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Monitoring the inner surface of teat cup liners made from different materials

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Abstract

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The modern milking equipment consists of several rubber parts. Among these rubber parts, the most important is a teat cup liner, which provides direct contact force to teat tissue. Properties of teat cup liners directly affect the technical and technological process of milking, udder health condition and quality of obtained milk. The aim of the study is to specify the inner surface roughness of cup liners made from different materials. Roughness was measured using Surftest-301 Mitutoyo connected to a printer. Teat cup liners were monitored and evaluated at three different locations of the inner surface, every three months in primary production. The obtained results showed linear regression between the inner surface roughness of teat cup liners and exposure time. Significant differences of selected indicators of silicone liners were observed with *P*-value (0.029) < alpha (0.05). The model equation shows that if the value of cup liners exposure time increases by one month, inner surface roughness is likely to increase by approximately 0.039 μm.

Keywords: teat cup liner; exposure; roughness

Teat cup liners belong to the most exposed structural element in the milking technology. According to (Bekényi et al. 2012; Mašková 1989), they must have suitable physical and mechanical properties and may not contain ingredients that would affect the milk quality. They also have to be suitable for economic production and must be resistant to the following factors: milk, fat, heat, oxygen, ozone, light, pull, bend, abrasion, cleaning and disinfection. Many authors focus on the rubber parts of milking equipment as potential sources of milk contamination (Gálik, Karas 2006; Karas et al. 2003; Krzyś et al. 2011; Kunc et al. 2007; Los et al. 2002a; Los et al. 2002b). Serious is the finding that cracks on the inner surface of teat cup liners are increasing proportionally with exposition time within the primary production and they are a source of pathogenic microorganisms. Fats, carbohydrates, proteins, etc. in cracks are a breeding ground for reproduction of pathogenic microorganisms. Tančin and Tančinová (2008) indicate that the functional parameters of milking equipment, especially the life of teat cup liners and other rubber parts, should be paid attention through regular checks of their technical condition. Because the milking machine effects directly on udder teats through the teat cup liner, the shape, size and material of teat cup liners must take into account the shape and size of teats in the cattle (Komárek 1973; Karas, Gálik 2004). According to the cited author, new prescriptions for rubber mixtures used for teat cup liners must be addressed comprehensively, i.e. the composition of mixtures should consider also the production method, economic aspects as well as properties and availability of various raw materials.

For the composition of rubber, the most important is the right choice of rubber, which is quite difficult with regard to a wide range of synthetic rub-

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bers. Their selection and appropriate use requires considerable experience. Special synthetic rubbers are applied only when products require having some special properties such as resistance to ageing, to ozone, etc. Synthetic rubbers for special purposes (teat cup liners included) are considerably more expensive than natural rubber or styrene butadiene. Attention should be paid to the selection of additives that improve the properties of final products. The aim of this study is to monitor the inner surface of teat cup liners made of different materials exposed in the primary production.

MATERIAL AND METHODS

The following methodology was used:

– Choice of teat cup liner:
  (a) black rubber liner,
  (b) silicone liner.
– Monitoring the inner surface roughness of examined teat cup liners exposed in the primary production under the following conditions:
  (a) in the longitudinal direction,
  (b) in the transversal direction.
– Roughness monitoring was set up as follows:
  Point 1: 20 mm below the heads of teat cup liners,
  Point 2: in the middle of working parts of teat cup liners,
  Point 3: 20 mm from the bottom working parts of teat cup liners.

For monitoring inner surface roughness of teat cup liner were used samples with length of their working part. The samples were with dimensions 0.5 × 0.5 cm and their roughness was monitored in the longitudinal and transverse direction.

– Evaluation and monitoring of selected teat cup liners in three-month intervals (new – 3 – 6 – 9 months of operation).
– Evaluation of the most important roughness parameters such as:
  R_a – arithmetic mean diameter (μm),
  R_z – maximum deviation (μm).
– The said intentions were performed by the device Surftest-301 Mitutoyo connected with the printer.

Data were expressed as regression and correlation analysis using Microsoft Excel.

RESULTS AND DISCUSSION

Monitoring the inner surface roughness of teat cup liners in the longitudinal direction. The results obtained are showed in Table 1. They show that the inner surface roughness of black rubber liners increased from 0.68 μm (new teat cup liner) to 1.43 μm (after 9 months of exposure). The coefficient of correlation $R = 0.893$ is interpreted as a high linear relationship between the inner surface roughness of teat cup liners and exposure time. The coefficient of determination $R^2 = 0.800$ indicates that 80% of variability in inner surface roughness explains the effect of exposure time. The 20% of variability can be explained by causes other than the linearity between exposure time and the inner

Table 1. The inner surface roughness of black rubber and silicone liners detected during exposure in the longitudinal direction

