



## Factor Analysis of Linear Type Traits and Their Relation with Longevity in Brazilian Holstein Cattle

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**ABSTRACT:** In this study we aimed to evaluate the reduction in dimensionality of 20 linear type traits and more final score in 14,943 Holstein cows in Brazil using factor analysis, and indicate their relationship with longevity and 305 d first lactation milk production. Low partial correlations ( $-0.19$  to  $0.38$ ), the medium to high Kaiser sampling mean ( $0.79$ ) and the significance of the Bartlett sphericity test ( $p < 0.001$ ), indicated correlations between type traits and the suitability of these data for a factor analysis, after the elimination of seven traits. Two factors had autovalues greater than one. The first included width and height of posterior udder, udder texture, udder cleft, loin strength, bone quality and final score. The second included stature, top line, chest width, body depth, fore udder attachment, angularity and final score. The linear regression of the factors on several measures of longevity and 305 d milk production showed that selection considering only the first factor should lead to improvements in longevity and 305 milk production. (**Key Words:** Autovalues, Final Score, Milk Production, Linear Regression, Longevity, Holstein)

### INTRODUCTION

Type traits are important when making selection and reproduction decisions in dairy cattle (Scheinder et al., 2003), influencing directly and indirectly on culling decisions (Zavadilová and Stipková, 2012), longevity and milk production (Rennó et al., 2003; Scheinder et al., 2003). They may be used as indirect predictors of longevity and milk production due to their moderate genetic correlations with these traits and can be determined early in the life of the animal (Cruickshank et al., 2002; Esteves et al., 2004).

The high number of linear type traits, as well as the high

degree of interrelations and colinearity between them (Montovani et al., 2005), such as those between udder and conformation traits (Campos et al., 2012), may give imprecise estimates of the relationship between these traits and longevity (Vukasinovic et al., 1997), resulting in overestimation of longevity, especially in small data banks (Visscher, 1995). According to Vukasinovic et al. (1997) a limited number of type traits, with a known biological relationship with longevity, should be used for indirect selection for the latter.

Factor analysis is a useful multivariate technique to explain the dependencies between traits (Corrales et al., 2011) as it aims to remove redundant information between correlated variables and represent them in a small group of new traits called factors (Vukasinovic et al., 1997). A large number of traits that are strongly interrelated can be analysed (Hair et al., 2009) without presenting colinearity (Corrales et al., 2011).

In this study, we aimed to evaluate the reduction in dimensionality using factor analysis of 20 linear type traits and final score to indicate those that have the strongest relationship with longevity and 305 d first lactation milk

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production in Brazilian Holsteins.

## MATERIAL AND METHODS

The data used was collected by the technicians of the Service for Linear Classification, Milk Control and Genealogy of the Brazilian Association of Holstein Breeders (ABCBRH) and its state affiliates between 1996 and 2008. A total of 14,943 cows, daughters of 397 bulls, belonging to 198 herds were used.

The linear classification system used by the ABCBRH included 20 type traits as well as the final score. These traits are based on direct measurements or visual scores of morphology expressed on a scale of one to nine points. These traits were divided in seven sections as in the Canadian model: i) Conformation (ST, stature; TL, top line; WE, weight; CW, chest width; BD, body depth; LS, loin strength), ii) Rump (RA, rump angle; RW, rump width), iii) Feet and legs (FA, foot angle; BQ, bone quality; SV, side view of rear legs), iv) Anterior udder (FU, fore udder attachment; FT, fore teat placement; TL, teat length), v) Posterior udder (RH, rear udder height; RUW, rear udder width; RT, rear teat placement), vi) Mammary system (UD, udder depth; UT, udder texture; UC, udder cleft) and vii) Dairy form (AN, angularity), as well as final score (FS) where dairy form accounted for 12%, conformation (18%), feet and legs (20%) and mammary system (8%), rump (10%), front udder (14%) and rear udder (18%) (Campos, 2012).

Longevity measures related to productive life or time in the herd were determined from production and reproduction records: total milk production in all lactations (Long 1); number of lactations initiated (Long 2); total number of days during all lactations (Long 3); time between birth and last milk control (Long 4) in months and time from first parturition to last milk control (Long 5) in months. Milk production in 305 d of the first lactation was also calculated.

