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Morphological and milkability breed differences of dairy cows

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Abstract

Anatomical characteristics of dairy cattle are not equal for all breeds, meaning that the morphological traits of udder and teats could favor an individual performance or a determined breed. Changes in teat tissue after machine milking occur because of the negative influence of the vacuum and mechanical forces of the teat cup liner. Duration and performance of machine milking also depend on the udder and teat conformation and milkability traits of cows. The aim of this study was to determine the differences in morphological characteristics of Simmental and Holstein cows before and after machine milking, as well as to elaborate the differences in some of milkability traits of the cows during process of milking. A correlation (from -0.30 to 0.37) was determined between exterior and interior traits of teats and the performance of milkability traits. In both cow breeds, statistically significant difference ($p<0.0001$) was found between the pre- and post-milking values in all investigated traits, with exception of teat end width. Holstein cows had significantly ($p<0.001$) higher amount of milk per milking, maximum and average milk flow, while cows of the Simmental breed had longer milking time duration, but without statistical significance. In comparison to Holstein breed, results of internal morphological traits of teats showed that cows of Simmental breed had longer teat canals and wider teat ends for both front and rear teats. Holstein breed compared to Simmental had thinner teats wall, but wider teat cistern. If compared to pre-milking stage, differences in teat cistern width and teat wall thickness that occur after milking were more expressed in the Holstein breed than in Simmental. Simmental cows had significantly ($p<0.05$) longer and wider rear teats. Future research should focus on proving the differences in changes of teat tissue due to milking between different groups of cows, as depending on the milk flow. Ultrasound method of recording can be applied in such assessment.

Key words: cattle breeds, differences, morphology, milkability, ultrasound

Introduction

Optimal conditions in modern dairy farms should be respected, and biological requirements of dairy cows should be followed to maintain high production in combination with animal welfare (Tančin and Bruckmaier, 2001). Anatomical characteristics of dairy cattle differ between breeds (Norman et al., 1988), in a way that the morphology traits of udder and teats could favor an individual performance or a determined breed. According to previous studies, there are significant relations between dimension and form of teats, end teat canal length and milkability traits, i.e. with milk flow speed (Baxter et al., 1950; Andreae, 1958; Loppnow, 1959; Rensing and Ruten, 2005). Size and shape of teat top and teat canal length in dairy cows is correlated with the risk of mastitis (Rathore, 1976; Thomas et al., 1984; Rupp and Boichard, 1999; Neijenhuis et al. 2000). According to Naumann and Fahr

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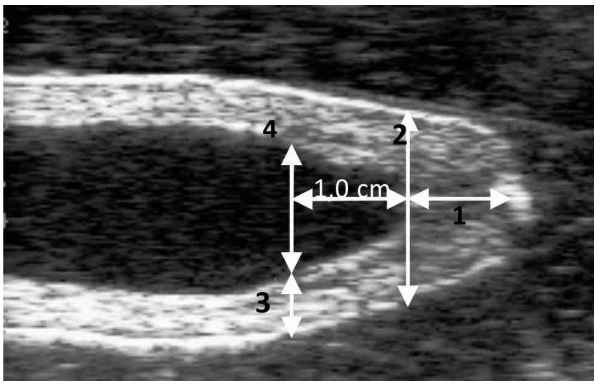


Figure 1. Internal teat parameters measured by ultrasound (1-teat canal length, 2-teat end width, 3-teat wall thickness, 4-teat cistern width)

