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Principal component analysis of conformation traits in Hungarian Simmental cows

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Abstract: The aim of the current research was to analyse the linear type traits of Hungarian Simmental dual-purpose cows scored in first lactation using principal component analysis and cluster analysis. Data collected by the Association of Hungarian Simmental Breeders was studied during the work. The filtered database contained the results of 8 868 cows, born after 1997. From the evaluation of main conformation traits, the highest correlations ($r = 0.35$, $P < 0.05$) were found between mammary system and feet and legs traits. Within linear type traits, the highest correlation was observed between rump length and rump width ($r = 0.81$, $P < 0.05$). Using the principal component analysis, main conformation traits were combined into groups. There were three factors having 84.5 as total variance ratio after varimax rotation. Cluster analysis verified the results of principal component analysis as most of the trait groups were similar. The strongest relationship was observed between feet and legs and mammary system (main conformation traits) and between rump length and rump width (linear type traits).

Keywords: linear type traits; cluster analysis; correlation

Conformation traits were among the earliest non-production traits which were included in selection indices of dairy cattle in the world (Shook 2006). According to the scientific literature, the conformation is the most important influencing factor regarding the productive life, reproduction or milk production (Schneider et al. 2003).

Analyses of correlations between conformation traits were reported in several studies. Campos et al. (2012) estimated correlations between linear type traits for Holstein-Friesian cattle. Higher genetic correlation coefficients were observed between weight and stature, chest width, as well as body depth, respectively. According to their results, chest width and body depth were also in close relation. Their research indicated that selection for heavier cows could result in the increased muscularity of cows having deeper body and wider chests. Roveglia et al. (2019) found correlations between angularity and rear udder height as well as between angularity and rear udder width whereas the strongest correlations were computed between locomotion and feet and leg traits, locomotion and front teat placement and locomotion and rear teat placement for Italian Jersey cattle. Bohlouli et al. (2015) reported that genetic cor-

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relations of conformation traits varied between −0.76 ± 0.01 (between angularity and rear view of rear legs) and 0.65 ± 0.02 (between angularity and rump width).

Factor analysis seems to be a suitable multivariate technique to describe the dependences among different traits (Corrales et al. 2011). Kern et al. (2014) found two factors having higher eigenvalues than one for Brazilian Holstein cattle: the first is in connection with udder traits, loin strength, bone quality and final score whereas stature, top line, chest width, body depth, fore udder attachment, angularity and final score were in the second. Chu and Shi (2002) reported that factor I determined a strong cow having deep body, well developed rump and high stature, factor II was in relation with well-attached fore udder and wide rear udder while factor 3 was in correlation with good dairyness, sickle hocks, high rear udders and udder depth above the hocks, and factor 4 influenced rump angle and steep foot angle. Karacaoren and Kadarmideen (2008) estimated the relationship between body condition score, milk yield, milking speed, dry matter intake and body weight using factor and cluster analysis. They found four principal components making up 70 as the total variance ratio. Based on cluster analysis, they reported the relationship between body condition score and body weight as well as between milk yield, milking speed and dry matter intake in the Swiss dairy population. Jiang et al. (2019) reported the highest relationship between rump width and stature and between central ligament and teat placement for Holstein cows based on cluster analysis.

Campos et al. (2015) found low genetic correlations between type and production traits, except for udder texture and angularity, which were in positive genetic correlations with milk, fat and protein yield. There were negative genetic correlations between udder depth and production traits (Campos et al. 2015). According to Bohlouli et al. (2015), very angular cows with well-attached fore udder have higher milk, fat and protein yields. Pryce et al. (2000) estimated correlations between linear type traits, body condition score and management traits (temperament and milking speed) for Holsteins whereas Frigo et al. (2013) computed genetic parameters for Italian Simmental cattle. A higher genetic correlation coefficient was observed between body condition score and muscularity, suggesting that the cows that received high body condition score are more likely to have also high values of muscularity.