To improve the consistency of the structure of the database and subsequent analysis, the records of cows without pedigree, dates of birth, parturition or end of lactation were removed from the data, as well as those that may still be alive, with less than two lactations, with parturition date less than 21 or greater than 48 months, without production records, cows that were not in the third month of lactation and those with a final score less than 60 points were removed from the analysis. For cows with more than one classification over the productive life, only the first was considered. Furthermore, it was considered number of classifications per technician greater than 176, number of daughters per bull greater than nine and number of cows per herd greater than 14.

The criterion used to verify if cows were alive included

the presence of the date of the end of the last lactation, and the difference between the last parturition of the cow and the last of its herd. If this difference was less than 24 months the cow was considered to be alive. The 24 month period was used because about 95% of this population of cows showed a new calving within this period. This criterion was also used by Caetano et al. (2012) in Nelore cows.

The factor analysis included 20 linear type traits and final score using the correlation matrix between the traits to ensure that all traits are standardized in the analysis (Vucasinovick et al., 1997). The matrix of partial correlations, Kaiser statistic for sampling adequacy (MSA) using a lower limit of 0.69, and Bartlett's sphericity test were used to determine the degree of interrelations between variables and adequacy for use in factor analysis.

Factors were chosen based on autovalues greater than one and *scree* test (graph) (Cattell, 1966). The point where the graph begins to become horizontal is considered indicative of the maximum number of factors to be extracted (Hair et al., 2009). Factors were rotated using varimax rotation to facilitate interpretation due to the reduction of ambiguities in non-rotated solutions (Hair et al., 2009). The value of 0.30 was used to assure a significant correlation between traits and factors.

The statistical analyses were carried out using the FACTOR procedure in SAS (Statistical Analysis System), version 9.2 (SAS, Institute, Inc., Cary, NC, USA) using the Maximum Likelihood method to reduce the dimensionality and reduce the information in a group of  $p$  original variables  $Z_1, Z_2, \dots, Z_p$ , to a new group of variables  $Y_1 (F_1), Y_2 (F_2), \dots, Y_p (F_p)$ . In this analysis a few of the first factors contain the greater part of the variability contained in the original variables (Cruz and Regazzi, 1997).

The relationship of these factors with measures of longevity and 305 d first lactation milk production, using general linear model in the GLM procedure of SAS Statistical Analysis System, version 9.2 (SAS, Institute, Inc., Cary, NC, USA):

$$Y_{ijkln} = \mu + H_i + CL_j + YC_k + CA_l + b_1(X - \bar{X})_{n1} + b_2(X - \bar{X})_{n2} + \dots + b_p(X - \bar{X})_{np} + \varepsilon_{ijkln}$$

where,  $Y_{ijkln}$  is the longevity measure or 305d milk production of the cows, in the  $i$ th fixed herd ( $H$ ), classified by the  $j$ th fixed classifier ( $CL$ ), in the  $k$ th fixed year ( $YC$ ),  $l$ th fixed calving age subclass ( $CA$ );  $\mu$  is the overall mean for the trait;  $b_p$  are the regression coefficients estimated for the  $p$  common factor scores;  $(X - \bar{X})_{np}$  are the  $n$  observations of the  $p$  variables; and  $\varepsilon_{ijkln}$  is the random error

associated with each observation,  $\varepsilon_{ijkln} \sim NID(0, \sigma_\varepsilon^2)$ .

## RESULTS AND DISCUSSION

The means of linear type scores varied between 7.28 for stature and 4.55 rear teat placement (Table 1). The traits that had an ideal score of nine points presented the greatest difference from ideal scores as defined by the ABCBRH, especially posterior udder width that had a difference of more than three points. Standard deviations are in agreement with those found in the literature for linear type traits in Holstein cattle in Brazil (Campos et al., 2012).

Linear type classification is an important tool in decision making as it focuses on the selection of animals that should have a longer herd life, expressing their productive and reproductive potential based on their morphologic traits (Pérez-Cabal et al., 2006; Posadas et al., 2008).

Angle rump, side view of rear legs, rear teat length and udder depth had Kaiser (MSA) score equal to or lower than 0.50, a level considered unacceptable for factor analysis (Hair et al., 2009). Foot angle, fore and rear teat placement had low communality values (less than 0.05) and so were also excluded from the factor analysis.

Corrales et al. (2011), studying 24 linear type traits in Holstein cows, also excluded traits that were not adequate for factor analysis using principal components, deleting traits such as isquio placement, leg position – posterior vision, teat length, height of posterior placement of the teats and loin strength.

