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Characterization of dystocia in a herd of Holstein dairy cows in Brazil

Caracterização da distocia em um rebanho de vacas da raça Holandesa no Brasil

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Abstract
The objective of this study was to characterize calvings with low and high difficulty based on the productive and reproductive performance of dairy cows. Calvings were grouped in no calving assistance, calving with low assistance, and calving with high assistance. The original data set comprised 1,902 calving records obtained from a large dairy farm in Southeast Brazil. Factor analysis was applied using the SAS® Studio 3.8 statistical program through the factor procedure, considering the Multivariate Analysis category. Milk fat (0.92–0.79) and total solids (0.91–0.80) were strongly correlated with Factor 1. Calving interval (0.87–0.68) and the number of AI (artificial inseminations) per conception (0.87–0.71) showed high correlations with Factor 2. Milk yield (0.84–0.76) and accumulated milk yield (0.84–0.77) were strongly correlated with Factor 3. Based on the results, we conclude that the three calving scenarios were characterized by well-defined and independent factors. Cows which required a high assistance at calving showed a lower variance explained by the model for milk fat and total solids contents, calving interval, and the number of AIs per conception.
Keywords: calving assistance; calving management; milk production; multivariate analysis

Resumo
O objetivo deste estudo foi caracterizar os partos com leve ou severa dificuldade e diferenciá-los com base no desempenho produtivo e reprodutivo de vacas leiteiras. Os partos foram agrupados em partos sem assistência, partos com baixa assistência e partos com elevada assistência. O banco de dados original continha 1902 registro de partos que foram obtidos de uma grande fazenda comercial localizada no Sudeste do Brasil. A análise fatorial foi aplicada através do programa estatístico SAS® Studio 3.8 por meio de procedimento fatorial, considerando a categoria de análise multivariada. Os teores de gordura do leite (0,92– 0,79) e de sólidos totais (0,91–0,80) foram altamente correlacionados com o fator 1. Intervalo entre partos (0,87–0,68) e número de IA (inseminações artificiais) por concepção (0,87–0,71) apresentaram alta correlação com o fator 2. Produção de leite (0,84–0,76) e produção acumulada de leite (0,84–0,77) foram altamente correlacionados com o fator 3. Baseados nos resultados, é possível concluir que as três situações de parto foram caracterizadas por fatores independentes e bem definidos. Vacas que necessitaram de alta assistência ao parto apresentaram menor variância explicada pelo modelo para teores de gordura e sólidos totais do leite, intervalo entre partos e número de IA por concepção.
Palavras-chave: assistência ao parto; análise multivariada; manejo do parto; produção de leite

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Introduction

Dystocia harms the health and the welfare of dairy cows and impairs the profitability of dairy herds. Its occurrence increases the labor costs on the farm, generates additional costs with veterinary assistance, increases calf mortality, reduces the productive performance of postpartum cows, decreases the fertility rate, and increases involuntary culling[1]. Several studies have sought to identify the prevalence of dystocia in dairy herds [2–4] and its impact on the subsequent lactation [5–7]. Several classification systems have been developed to identify the degree of calving difficulty. However, there is no standardization among these classification systems [8].

Cattle behavior undergoes numerous changes on the day of calving. However, cattle behavior in late gestation cannot be considered a good predictor of dystocia [9]. Another study showed that dry matter intake, as percentage of body weight and energy balance pre-partum (-21 d relative to birth), were not associated with calving disorders (twins, stillbirth, and dystocia) [10]. Within this aspect, there is currently a controversy for the classification of dystocia based on calving difficulty. Most classification systems consider only dystocia as an issues that requires assistance by one person or a veterinarian procedure for calving [11–13]. These classification systems do not consider births that require little assistance for calving. This question generates doubts when comparing different groups of calving difficulties with those calvings that do not need any veterinary intervention.

Factor analysis is a statistical technique commonly used in the social sciences. Nevertheless, it has been applied in other areas, for example in the field of animal science, precisely because it is a multivariate technique that enables understanding the behavior of variables that are associated or not. Factor analysis has three uses: (1) understanding the structure of a set of variables; (2) building a questionnaire to measure an underlying variable; (3) reducing data sets to a more manageable size while retaining as much original information as possible [14,15].

