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Regression analysis to evaluate the effect of pulsation rate on the morphological structures of cow teats

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Abstract

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In a previous study (Dineva et. al., 2019) an ultrasound examination of the following morphological structures of the cow teats was performed: the length and diameter of the teat canal, the teat wall thickness, the teat diameter in the region of Furstenberg's rosette, the diameter of teat cistern in its middle part and the cistern diameter at the teat base. The scan was performed before milking, immediately after milking, at the 1st and 2nd hours after milking. During milking two types of milking units (with a cylindrical shape of the pulsation chamber and the so-called tri-circle) were used in combination with different frequency modes. The present study is a continuation of the above by performing statistical processing of the obtained data to determine the coefficients of variation, correlation and correlation ratio, the regression equations are derived to determine the influence of pulsation rate on the observed morphological structures of cow teats. The obtained regression models allow extrapolation and estimation of the change in the structures of the milk papilla outside the experimental gradations of the pulsation rate.

Keywords: cow; correlations; pulsation rate; regression equations; teat health

Introduction

The udder as the main organ related to milk production is the main subject of study in cattle from milk breeds. Apart from being a biological prerequisite for higher productivity, its functional and morphological qualities are the subject of continuous research in connection with machine milking (Hamann & Mein, 1996; Forsback et. al., 2005; Klein et. al., 2005; Schukken et. al., 2006; Haeussermann et. al., 2011).

Damage to the cow teats by milking units is the main cause of disorders in milk production, milk secretion and general health of the animal. The emphasis in recent scientific studies is entirely focused on the state of the tip teat due to its interaction with the milking shells or milking liners (Hamann & Mein, 1996; Forsback et al., 2005; Schukken et al., 2006; Haeussermann et al., 2011; Odorčić et al., 2019). Efforts of scientists, designers and milking producers ultimately led to the creation of milking units with a different form of milking liners and milking cups (Hillerton et al. 2000; Schukken et al., 2006; Haeussermann et al., 2011).

With the new type of milking units the stereometric shape of the pulsation chamber is completely changed. It is known as the "tri-circle" and is presented as the "safest" in terms of health on the tip of the udder. Numerous studies have been found to have a contradictory character but it may well be the opinion that truly milking units with a three-segment configuration of the pulsation chamber compare to the cylindrical shape provide milder and more supple milking (Hillerton et al., 2000; O'Callaghan, 2001; Forsback et al., 2005; Schukken et al., 2006).

There are conflicting literature data on the influence of the pulsation parameters of the milking machine (in particular the pulsation rate) on the size of the morphological structures of the milk papilla in lactating cows (Klein et. al., 2005; Schukken et al., 2006; Wieland et al., 2019). We have not found in the scientific literature the conduct of such studies in cows in our country. This gave us reason to conduct research in this direction and we set ourselves the goal to study the influence of pulsation rate on the size of the main morphological structures of the teats in cows in different milking conditions.

Material and Methods

The subject of the present study is the change in the size of some morphological structures of the teat before and after milking. The findings were established on the basis of ultrasound examination in the conditions of different modes of machine milking. The experimental group included 12 clinically healthy cows (of the same breed and on first lactation) kept under the same conditions. During the first month of the experiment the cows were milked with conventional milking units at a pulsation rate of 60 min-1 and a pulsation ratio of γ = 60/40%.

During the second month of the experiment, the same animals were milked with modified (three-segment configuration of the pulsation chamber) milking units at frequency modes f = 60 min-1, f = 70 min-1 and f = 80 min-1 (γ = constant = 60/40%).

The measurements of the following morphological structures are accepted as indicators for assessment of the condition of the milk papilla before and after milking: length of teat canal and diameter of teat canal; diameter of the teat in the area of the Fürstenberg rosette; teat wall thickness; diameter of the teat part of the milk cistern in its middle (widest) part and diameter of the teat cistern in the area of the transition between the papillary and glandular part.

The basic statistical processing to obtain the mean values (), dispersion (σ2), standard deviation (σ), standard error (Sx), minimum and maximum value (min - max) was performed by descriptive statistics included in the software package STATISTICA10.

In the processing of the experimental results between the pulsation rate and the internal structures of the milk papilla a correlation dependence was sought.

The correlation coefficient shows the relationship between the features in relative units and assumes values from 0 to ± 1.

All experimental data included in the analysis have statistical reliability established by the Student's t test.

The difference between the squares of the correlation coefficient and the correlation ratio for each experimental function of the indeterminate type is used as a criterion for linear and quasilinear dependence:

yi = f (xi), for the milking liner type parameter (1)

where:

yi - the values in the dimensions of a specific morphological structure; xi - specific frequency parameter (mode) of the pulsation system of the milking machine of a given type.

yi = a + bxi (2)

where: a - initial value in the dimension of a specific morphological structure when the argument xi changes; b - the coefficient taking into account the correlation between variable/argument.