The low estimates of partial correlation, varying between –0.19 and 0.38 for linear type traits, the significant Bartlett sphericity test ( $p < 0.001$ ), general mean value of

**Table 1.** Ideal score, mean and standard deviation (SD) for linear type traits in Brazilian Holstein cows

Section/trait	Abbreviation	Ideal score	Mean±SD
<b>Conformation</b>			
Stature	ST	7	7.28±1.28
Top line	TL	5-6-7	5.11±1.00
chest width	CW	7	5.75±1.20
Body depth	BD	7	6.20±1.07
Loin strength	LS	9	6.36±1.30
<b>Rump</b>			
Angle	RA	5-6-7	4.99±0.99
Width	RW	9	6.44±1.18
<b>Feet and legs</b>			
Foot angle	FA	7	5.19±1.21
Bone quality	BQ	9	6.59±1.34
Side view of rear legs	SV	5	5.54±1.11
<b>Anterior udder</b>			
Attachment	FU	9	6.09±1.46
Teat placement	FT	5	4.55±1.16
Teat length	UTL	5	5.17±1.05
<b>Rear udder</b>			
Height	RH	9	6.45±1.32
Width	RUW	9	5.93±1.42
Teat placement	RT	5-6	6.23±1.13
<b>Mammary system</b>			
Depth	UD	5-6	4.89±1.16
Texture	UT	9	6.82±1.13
Cleft	UC	9	6.44±1.46
<b>Dairy form</b>			
Angularity	AN	9	6.35±1.11
Final score	FS	>80	80.93±2.89

MSA score of 0.79, with individual MSA estimates varying from 0.69 for body depth to 0.88 for top line indicated the

**Table 2.** Measurement of sample adequacy (MSA) and partial correlations\* between linear type traits

	ST	TL	CW	BD	LS	RW	BQ	FU	RH	RUW	UT	UC	AN	FS
ST	0.82													
TL	0.05	0.88												
CW	0.14	0.11	0.70											
BD	-0.03	0.03	0.30	0.69										
LS	0.14	0.00	-0.08	0.10	0.80									
RW	0.23	0.02	0.10	-0.06	0.01	0.82								
BQ	-0.05	0.01	-0.19	-0.13	0.01	-0.03	0.75							
FU	-0.01	-0.02	0.04	0.03	-0.05	-0.07	0.00	0.70						
RH	-0.03	-0.05	-0.09	-0.05	0.03	-0.05	0.03	-0.03	0.82					
RUW	-0.04	-0.01	0.12	-0.01	-0.05	0.18	0.01	0.02	-0.06	0.85				
UT	0.00	0.01	-0.01	-0.10	0.00	-0.03	0.14	0.03	0.13	0.13	0.82			
UC	-0.02	-0.03	0.01	0.01	-0.06	0.00	-0.01	0.13	0.01	-0.02	0.32	0.75		
AN	0.10	0.07	-0.10	0.25	0.24	0.11	0.23	-0.05	0.11	0.07	0.15	-0.04	0.81	
FS	0.12	0.11	0.10	0.09	0.07	0.15	0.08	0.38	0.26	0.20	0.12	0.26	0.18	0.79

\* Measure of sample adequacy (MSA) on the diagonal and partial correlations off diagonal; ST, stature; TL, top line; CW, chest width; BD, body depth; LS, loin strength; RW, rump width; BQ, bone quality; FU, fore udder attachment; RH, rear udder height; RUW, rear udder width; UT, udder texture; UC, udder cleft; AN, angularity; FS, final score.

existence of significant correlations between linear type traits and the existence of true factors, reinforcing the suitability of the data for factor analysis (Table 2).

According to Hair et al. (2009), partial correlations above 0.70 may be considered high indicating the presence of high correlations between all traits but low correlations between factors which is not desirable. A similar value of general sample adequacy (0.75) was observed for linear type traits in Colombian Holstein cattle (Corrales et al., 2011).

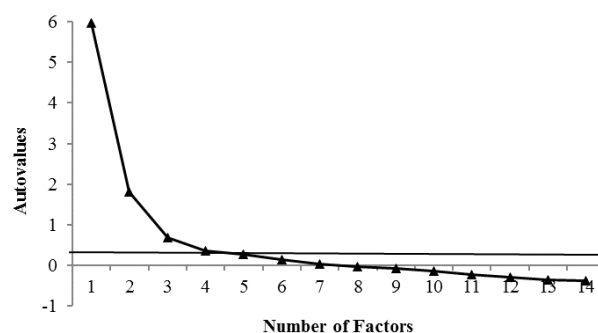
The autovalues had estimates between  $-0.38$  and  $5.96$ , but only two had estimates above one, suggesting two factors with common variance for linear type traits of 76% and 23% (Table 3). The presence of negative autovalues occurs due to the restriction of the common factor analysis where the sum of the autovalues should be equal to the common variance (communality) estimated by the factors which was 7.76 and not the total variance as in the principal component analysis (SAS, 2010).