Hypothetically, both calvings with low and high degree of difficulty influence the behavior of variables related to the performance of dairy cows. Therefore, this study aimed to characterize calvings with no dystocia and with low or high calving difficulty and to differentiate them based on the behavior of variables related to milk production and its composition, accumulated production, and fertility of dairy cows.

Material and methods

This study was approved by the Ethics Committee on the Use of Animals (CEUA) of the State University of Maringá (Universidade Estadual de Maringá - UEM), under the protocol Nº. 2484280618. The Santa Rita Agrindus Farm, located at São Paulo State, Southeast Brazil, provided the data for this study. The coordinates of the experimental area are 21°57'50.6 latitude south, 47°41'37.8 longitude west, and the farm is located in a subtropical region with hot and humid summers. The herd consisted of 3,500 Holstein animals, of which 1,700 were lactating cows, producing around 60,000 kg of milk per day, accounting for an average of 35 kg/milk per day. Lactating cows are housed in free-stall barns equipped with ventilated troughs.

Of the total calvings, 949 were primiparous (nulliparous that became primiparous cows) and 953 were multiparous. Of these, 17 had a low body condition score (BCS) (<3.00), 22 had a high BCS (>3.50), and 1,863 had an intermediate and desirable score (3.00–3.50), according to a scale of 1 to 5 score (16). Of the 1,902 births, 919 were female, 855 male, 74 stillbirths (no calving assistance = 31; calving with low assistance = 18; calving with high assistance = 25), and 54 twins (no calving assistance = 30; calving with low assistance = 12; calving with high assistance = 12). Calvings occurred in summer (604), fall (435), winter (471), and spring (392) during the years 2015 (644), 2016 (629), and 2017 (629).

The degree of calving difficulty was classified as grade 1 = no assistance; 2 = assistance by one person without mechanical traction; 3 = assistance by two or more people; 4 = assistance with mechanical traction; and 5 = surgical procedure (17). The dystocia score was based on the degree of assistance required during delivery. Calvings were grouped in no calving assistance (n = 1,125), which it is characterized as parturition without aid for the birth of the calf; calving with low assistance (n = 672), when it was necessary to draw a small re-positioning of the fetus; and calving with high assistance (n = 105), requiring assistance by two or more people or strong traction and veterinary intervention.

The reproduction variables were collected by the technical team responsible for the farm and were as follows: FS = calving to first service interval (d), CCI = calving to conception interval (d), CI = calving interval (d), and NAIC = the number of AIs per conception. Cows with intervals to the first service higher than 145 d, conception intervals greater than 300 d, and calving intervals higher than 500 d were excluded from the database.

The variables corresponding to the cows' productive performance (1st to 5th lactations) were the following: MY = milk yield (kg/d^{-1}), FCM = 4% fat-corrected milk (kg/d^{-1}), AMY = accumulated milk yield (kg) of the subsequent lactation, and LL: lactation length (d). Values higher than 54 kg/d of milk were deleted from the database. Those cows that remained in lactation for more than 500 d or produced more than 19,000 kg of milk in a single lactation were also excluded. The 4% fat-corrected milk was calculated following the Gaines equation [18].

Milk samples were collected during the morning milking for milk composition analysis. Data corresponding to the first two monthly test-day records were considered valid for milk composition variables. The variables related to milk composition were fat (%), protein (%), lactose (%), and total solids (%). The milk somatic cell count was converted into a linear scale (19). The original dataset contained 3,487 calving records obtained from farm records but was edited for erroneous or incomplete data (1,585). The data (1,902) were checked for outliers and normal distribution by normal density curve analysis and Kernel density by histogram construction. Based on these data, tables containing the means and standard deviations of the independent variables were generated (Table 1).

