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MEASUREMENT OF CHANGE OF LINER PROPERTIES WITH AGE

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Summary:

Seven physical liner properties were measured on three groups of eight liners as they aged naturally and artificially to determine: (a) the change of each measurement with age, (b) if use time before washing is a factor in the rate of change of these measurements and (c) a calibration curve for an artificial aging method. Liners were aged in three different ways: (1) on a small farm milking twice a day for three hours at a time, (2) on a large dairy milking three times per day for six hours at a time, and (3) by soaking liners in clarified butter oil at 100°C. The physical liner measurements were: mouthpiece lip flex, mounted liner tension, mouthpiece bore, outside barrel diameter, collapsed thickness of barrel walls, barrel length, and total weight. Each group was measured new and at intervals during aging. Similarities and differences among the three different aging methods were noted. The change in mouthpiece flex, mounted tension, barrel length and total weight appeared to be the best predictors of change in liner condition. Artificial aging of a liner for two days in 100°C clarified butter oil resulted in changes in mouthpiece lip flex and mounted tension similar to 840 cow milkings on a dairy farm milking for three hours at a time, twice daily.

Keywords:

liner, milking characteristics, liner age, liner measurements, rubber

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MEASUREMENT OF CHANGE OF LINER PROPERTIES WITH AGE

INTRODUCTION

The rubber liner is the only part of the milking machine that contacts the cow's teat. This interaction between liner and teat has a critical influence on milking performance but is often ignored (14). The reaction of the cow's teat to the liner and resulting milking characteristics are highly dependent upon the physical characteristics of the liner (1, 2, 3, 15). These physical characteristics change with age and use, thus changing the milking performance of the liner (5, 9, 17).

Past studies have examined the milking characteristics of various milking clusters (10, 11, 12) and the milking characteristics of different types of liners (5, 6, 13). The change of physical measurements of the aging liner has also been investigated. The liner's exposure to fat, oil, oxygen, sunlight, and chemical cleaners are known to change the physical dimensions of the liner over time (9, 16, 17, 18). Previous studies involving the aging of liners were done outside of the USA and involved liners with a higher carbon black content, which is largely responsible for the lengthy useful life (9). US liners must have less than 10% carbon black to meet food handling requirements, while liners used outside of the USA may typically have 25% carbon black in the rubber mixture (3). Therefore, this study sought to record data on the changes in physical measurements of US liners as they were aged naturally and artificially.

Previous studies have reported the liner age in terms of cow milkings or days of use (16, 18, 19). The expansion of the dairy industry has changed the way liners are used. In years past, liners were typically used for 2 to 3 hours, washed, and then were unused for up to 12 hours before being used again. As farms become larger, liners may be used continuously for up to 12 hours, washed, and then immediately put back into service. The liners consequently spend more time in contact with fat and oil, which are known to change the physical properties of the rubber. One goal of this study is to investigate the differences between liner aging for these two types of use.

Past studies on artificial aging methods involved a simulation machine or simply soaked the liners in milk or various oils and fats (8, 18). These studies provided useful information on the detrimental effects of liner exposure to fats and oils, but did not relate these effects to liners aged naturally in the field. This study seeks to calibrate an artificial aging method to represent liners aged on both small and large dairy operations.

The traditional method to recommend a liner's useful life is to specify a number of cow milkings. This criterion ignores differences in milking and cleaning practices and other environmental conditions on dairy farms. It is hypothesized that physical measurements of the liner itself may be good indicators of liner age and thus milking performance (2, 16). Another goal of this research is to gain a better understanding of how the physical properties of liners affect milking characteristics. This information will provide manufactures with better criteria to specify liner life and add to the understanding of the influence of liner properties on milking characteristics.

The primary focus of this paper is the measurement of change of seven physical liner characteristics as the liners are aged. The second focus of this study is the calibration of an artificial aging technique. While it is known that physical measurements and milking performance measurements of the liner change with age and use, aged liners must be studied in order to understand this relationship. Studies to show differences in liner performance have frequently required that liners be used twice or three times their suggested life. Liners used in this way may threaten herd health; therefore, a system to artificially age liners will prove useful for liner research.

Future work in this area will attempt to correlate physical liner measurements with milking characteristic measurements to eventually create a liner replacement schedule based upon both. A properly functioning milking machine should remove milk quickly, completely, efficiently, yet gently (1, 2, 4). These four adjectives represent four milking characteristics that will be used to assess milking performance: milk flow rate, amount of cisternal milk left in the teats after milking, stability of the unit during milking, and post-milking teat condition (2).