(2000), the level of maximal end average milk flow depends, among other influences, of the teat end morphology. A machine-induced change of teat tissue occurs because of vacuum and mechanical force of the teat cup liner during machine milking (Hamann et al., 1993, 1994; Neijenhuis et al., 2001). Performances and duration of machine milking depend on the udder and teat conformation, and on production and milkability traits of animals. External measurements were performed to prove these findings (Weiss et al., 2004; Stádník et al., 2010; Pařilová et al., 2011) and internal morphology characteristics of the mammary gland were examined by ultrasonography (Bruckmaier and Blum, 1992; Ayadi et al., 2003; Porcionato et al., 2010). The ultrasound is very good, fast, precise and modern method for studying machine-induced changes of the mammary gland (Paulrud, 2005; Weiss et al., 2004; Celik et al., 2008; Fasulkov, 2012), which provides important data for genetic selection, mastitis prevention and improvement of overall farm management (Porcionato et al., 2005). Changes can be monitored by ultrasound in certain parts of teat, such as teat canal length, teat thickness, teat wall thickness or teat cistern width, in order to determine impact that milking machines, performances and duration of milking can induce on morphological and health conditions of teat tissue and udders. This study tested the differences in morphological traits within pre- and post-machine milking stage, as well as the differences in some milkability traits during process of milking in dairy cows.

Materials and methods

The study was performed on two dairy farms on the Holstein (n=30) and Simmental (n=30) cows, up to the 250th day of lactation, from the first to the third lactation. Milking was done in milking parlous tip DeLaval (herringbone 2x10). Cows were exposed to equal vacuum level (43-45 kPa) and pulsation ratio (60 : 40) during milking. Amount of milk (AM), and maximal (MFR) and average milk flow (AFR) were measured with the Lacto-corder measuring device. External and internal morphological traits of the front and rare teats of udder were observed within pre- and post-machine milking. Caliper was used for measuring of external morphological traits, such as length of the teat (TL) from the base to the apex of the teat, and width of the teat in the middle (TW). Internal morphology traits were monitored by an ultrasound machine (Esaote Pia Medical, Tringa Linear) with linear probe (4.5-8.0 Mhz) and water bath method by Fasulkov (2012). Determination of measuring points was made according to Neijenhuis et al. (2001) and Gleeson et al. (2002). These measuring points referred to teat canal length (TCL), teat end width (TEW), teat wall thickness (TWT) end teat cistern width (TCW). The teat canal length was measured from the crossing of teat cistern and teat canal (Furstenberg's rosette), until the teat end. Teat width was measured perpendicular to the distal end of the teat canal. Teat wall thickness and teat cistern width were measured at a distance of 1.0 cm (10 mm) from the distal end of the teat canal (Figure 1). Statistical analysis was made by using StatSoft Statistica 8 (2008). Effect of breed on morphological and milkability traits, and multiple comparison between the mean values was made with the One - Way ANOVA and significance of differences was tested with Tukey HSD test ($p<0.0001$).

Descriptive statistical data about milkability traits depending on the breed are shown in the Table 1. Average amount of milk per milking of Simmental was 8.46 kg and of Holstein cows 13.95 kg. MFR in the Holstein breed was 3.60 kg/min, while the AMF was 2.40 kg/min. Values for HMF or AFM in Simmental amounted to 2.56 and 1.65 kg/min, respectively. The average milking duration was slightly longer in Simmental than in Holstein cows, amounting to 7.96 and 7.26 minutes, respectively.