Table 1. Means (± standard deviations) of continuous variables

Variable	No Calving Assistance	Calving with Low Assistance	Calving with High Assistance
Reproductive Parameters			
FS[1] (d)	53.0 ± 24.5	52.0 ± 22.9	60.0 ± 27.9
CCI[2] (d)	150.9 ± 72.0	146.5 ± 69.4	166.1 ± 69.1
CI[3] (d)	373.8 ± 46.9	378.1 ± 46.7	377.9 ± 48.3
NAIC[4]	1.9 ± 1.0	2.1 ± 1.0	1.9 ± 1.0
Productive Parameters			
MY[5] (kg/d^{-1})	35.6 ± 6.8	35.7 ± 6.9	35.6 ± 6.0
FCM[6] (kg/d^{-1})	33.1 ± 7.5	33.0 ± 7.8	32.7 ± 7.4
AMY[7] (kg)	10,672.7 ± 3,724.0	10,732.4 ± 3,517.4	10,434.7 ± 3,392.3
LL[8] (d)	299.3 ± 89.4	300.5 ± 81.1	294.7 ± 91.3
Milk Components			
Fat (%)	3.53 ± 0.7	3.47 ± 0.7	3.43 ± 0.8
Protein (%)	2.97 ± 0.2	2.97 ± 0.2	2.98 ± 0.2
Lactose (%)	4.67 ± 0.1	4.66 ± 0.1	4.64 ± 0.1
Total Solids (%)	12.14 ± 0.8	12.08 ± 0.8	12.05 ± 0.9
LSCS[9]	2.28 ± 2.03	2.56 ± 2.0	2.16 ± 1.9

[1]FS: days to first service; [2]CCI: calving to conception interval; [3]CI: calving interval; [4]NAIC: number of AIs per conception; [5]MY: milk yield; [6]FCM: 4% fat-corrected milk; [7]AMY: accumulated milk yield; [8]LL: lactation length; [9]LSCS: linear somatic cell score.

The Kaiser-Meyer-Olkim and Communality tests were used to assess the adequacy of the samples (Table 2). Thus, two variables were selected within each parameter (productive and reproductive parameters) that had high KMO (>0.3) and Communality (>0.7) in at least two calvings situations; the following variables were selected: calving interval, number of AIs per conception, milk production, cumulative milk production, milk fat and total solids contents. Factor analysis was carried out independently for dystocia. The values of eigenvectors explained and accumulated variance corresponding to the factors were also displayed. The accumulated variance approached 100% when three factors were accounted for all groups of dystocia (Table 3).

Table 2. Sample adequacy of continuous variables

Variable	No Calving Assistance		Calving with Low Assistance		Calving with High Assistance	
	KMO	Communality	KMO	Communality	KMO	Communality
Reproductive Parameters						
FS[1] (d)	0.37	0.02	0.41	0.03	0.63	0.40
CCI[2] (d)*	0.84	0.23	0.71	0.21	0.47	0.39
CI[3] (d)*	0.49	0.87	0.47	0.85	0.50	0.20
NAIC[4]	0.49	0.89	0.47	0.83	0.48	0.20
Productive Parameters						
MY[5] (kg/d^{-1})*	0.53	0.95	0.51	0.95	0.45	0.89
FCM[6] (kg/d^{-1})	0.44	0.47	0.48	0.48	0.37	0.56
AMY[7] (kg)*	0.58	0.79	0.65	0.83	0.61	0.82
LL[8] (d)	0.46	0.67	0.38	0.67	0.43	0.88
Milk Components						
Fat (%)*	0.31	0.75	0.32	0.70	0.37	0.79
Protein (%)	0.10	0.17	0.09	0.17	0.19	0.45
Lactose (%)	0.05	0.02	0.07	0.05	0.20	0.55
Total Solids (%)*	0.33	0.82	0.34	0.78	0.38	0.79
Linear SCS[9]	0.89	0.06	0.83	0.06	0.54	0.34

[1]FS: days to first service; [2]CCI: calving to conception interval; [3]CI: calving interval; [4]NAIC: number of AIs per conception; [5]MY: milk yield; [6]FCM: 4% fat corrected milk; [7]AMY: accumulated milk yield; [8]LL: lactation length; [9]LSCS: linear somatic cell score *Highlighted for variables selected based on Kaiser-Meyer-Olkim (KMO) and communality estimates.

