used to assess the significance of the model coefficients. To check for potential interactions among these variables, the likelihood ratio test was employed (Montgomery et al., 2012). The software used for the analyses was R version 3.2.2.

3 RESULTS

The correlation between variables can be calculated to assess proportional or inverse variations. The analysis of the results revealed that, apart from fat and lactose, all the other components showed positive correlations with each other, and all these correlations were statistically significant (Table 1).

Defatted dry extract demonstrated a strong correlation with protein and a moderate correlation with lactose. Total dry extract showed a strong correlation with fat, a moderate correlation with protein and non-fat dry extract, and a weak correlation with lactose. Therefore, there is a clear association between these components, with total dry extract being considerably dependent on fat (Table 1).

The amount of variation explained by the two main components was 88.37%, with 59.11% attributed to the first component and 29.26% attributed to the second component. Therefore, it is evident that protein, defatted dry extract, and total dry extract exhibited strong positive correlations with each other, as their arrows indicate the same direction. The same pattern occurred between lactose-defatted dry extract and fat-total dry extract. Furthermore, a positive correlation, although on a smaller scale, was observed between lactose-protein, lactose-total dry extract, and fat-protein. On the contrary, the lactose and fat components showed negative correlations, as their arrows pointed in opposite directions (Figure 1).

The Midwest and South regions exhibited the highest values for fat content, while the Northwestern region had the highest values for protein content. However, in all regions, the average protein content during the dry season has remained relatively constant over the years. Lactose levels were lower during the dry season (Table 2).

The North and Northwest regions recorded the highest levels of lactose as well as average values of non-fat dry extract. However, regardless of region, the average lactose content remained relatively constant over time, both in the dry and the rainy seasons (Table 2).

Table 1. Pearson correlation between milk components.

Component	Fat	Protein	Lactose	Defatted dry extract	Total dry extract
Fat	-				
Protein	0.36*	-			
Lactose	-0.18*	0.19*	-		
Defatted dry extract	0.19*	0.83*	0.68*	-	
Total dry extract	0.87*	0.70*	0.21*	0.65*	-

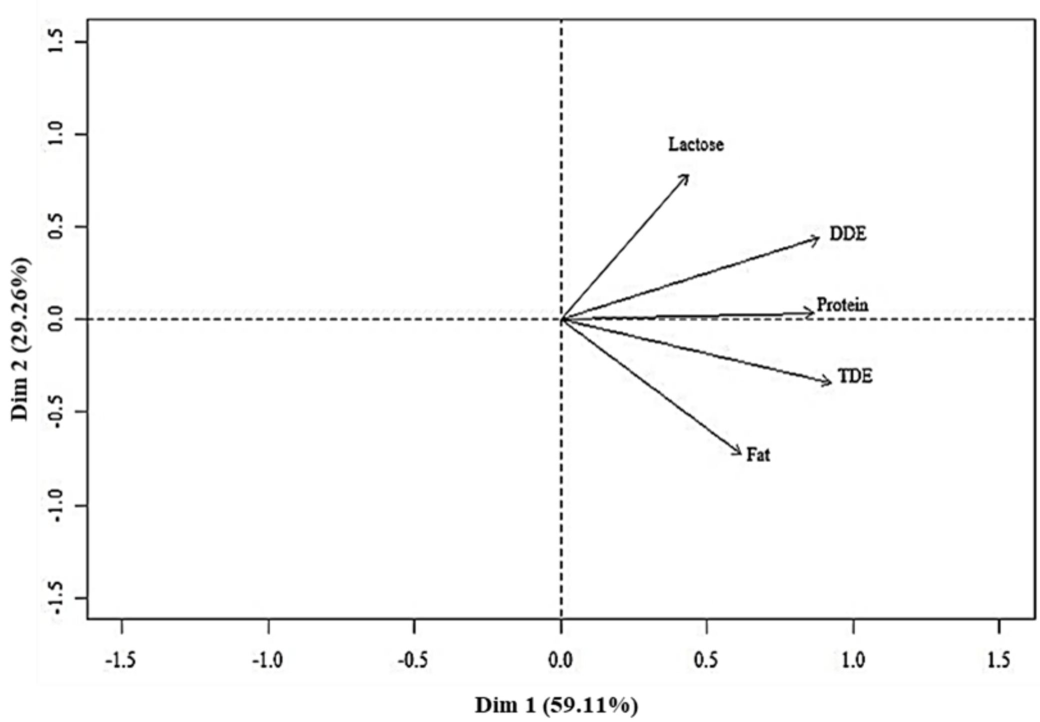
*Significant at 1% ($p < 0.001$).