OBJECTIVES

The specific objectives of this study are**:**

1. To measure changes in mouthpiece lip flex, mounted liner tension, mouthpiece bore, outside barrel diameter, collapsed thickness of barrel walls, barrel length and total weight as liners are aged both artificially and naturally.
2. To determine how the time-of-use between washings affects changes in physical characteristics of liners.
3. To compare liners aged by an artificial aging method to liners aged naturally on both small and large dairy operations.

MATERIALS & METHODS

Three groups of liners were aged three different ways: artificially, naturally on a small dairy operation, and naturally on a large dairy operation. The seven physical measurements were taken when the liners were new and throughout the aging periods. The specific details of the equipment, aging techniques, and measurement techniques follow.

Liners

The liners artificially aged and naturally aged on the small dairy operation were BouMatic, model R-2CV, lot number 9082. The liners naturally aged on the large dairy operation liners were BouMatic, model R-1D, lot number 8349 (for the 1242 cow milkings measurement) and lot number 9079 (for new measurement).

Artificial Aging

Eight liners were aged by soaking in clarified butter held at 100°C in a constant air temperature oven; these conditions were based upon a British Standard for rubber absorption tests (7). All eight liners were submerged in butter oil in the same vessel, lying on their side and not touching to prevent distortion. Liners were aged for seven days. The anhydrous/clarified butter oil was manufactured by Madison Farms Butter Co., St. Louis, MO, USA, plant 29-021. The disposable aluminum pan containing the butter oil and liners during aging was 342 mm x 241 mm x 76 mm.

Seven measurements were conducted on the artificially aged liners when they were new. These measurements were repeated after each 24 hours of aging. Liners were removed from the butter oil and washed with mild detergent and warm water before measurement. After measurement, the liners were returned as a group to the bath of clarified butter for the next 24 hours of aging.

Natural Aging - Small Dairy Operation

These liners were aged at the UW-Madison milking parlor. Eight liners were aged by normal use for three hours, followed by a wash, twice daily. The normal replacement schedule at the UW milking parlor is every 21 days which is about 840 cow milkings, 126 hours of use and 42 wash cycles. Liner properties were measured when new and removed from the parlor, measured and returned to the parlor after every 840 milkings. The liners were aged for a total of 2520 milkings.

Natural Aging - Large Dairy Operation

This set of liners was aged at the University of Florida Dairy Research facility, which is a double 12 milking parlor milking 560 cows three times per day. Eight liners were aged by normal use for six hours, followed by a wash, three times daily. The normal replacement schedule for this facility is every 18 days, which is about 1242 cow milkings, 324 hours of use and 54 wash cycles. The distant location of the large dairy farm prevented measurements of the liners immediately after removal from the milking machine. One set of liners was measured after 1242 cow milkings. A second set was to be used for 2484 cow milkings; however, the liners began to tear before reaching this goal and were replaced and not available for measurement.

Physical Measurements

Mouthpiece Lip Flex

Mouthpiece lip flex in mm was measured for an axial load of 500-g using a device illustrated in Figure 1. The fixed guide collar was held in place on a ring stand. The liner was mounted in the top part of a BouMatic Visi-Shell®, also held in place on the ring stand approximately 46 mm below the bottom of the fixed guide collar. The string attached to the hook was then threaded through the liner. The petroleum jelly lubricated tip of the movable shaft then rested on the mouthpiece lip of the liner. The weight of the shaft was 120 g.

The resting position of the device, referred to as the baseline position, was recorded as a pencil mark on the shaft of the flex device just above the fixed collar. An additional 500-g load was then attached to the string and lowered by hand to a point at which the mouthpiece lip began to flex; at this point the weight was gently released. While the weight was suspended, the new resting point was recorded by a second pencil mark on the movable shaft of the flex device. The flex of the mouthpiece in mm was measured as the distance from the baseline to the second pencil mark using a caliper (Starrett, No.120M, 150 mm capacity). The accuracy of this method is estimated as ±0.5 mm.