Table 1. Descriptive statistics for milkability traits

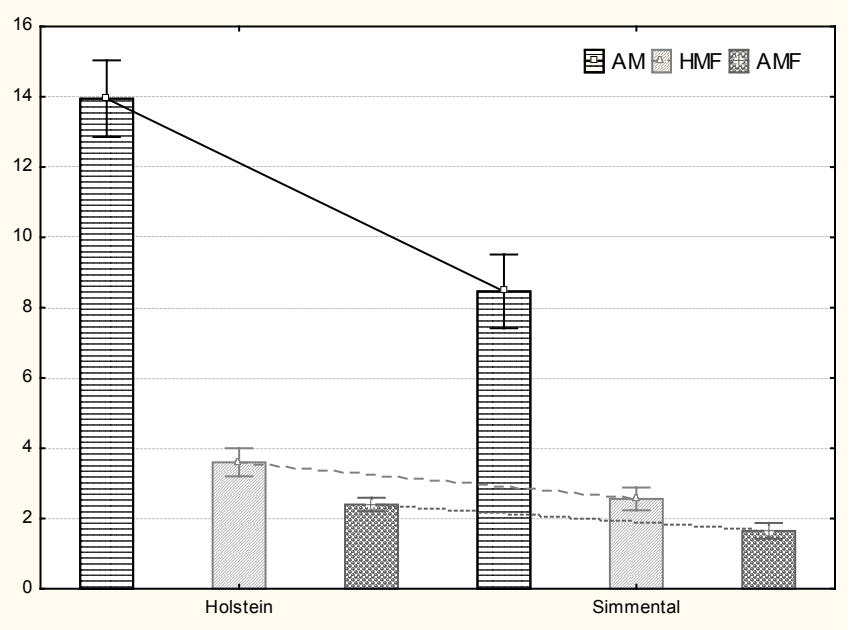
Traits	Unites	Mean	SD	Min	Max
SIMMENTAL (n=30)					
AM	kg	8.46	2.81	5.00	15.04
HMF	kg/min	2.56	0.87	1.15	4.57
AMF	kg/min	1.65	0.60	0.56	2.65
TMT	min	7.96	2.03	4.95	12.55
HOLSTEIN (n=30)					
AM	kg	13.95	2.92	10.50	21.88
HMF	kg/min	3.60	1.07	1.70	6.57
AMF	kg/min	2.40	0.51	1.34	3.10
TMT	min	7.26	1.94	4.39	13.44

n - number of animals; Mean - average mean; SD - standard deviation; Min - minimum; Max - maximum; AM - amount of milk per milking; HMF - high milk flow; AMF - average milk flow; TMT - total milking time

Results and discussion

Results of this study showed highly significant ($p<0.001$) differences for all milkability traits, except for the milking duration (Fig. 1). Holstein cows had significantly ($p<0.001$) higher amount of milk per milking, maximal and average milk flow, while Simmental cows had longer duration of milking, however with no statistical significance.

Average means of the front and rear teats traits measured before and after milking were presented in the Table 2. The average means of Simmental breed were: 13.28 and 13.38 mm for the teat canal length (TCL), 21.96 and 22.36 mm for the teat end width (TEW), 7.46 and 7.41 mm for the teat wall thickness (TWT), 9.93 and 11.90 mm for the teat cistern width (TCW).



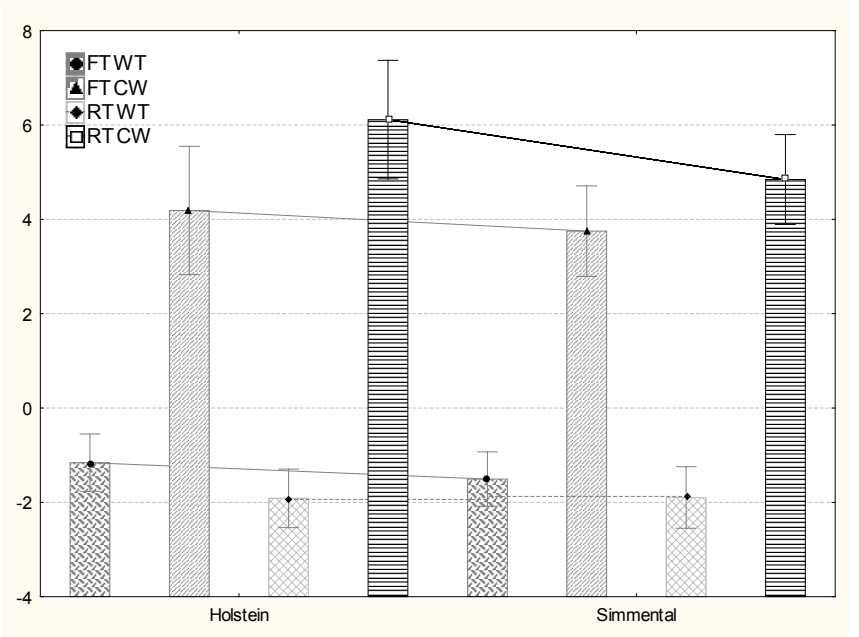
AM - amount of milk per milking; HMF - high milk flow; AMF - average milk flow