The linear regression parameters adjusted for fat showed that there was a year effect for this characteristic. As the years go by, there may be a reduction in the fat content of the milk produced in the regions where the data were collected. With regard to season, in the Northern mesoregion, there was no significant influence of season on fat. In the Northwest, Midwest, and Sul Goiano mesoregions, there was an influence of season on fat, with fat being higher in the dry season than in the rainy season (Table 3).

The protein content of milk has remained constant over the years in the Northern, Northwestern, and Midwest mesoregions. However, in the South region, a significant influence of the year was observed, with a trend of reduction in this characteristic each year. Regarding the season, in the Northern mesoregion, no significant influence on protein content was observed. On the contrary, in the Northwestern, Midwest, and Southern Goiás mesoregions, the season showed a significant impact, with higher protein levels during the dry season compared to the rainy season (Table 4).

Lactose was not significantly influenced by the year in the North ($p = 0.052$), Midwest ($p = 0.115$), and South ($p = 0.705$) regions. However, there was a significant influence ($p = 0.010$) of the year on lactose in the Northwestern mesoregion, where there was an increase of 0.008 units in lactose each year (Table 5).

Regarding the year, in the Northern mesoregion, there was no significant influence of time on lactose. In the Northwestern, Midwestern, and Southern Goiás mesoregions, there was a significant influence of time on lactose, with lactose being lower in the dry season compared to the rainy season. A lower



DDE: defatted dry extract; TDE: total dry extract.

Figure 1. Perceptual map via main component analysis.

Table 2. Description of the variables related to the chemical composition of milk stratified by mesoregion, year, and season.

Mesoregion	2011				2012				2013				2014			
	Dry		Rainy		Dry		Rainy		Dry		Rainy		Dry		Rainy	
	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
Fat																
North	3.51	10.63	3.50	9.18	3.49	8.80	3.55	11.37	3.53	10.63	3.48	13.25	3.46	10.31	3.46	10.42
Northwest	3.71	12.24	3.38	11.52	3.65	9.41	3.38	10.88	3.63	12.98	3.37	12.04	3.56	11.55	3.34	12.35
Midwest	3.71	9.24	3.60	8.68	3.67	9.44	3.56	9.07	3.70	8.64	3.58	10.04	3.68	9.96	3.54	9.59
South	3.73	10.16	3.59	9.92	3.69	10.08	3.56	10.52	3.75	9.63	3.58	11.05	3.67	10.81	3.55	10.92
Protein																
North	3.30	5.45	3.24	4.60	3.31	5.76	3.26	5.28	3.28	6.25	3.32	5.43	3.30	3.82	3.18	5.29
Northwest	3.36	6.09	3.30	5.97	3.37	5.66	3.30	5.19	3.41	5.58	3.35	5.22	3.37	5.79	3.30	5.55
Midwest	3.24	5.71	3.23	5.43	3.26	5.62	3.20	4.79	3.24	5.10	3.23	4.79	3.26	5.35	3.21	5.17
South	3.27	5.87	3.23	4.92	3.29	5.81	3.21	4.92	3.26	5.55	3.25	5.07	3.25	5.72	3.19	6.90
Lactose																
North	4.63	1.36	4.60	1.78	4.59	2.29	4.59	2.72	4.57	2.54	4.58	2.62	4.57	1.99	4.56	2.72
Northwest	4.53	2.25	4.61	2.34	4.55	2.15	4.63	2.35	4.58	2.64	4.63	2.40	4.57	2.56	4.63	2.20
Midwest	4.49	2.85	4.53	2.67	4.50	2.80	4.54	2.69	4.51	2.46	4.55	2.57	4.49	2.76	4.54	2.51
South	4.50	2.98	4.54	2.47	4.51	2.84	4.54	2.62	4.51	2.75	4.55	2.75	4.50	2.71	4.54	3.06
Defatted dry extract																
North	8.89	2.16	8.81	2.38	8.87	2.10	8.82	2.31	8.83	3.44	8.89	2.77	8.88	2.20	8.73	2.58
Northwest	8.85	2.57	8.88	2.97	8.88	2.36	8.90	2.44	8.99	2.74	9.01	2.64	8.97	3.03	8.93	2.60
Midwest	8.68	2.73	8.73	2.91	8.72	2.82	8.69	2.49	8.73	2.55	8.77	2.47	8.76	2.72	8.75	2.55
South	8.73	2.79	8.74	2.68	8.75	2.86	8.72	2.49	8.74	2.72	8.79	2.62	8.77	2.87	8.72	3.26
Total dry extract																
North	12.40	3.26	12.31	3.42	12.36	3.07	12.37	3.29	12.36	5.22	12.37	4.75	12.34	3.69	12.19	3.98
Northwest	12.55	4.57	12.26	4.33	12.52	3.63	12.28	3.62	12.62	4.78	12.38	3.98	12.53	4.38	12.27	4.21
Midwest	12.39	3.83	12.33	3.50	12.38	3.93	12.25	3.21	12.43	3.59	12.35	3.54	12.44	4.03	12.29	3.67
South	12.45	4.10	12.33	3.73	12.44	4.03	12.28	3.77	12.49	3.85	12.37	3.88	12.44	4.17	12.27	4.34