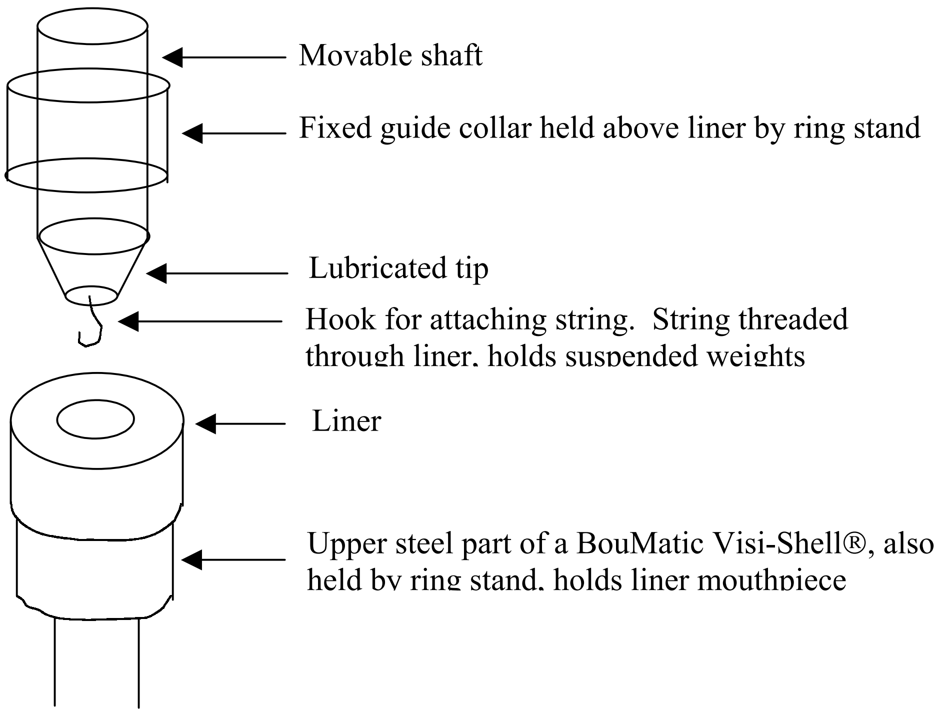


Figure 1. Detail of mouthpiece lip flex device

Mounted Tension

The mounted tension of each liner was determined by measuring the axial tension of the liner when it was stretched to its mounted length. A device called a tensiometer was used for this measurement and is illustrated in Figure 2.

The tensiometer consists of a fixed and movable plate; the movable plate is moved up or down by the actuating screw. The top of the liner is suspended in a hanger, which is attached to a load beam on the fixed plate, while the bottom of the liner is attached to the movable plate. The mounted length of the liner was first measured with a caliper, then was recreated by moving the movable plate downwards until the liner was extended to the same length. When the mounted length of the liner was reached, the output in N from the load beam was recorded as the mounted tension. The sensor output was read immediately to avoid creep of the rubber. This test was conducted as quickly as possible to avoid permanent set or possible damage to the liners.