Table 3. Eigenvalue, variance explained, and variance accumulated for dystocia

Variables	No Calving Assistance			Calving with Low Assistance			Calving with High Assistance		
	F1	F2	F3	F1	F2	F3	F1	F2	F3
Eigenvalue	1.94	1.80	1.51	2.07	1.73	1.44	2.15	1.68	1.30
Variance explained (%)	36.9	34.4	28.7	39.4	33.0	27.4	41.8	32.8	25.3
Variance accumulated (%)	36.9	71.3	100.0	39.4	72.4	99.8	41.8	74.6	99.9

Factor analysis was applied using the SAS® Studio 3.8 statistical program through the factor procedure, considering the multivariate analysis category. This analysis is characterized by performing a factor analysis with a variety of methods and rotations. The method for factor extraction used was principal components analysis considering three factors. The selected statistics to display were descriptive statistics, correlations, residual correlations, eigenvectors, factor scoring coefficients, Kaiser's measure of sampling adequacy, and display factor loadings with the largest absolute loading first. The selected plots to display were eigenvalue by component (screen plot). The model for the analysis of each factor was as follows:

$$Yi = b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 + \mathcal{E}_i,$$

where Yi = value corresponding to the factor, b = value of the factor loading, X_1 = calving interval, X_2 = number of AIs for conception, X_3 = milk yield, X_4 = accumulated milk yield, X_5 = milk fat, X_6 = total solids, and $\mathcal{E}_{i}$ = random error.

Results and Discussion

We sought to characterize normal calving and two levels of calving difficulty (mild and severe assistance) through factor formation. This characterization was accomplished by forming three factors for dystocia, which, in this case, explained nearly 100% of the specific variation in six variables linked to production, milk composition, and reproduction (Table 3). When we evaluated the formation of Factor 1 (Table 4), we noticed that the highest factor loadings (>0.75) were milk fat and milk total solids contents. Considering Factor 2, the highest (>0.65) factor loadings corresponded to the calving interval and the number of inseminations to achieve pregnancy. In Factor 3, the variables related to milk production had the highest (<0.70) factor loadings. This suggests the formation of three well-defined factors consisting of pairs of variables, and this condition was similar for all three groups of calving assistance.

Table 4. Factorial load for each calving type

Variables	No Calving Assistance			Calving with Low Assistance			Calving with High Assistance		
	F1	F2	F3	F1	F2	F3	F1	F2	F3
Reproductive Parameters									
CI[1] (d)	-0.34	0.87	-0.14	0.35	0.86	-0.11	-0.65	0.68	0.11
NAIC[2]	-0.30	0.87	-0.21	0.40	0.84	-0.13	-0.61	0.71	0.21
Productive Parameters									
MY[3] (kg/d)	-0.09	0.12	0.84	0.44	-0.01	0.76	0.21	-0.15	0.76
AMY[4] (kg)	-0.16	0.19	0.84	0.42	-0.04	0.77	0.14	-0.07	0.80
Milk Components									
Fat (%)	0.92	0.32	0.07	0.83	-0.38	-0.34	0.79	0.59	-0.06
Total Solids (%)	0.91	0.32	0.04	0.84	-0.36	-0.32	0.80	0.56	-0.02

[1]CI: calving interval; [2]NAIC: number of AIs per conception; [3]MY: milk yield; [4]AMY: accumulated milk yield.

The relationships among the variables are shown in the factor diagram in Figure 1. For the three calving conditions (a, b, and c), the milk fat content was close to the point of the milk total solids content, revealing that these variables are strongly associated. This also occurred with the variables related to milk production and those linked to reproduction. There were slight variations in the coordinates of each variable, indicating that there is a point difference in the positioning of each variable that is dependent on the degree of calving difficulty.

A factor is composed of a subset of variables that have a given correlation coefficient, and this association builds a dimension, thus being able to explain a particular aspect (14). Within this perspective, the factor could be defined as a linear combination of original variables, which together represent the latent dimensions that summarize the set of variables, maintaining the representativeness of the characteristics of the variables [(15)].

In Factor 1, we found a strong association between milk fat and milk total solids contents. This fact is also well described in studies that evaluate the interference of management or a specific feed or nutritional practice with the performance of dairy cows. When a factor causes a variation in the milk fat content, there is usually a rise in the total solids concentration [(21)]. This combination occurs precisely because total solids include all milk components except water [(22)] and because milk fat has a greater variability than the remaining milk solids, such as protein and lactose.