CV (%): coefficient of variation.

Table 3. Variation of milk fat of mesoregions of the State of Goiás during the years 2011 to 2014 in the rainy and dry periods.

Source		β	SE (β)	95%CI	*p*-value
Year		**-0.012**	**0.003**	**[-0.02–-0.01]**	**< 0.001**
	Rainy				
	Dry	0.000	0.054	[-0.11–0.11]	0.997
Northwest	Rainy				
	Dry	0.266	0.021	[0.23–0.31]	< 0.001
Midwest	Rainy				
	Dry	0.118	0.012	[0.10–0.14]	< 0.001
South	Rainy				
	Dry	0.137	0.008	[0.12–0.15]	< 0.001
Rainy	North				
	Northwest	-0.128	0.041	[-0.21–-0.05]	0.002
	Midwest	0.076	0.040	[0.00–0.15]	0.055
	South	0.075	0.039	[0.00–0.15]	0.055
	Northwest				
	Midwest	0.204	0.017	[0.17–0.24]	< 0.001
	South	0.204	0.015	[0.17–0.23]	< 0.001
	Midwest				
	South	-0.001	0.010	[-0.02–0.02]	0.940
Dry	North				
	Northwest	0.137	0.040	[0.06–0.22]	0.001
	Midwest	0.194	0.038	[0.12–0.27]	< 0.001
	South	0.212	0.038	[0.14–0.29]	< 0.001
	Northwest				
	Midwest	0.057	0.017	[0.02–0.09]	0.001
	South	0.075	0.016	[0.04–0.11]	< 0.001
	Midwest				
	South	0.018	0.010	[0.00–0.04]	0.067
R^2		4.99%			

β: regression coefficients; SE: standard error; 95%CI: 95% confidence interval; Significance at 5% ($p < 0.05$) by the Wald test.

percentage of lactose was observed in the Central and Southern regions of Goiás in both periods evaluated (Table 5).

A lower percentage of non-fat dry extract was observed in the Central and Southern regions of Goiás in both periods evaluated (Table 6). In the Northwestern, Midwestern, and Southern Goiás mesoregions, there was a significant influence of the season on total dry extract, with total dry extract being higher in the dry season compared to the rainy season (Table 6).

4 DISCUSSION

The Brazilian Cerrado is characterized by climatic conditions similar to those in savanna regions, where well-defined rainy and dry periods occur. During the rainy season, it is possible to produce a sufficient quantity and quality of forage to meet the maintenance and production needs of domestic ruminants in general (Fernandes et al., 2020). However, to maximize milk production during this period, it is crucial to adopt supplementary strategies since the predominant pastures in this region are Urochloa brizantha and Megathyrsus maximus pastures, which have maximum values of up to 13% crude protein and 58% total digestible nutrients (Cruvinel et al., 2017).

During the dry season, with a decrease in temperature and a reduction in precipitation levels, there are recorded reductions of 63% in forage production (Euclides et al., 2022; Montagner et al., 2012). Furthermore, the chemical composition of forage also decreases during this period, negatively impacting the quality of the milk produced (Weber et al., 2020). This decrease in milk protein percentages in the most productive region of

Goiás also serves as a warning, indicating that further investigation is needed.