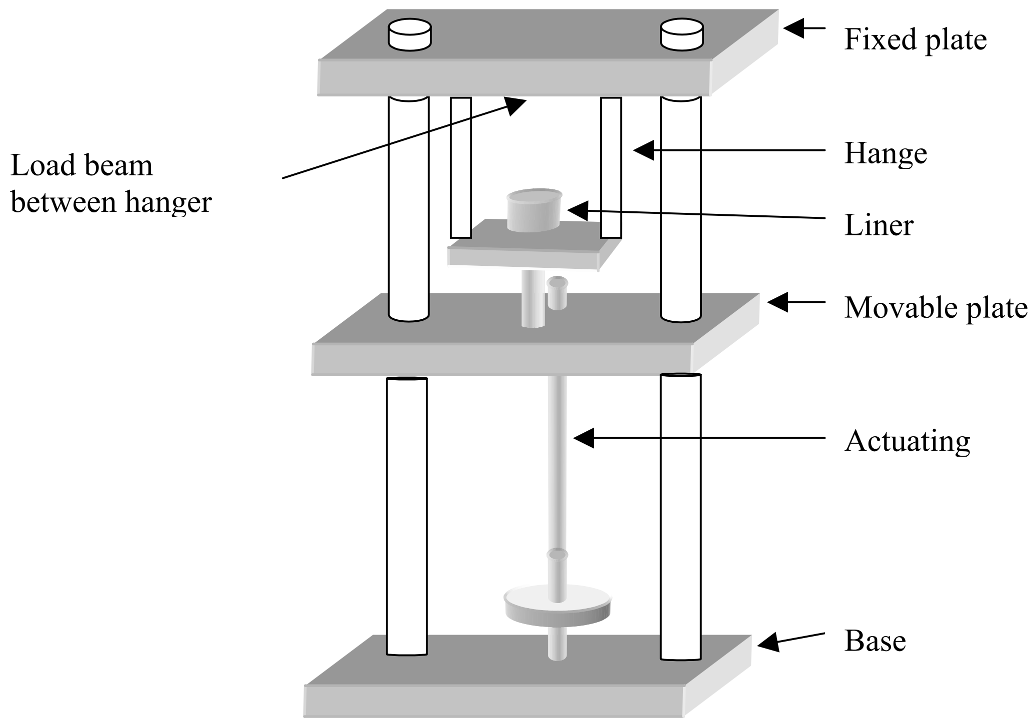


Figure 2. Detail of tensiometer

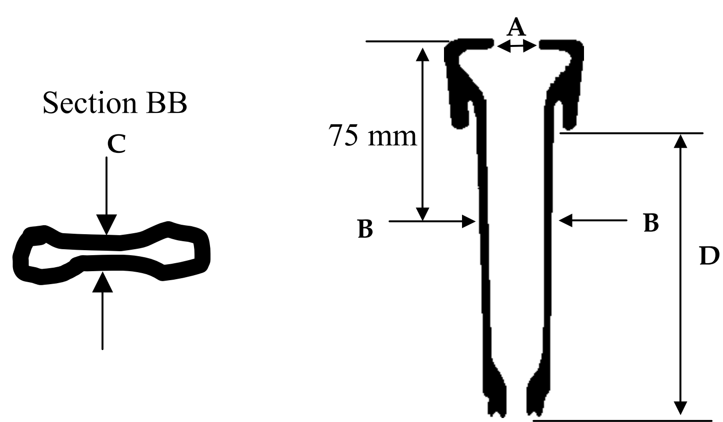
Figure 3: Physical liner measurements

Measurements:
A: Mouthpiece bore

B: Outside barrel diameter

C: Collapsed wall thickness

D: Barrel length



Picture Credit: Reference 12

Mouthpiece Bore
The mouthpiece bore (mm) was measured with a caliper (8). *(Refer to Figure 3 for the following four measurements)*

Outer Diameter of Liner Barrel
The outer diameter of the liner barrel (mm) was measured with a caliper 75 mm below the top of the mouthpiece. The measurement was made relative to the location of the printed lot number on the liner barrel as a consistent measurement location.

Thickness of Collapsed Walls
The liner barrel was collapsed and measured at a point 75 mm below the top of the mouthpiece (section BB in Figure 3). The thickness of the two collapsed walls (mm) was measured with a caliper.

Barrel Length
The length of the liner barrel (mm) was measured with a caliper (8).

Liner Weight
The weight of the liner (g) was measured on a digital scale (Denver Instruments, XL-3100D, 450 g capacity), with accuracy of +/- 0.01 g.

RESULTS AND DISCUSISON

Data for the seven physical liner measurements for each liner group is presented in Tables 1 (large dairy), 2 (small dairy) and 3 (artificial aging). The characteristics with the largest percentage change were mouthpiece lip flex, axial mounted tension and barrel length (Figure 4). The change in these characteristics over time is illustrated in Figures 5, 6, and 7.

Figure 4. Percentage change in physical measurements of liners for large (1242 milkings) and small (840 milkings) dairies.