The scree test indicated the extraction of four factors (Figure 1), two more than those indicated with a critical value greater than one. A similar situation occurred with Pundir et al. (2011) studying body traits in native Indian cows. The scree test can frequently indicate a greater number of factors (two to three) compared with other tests (Hair et al., 2009). Difficulties in obtaining a clear indication of when the line in the scree test becomes horizontal as a definition the number of factors to extract also makes this test confusing (SAS, 2010).

Studies using principal components found a higher number of factors to be extracted for linear type traits. Chu et al. (2002) in China and Corrales et al. (2011) in Antioch identified four and seven factors respectively, with autovalues greater than one. Differences in the statistical

**Table 3.** Autovalues, common variance and accumulated proportion of factors

Factor	Autovalue	Common proportion (%)	Accumulated proportion (%)
1	5.96	76.82	76.82
2	1.80	23.18	100.00
3	0.68	8.73	108.73
4	0.37	4.71	113.45
5	0.28	3.57	117.01
6	0.15	1.92	118.94
7	0.03	0.40	119.33
8	-0.04	-0.46	118.87
9	-0.07	-0.85	118.03
10	-0.14	-1.83	116.2
11	-0.24	-3.03	113.16
12	-0.28	-3.66	109.5
13	-0.36	-4.59	104.91
14	-0.38	-4.91	100.00



**Figure 1.** Relationship between number of factors and their respective autovalues from the Scree test.

methods, as well as populations, may explain the different number of extracted factors. The factor extraction method by the principal components has been the most used method in factor analysis. However, the maximum likelihood method used in this study has been highlighted by statisticians as it provides more accurate estimates in large samples, and allows testing hypotheses on the number of common factors and obtains estimates of standard errors and confidence intervals for many classes of rotated or unrotated factor loadings (SAS, 2010).

The factor weights varied from 0.00 to 0.66 for Factor 1 for body depth and final score respectively (Table 4). Most factor values were positive except for chest width and bone quality which were negative but not significant (less than 0.30) in Factor 1 and 2, respectively.

The correlation between the factors and original traits is represented by its weight where traits with a higher weight are more representative of that factor. Depending on the

**Table 4.** Estimates of factor weights for linear type traits using varimax rotation

Trait	Factor 1	Factor 2	Communality
ST	0.16	0.43*	0.21
TL	0.10	0.32*	0.12
CW	-0.19	0.66*	0.48
BD	0.00	0.51*	0.26
LS	0.30*	0.18	0.13
RW	0.21	0.45*	0.24
BQ	0.51*	-0.17	0.29
FU	0.26	0.32*	0.16
RH	0.52*	0.04	0.27
RUW	0.33*	0.40*	0.26
UT	0.63*	0.12	0.41
UC	0.45*	0.15	0.22
AN	0.57*	0.33*	0.43
FS	0.66*	0.54*	0.72

ST, stature; TL, top line; CW, chest width; BD, body depth; LS, loin strength; RW, rump width; BQ, bone quality; FU, fore udder attachment; RH, rear udder height; RUW, rear udder width; UT, udder texture; UC, udder cleft; AN, angularity; FS, final score.

\* Factor weights equal to or greater than 0.30 were significant.

**Table 5.** Extracted factors and their respective descriptions obtained from linear type traits in Brazilian Holstein cows

Factor	Nome	Characterization of the factor
1	Mammary system	Cows with deep, wide, soft, elastic udder, with Strong central ligament. Strong cows with good bone quality.
2	Body structure	Large, deep bodied, angular cows, with wide thorax and hips, good rib level and well attached udder.

sign and magnitude of the factor weight each factor can be interpreted physiologically or biologically (Vukasinovic et al., 1997).

Most communality estimates were low (Table 4), especially for top line, loin strength and fore udder attachment, inferring that these traits are less effective in explaining variation shared with the other traits. Final score had the highest communality (0.72), confirming its equilibrium position between linear type traits.