Considering Factor 2, we noticed a strong relationship in variables related to reproductive performance, precisely because of the strong association between calving interval and the number of inseminations until conception. Factors such as the number of inseminations until conception and the calving interval influence the time between one calving and another [(23)]. The association between daily and cumulative milk production, found in Factor 3, was also expected. As for Factors 1 and 2, these two variables are strongly correlated and are often described in studies evaluating the productive performance of dairy cows. Number and stage of lactation, milking time, and milking frequency are factors that directly interfere with the variables that are linked to milk production [(24)]. Therefore, in this study, each factor was basically composed of two variables (Fig. 2).

As the second objective of this study, we attempted to differentiate the calving difficulty groups by considering the factor loading values generated by Factor analysis. Overall, the lowest factor loading values occurred in calving conditions with high assistance (Fig. 3). This pattern was observed in variables related to milk composition (milk fat and total solids contents) and those linked to reproductive parameters (calving interval and number of inseminations until conception).

Other authors have shown detrimental effects of dystocia on productive and reproductive parameters. For example, Kaya et al. [(7)] found that dystocia reduced milk production during lactation in primiparous Holstein cows and that it had no significant effects on reproductive measures. In that study, primiparous cows with dystocia produced 85 kg less milk in the first 100 days of lactation than cows with eutocia. In a study by Atashi et al. [(25)], the lactation performance was influenced by dystocia, where the total 305-d milk, fat, and protein yields were 135, 3.16, and 6.52 kg lower in cows that experienced dystocia at calving compared with those that did not.