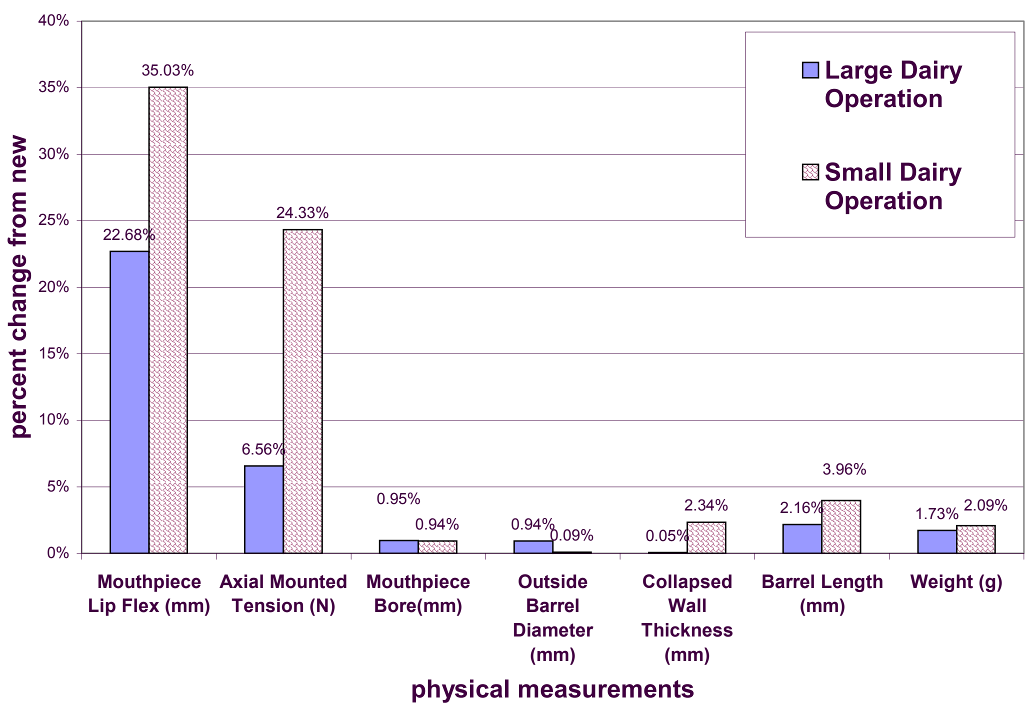


Figure 5. Changes in mouthpiece lip flex over time for all liner groups

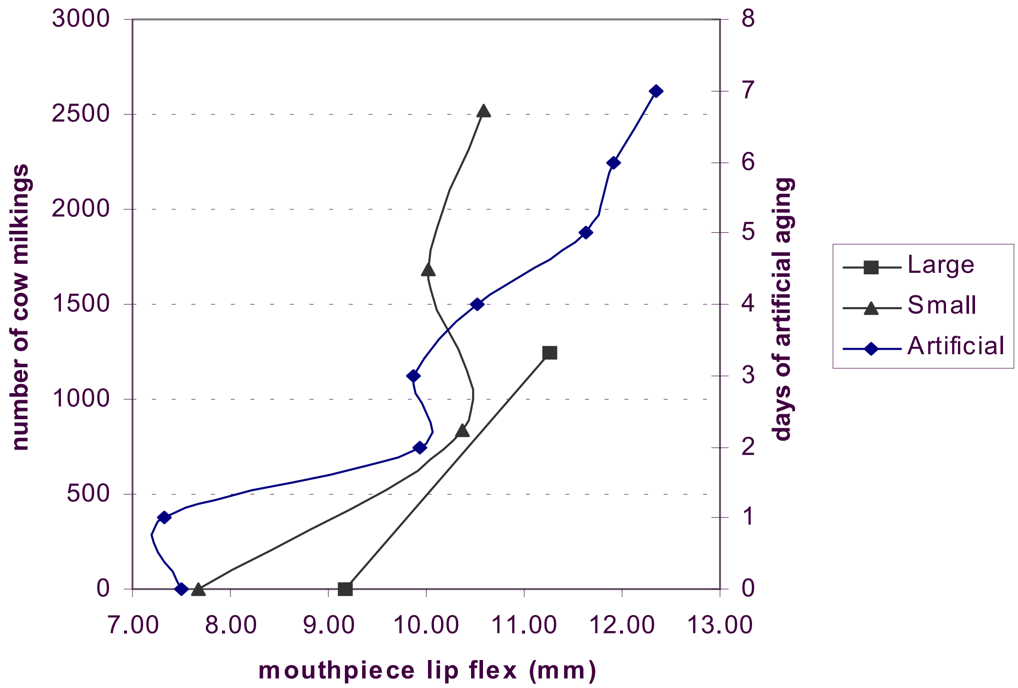


Figure 6. Changes in mounted tension over time for all liner groups

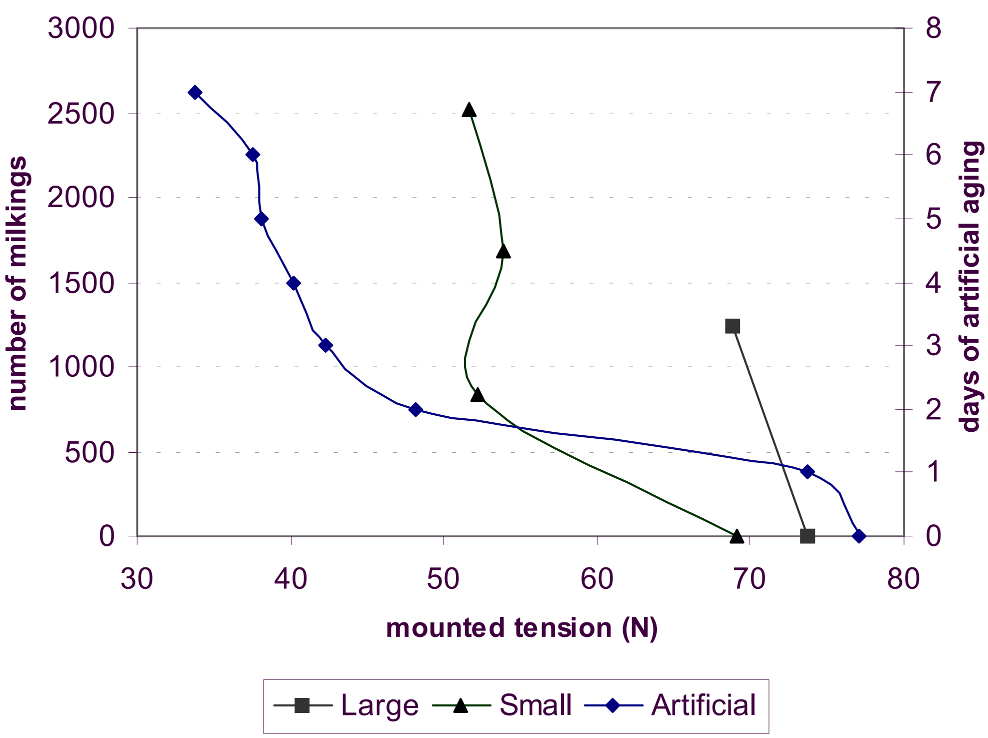
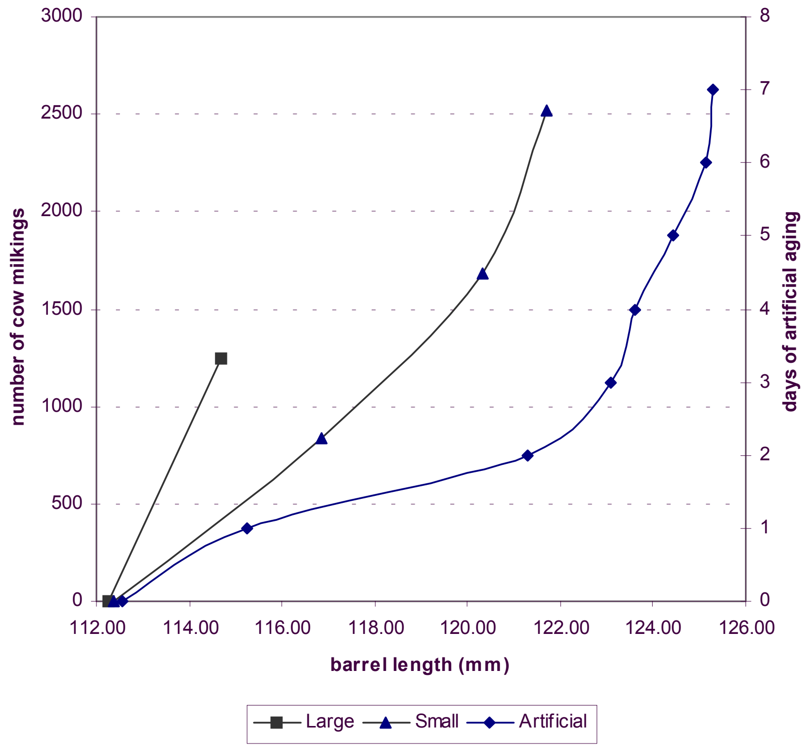


Figure 7. Changes in barrel length over time for all liner groups



Large Dairy

The averages of the physical measurements after aging were compared to the measurements taken on new liners using a t-test. For liners aged on the large dairy, barrel length, weight, tension, and mouthpiece lip flex showed significant changes ($p<0.05$) after 1242 milkings. The change in barrel OD, mouthpiece bore, and collapsed wall thickness was not significant ($p>0.05$). Another set of liners was planned to be aged for twice the normal life (2484 milkings). Several liners experienced catastrophic failure (tears at the lower mounting point) shortly after 1242 milkings and this aging trial was discontinued. It should also be noted that the liners had been removed from their shells and not in use for several weeks before the physical measurements were made. The barrel length was measured for liners aged 1242 milkings immediately after removal from the shells; the difference in length was found to be 6.35 mm as compared to 2.43 mm for the liners measured several weeks after removal. It appears that the liners relaxed during this period of no use. This period of no use may have affected other physical measurements as well.

It was originally hypothesized that longer use time before washing would age the liners faster, resulting in more dramatic changes of the physical measurements. The physical measurements did not support this hypothesis, however, and further work is needed to eliminate effects of prolonged period of no use before physical measurements are made. It is interesting to note that a number of the liners aged on the large dairy experienced catastrophic failure shortly after the recommended useful life, while none of the liners on the small dairy failed even after twice their rated life. Fatigue failure and/or liner type may have accounted for this difference.

Small Dairy

All physical measurements of liners aged on the small dairy were significantly different ($p<0.05$) from the initial values after 840 milkings except barrel OD and collapsed wall thickness. The change in wall thickness became significant after 1680 milkings. The change in barrel OD did not became significant for up to 2520 milkings.