According to ample scientific literature, fertility, productive life, and health status are influenced by a cow's body conformation. Strapak et al. (2010) analysed effects of conformation traits on longevity for Slovak Simmental breed. They concluded that the sire, farm effect, body frame, udder traits (udder depth, teat length, rear udder attachment) and feet and legs (fetlock, feet and rear legs) were the most important factors in relation to longevity. Zavadilova et al. (2011) found a relationship between the longevity and dairy form, udder, final score, body condition score, angularity, udder attachment and udder depth for Czech Holstein cows. Erdem et al. (2017) estimated non-genetic factors (calving season, age at first calving, body condition scores, stage of lactation) impacting type traits. Based on their results, the age at first calving and body condition scores affected the type traits.

For the Hungarian Simmental breed, the principal goal is the earliest possible identification and description of exterior traits which might positively influence the productive life length. There is a demand from breeders to evaluate the present scoring method and identify possible background variables behind the classified traits. The aim of the present study was the analysis of the main and linear type traits for the Hungarian Simmental population using principal component analysis and cluster analysis to help the evaluation and the modernisation of the current conformation scoring method.

MATERIAL AND METHODS

The linear type trait dataset was collected by the Association of Hungarian Simmental Breeders. The filtered database contained the results of 8 868 Hungarian Simmental dual-purpose cows, born after 1997. All cows were evaluated after first calving between 30 and 180 days of the first lactation and there were between 245 and 638 cows/year during the analysed time period (2000–2018). The number of cows was equally distributed among the classifiers based on the geographical area of the farms.

The following type traits were analysed: main conformation traits: frame, musculature, feet and legs, mammary system; linear type traits: stature, rump length, rump width, muscularity, shoulder

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(shoulder tension), kidney (kidney tension), rump angle, rear legs set, pasterns, hoof height, fore udder length, rear udder length, central ligament, teat length, teat placement.

Scores for main and linear type traits are on a 1–9 scale covering the biological extremes of the population where intermediate animals receive 5 (ICAR 2018). The linear scoring system traits describe the conformation objectively and were evaluated by three judges during the research period.

Data were analysed using the SAS PROC FACTOR, VARCLUS and TREE (SAS/STAT® v9.2; SAS Institute Inc., Cary, NC, USA) software packages. Relationships between main and linear type traits were evaluated using principal component analysis. The principal component analysis was used to define the contribution of factors to total variation of the traits. Eigenvalues of factors present the contribution of each component to total variation. To maximise the variance of the squared loadings of factors, varimax rotation of H. F. Kaiser (Kaiser 1958) was used. The rotation method takes into consideration the correlation between background variables. In this case, background variables are not independent on one another. Components with eigenvalues exceeding 1.0 were considered only as significant and were taken into account in the analysis (Girden 2001).

Cluster analysis was used for representation of the grouping of traits (Everitt et al. 2001).

RESULTS AND DISCUSSION

Means and standard deviation

Descriptive statistics for each of the conformation traits are presented in Table 1. Based on our results, frame, musculature, feet and legs, mammary system, stature, rump length, rump width, muscularity, shoulder, kidney, rump angle, rear legs set, pasterns, rear udder length, central ligament had higher means than the median of the scale. Standard deviations were high for mammary system, feet and legs, pasterns and kidney. The means of main conformation scores varied between 5.1 for musculature and 5.6 for frame. The means of linear type traits varied between 4.5 for hoof height and 6.2 for kidney. The standard deviation for rump angle was lowest. Score of muscularity and rear legs set are in agreement with Zavadilova et al. (2009) computed for Czech Fleckvieh cows. The Hungarian Simmental population seems to have wider and longer rump, stronger pasterns, more sickled rear legs set, stronger central ligament, shorter fore udder length and shorter teats than the values computed for Czech Fleckvieh cows. In a similar study, Canji et al. (2008) reported about the conformation traits of Slovak Simmental breed. Compared to the Slovak Simmental population, the Hungarian Simmental cows seem to have wider and longer rump, more sloped rump, more sickled rear legs set, stronger central ligament, shorter teats and closer teat placement. Though the breeding goal is a dual-purpose breed in each country, different