Results and Discussion

The sensitivity of a morphological structure to the type of milking machine and its pulsation parameters is statistically "overcome" by the coefficient of variation of its dimensions. The results are presented in tabular form (Table 1) and are graphically interpreted in Fig. 1.

The coefficient of variation for the wall thickness increases slightly when changing the type of milking machine and increasing the frequency mode. The data is confirmed by Klein et al. (2005). The coefficient for variation of the length of the teat canal shows the same tendency, but in the opposite direction. As the frequency load increases, the coefficient decreases slightly. This is contrary to the data received from Neijenhuis et al. (2001). The authors claim that the length of the teat canal is reduced after milking

The structures of the cow teat that are most insensitive to changes in the type of milking unit and increase in frequency load are the length of the canal, the diameter of the rosette and the thickness of the papillary wall.

The most sensitive to the change of arguments are the diameter of the cistern and the diameter of the transition from the papillary to the glandular part. The significant change in the diameter of the milk cistern before and after milking is most likely a consequence of a purely physical-mechanical effect following the emptying of the conductive part of the udder and the teat.

An increase in the coefficient of variation of the transition diameter was found at the frequency modes 60 min-1 and 80 min-1. This is most likely due to the following factors: the type of milking unit and the pressure exerted by the milking liner on the teat tissue.

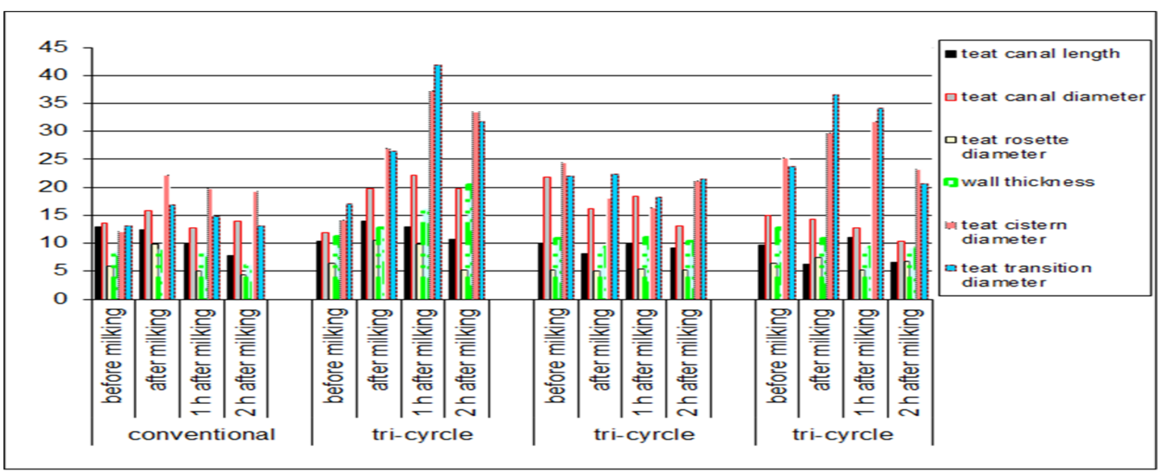

Figure 1. Graph of the coefficient of variation of the studied parameters of the milking teat

Table 1. Coefficient of variation (Cv, %) for the measured parameters of the cow teats

Type of milking units and pulsation rate	Measurement time	The teat canal length, mm	The diameter of the canal, mm	The diameter of the rosette, mm	The teat wall thickness, mm	The diameter of the cistern, mm	The diameter of the transition, mm
Conventional	Before milking	12.9	13.6	5.9	8.4	12.1	13.1
milking unit	After milking	12.4	15.8	9.9	9.0	22.2	16.9
60 min^{-1}	1 h after milking	9.8	12.7	5.1	8.3	19.8	14.8
	2 h after milking	7.8	13.9	4.4	6.1	19.3	13.1
Modified	Before milking	10.4	11.9	6.5	11.2	14.1	17.1
milking unit	After milking	14.0	19.8	10.5	12.8	26.9	26.4
60 min^{-1}	1 h after milking	12.9	22.2	9.9	16.2	37.3	41.9
	2 h after milking	10.7	19.8	5.2	20.4	33.4	31.7
	Before milking	10.0	21.8	5.3	10.9	24.3	22.0
Modified	After milking	8.2	16.2	5.1	9.4	18.1	22.3
milking unit	1 h after milking	9.9	18.4	5.4	11.1	16.3	18.2
70 min^{-1}	2 h after milking	9.1	13.1	5.2	10.3	21.1	21.4
	Before milking	9.7	15.0	6.5	12.8	25.2	23.7
Modified	After milking	6.3	14.3	7.4	10.8	29.7	36.6
milking unit	1 h after milking	11.1	12.8	5.3	9.3	31.7	34.1
80 min^{-1}	2 h after milking	6.6	10.3	6.7	9.2	23.2	20.6