Visual inspection of the small dairy liners revealed an elliptical shaped barrel, evident at 840 cow milkings. A measurement of the difference in the maximum and minimum barrel OD and visual observations of the liner would provide information about the degree of liner barrel deformation. This could be a significant factor in mouthpiece chamber vacuum and/or liner slips. After 2520 cow milkings, wear marks and stress cracks on the side of the barrel normal to the plane of collapse and distortion of the mouthpiece lip were observed. These strong indicators of extreme wear are better indicated by visual examination than by the measurements used here.

Artificial Aging

The change in physical measurements was significant ($p<0.05$) for all parameters except tension, mouthpiece bore, and mouthpiece flex after 1 day of artificial aging. Change in these three parameters became significant after 2 days of artificial aging.

The comparison between natural and artificial aging differed for the different physical measures. This comparison will focus on artificial aging and aging on the small dairy for mouthpiece lip flex, mounted tension, barrel length and liner weight. Two days of artificial aging produced a change in mouthpiece lip flex and mounted tension approximately equal to 840 cow milkings on the small dairy. Two days of artificial aging produced a change in barrel length approximately equal to 1680 cow milkings on a small dairy farm.

While the artificial aging method produced changes similar to natural aging for some measures, there were also differences in the two aging methods. The elliptical barrel shape observed in the naturally aged liners was not produced by this method of natural aging. This type of change, as well as other changes related to fatigue, would require repeated collapse of the liner during aging. The amount of fat absorbed in the artificial aging method was greater than for natural aging as indicated by the change in liner weight (Figure 8). This is likely due, in part, to the total immersion of the liner in fat (both inner and outer walls), whereas naturally aged liners are in contact with butterfat only on the inner wall. The artificial aging method also lacks the regular exposure to chemical cleanings, which may help or harm the liner. There are other aging media (light, heat, manure, iodine teat dip and shock loads from removal) that are not simulated in the artificial method and may be challenging to incorporate. The methods used here have a narrow inference base and indicate the need for further research before the artificial aging method can be used with confidence.

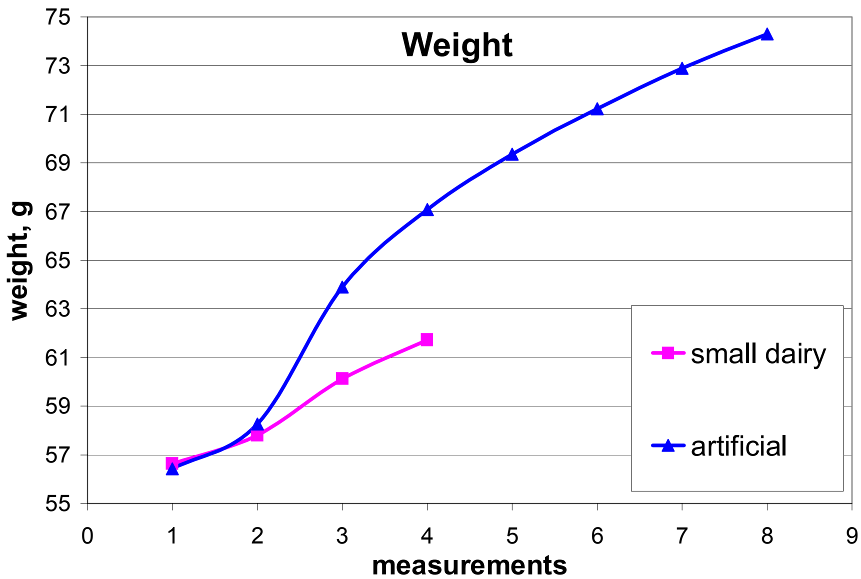


Figure 8. Weight gain of the artificially and naturally aged liners.

CONCLUSIONS

The number of milkings is used as the most common current indicator of liner age. Such a number does not take into account the amount of time the liner spends in contact with agents that induce aging such as milk, teat skin, udder hair, light, oxygen, and chemical washes. Simple physical measurements may provide a more precise indication of the need for liner replacement than the number of milkings. These physical measurements could take into account the variety of factors that influence liner life. Mouthpiece lip flex, mounted tension, barrel length, and total weight appear to be sensitive measures of changes in liners due to age. The artificial aging method produced changes in these measures similar to natural aging on an operating dairy. Other changes related to fatigue and deformation were not reproduced by the artificial aging method. Further work to correlate physical measurements and milking characteristics is being conducted.

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APPENDIX

Table 1. Means, standard deviations and percent change from new for large dairy operation liner group; unless noted, n=8.