Table 1. Descriptive statistics of conformation trait scores evaluated in cows (n = 8 868)

Traits	Mean	SD	Min.	Max.	Optimal
Frame	5.6	1.21	1	9	9
Musculature	5.1	1.22	1	9	9
Feet and legs	5.5	1.48	1	9	9
Mammary system	5.3	1.67	1	9	9
Stature	5.6	1.32	1	9	9
Rump length	5.5	1.34	1	9	9
Rump width	5.5	1.24	1	9	9
Muscularity	5.1	1.20	1	9	9
Shoulder	5.7	1.30	1	9	5
Kidney	6.2	1.46	1	9	5
Rump angle	5.5	0.88	2	9	5
Rear legs set	5.6	1.01	1	9	5
Pastern	5.9	1.52	1	9	9
Hoof height	4.5	1.40	1	9	9
Fore udder length	4.9	1.27	1	9	9
Rear udder length	5.6	1.15	2	9	9
Central ligament	6.0	1.22	1	9	9
Teat length	4.0	1.33	1	9	5
Teat placement	4.9	1.14	1	9	5

Table 2. Phenotypic correlations among main conformation traits

	Traits	1	2	3	4
1	Frame	1	–	–	–
2	Musculature	0.24*	1	–	–
3	Feet and legs	–0.02*	0.11*	1	–
4	Mammary system	–0.07*	0.07*	0.35*	1

*Significant at $P < 0.05$

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breeder preferences could be the reason for the differences between traits. Differences in rump length and rump width could be a result of environmental differences, whereas the stronger central ligament and stronger pasterns might be because of the strong selection for these traits. The shorter teat length and higher teat placement scores suggest a potential to improve the Hungarian Simmental population.

Correlation analysis

Correlations between conformation traits are presented in Table 2 and Table 3. From the evaluation of main conformation traits, the highest correlations (r = 0.35, P < 0.05) were found between mammary system and feet and legs. The second highest correlation coefficients were found between frame and musculature (r = 0.24, P < 0.05). There was a low to moderate correlation between other main conformation traits (Table 2). Within linear type traits, the highest correlation was observed between rump length and rump width (r = 0.81, P < 0.05). Moderate correlation coefficients were found between stature and rump width (r = 0.48, P < 0.05) and between stature and rump length (r = 0.42, P < 0.05). Low correlation was found between fore udder length and rear udder length (r = 0.38, P < 0.05) and between shoulder and kidney (r = 0.36, P < 0.05) (Table 3). These positive correlations make the selection work easier and might allow breeders to decrease the number of traits during their selection procedure. Our estimations are in align with reported values of Roveglia et al. (2019) between udder and feet and legs traits, as they identified the strongest correlations between locomotion and front teat placement for Italian Jersey cattle. In contrast, Campos et al. (2012) revealed a higher genetic correlation between stature and weight for Holstein-Friesian. Van der Waaij et al. (2005) identified stronger genetic correlations between rear leg side view and foot angle (–0.72) as well as between locomotion and feet and legs (0.98) in Dutch Dairy cattle. Compared to our estimated values, Nemcova et al. (2011) detected higher genetic correlations between foot angle and rear leg side view (–0.67) for Czech Holstein cattle.

Principal component matrix

Principal component analysis was used to combine main conformation traits into groups. There were three factors having 84.5 as total variance ratio after varimax rotation. The coefficients of the rotated factors and their correlations with main conformation traits are presented in Table 4.