In summary, the lowest coefficients of variation are observed when milking with the modified milking unit and pulsation rate 70 min-1.The parameters of the milk papilla that have the highest coefficient of variation should be included as an indicator of the efficiency of a milking unit. In this case, these are the diameters of the transition and the cistern followed by the thickness of the teat wall.

The influence of the pulsation rate and milking unit type on the measurements of the studied morphological structures of the teat is summarized by correlation analysis the results of which are given in Table 2.

Table 2. Correlation coefficients (r) of the measured teats parameters

Measurement time	The teat canal length , mm	The diameter of the canal, mm	The diameter of the rosette, mm	The teat wall thickness, mm	The diameter of the cistern, mm	The diameter of the transition, mm
Before milking	1.001	1.001	1	1.002	1.01	1.001
After milking	1	1.002	1	1	1.003	1.01
1 h after milking	1	1.003	1	1.001	1.001	1.01
2 h after milking	1	1.001	1	1.002	1.01	1.01

A rectilinear correlation was found between the frequency load and the studied parameters of the milk papilla (internal structures) at a confidence level of $p \leq 0.001$. Exceptions are the diameters of the cistern and the transition when measured two hours after milking where the correlation coefficient is respectively r = 0.85 and r = 0.88. However, there is a strong relationship between the frequency load and these two structures at a confidence level of $p \leq 0.001$.

The correlation method to determine the type of relationship (linear or nonlinear) was used. The data are visible in Table 3.

Table 3. Correlations ratios at the measured teats parameters

Measurement time	The teat canal length , mm	The diameter of the canal, mm	The diameter of the rosette, mm	The teat wall thickness, mm	The diameter of the cistern, mm	The diameter of the transition, mm
Before milking	0.98	0.98	0.98	0.92	0.96	0.97
After milking	1	0.98	0.99	1	0.93	0.95
1 h after milking	1	0.96	1	1	0.91	0.94
2 h after milking	1	0.98	1	1	0.85	0.88

After calculating the nonlinearity coefficient (L) it was found that the relationship between the frequency load and the structures of the milk papilla is linear or quasilinear for all parameters studied. This gives us a basis for studying the relationship between factors and signs using linear models. Exceptions to this are the tank diameters and the transition when measured two hours after milking, where the nonlinearity coefficient is L≥0.2.

Each equation (Table 4) describes the expected change in the dimensions of a specific morphological structure when changing the corresponding argument with a conditionally accepted differential unit. In this way, extrapolation can be performed for the change in the structures of the milk papilla outside the experimental gradations for the pulse rate.

Table 4. Regression equations for the studied parameters of the milk papilla

Measurement time	The teat canal length, mm	The diameter of the canal, mm	The diameter of the rosette, mm	The teat wall thickness, mm	The diameter of the cistern , mm	The diameter of the transition, mm
Before milking	*y=0.13+0.124x*	*y=0.04+0.03x*	*y=0.03+0.24x*	*y=0.17+0.07x*	*y=0.17+0.18x*	*y=0.18+0.2x*
After milking	*y=0.04+0.12x*	*y=0.025+0.025 x*	*y=0.198+0.231 x*	*y=0.045+0.093 x*	*y=0.228+0.113 x*	*y=0.245+0.123 x*
1 h after milking	*y=0.39+0.116x*	*y=0.045+0.023 x*	*y=0.192+0.235 x*	*y=0.04+0.096x*	*y=0.26+0.104x*	*y=0.228+0.113 x*
2 h after milking	*y=0.043+0.124 x*	*y=0.01+0.024x*	*y=0.19+0.236x*	*y=0.002+0.089 x*	-	-

Conclusions

It was found that: (i) the diameters of the milk cistern and the transition from the papillary to the glandular part of the udder are the most sensitive morphological structures in terms of the type of milking unit and its frequency parameters; (ii) ultrasound scan revealed the lowest changes in the dimensions of the morphological structures of the teat during milking with units whose cups have a triangular stereometry of the pulsation chamber in the mode 70 min^{-1}; (iii) there is a very high degree of correlation between the frequency regime of the milking machine and the dimensions of the basic morphological structures of the milk papilla; (iv) the linear nature of the established dependences allows for a prediction regarding the state of the main morphological structures of the teat under different conditions of machine milking.

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