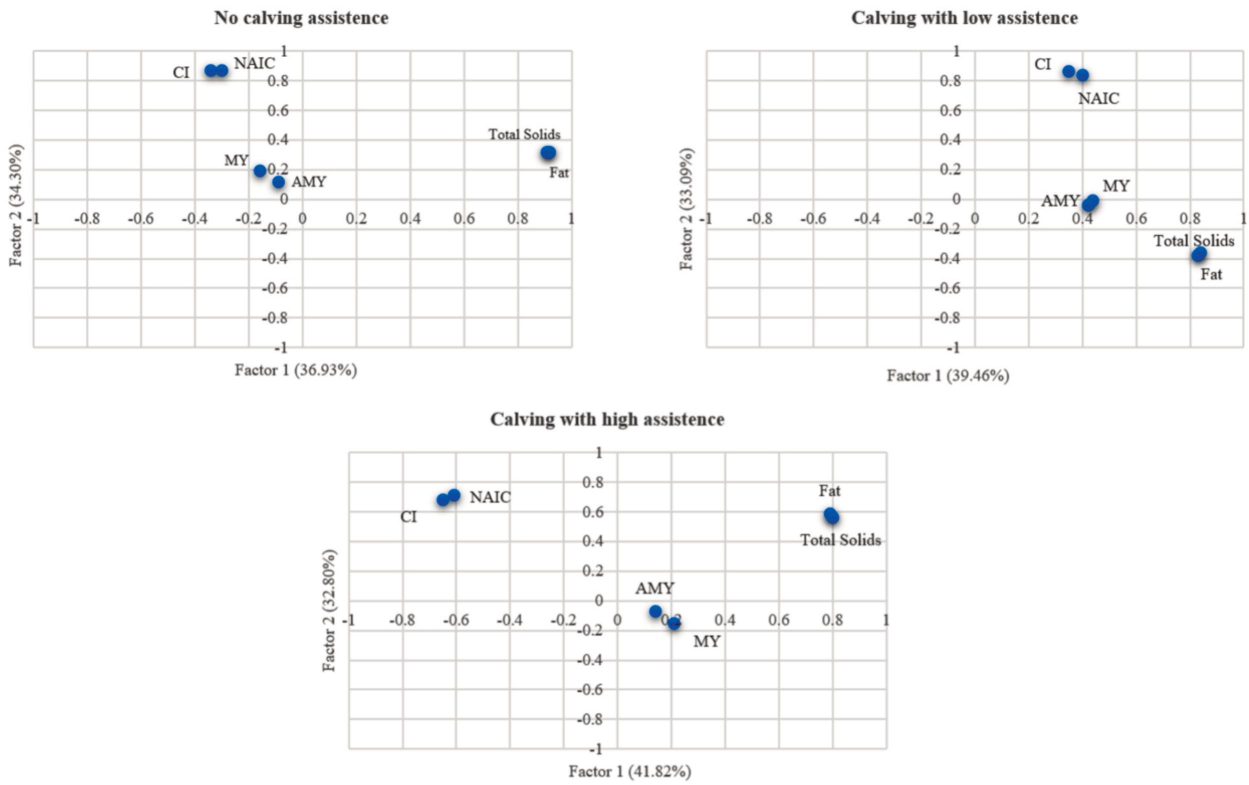

Figure 1. Diagram factors for groups of calving. CI: calving interval; NAIC: number of AIs per conception; MY: milk yield; AMY: accumulated milk yield.

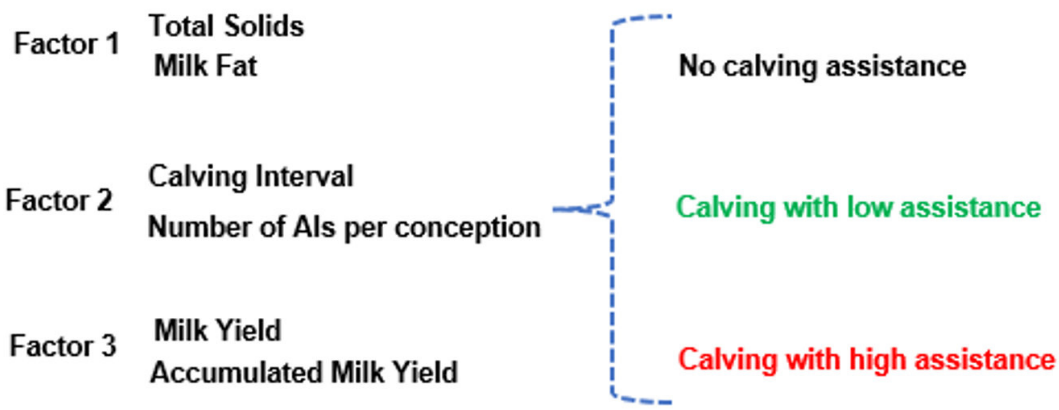

Figure 2. Characterization of factors for normal calvings and two levels of dystocia.

According to Barrier and Haskell [26], calving difficulty reduces milk yield in the cow, but it is not clear how long the adverse effect on milk production lasts. Some studies suggest shorter-term effects, which disappear beyond 14 DIM [27], 90 DIM [28], or 6 mo [29] postpartum. Furthermore, the degree of difficulty at which milk losses are reported ranges from slight degrees of difficulty to severe cases that require surgery. Additionally, losses are thought to increase with increasing degrees of difficulty. However, the pattern of milk loss variation is not always obvious.

Considering the results found by Gaafar et al. [6], the incidence of dystocia has an adverse effect on the reproductive intervals of dairy Friesian cows, where the first estrus, first service, days open, and calving interval were longer in cows that exhibited dystocia compared to normal cows. These results indicate that dystocia leads to an increase in the days to first insemination, more days open, and a higher calving interval.