Figure 1. Mean differences in milkability traits among breeds

Table 2. Evaluated traits of internal teat conformation, according to the breed

Trait	SIMMENTAL (n = 30)			HOLSTEIN (n = 30)			p
	Mean (mm)	SD	SE	Mean (mm)	SD	SE	
	Before milking						
FTCL	13.28	2.39	0.44	12.37	2.11	0.39	NS
FTEW	21.96	1.98	0.36	21.42	1.74	0.32	NS
FTWT	7.64	1.43	0.26	6.34	1.42	0.26	***
FTCW	9.93	3.26	0.59	12.44	3.34	0.61	**
RTCL	13.38	2.61	0.48	12.27	2.10	0.38	NS
RTEW	22.36	1.92	0.35	21.79	1.95	0.36	NS
RTWT	7.41	1.70	0.31	5.90	1.38	0.25	***
RTCW	11.90	3.08	0.56	14.72	3.21	0.59	**
	After milking						
FTCL	14.78	2.43	0.44	14.16	2.36	0.43	NS
FTEW	21.98	1.86	0.34	21.21	1.72	0.31	NS
FTWT	9.15	1.19	0.22	7.50	1.34	0.25	***
FTCW	6.18	1.85	0.34	8.26	2.67	0.49	**
RTCL	14.79	2.49	0.45	13.76	2.20	0.40	NS
RTEW	22.69	2.22	0.40	21.59	1.23	0.22	*
RTWT	9.30	1.37	0.25	7.81	1.75	0.32	***
RTCW	7.05	2.72	0.59	8.61	2.77	0.51	*

***p<0.001; **p<0.01; *p<0.05; p - level of significance; NS - no significant; n - number of animals; SD - standard deviation; SE - standard error; FTCL - front teat canal length; FTEW - front teat end width; FTWT - front teat wall thickness; FTCW - front teat cistern width; RTCL - rear teat canal length; RTEW - rear teat end width; RTWT - rear teat wall thickness; RTCW - rear teat cistern width



FTWT - front teat wall thickness; FTCW - front teat cistern width; RTWT - rear teat wall thickness; RTCW - rear teat cistern width

Figure 2. Mean differences in internal morphology traits of both breeds within post-milking and pre-milking time

Table 3. Evaluated traits of external teat conformation according to breed

Trait	SIMMENTAL (n = 30)			HOLSTEIN (n = 30)			p
	Mean	SD	SE	Mean	SD	SE	
Before milking							
FTL	57.37	10.29	1.88	53.87	9.86	1.80	NS
FTW	22.73	3.51	0.64	21.20	3.95	0.72	NS
RTL	51.47	9.01	1.65	45.50	8.82	1.61	*
RTW	22.67	3.25	0.59	20.27	3.90	0.71	*
After milking							
FTL	63.00	9.50	1.74	57.42	9.22	2.66	NS
FTW	20.78	2.37	0.43	20.33	3.20	0.92	NS
RTL	53.47	8.59	1.57	52.00	7.29	2.10	NS
RTW	20.50	2.93	0.54	19.08	3.37	0.97	NS

p - level of significance; NS - no significant; *p<0.05; n - number of animals; SD - standard deviation; SE - standard error; FTL - front teat length; FTW - front teat width; RTL - rear teat length; RTW - rear teat width

Obtained average means of internal teat traits of the Simmental breed were slightly lower than those published by Klein et al. (2005). For Holstein breed, these values were different, as follows: 12.37 and 12.27 mm (TCL), 21.42 and 21.79 mm (TEW), 6.34 and 5.90 mm (TWT), 12.44 and 14.72 mm (TCW). In comparison to results of Gleeson et al. (2002), our study resulted in TCL that was for 1 mm longer, TEW was narrower for approximately 2 mm, while values of TWT and TCW for Holstein breed were similar. If compared to Holstein cows, obtained results of internal morphology traits of teats, measured before and after milking, showed that Simmental cows had longer teat canal length and wider teat end at the front and rare teat. However, these differences were not significant. On the contrary, Klein et al. (2005) found high significance ($p<0.05$; $p<0.001$) in all morphology traits between Brown Swiss, Holstein and Simmental cows. Significant ($p<0.001$; $p<0.01$) difference in this study was found in TWT and TCW for both teats.