The higher significant factor weights in Factor 1 (Table 4) were for final score and traits related to the mammary system so this factor was called Mammary System (Table 5), but traits such as loin strength, bone quality and angularity also had a significant correlation with Factor 1.

The traits with higher weights in Factor 2 (Table 4) were related to the structure of the cow, for example stature, top line, body depth and chest width (Table 5). Factor 2 also presented significant weights for rear udder width, fore udder attachment and final score. Final score was significant in both factors, with high factor weight, communality (Table 4) and represents the full group of traits in the analysis.

Udder width and angularity also appeared in both

factors but higher weights were seen in factors that did not represent the group of traits to which they belong. For example, udder width had a higher weight in Factor 2, which represented the cow structure, whereas Factor 1 represented the mammary system. The opposite was seen for angularity.

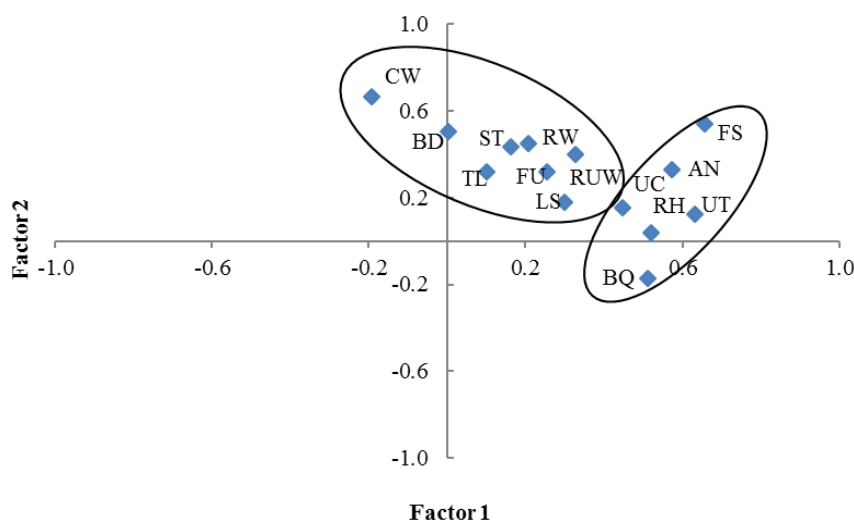
Chu et al. (2002) also found linear type traits with significant weights in different factors. According to Vukasinovic et al. (1997), difficulties occur in interpreting which traits would form factors, as a single trait may contribute to more than one factor, and sometimes with a different sign.

In general, two well defined factors were formed (Figure 2). Factor 1 had a common variance of 4.29 and Factor 2 had a common variance of 3.48, totalling 7.76 total common variance between linear type traits.

A higher number of factors was observed by Chu et al. (2002) and Mantovani et al. (2005), which consisted of four and six factors in Holstein cows and dual purpose Rendena cows, respectively. However, in both studies, the traits related to the structure of the cow also appeared in different factors of the mammary system traits.

Including the traits of Factor 1 in selection decisions (Table 5), cows are expected to have a deep, wide udder that is soft to the touch, well irrigated with strong central ligament all important for udder health and greater production, as well as have a wide well arched back and with flat clean bones able to support the cows in high milk production as well as longevity within the herd.

When Factor 2 is used in for selection, the cows should be larger, with a wide thorax, deep body, wide hips, level top line and angular, resulting in cows with good rib arch and space between ribs, so that the cow can support its own



**Figure 2.** Extracted factors after varimax rotation. ST, stature; TL, top line; CW, chest width; BD, body depth; LS, loin strength; RW, rump width; BQ, bone quality; FU, fore udder attachment; RH, rear udder height; RUW, rear udder width; UT, udder texture; UC, udder cleft; AN, angularity; FS, final score.

weight, respiratory and digestive systems. Because of the positive and significant values of these traits in Factor 2, selection for these traits should result in well inserted udders.

Factor 1 had a better relationship with longevity (Table 6). Cows with a deep, wide, elastic, soft udder with a strong central ligament and good bone structure are associated with greater time in the herd and produce more milk in the first lactation.

Involuntary culling should be avoided, such as that caused by reproduction, health and locomotion problems. A decrease in culling for these reasons increase the proportion of animals culled due to problems related to milk production, resulting in a herd with animals with greater genetic potential for production (Logrotta et al., 2010). Also, the number of adult cows in production increases and consequently the costs related to heifer rearing are offset (Rennó et al., 2003).