For F1 Holstein/Zebu cows managed on traditionally stocked Urochloa brizantha pasture and supplemented with protein, it is possible to maintain an average daily milk production of 12.10 kg day^{-1} with 3.21% protein, 3.81% fat, 4.48% lactose, 8.71% non-fat dry extract, and 12.51% total dry extract (Lima et al., 2021). Furthermore, the lack of protein supplementation in stocked pastures leads to a decline in milk production and exacerbates weight loss in cows, directly affecting reproductive performance.

Inversely proportional, raw materials are received by dairy companies, with the reasons for this behavior including seasonality in milk production, with higher supply during the rainy season and lower during the dry season; seasonality in the cost of milk production due to the predominance of pasture-based production systems; and the lack of specialization in the dairy herd. This reality, shared by the majority of Brazilian states, is a situation that needs to be properly managed by their dairy industries (Lins & Vilela, 2006).

Table 4. Milk protein variation of mesoregions of the State of Goiás during the years 2011 to 2014 in the rainy and dry periods.

Source			β	SE (β)	95%CI	*p*-value
North		Year	-0.009	0.012	[-0.03–0.01]	0.432
Northwest		Year	0.006	0.005	[0.00–0.01]	0.210
Midwest		Year	0.001	0.003	[0.00–0.01]	0.777
South		Year	-0.008	0.002	[-0.01–0.00]	< 0.001
North		Rainy				
		Dry	0.050	0.026	[0.00–0.10]	0.057
Northwest		Rainy				
		Dry	0.065	0.010	[0.05–0.08]	< 0.001
Midwest		Rainy				
		Dry	0.031	0.006	[0.02–0.04]	< 0.001
South		Rainy				
		Dry	0.048	0.004	[0.04–0.06]	< 0.001
Year = 2012.5	Rainy	North				
		Northwest	0.064	0.020	[0.03–0.10]	0.001
		Midwest	-0.032	0.019	[-0.07–0.01]	0.100
		South	-0.026	0.019	[-0.06–0.01]	0.164
		Northwest				
		Midwest	-0.096	0.008	[-0.11–-0.08]	< 0.001
		South	-0.091	0.008	[-0.11–-0.08]	< 0.001
		Midwest				
		South	0.005	0.005	[0.00–0.01]	0.277
	Dry	North				
		Northwest	0.080	0.020	[0.04–0.12]	< 0.001
		Midwest	-0.050	0.019	[-0.09–-0.01]	0.007
		South	-0.029	0.018	[-0.06–0.01]	0.119
		Northwest				
		Midwest	-0.130	0.008	[-0.15–-0.11]	< 0.001
		South	-0.108	0.008	[-0.12–-0.09]	< 0.001
		Midwest				
		South	0.022	0.005	[0.01–0.03]	< 0.001
R^2				4.31%		

β: regression coefficients; SE: standard error; 95%CI: 95% confidence interval; Significance at 5% ($p < 0.05$) by the Wald test.

Large producers adopt technologies that reduce the seasonality of production, but this result may have been influenced by the large number (49%) of small producers with pasture-raised animals in the state of Goiás, where only 4.0% are considered large milk producers. The nutritional values of tropical grasses during the dry season are low, so the drop in milk production observed during this period is associated with the low availability and nutritional quality of pastures, given that production systems in Goiás are predominantly extensive (Gomes, 2009).

It is important to note that in the study by Gomes (2009), only 39.0% of the producers interviewed provided concentrate for their lactating cows throughout the year, ranging from 29.50% among small producers to 89.50% among large producers. In the lower production stratum, massive supplementation with sugarcane was more frequent (64.80%), while in the higher production stratum, the use of maize/sorghum silage was predominant (100.0%).

Table 5. Milk lactose variation of mesoregions of the State of Goiás during the years 2011 to 2014 in the rainy and dry periods.