In contrast to Simmental, Holstein breed had thinner walls and wider cistern of teats, which can be associated with higher milk flow, probably because of bigger cistern capacity and larger amount of milk in them, since the increase in the amount of milk increases the milk flow (Bobić et al., 2013). Compared to pre-milking stage, differences which occurred after milking were more expressed in Holstein cows than in Simmental, if referring to TCW and TWT (Fig. 2).

Statistically significant ($p<0.0001$) differences between the value of pre- and post-milking traits were found in both breeds for all traits, except for teat end width. Our research showed that there was no significant extension, thickening or reduction in teat traits after milking, if compared to the values obtained in pre-milking.

The average means of external morphology teat traits were shown in the Table 3. The average length (TL) of front and rear teats in Simmental breed were 57.37 and 51.47 mm, while those values in Holstein breed were 53.87 and 45.50 mm. The width of front and rear teats (TW) were in average 22.73 and 22.67 mm in Simmental cows, while TW in Holstein were smaller (21.20 and 20.27 mm). Such results correlate to length and width values of teats obtained by Gleeson and O'Callaghan (1998), Špoljar et al. (2004) and Stádník et al. (2010). Although values for external traits of teats were higher in Simmental than in Holstein cows, both pre- and post-milking, the statistically significant ($p<0.05$) difference was found only for the length and width of rear teats measured before milking.

Correlation coefficients (Tables 4 and 5) prove that morphology of teats and milkability traits are connected. Size of udder quarter and teats cistern, as well as total quantity of milk, lead to significant changes in the dimension of morphological traits of cows, which is also a proof that the breed can affect the level of such changes. This study confirmed statistically significant ($p<0.05$) negative correlation

Table 4. Correlation coefficients between milkability and internal morphological traits

Trait	FTCL	FTEW	FTWT	FTCW	RTCL	RTEW	RTWT	RTCW
AM	-0.11	-0.02	-0.30*	0.27*	-0.24	-0.11	-0.30*	0.37*
HMF	-0.05	0.06	-0.23	0.28*	-0.23	-0.09	-0.30*	0.32*
AMF	-0.12	-0.01	-0.18	0.18	-0.29*	-0.18	-0.40*	0.35*
TMT	0.14	0.02	0.13	-0.14	0.29*	0.14	0.19	-0.09

*$p<0.05$, AM - amount of milk per milking; HMF - high milk flow; AMF - average milk flow; TMT - total milking time; FTCL - front teat canal length; FTEW - front teat end width; FTWT - front teat wall thickness; FTCW - front teat cistern width; RTCL - rear teat canal length; RTEW - rear teat end width; RTWT - rear teat wall thickness; RTCW - rear teat cistern width

Table 5. Correlation coefficients between milkability and external morphological traits

Trait	FTL	FTW	RTL	RTW
AM	-0.19	-0.07	-0.23	-0.16
HMF	-0.12	-0.08	-0.20	-0.15
AMF	-0.13	-0.10	-0.28*	-0.13
TMT	0.21	0.20	0.30*	0.05

*$p<0.05$; AM - amount of milk per milking; HMF - high milk flow; AMF - average milk flow; TMT - total milking time; FTL - front teat length; FTW - front teat width; RTL - rear teat length; RTW - rear teat width

between milk production, maximal and average milk flow with teat wall thickness, while statistically significant ($p<0.05$) positive relation was found between AM, HMF and AMF with teat cistern width. It is important to emphasize the existence of significant ($p<0.05$) connections between AMF and TMT with TCL, indicating that the increases in milk flow reduces the milking time. Because of that, teats canal stretches less, which is an important factor in the defense of the organism against penetration of microorganisms in the teat canal and the occurrence of mastitis (Neijenhuis et al., 2000; Kleinet al., 2005).