Table 3. Phenotypic correlations among linear type traits

	Traits	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Stature	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2	Rump length	0.42*	1	–	–	–	–	–	–	–	–	–	–	–	–	–
3	Rump width	0.48*	0.81*	1	–	–	–	–	–	–	–	–	–	–	–	–
4	Muscularity	0.11*	0.16*	0.22*	1	–	–	–	–	–	–	–	–	–	–	–
5	Shoulder	0.01	0.04*	0.05*	0.18*	1	–	–	–	–	–	–	–	–	–	–
6	Kidney	0.11*	0.15*	0.16*	0.22*	0.36*	1	–	–	–	–	–	–	–	–	–
7	Rump angle	–0.01	–0.03*	–0.04*	0.07*	0.04*	0.08*	1	–	–	–	–	–	–	–	–
8	Rear legs set	–0.00	0.06*	0.05*	0.02	–0.07*	–0.04*	0.08*	1	–	–	–	–	–	–	–
9	Pasterns	0.13*	0.14*	0.14*	0.04*	0.12*	0.13*	–0.04*	–0.23*	1	–	–	–	–	–	–
10	Hoof height	–0.07*	–0.02	–0.01	0.09*	0.17*	0.01	0.01	–0.11*	0.17*	1	–	–	–	–	–
11	Fore udder length	–0.06*	–0.04*	–0.04*	0.04*	0.04*	–0.00	–0.03*	–0.01	–0.04*	0.08*	1	–	–	–	–
12	Rear udder length	0.01	0.00	0.01	–0.05*	–0.02	0.04*	–0.02*	0.01	0.05*	–0.04*	0.38*	1	–	–	–
13	Central ligament	0.06*	0.04*	0.03*	–0.03*	–0.00	0.06*	–0.02	–0.04*	0.12*	–0.08*	0.08*	0.18*	1	–	–
14	Teat length	–0.07*	0.08*	0.07*	0.08*	0.10*	0.03*	0.02*	–0.01	–0.05*	0.23*	0.14**	0.01	–0.09*	1	–
15	Teat placement	0.06*	0.03*	0.03*	–0.01	–0.02*	0.02	–0.05*	–0.02	0.04*	–0.03*	0.03*	0.02	0.27*	–0.13*	1

*Significant at P < 0.05

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Table 4. Eigenvalues, percentage of total variance and factor loadings of background factors after rotation based on the analysis of main conformation traits

Traits	Factor I	Factor II	Factor III
Eigenvalues	1.381	1.001	1.001
Variance of eigenvalues (%)	34.5	25.0	25.0
Frame	–0.04	0.99	0.12
Musculature	0.07	0.12	0.99
Feet and legs	0.83	0.01	0.09
Mammary system	0.83	–0.06	0.01

Factor I (eigenvalues: 1.381, variance of eigenvalues: 34.5%) was determined mainly by feet and legs and mammary system. This suggests high variability of the original traits within the analysed population. Feet and legs as well as mammary system problems could be a frequent reason for culling, so selection for this background trait might improve the population.

Factor II (eigenvalues: 1.001, variance of eigenvalues: 25.0%) was related to frame.

Factor III (eigenvalues: 1.001, variance of eigenvalues: 25.0%) was affected by musculature.

Background factors, their eigenvalues and contribution to the total variance as well as factor loadings to linear type traits after rotation are presented in Table 5. There were 11 factors with the total ratio of variance equal to 86.9 received for the type traits after varimax rotation during our analysis.

Factor I (eigenvalues: 2.193, variance of eigenvalues: 14.4%) was related to stature, rump length and rump width. This suggests that rump was the most important background trait within the total phenotypic variance of the population. Animals having taller, wider and longer rump as well as smaller cows having shorter and narrower rump can be found in the analysed population. This factor could be also related to reproduction and calving ease.

Factor II (eigenvalues: 1.387, variance of eigenvalues: 9.2%) was dependent upon fore udder length and rear udder length. This background variable could be identified as udder. These original traits are in close relation with milking ability, so it confirms that milking ability is an important influencing factor during conformation judgement.