Source			β	SE (β)	95%CI	*p*-value
North		Year	-0.016	0.008	[-0.03–0.00]	0.052
Northwest		Year	0.008	0.003	[0.00–0.01]	0.010
Midwest		Year	0.003	0.002	[0.00–0.01]	0.115
South		Year	0.000	0.001	[0.00–0.00]	0.705
North		Rainy				
		Dry	0.005	0.018	[-0.03; 0.04]	0.765
Northwest		Rainy				
		Dry	-0.068	0.007	[-0.08–-0.05]	< 0.001
Midwest		Rainy				
		Dry	-0.041	0.004	[-0.05–-0.03]	< 0.001
South		Rainy				
		Dry	-0.037	0.003	[-0.04–-0.03]	< 0.001
Year = 2012.5	Rainy	North				
		Northwest	0.044	0.014	[0.02–0.07]	0.001
		Midwest	-0.043	0.013	[-0.07–-0.02]	0.001
		South	-0.040	0.013	[-0.07–-0.01]	0.002
		Northwest				
		Midwest	-0.087	0.005	[-0.10–-0.08]	< 0.001
		South	-0.084	0.005	[-0.09–-0.07]	< 0.001
		Midwest				
		South	0.002	0.003	[0.00–0.01]	0.449
	Dry	North				
		Northwest	-0.030	0.013	[-0.06–0.00]	0.026
		Midwest	-0.089	0.013	[-0.11–-0.06]	< 0.001
		South	-0.083	0.013	[-0.11–-0.06]	< 0.001
		Northwest				
		Midwest	-0.059	0.006	[-0.07–-0.05]	< 0.001
		South	-0.053	0.005	[-0.06–-0.04]	< 0.001
		Midwest				
		South	0.006	0.003	[0.00–0.01]	0.056
R^2				5.45%		

β: regression coefficients; SE: standard error; 95%CI: 95% confidence interval; Significance at 5% ($p < 0.05$) by the Wald test.

Table 6. Variation of the defatted dry extract and total dry extract of the milk of mesoregions of the State of Goiás during the years 2011 to 2014 in the rainy and dry periods.

Source			β	SE (β)	95%CI	*p*-value
Defatted dry extract						
Rainy	North	Year	-0.019	0.016	[-0.05–0.01]	0.244
	Northwest	Year	0.032	0.006	[0.02–0.04]	< 0.001
	Midwest	Year	0.013	0.004	[0.01–0.02]	< 0.001
	South	Year	0.001	0.003	[-0.01–0.01]	0.839
Dry	North	Year	-0.006	0.016	[-0.04–0.03]	0.708
	Northwest	Year	0.045	0.006	[0.03–0.06]	< 0.001
	Midwest	Year	0.026	0.004	[0.02–0.03]	< 0.001
	South	Year	0.013	0.003	[0.01–0.02]	< 0.001
Year = 2012.5	North	Rainy				
		Dry	0.051	0.035	[-0.02–0.12]	0.147
	Northwest	Rainy				
		Dry	-0.009	0.013	[-0.04–0.02]	0.491
	Midwest	Rainy				
		Dry	-0.013	0.008	[-0.03–0.00]	0.077
	South	Rainy				
		Dry	0.010	0.005	[0.00–0.02]	0.042
Year = 2012.5	Rainy	North				
		Northwest	0.117	0.027	[0.06–0.17]	< 0.001
		Midwest	-0.082	0.026	[-0.13–-0.03]	0.001
		South	-0.076	0.026	[-0.13–-0.03]	0.003
		Northwest				
		Midwest	-0.199	0.011	[-0.22–-0.18]	< 0.001
		South	-0.193	0.010	[-0.21–-0.17]	< 0.001
		Midwest				
		South	0.006	0.006	[-0.01–0.02]	0.370
	Dry	North				
		Northwest	0.056	0.026	[0.00–0.11]	0.032
		Midwest	-0.146	0.025	[-0.20–-0.10]	< 0.001
		South	-0.117	0.025	[-0.17–-0.07]	< 0.001
		Northwest				
		Midwest	-0.203	0.011	[-0.22–-0.18]	< 0.001
		South	-0.173	0.010	[-0.19–-0.15]	< 0.001
		Midwest				
		South	0.029	0.006	[0.02–0.04]	<0.001
R^2					5.46%	
Total dry extract						
Year			0.001	0.004	[-0.01–0.01]	0.729
North	Rainy					
	Dry		0.055	0.071	[-0.08–0.19]	0.442
Northwest	Rainy					
	Dry		0.259	0.027	[0.21–0.31]	< 0.001
Midwest	Rainy					
	Dry		0.106	0.015	[0.08–0.14]	< 0.001
South	Rainy					
	Dry		0.147	0.010	[0.13–0.17]	< 0.001
Rainy	North					
	Northwest		-0.012	0.054	[-0.12–0.09]	0.827
	Midwest		-0.004	0.052	[-0.11–0.10]	0.932
	South		0.002	0.051	[-0.10–0.10]	0.974
	Northwest					
	Midwest		0.007	0.022	[-0.04–0.05]	0.731
	South		0.014	0.020	[-0.03–0.05]	0.504
	Midwest					
	South		0.006	0.013	[-0.02–0.03]	0.635
Dry	North					
	Northwest		0.193	0.053	[0.09–0.30]	< 0.001
	Midwest		0.047	0.050	[-0.05–0.15]	0.353
	South		0.094	0.050	[0.00–0.19]	0.059
	Northwest					
	Midwest		-0.146	0.022	[-0.19–-0.10]	< 0.001
	South		-0.099	0.021	[-0.14–-0.06]	< 0.001
	Midwest					
	South		0.047	0.013	[0.02–0.07]	< 0.001
R^2					2.42%	