Measurement location	Exposure time (months)							
	0		3		6		9	
	R_a (μm)	R_z (μm)	R_a (μm)	R_z (μm)	R_a (μm)	R_z (μm)	R_a (μm)	R_z (μm)
Black rubber liners								
1	1.04	2.30	0.56	2.40	0.93	2.60	1.25	2.40
2	0.55	2.20	0.57	2.40	0.97	2.40	1.46	2.50
3	0.46	1.50	0.66	2.80	0.95	2.90	1.65	2.90
$\bar{x}$	0.68	2.00	0.59	2.53	0.95	2.63	1.43	2.60
Silicone liners								
1	0.49	1.70	0.39	1.40	0.53	1.40	0.71	1.40
2	0.42	2.60	1.08	1.80	1.09	1.90	1.10	1.80
3	0.57	1.60	0.39	1.50	0.65	1.60	0.73	1.70
$\bar{x}$	0.49	1.96	0.62	1.56	0.75	1.63	0.84	1.63

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surface roughness of teat cup liners. The equation model is in the form: $y = 0.521 + 0.087x$. By comparing the P-value and significance level α (0.05), we observed that the P-value (0.107) > α (0.05), which means that no significant dependence was obtained between inner surface roughness and exposure time. This is mainly due to the low value of roughness observed after three months of exposure (0.59 µm in Table 1). On the other hand, a surprisingly high roughness value was obtained for the first measurement at the beginning of experiment (1.04 µm in Table 1). However, the relationship between exposure time and the inner surface roughness of black rubber liners is obvious. The inner surface roughness of silicone liners increased from 0.49 µm (new teat cup liners) to 0.84 µm (after 9 months of exposure). The coefficient of correlation $R = 0.996$ is interpreted as a high linear relationship between the inner surface roughness of teat cup liners and exposure time. The coefficient of determination $R^2 = 0.993$ indicates that 99% of variability in the inner surface roughness of teat cup liners could be explained by exposure time and 1% of variability can be explained by causes other than the linearity between exposure time and the inner surface roughness of teat cup liners. The equation model is in the form: $y = 0.498 + 0.039x$. By comparing the P-value and significance level α (0.05), we observed that the P-value (0.029) < α (0.05), which means that a significant dependence was obtained between inner surface roughness and exposure time. The equation model shows that if exposure time increases by one month, the inner surface roughness of teat cup liners is likely to increase by about 0.039 µm. Fig. 1 depicts the inner surface roughness and exposure time.

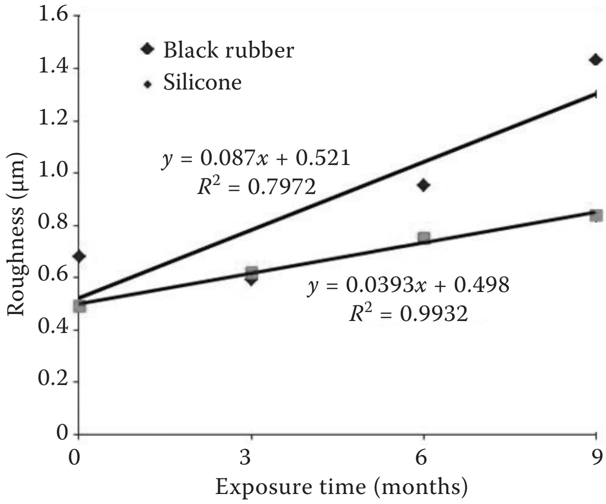

Fig. 1. Relationship between the inner surface roughness of teat cup liners and exposure time in the longitudinal direction

Monitoring the inner surface roughness of teat cup liners in the transversal direction. The results obtained are described in Table 2. In black rubber liners, roughness increased from 0.89 µm (new teat cup liners) to 3.03 µm (after 9 months of exposure). The coefficient of correlation $R = 0.989$ is interpreted as high linear relationship between the inner surface roughness of teat cup liners and exposure time. The coefficient of determination $R^2 = 0.978$ indicates that 98% of variability in the inner surface roughness of cup liners is explained by

Table 2. The inner surface roughness of black rubber and silicone liners investigated during exposure in the transversal direction

Measurement location	Exposure time (months)							
	0		3		6		9	
	R_a (µm)	R_z (µm)	R_a (µm)	R_z (µm)	R_a (µm)	R_z (µm)	R_a (µm)	R_z (µm)
Black rubber liners								
1	0.96	2.40	1.32	2.60	2.37	3.60	3.04	4.10
2	0.83	2.50	1.40	2.90	2.50	3.80	2.95	4.80
3	0.90	2.60	1.38	3.30	2.47	3.60	3.10	3.90
$\bar{x}$	0.89	2.50	1.36	2.93	2.44	3.66	3.03	4.26
Silicone liners								
1	0.63	1.80	0.93	1.90	1.51	2.30	1.73	2.70
2	0.70	2.90	1.07	2.30	1.35	2.80	1.50	2.90
3	0.69	1.90	1.10	2.20	1.40	2.30	1.63	2.30
$\bar{x}$	0.67	2.20	1.03	2.13	1.42	2.46	1.62	2.63

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exposure time and 2% of variability can be explained by causes other than the linearity between exposure time and the inner surface roughness of liners.