Factor III (eigenvalues: 1.356, variance of eigenvalues: 9.0%) was primarily determined by shoulder and kidney. Both traits were in strong positive correlation with this factor. Probably cows receiving higher scores for shoulder tension and for kidney tension might be longer in production, so this component was in relation with durability.

The further components were covered by only one trait, respectively.

Table 5. Eigenvalues, percentage of total variance and factor loadings of background factors I–XI after rotation based on the analysis of linear type traits

Traits	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
Eigenvalues	2.193	1.387	1.356	1.061	1.047	1.015	1.009	1.006	1.005	1.005	1.005
Variance of eigenvalues (%)	14.4	9.2	9.0	7.1	6.9	6.8	6.7	6.7	6.7	6.7	6.7
Stature	0.75	–0.01	0.05	0.08	–0.34	–0.15	–0.03	–0.14	0.07	0.12	–0.06
Rump length	0.88	–0.02	0.03	–0.07	0.17	0.09	0.06	0.14	–0.03	–0.03	0.05
Rump width	0.89	–0.00	0.04	–0.04	0.11	0.07	0.12	0.11	–0.05	–0.03	0.03
Muscularity	0.13	–0.01	0.13	0.06	0.01	0.01	0.97	–0.01	0.03	–0.00	–0.02
Shoulder	0.01	–0.00	0.85	0.29	–0.02	–0.03	0.02	–0.08	–0.03	0.04	–0.07
Kidney	0.10	0.02	0.77	–0.27	0.09	–0.01	0.17	0.21	0.09	–0.03	0.08
Rump angle	–0.03	–0.02	0.04	0.01	0.02	0.05	0.03	–0.01	0.99	–0.01	–0.02
Rear legs set	0.05	0.01	–0.03	–0.02	–0.04	0.97	0.01	–0.15	0.05	–0.01	–0.02
Pasterns	0.13	0.00	0.08	0.18	–0.10	–0.17	–0.01	0.88	–0.02	0.08	–0.00
Hoof height	–0.04	0.01	0.05	0.88	0.18	–0.02	0.07	0.18	0.01	–0.07	0.02
Fore udder length	–0.04	0.84	0.01	0.15	0.08	–0.07	0.08	–0.17	–0.02	–0.03	0.08
Rear udder length	0.01	0.82	0.00	–0.14	–0.02	0.07	–0.09	0.18	–0.00	0.14	–0.07
Central ligament	0.02	0.09	0.02	–0.06	–0.01	–0.01	–0.00	0.08	–0.01	0.97	0.16
Teat length	0.06	0.06	0.05	0.18	0.91	–0.05	0.01	–0.10	0.02	–0.01	–0.09
Teat placement	0.03	0.01	–0.00	0.02	–0.09	–0.02	–0.02	–0.00	–0.03	0.15	0.97

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Factor IV (eigenvalues: 1.061, variance of eigenvalues: 7.1%) was affected by hoof height.

Factor V (eigenvalues: 1.047, variance of eigenvalues: 6.9%) was related to teat length.

Factor VI (eigenvalues: 1.015, variance of eigenvalues: 6.8%) was determined by rear legs set.

Factor VII (eigenvalues: 1.009, variance of eigenvalues: 6.7%) was dependent upon muscularity.

Factor VIII (eigenvalues: 1.006, variance of eigenvalues: 6.7%) was determined primarily by pasterns.

Factor IX (eigenvalues: 1.005, variance of eigenvalues: 6.7%) was dependent upon rump angle.

Factor X (eigenvalues: 1.005, variance of eigenvalues: 6.7%) was related to central ligament.

Factor XI (eigenvalues: 1.005, variance of eigenvalues: 6.7%) was affected by teat placement.

There are some studies in this field; Kern et al. (2014) found two factors for Brazilian Holstein cattle, Chu and Shi (2002) reported four factors for Holstein cows, while Mazza et al. (2016) found six factors for Rendena and Aosta Red Pied dual-purpose Italian breeds.