β: regression coefficients; SE: standard error; 95%CI: 95% confidence interval; Significance at 5% ($p < 0.05$) by the Wald test.

The amount of lactose produced in the mammary gland is directly related to the amount of milk produced per day. The concentration of lactose in milk is relatively stable, and water is added to maintain the concentration of lactose at around 4.5 g 100 g^{-1} of milk, as reported by Wattiaux (2006). Unlike milk fat, lactose concentration is consistent across all dairy breeds and is not easily modified by dietary practices, as observed by Wattiaux (2006). Therefore, the increase in lactose levels in milk in the Northwestern region may be related to the increase in production and productivity over the years evaluated.

However, it is important to note that, according to the findings of Botton et al. (2019), significant changes in cows' diets, such as replacing maize silage with oat and ryegrass hay, can have a direct impact on milk production and lactose concentration. Therefore, changes in diets during periods of transition between seasons, such as from wet to dry, can also affect the concentration of fat and lactose in milk, as these two characteristics do not show a positive relationship (Figure 1).

Dias et al. (2015) found no differences in the defatted dry extract of milk between seasons in the southwest of Goiás. Similarly, De Andrade et al. (2014) also found no differences between the dry and rainy periods, which is contrary to this study. Martins et al. (2006) reported the lowest percentage of defatted dry extract in July (8.00 g 100 g^{-1}) and the highest in September (8.61 g 100 g^{-1}). Similarly to this study, Rosa et al. (2012) found a higher content of defatted dry extract in tank and individual milk samples in autumn and winter and a lower content in spring and summer.

The total solids content in milk represents the sum of all the constituents of milk (with the exception of water), with fat being the main factor responsible for its variation. Therefore, as a result of the higher fat and protein content in milk in the months with low rainfall, the total solids content was also higher in this period. As in this study, Henrichs et al. (2014) found average total solids percentages to be higher in winter (12.40 g 100 g^{-1}) and lower in summer (12.07 g 100 g^{-1}). On the contrary, De Andrade et al. (2014) did not identify any differences in the total dry extract between the dry (12.13 g 100 g^{-1}) and rainy (12.25 g 100 g^{-1}) periods.

According to Souza Júnior et al. (2016), there is a strong correlation between total solids and milk fat content, since this is the most variable component of milk when diets are modified. In the case of defatted dry matter, there is also a positive correlation with protein and lactose rates, as they are the main constituents of this characteristic.

However, despite the environmental influences on quality and chemical composition, in the mesoregions of the Brazilian Cerrado, it is possible to verify that the levels of fat, protein, total dry extract, defatted dry extract, and lactose comply with the standards established in Normative Instruction 62/2011 (Brasil, 2011).

Based on the results of the research, it is clear that it is important to implement public policies aimed at mitigating the impacts of seasonality on food production, especially with regard to obtaining bulk feed with high nutritional value. This is essential to optimize the performance of herds in the various mesoregions of the state of Goiás. In addition, it is crucial to consider the need for constant monitoring of the chemical composition of the milk produced in order to identify and resolve any problems that could result in both productivity and economic losses (Calgaro et al., 2020).

5 CONCLUSIONS

The chemical composition of the milk showed seasonal and regional behaviors. In the dry season, the percentages of fat, protein, defatted dry extract, and total dry extract were higher than in the rainy season. However, in the regions with the highest production and productivity, a lower percentage of protein and lactose was observed, and it was also noted that each year, the percentages of fat and protein decreased. However, it is important to emphasize that in these same regions, the fat content was higher and all the requirements met the legislation in force in the four mesoregions assessed. The seasonality of milk production is an important issue for the dairy sector, as it can affect milk quality and the existence or absence of seasonal and cyclical behavior.