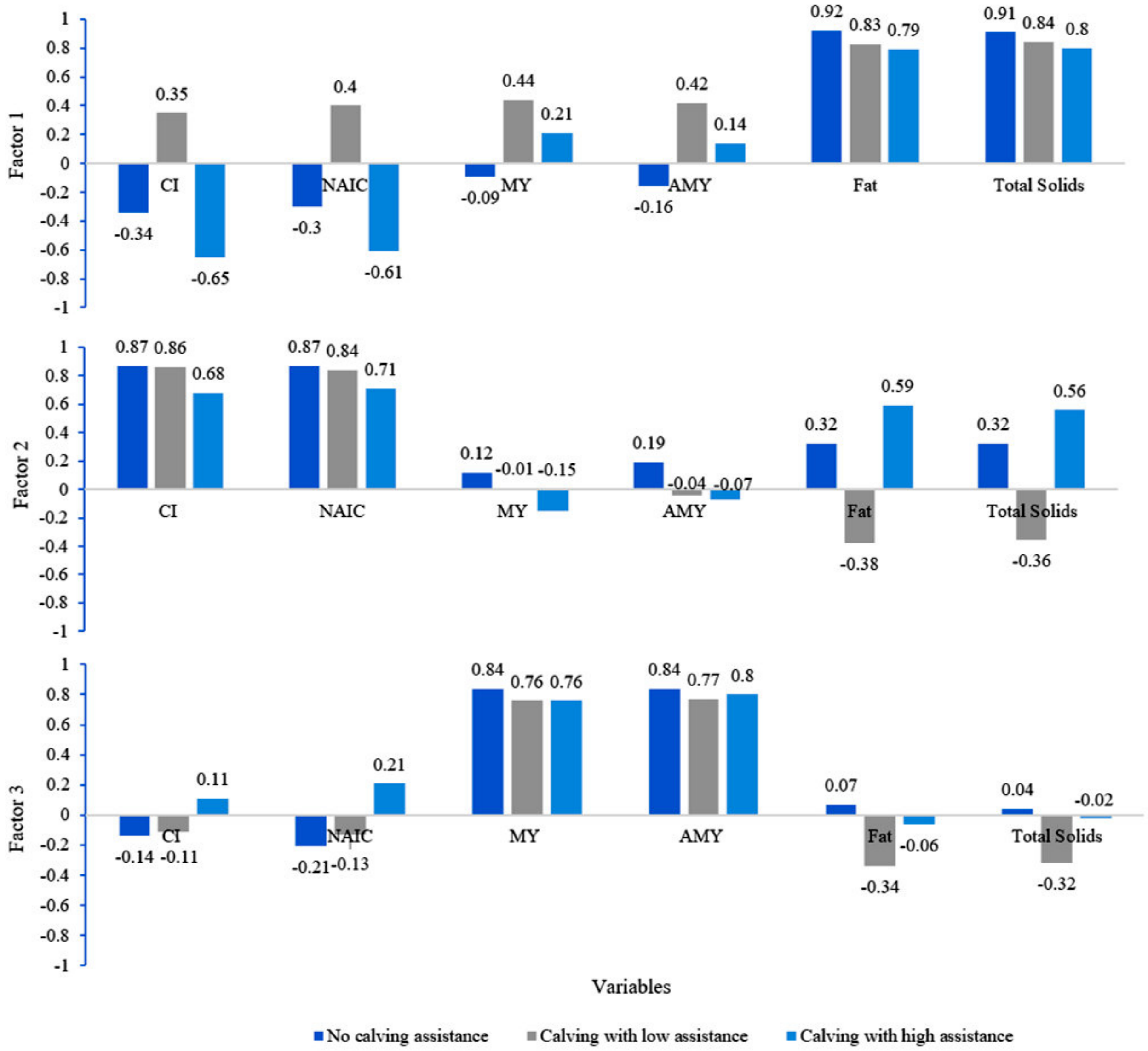

Figure 3. Graphic factors with factorial loads for groups of dystocia. CI: calving interval; NAIC: number of AIs per conception; MY: milk yield; AMY: accumulated milk yield.

We observed the formation of three factors (vertical) constituted basically by pairs of variables linked to production (daily and accumulated milk production), milk composition (milk fat and total solids contents), and reproductive parameters (calving interval and number of inseminations per conception). When looking at the representative scheme considering the degree of calving difficulty (horizontal), we notice that the indicator (blue arrow) informs the value of the factorial load attributed to each variable (Fig. 4).

This scheme reveals how much a given variable is associated with a factor through the factor loading value. When considering the first situation (I), we can see that the factorial load values are higher than 0.8 for Factors 1, 2, and 3. These values are close when considering the second situation (II). In this case, the factorial load value exceeds 0.80 in Factors 1 and 2. When considering the third situation (III), we notice that the factorial loadings have a maximum amplitude of 0.80 and a minimum of 0.68 and differ from the no calving assistance and calving with low assistance mainly in Factors 1 and 2.