Figure 1 and Figure 2 show the separation of main and linear type traits by cluster analysis. The highest relationship was observed between feet and legs and mammary system and between frame and musculature (Figure 1), which is in agreement with our findings based on the principal component analysis (Table 4). Figure 2 illustrates the highest correlation between rump length and rump width, between fore udder length and rear udder length, shoulder and kidney. These are quite similar to factor I, factor II and factor III computed for the linear scores (Table 5). There were also relationships between central ligament and teat placement, between rear legs set and pasterns as well as between hoof height and teat length (Figure 2). Our results are quite similar to those reported by Jiang et al. (2019) for a Holstein population as they found a relation between rump width and stature and between central ligament and teat placement.

CONCLUSION

Three factors were identified as more than 84% of the variances of main conformation traits. The most important factor covered 34.5% of total variance and was in close correlation with feet and legs and mammary system. There were three factors in correlation with more than one linear trait. Factor I (14.4% of total variance) was in close correlation with rump traits (stature, rump length and rump width), factor II (9.2% of total variance) was in close relation with udder length (fore udder length and rear udder length), whereas factor III (9.0% of total variance) was in correlation with shoulder and kidney. These factors could be identified as rump, udder length and durability as background variables which influence reproduction, milking capacity and length of productive life.

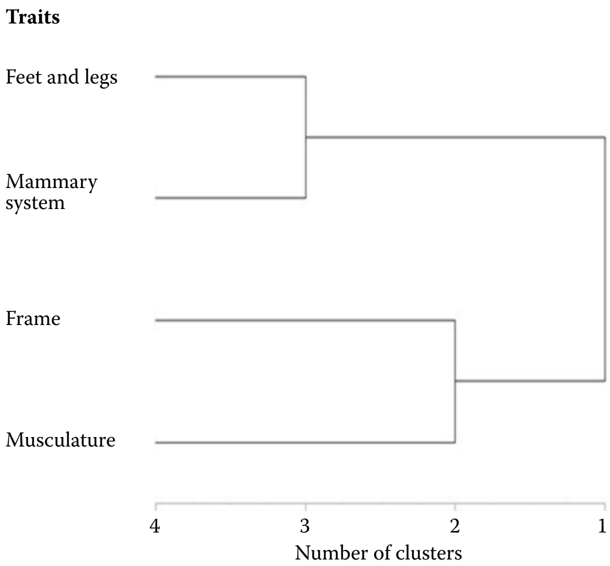

Figure 1. Dendrogram of main conformation traits

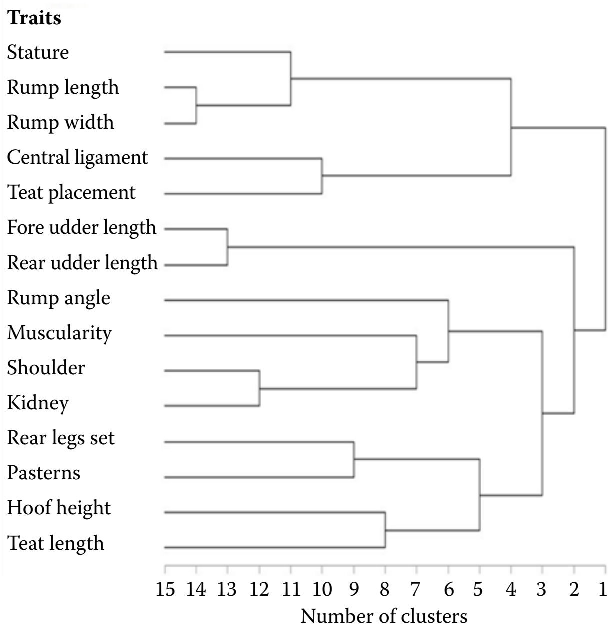

Figure 2. Dendrogram of linear type traits

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Conflict of interest

The authors declare no conflict of interest.

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