A relation between Factor 1 and longevity measures were significant except for with Long 4, indicating that linear type traits in Factor 1 are not related to time between birth and last milk control and at least one trait in this factor is related with the other longevity measures. Other factors such as those observed in the period from birth to first calving may be more important for Long 4 than linear type traits measured from the first lactation.

Factors that included udder and teat traits as well as body traits showed a significant relationship with Long 5, both adjusted for or not for milk production in Brown Swiss cows, indicating that cows with good udders and teats remained longer in the herd while cows with better body score contributed to lower longevity and milk production, due to the negative relationship between body traits and longevity (Vukasinovic et al., 1997).

Survival analyses also showed that udder traits such as anterior insertion, texture and depth as well as anterior teat position and udder support were more important in

determining cow longevity (Caraviello et al., 2003; Sewalem et al., 2004; Morek-Kopéc and Zarnecki, 2012).

Factor 2 only showed relationship with Long 1 and 305 d milk production indicating that selection based on these traits may result in an improvement in total milk production, because besides the Long1 indicate longevity, is also related to milk production, because of their training is the sum of milk yield of whole cow's life.

Estimates of genetic correlations between type traits and milk production range from  $-0.49$  to  $0.65$  demonstrating that the selection for the type is performed genetic improvements can be acquired in milk production of animals (Cruickshank et al., 2002; Rennó et al., 2003).

Corrales et al. (2011) also found a significant linear relationship between 305 d adjusted milk production and six out of seven factors, suggesting that large cows with good udder conformation, udder depth, a strong central ligament, deep angular bodies and good quality bones tend to produce more milk.

The factor analysis reduced the number of linear type traits used in the Brazilian classification system, forming two distinct but interrelated groups, one linked to the mammary system and the other to the structure of the cow, both being related to 305 d first lactation milk production. The significant phenotypic between Factor 1 linear type traits and longevity measures may help in the indication of traits for use in a selection index which helps in increasing longevity, together with an increase in milk production, thereby increasing profits in Brazilian dairy systems.

Moreover, the values of the genetic correlations of longevity with udder traits and milk production, which range from  $-0.56$  to  $0.42$  and  $-0.49$  to  $0.65$ , respectively, may indicate the existence of genetic gains for longevity and milk production based on selection for udder traits (Cruickshank et al., 2002; Samoré et al., 2010).

In Brazil there is currently no selection index for dairy cattle which considers longevity, type traits and production traits. The formation of a selection index which ponders these traits according to their economic importance is a viable alternative (Vanraden et al., 2004) considering the moderate genetic correlation between these traits (Cruickshank et al., 2002; Zavadilová and Stipková, 2012). Several countries consider selection indices that include all of these traits to improve herd efficiency, reducing involuntary culling and increasing longevity and therefore herd profit (Vanraden, et al., 2004; Miglior et al., 2005).

Additionally it can be inferred that a possible revision of Brazilian classification system and a definition of fewer type traits, which better explain the variation in longevity and milk production are necessary. The results also indicated that the cows with good body condition tend to have higher longevity and produce more of milk.

**Table 6.** Linear regression coefficients (*b*) of factors and their respective standard error on different longevity measures and first lactation milk production

Phenotypic measure	Linear regression coefficients ( <i>b</i> )	
	Factor 1	Factor 2
Long 1	330.041±26.930*	301.293±34.436*
Long 2	0.007±0.002*	-0.002±0.003 <sup>ns</sup>
Long 3	5.092±0.010*	1.714±1.290 <sup>ns</sup>
Long 4	0.042±0.039 <sup>ns</sup>	-0.029±0.049 <sup>ns</sup>
Long 5	0.178±0.040*	0.072±0.049 <sup>ns</sup>
MP	91.894±3.807*	127.965±4.838*

Long 1, total milk production in all lactations; Long 2, number of lactations initiated; Long 3, total number of days during all lactations; Long 4, time between birth and last milk control in months; Long 5, time from first parturition to last milk control in months.

MP, milk production in 305 d of the first lactation.

<sup>ns</sup>  $p > 0.05$ ; \*  $p < 0.01$ .

## CONCLUSION

The factor analysis as useful in reducing the dimensionality of the group of linear type traits studied, forming two factors and eliminating seven redundant traits.

Selection for Factor 1, which included the traits loin strength, bone quality, rear udder width, udder texture, udder cleft and final score, showed a positive association with longevity and 305 d milk in first lactation, indicating that this factor could contribute to the improvement of these two characteristics in dairy cows in Brazil.

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