Measurement	Milkings	Mean	Std. Dev.	% Change from New
Mouthpiece Lip Flex, mm	0	9.2	0.3	
	1242	11.3	0.6	23
Axial Mounted Tension, N	0	73.7	1.86	
	1242	68.8	1.20	6.6
Mouthpiece Bore, mm	0	19.8	0.13	
	1242	20.0	0.27	0.95
Outside Barrel Diameter, mm	0	25.5	0.10	
	1242	25.3	0.35	0.94
Collapsed Wall Thickness, mm	0	5.08	0.06	
	1242	5.08	0.11	0.05
Barrel Length, mm	0	112.3	0.61	
	1242	114.7	0.51	2.2
Weight, g	0	90.2	0.23	
	1242	91.8	0.18	1.7

Table 2. Means, standard deviations and percent change from new for small dairy operation liner group; unless noted, n=8.

Measurement	Milkings	Mean	Std. Dev.	% Change from New
Mouthpiece Lip Flex, mm	0	7.7	0.4	
	840	10.4	0.6	35
	1680	10.0	0.7	31
	2520	10.6	0.3	38
Axial Mounted Tension, N	0	69.0	1.68	
	840	52.2	1.62	24
	1680	53.8	1.22	22
	2520	51.7	1.33	25
Mouthpiece Bore, mm	0	20.0	0.09	
(n=4)	840	19.8	0.12	0.94
	1680	20.2	0.17	0.96
	2520	20.7	0.24	3.5
Outside Barrel Diameter, mm	0	25.8	0.09	
(n=4)	840	25.8	0.65	0.09
	1680	26.6	1.13	3.0
	2520	26.4	1.57	2.3
Collapsed Wall Thickness, mm	0	5.24	0.08	
(n=4)	840	5.12	0.12	2.3
	1680	5.39	0.09	2.9
	2520	5.26	0.11	0.38
Barrel Length, mm	0	112.4	0.24	
(n=4)	840	116.8	0.24	4.0
	1680	120.3	0.52	7.1
	2520	121.7	0.50	8.3
Weight, g	0	56.6	0.21	
(n=4)	840	57.8	0.45	2.1
	1680	60.1	0.48	6.2
	2520	61.7	0.36	9.0

Table 3. Means, standard deviations and percent change from new for artificially aged liner group; unless noted, n=8.

Measurement	Days of Aging	Mean	Std. Dev.	% Change from New
Mouthpiece Lip Flex, mm	0	7.5	0.3	
	1	7.3	0.8	2.3
	2	9.9	0.6	33
	3	9.9	0.5	32
	4	10.5	0.8	41
	5	11.6	0.4	55
	6	11.9	0.5	59
	7	12.4	0.7	65
Axial Mounted Tension, N	0	77.0	1.69	
	1	73.6	4.17	4.4
	2	48.2	2.95	37
	3	42.3	2.57	45
	4	40.1	2.45	48
	5	38.0	1.36	51
	6	37.5	1.42	51
	7	33.8	1.5	56
Mouthpiece Bore, mm	0	20.1	0.04	
	1	20.1	0.21	0.25
	2	20.8	0.16	3.6
	3	20.8	0.33	3.8
	4	21.0	0.22	4.6
	5	21.2	0.20	5.5
	6	21.4	0.19	6.7
	7	21.8	0.32	8.8
Outside Barrel Diameter, mm	0	25.6	0.13	
	1	28.6	0.42	12
	2	28.5	0.34	11
	3	29.1	0.31	14
	4	29.6	0.32	15
	5	29.9	0.32	17
	6	30.1	0.61	17
	7	30.2	0.36	18

(Table 3 continued)

Measurement	Days of Aging	Mean	Std. Dev.	% Change from New
Collapsed Wall Thickness, mm	0	5.16	0.10	
	1	5.30	0.07	2.7
	2	5.59	0.10	8.3
	3	5.68	0.09	10
	4	5.75	0.05	11
	5	5.87	0.10	14
	6	5.88	0.10	14
	7	5.89	0.08	14
Barrel Length, mm	0	112.5	0.12	
	1	115.3	0.56	2.4
	2	121.3	1.25	7.8
	3	123.1	0.89	9.4
	4	123.6	0.59	9.8
	5	124.5	0.53	10
	6	125.2	0.81	11
	7	125.3	1.20	11
Weight, g	0	56.4	0.36	
	1	58.3	0.52	3.3
	2	63.9	0.68	13
	3	67.1	0.68	19
	4	69.4	0.69	23
	5	71.2	0.68	26
	6	72.9	0.68	29
	7	74.3	0.64	32

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