The equation model is in the form: $y = 0.805 + 0.25x$. In this case, we observed that the P-value (0.029) < α (0.05), which means that a significant dependence was obtained between inner surface roughness and exposure time. After exposure time increases by one month, inner surface roughness is likely to increase by about 0.25 μm, which was described by the equation model.

In silicone liners, inner surface roughness increased from 0.67 μm (new teat cup liners) to 1.62 μm (after 9 months of exposure). A significant linear dependence between inner surface roughness and exposure time was obtained. The coefficient of correlation $R = 0.992$ is interpreted as a high linear relationship between inner surface roughness and exposure time. The coefficient of determination $R^2 = 0.983$ expresses that 98% of variability in the inner surface roughness of teat cup liners is explained by exposure time and 2% of variability can be explained by causes other than the linearity between exploitation time and the inner surface roughness of liners. The equation model is in the form: $y = 0.699 + 0.108x$. By comparing the P-value and significance level α (0.05), we observed that the P-value (0.008) < α (0.05), which means that a significant dependence was obtained between inner surface roughness and exposure time. The equation model shows that if exposure time increases by one month, the inner surface roughness of teat cup liners is likely to increase by about 0.108 μm. The inner surface roughness of teat cup liners and exposure time is shown in Fig. 2.

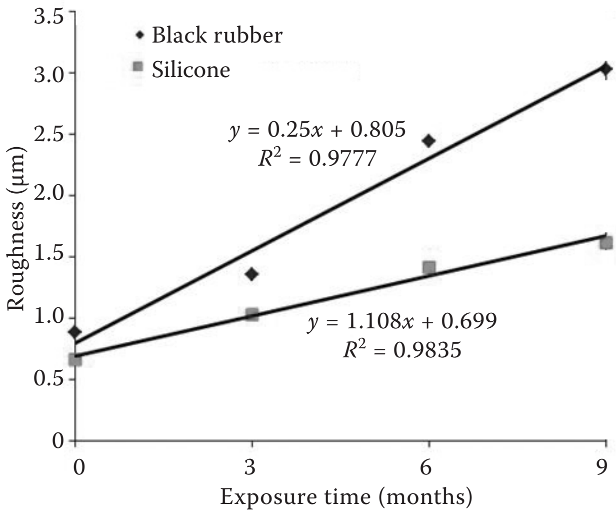

Fig. 2. Relationship between the inner surface roughness of teat cup liners and exposure time in the transversal direction

During exploitation, teat cup liners are exposed to extreme conditions. In addition to mechanical wear, liners are damaged by milk fat, water and chemicals such as detergents. The quality of teat cup liners is negatively affected by solar radiation, high temperature, etc. (Bekényi 2012). The results presented by Gálik et al. (2002) clearly show a significant deterioration of the inner surface during the use of teat cup liners. Destructive and non-destructive methods can be used to diagnose their condition. Destructive methods have a disadvantage – a product can no longer be used. With non-destructive methods (detection of tensile forces), diagnosed teat cup liners can be longer used in the primary production, respectively in further studies. Besides these methods of diagnosing the condition of teat cup liners, surface microgeometry by using a profilometer can also be used. Alternative materials such as silicone rubber teats (non-porous) should have longer operating life (http://www.nadis.org.uk/bulletins/mastitis-control-and-management/mastitis-part-9-the-milking-machine.aspx). In general, irregular controls and delayed controls of milking equipment based on the idea of saving money usually lead to subsequent higher expenses (Tančin et al. 2013).

CONCLUSION

The following conclusions were drawn based on the results obtained:

– In monitoring the inner surface roughness of teat cup liners in the longitudinal direction, both the black rubber liners and silicone liners showed a significant linear relationship between inner surface roughness and exposure time (R^2 = 0.800 and R^2 = 0.993, respectively).
– By comparing the P-value and significance level α (0.05), there was no significant relationship between inner surface roughness and exposure time for black rubber liners (0.107 > 0.05). On the contrary, a significant dependence was observed for silicone liners (0.029 < 0.05).
– The equation model for silicone liners is in the form: $y = 0.498 + 0.039x$, i.e. when exposure time increases by one month, inner surface roughness is likely to increase by about 0.039 μm.

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– When monitoring the inner surface roughness of teat cup liners in the transversal direction, both the black rubber liners and silicone liners showed a significant linear relationship between inner surface roughness and exposure time (R^2 = 0.978 and R^2 = 0.983, respectively).
– By comparing the P-value and significance level α (0.05), a significant relationship was observed for black and also silicone teat cup liners between inner surface roughness and exposure time (0.011 < 0.05 and 0.008 < 0.05, respectively).
– The equation model for silicone liners is in the form: $y = 0.699 + 0.108x$, i.e. a significant relationship was obtained between inner surface roughness and exposure time. The equation model shows that if exposure time increases by one month, the inner surface roughness of teat cup liners is likely to increase by about 0.108 μm.
– The results clearly indicate that monitoring the inner surface of teat cup liners in the longitudinal and transversal direction showed higher roughness values for black rubber liners.

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