Statistical analysis proved significance ($p<0.05$) between the milk flow rate and the length of rear teats, indicating that shorter teats have shorter teat canals, which makes the milk to flow faster thus reducing milking time. Simmental cows have longer teats, lower milk production and lower average milk flow than the Holstein breed.

Conclusions

Results obtained in this study proved significant ($p<0.001$; $p<0.05$) differences between breeds in morphological and milkability traits of dairy cows. A correlation (from -0.30 to 0.37) was established between exterior and interior traits of cow teats and milkability traits. Statistically significant ($p<0.0001$) difference between Simmental and Holstein cows determined for values of pre- and post-milking stages in all investigated traits, with exception of teat end width. Holstein cows had significantly ($p<0.001$) higher amount of milk per milking, maximal and average milk flow, while Simmental cows had longer milking time duration, but without statistical significance. Results of internal morphological traits of teats showed that Simmental cows had longer teat canals and wider teat ends for both front and rear teats than Holstein breed. Holstein cows compared to Simmental had thinner teats wall, but wider teat cistern. If compared to pre-milking, differences in teat cistern width and teat wall thickness that occur after milking were more expressed in Holstein cows than in Simmental cows. Cows of Simmental breed had significantly ($p<0.05$) longer and wider rear teats. Further research into different breeds of cows is required to examine differences in changes of teats tissue due to

machine milking, as referring to milk flow, and to estimate parameters of teat tissue by applying ultrasound as a method of recording.

Acknowledgment

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Morfološke i muzne različitosti između pasmina krava u proizvodnji mlijeka

Sažetak

Anatomske karakteristike krava za proizvodnju mlijeka nisu jednake kod svih pasmina. Promjene u tkivu sisa nakon mužnje posljedica su negativnog utjecaja podtlaka i mehaničkog pritiska sisne gume, a tijek mužnje ovisi i o izgledu vimena i muznih svojstava mliječne krave. Cilj ovog rada bio je utvrditi razlike u morfološkim karakteristikama prije i nakon strojne mužnje, te razlike u nekim muznim svojstvima krava tijekom mužnje. Utvrđena je povezanost (od -0,30 do 0,37) vanjskih i unutarnjih svojstava sisa krava s performansama muznih svojstava. Statistički značajne ($p<0,0001$) razlike između vrijednosti svojstava prije i nakon mužnje utvrđene su kod obje pasmine za sva istražena svojstva osim za širinu vrha sise. Krave holstein pasmine imale su značajno ($p<0,001$) veću količinu mlijeka po mužnji, maksimalni i prosječni protok mlijeka, dok su krave simentalske pasmine imale duže trajanje mužnje. Rezultati istraživanja unutarnjih morfoloških svojstava sisa ukazuju da krave simentalske pasmine imaju dulje sisne kanale i šire vrhove sisa u odnosu na krave holstein pasmine. Holstein krave u odnosu na simentalske imaju tanje zidove i širu cisternu sisa. Razlike širine cisterne i debljine zida sise koje nastanu nakon mužnje izraženije su kod holstein pasmine u odnosu na simentalsku. U pogledu eksterijernih svojstava, krave simentalske pasmine imale su značajno ($p<0,05$) veću duljinu i širinu stražnjih sisa. Daljnja istraživanja trebala bi ići u pravcu dokazivanja razlike u promjenama na tkivu sisa uslijed mužnje između različitih skupina krava ovisno o protoku mlijeka, pri čemu se može primijeniti ultrazvučna metoda snimanja.

Ključne riječi: pasmine krava, razlike, morfologija, muznost, ultrazvuk

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