REFERENCES

Allam, Z., Bibri, S. E., & Sharpe, S. A. (2022). The rising impacts of the COVID-19 pandemic and the Russia-Ukraine war: energy transition, climate justice, global inequality, and supply chain disruption. *Resources*, *11*(11), 99. https://doi.org/10.3390/resources11110099

Botton, F. S., Alessio, D. R. M., Busanello, M., Schneider, C. L. C., Stroeher, F. H., & Haygert-Velho, I. M. P. (2019). Relationship of total bacterial and somatic cell counts with milk production and composition-multivariate analysis. *Acta Scientiarum. Animal Sciences*, *41*, e42568. https://doi.org/10.4025/actascianimsci.v41i1.42568

Brasil (2011). Ministério da Agricultura, Pecuária e Abastecimento. *Instrução Normativa nº 62, de 29 de dezembro de 2011*. Ministério da Agricultura, Pecuária e Abastecimento.

Brasil (2018). Ministério da Agricultura, Pecuária e Abastecimento. *Instrução normativa nº 76, de 26 de novembro de 2018*. Ministério da Agricultura, Pecuária e Abastecimento.

Calgaro, J. L. B., Fioresi, J., Velho, J. P., Stroeher, F. H., Alessio, D. R. M., Piuco, M. A., & Haygert-Velho, I. M. P. (2020). Production and composition of milk per Holstein and Jersey cow from two farms in northwest Rio Grande do Sul. *Revista Brasileira de Saúde e Produção Animal*, *21*, e2121212020. https://doi.org/10.1590/S1519-99402121212020

Cruvinel, W. S., Costa, K. A. D. P., Teixeira, D. A. A., Silva, J. T., Epifanio, P. S., Costa, P. H. C. P., & Fernandes, P. B. (2017). Fermentation profile and nutritional value of sunflower silage with *Urochloa brizantha* cultivars in the off-season. *Revista Brasileira de Saúde e Produção Animal*, *18*(2), 249-259. https://doi.org/10.1590/S1519-99402017000200004

Da Silva, L. C. C., Beloti, V., Tamanini, R., Yamada, A. K., Giombelli, C. J., & Silva, M. R. (2012). Estabilidade térmica da caseína e estabilidade ao álcool 68, 72, 75 e 78%, em leite bovino. *Revista do Instituto de Laticínios Cândido Tostes*, *67*(384), 55-60. https://doi.org/10.5935/2238-6416.20120008

Da Silva, S. C., Sbrissia, A. F., & Pereira, L. E. T. (2015). Ecophysiology of C4 forage grasses—understanding plant growth for optimising their use and management. *Agriculture*, *5*(3), 598-625. https://doi.org/10.3390/agriculture5030598 de Andrade, K. D., do Nascimento Rangel, A. H., de Araújo, V. M., de Medeiros, H. R., Bezerra, K. C., Bezerril, R. F., & de Lima Júnior, D. M. (2014). Qualidade do leite bovino nas diferentes estações do ano no estado do Rio Grande do Norte. *Revista Brasileira de Ciência Veterinária*, *21*(3), 213-6. https://doi.org/10.4322/rbcv.2014.387

Dias, M., Assis, A. C., Nascimento, V., Saenz, E., & Lima, L. (2015). Sazonalidade dos componentes do leite e o programa de pagamento por qualidade. *Enciclopédia Biosfera*, *11*(21), 1712.

Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA) (2001). *Coleta de amostras de leite para determinação da composição química e contagem de células somáticas*. Embrapa Gado de Leite.

Euclides, V. P. B., Montagner, D. B., Araujo, A. R., Pereira, M. A., Difante, G. S., Araujo, I. M. M., Barbosa, L. F., Barbosa, R. A., & Gurgel, A. L. C. (2022). Biological and economic responses to increasing nitrogen rates in Mombaça guinea grass pastures. *Scientific Reports*, *12*(1), 1937. https://doi.org/10.1038/s41598-022-05796-6

Fernandes, P. B., Barbosa, R. A., De Oliveira, R. T., De Oliveira, C. V. V., & Medeiros-Neto, C. (2020). Defoliation dynamics of Brachiaria brizantha pastures with distinct structural characteristics. *Bioscience Journal*, *36*(1), 203-211. https://doi.org/10.14393/BJ-v36n1a2020-42211

Gomes, S. T. (2009). Federação da Agricultura e Pecuária de Goiás. Diagnóstico da 19. In: Wattiaux, M. A., & Armentano, L. E. (eds.), *Metabolismo de carboidratos em vacas leiteiras* (pp. 9-12). Laticínios Essenciais.