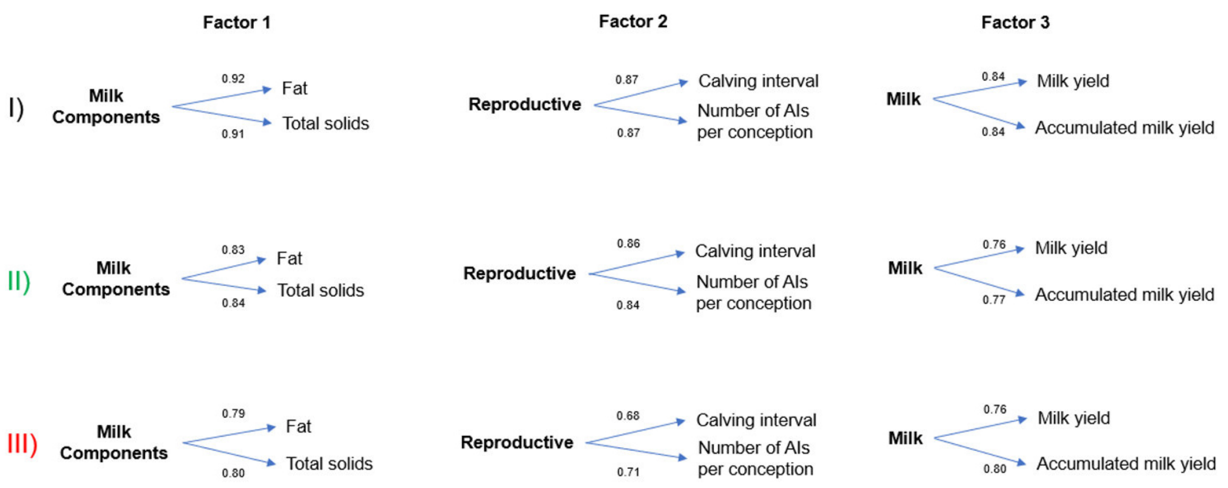

Figure 4. Pathway model for two variables with three factors in common. I = no calving assistance; II = calving with low assistance; III = calving with high assistance.

When a factor suffers interference from a particular agent causing variation, probably all variables contained in this factor (which are highly associated) will also suffer variation. This is because the degree of correlation between variables is based on estimates of covariance and standard deviation [20]. Extrapolating these conditions to the results in this study, we could infer that milk fat and total solids concentrations, calving interval, and the number of inseminations required for conception have less explained variance at a high degree of dystocia when compared to the other calving situations.

We might expect that cows that go through a condition of no calving assistance or that require a minor intervention for calf birth would have a smaller fluctuation in milk fat content and milk total solids after calving. In addition, these cows might experience less variation in calving interval. It appears that those cows that experience a high degree of dystocia (high assistance) suffered more from factors causing variations than those studied in this study, possibly due to the lower variance explanation of the model for this calving situation.

For these data, we can state that cows that go through a calving with high difficulty could present a greater instability regarding productive and reproductive parameters and that these additional factors may influence the performance of these animals. In the literature, there are several studies that point out that dystocia is responsible for interfering with the reproductive performance of a dairy herd, precisely because it causes problems such as retained placenta, metritis, and fetal reabsorption [7,27, 30,31,32].

Based on these results, we advise dairy farmers and their technicians to monitor mainly the health of cows that have had a calving with high degree of assistance. This group of cows can be more influenced by factors that are not associated with normal calving. We emphasize which premature obstetrical assistance may result in a high prevalence of severe dystocia and has a negative effect on postpartum health of the dam and on newborn calf vitality [33]. Furthermore, the appropriate time for assistance is paramount for peripartal well-being of both the dam and her offspring.

Conclusion

The three calving situations were characterized by well-defined and independent factors. Each factor was composed of two variables related to milk production, milk composition, and reproductive parameters. Cows that required a high assistance for calving showed a lower factor loading value by the model for milk fat and total solids contents, calving interval, and the number of inseminations until conception. We recommend that calving be classified into at least two categories: normal calving (no calving assistance) and dystocia (high assistance for calving). More studies should be performed to classify the types of calving, and more variables should be employed in the multivariate model.

Conflict of Interest Declaration

The authors declare that they have no conflicts of interest.

Author Contributions

Conceptualization: G. T. Santos. *Data curation*: M. S.V. Salles. *Formal analysis*: P. C. Ossani, F. I. Bánkuti and D. F. Rossoni. *Writing (original draft)*: J. C. S. Lourenço. *Writing (review & editing)*: R. Almeida and J. A. C. Osorio.

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