Hair, J. F., Black, W. C., Babin, B. J., Anderson, R. E., & Tatham, R. L. (2009). *Análise Multivariada de Dados*. Bookman.

Henrichs, S. C., de Macedo, R. E. F., & Karam, L. B. (2014). Influência de indicadores de qualidade sobre a composição química do leite e influência das estações do ano sobre esses parâmetros. *Revista Acadêmica Ciência Animal*, *12*(3), 199-208. https://doi.org/10.7213/academica.12.03.AO05

Instituto Mauro Borges de Estatísticas e Estudos Socioeconômicos (IMB) (2014). *Estatísticas das Mesos e Microrregiões do Estado de Goiás 2013*. SEGPLAN/Governo de Goiás, 49 p.

Instituto Mauro Borges de Estatísticas e Estudos Socioeconômicos (IMB) (2016). *Estatísticas Municipais (Séries Históricas)*. SEGPLAN/Governo de Goiás.

Lima, T. M. R., Ruas, J. R. M., Gomes, V. M., Rocha Júnior, V. R., Monção, F. P., & Silva, C. B. (2021). Effect of protein supplementation on yield and milk composition of F1 Holstein x Zebu cows kept in deferred pasture of brachiaria grass. *Arquivo Brasileiro de Medicina Veterinária e Zootecnia*, *73*(2), 477-486. https://doi.org/10.1590/1678-4162-12090

Lins, P. M. G., & Vilela, P. S. (2006). *Diagnóstico da pecuária leiteira do Estado de Minas Gerais em 2005: relatório de pesquisa*. FAEMG.

Martins, P. R. G., Silva, C. A. D., Fischer, V., Ribeiro, M. E. R., Stumpf Júnior, W., & Zanela, M. B. (2006). Produção e qualidade do leite na bacia leiteira de Pelotas-RS em diferentes meses do ano. *Ciência Rural*, *36*(1), 209-214. https://doi.org/10.1590/S0103-84782006000100032

Montagner, D. B., Nascimento Júnior, D. D., Sousa, B. M. D. L., Vilela, H. H., Silveira, M. C. T. D., Euclides, V. P. B., Da Silva, S. C., & Carloto, M. N. (2012). Morphogenesis in guinea grass pastures under rotational grazing strategies. *Revista Brasileira de Zootecnia*, *41*(4), 883-888. https://doi.org/10.1590/S1516-35982012000400008

Montgomery, D. C., Peck, E. A., & Vining, G. G. (2012). *Introduction to Linear Regression Analysis*. John Wiley & Sons.

Neves, R. B. S. (2015). *Distribuição temporal e espacial da qualidade do leite no estado de Goiás* (Tese de doutorado). Universidade Federal de Goiás.

Rosa, D. C., Trentin, J. M., Pessoa, G. A., Silva, C. A. M., & Rubin, M. I. B. (2012). Qualidade do leite em amostras individuais e de tanque de vacas leiteiras. *Arquivos do Instituto Biológico*, *79*(4), 485-493.

Souza Júnior, A. H. D., Lana, R. D. P., Teixeira, C. R. V., Gionbelli, M. P., Veloso, C. M., & Rennó, L. N. (2016). Gordura protegida e nível variável de proteína em dietas para vacas mestiças no terço inicial da lactação. *Acta Scientiarum. Animal Sciences*, *38*(1), 107-112. https://doi.org/10.4025/actascianimsci.v38i1.29150

Wattiaux, M. A. (2006). *Composição do leite e valor nutricional*. Dairy Essentials-Lactation and Milking, Babcock Institute for International Dairy Research and Development, Babcock Institute.

Weber, C. T., Schneider, C. L. C., Busanello, M., Calgaro, J. L. B., Fioresi, J., Gehrke, C. R., Conceição, J. & Haygert-Velho, I. M. P. (2020). Season effects on the composition of milk produced by a Holstein herd managed under semi-confinement followed by compost bedded dairy barn management. *Semina: Ciências Agrárias*, *41*(5), 1667-1678. https://doi.org/10.5433/1679-0359.2020v41n5p1667