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Optimization of the Pulsation Ratio During the Course of Milk Removal after using A Quarter Individual Milking System "MultiLactor"

Shehadeh Kaskous
Department of Research and Development, Siliconform, Schelmengriesstrasse 1, 86842 Türkheim, Germany, Tel. +49-8245-614.
Corresponding author email id: skaskous@siliconform.com

Abstract – **The pulsation system of the milking machine impacts milk flow rate, milk harvesting time, udder health and milk let-down, which are important factors in farm productivity and profit. This study investigated the effect of pulsation ratio on daily milk yield, milk flow rate and milking-on time in a conventional milking parlor with a MultiLactor (ML) milking system, where each udder quarter is milked separately. In total, 170 dairy cows on two commercial farms were included comparing pulsation ratios of 65:35 with the standard pulsation ratio of 60:40. Vacuum level was 34 kPa and pulsation rate 60 cycles/min.**

Total milk yield per milking, average flow rate and machine-on time differed significantly (P<0.001) after the change of pulsation ratio from 60:40 to 65:35. However, total milk yield per milking (13.67 ± 0.33 vs. 14.00 ± 0.33 kg) and average flow rate (1.75 ± 0.05 vs. 1.86 ± 0.05 kg/min) increased, whereas milking–on time (8.36 ± 0.25 vs. 8.03 ± 0.25 min) decreased. Moreover, the highest percentage of increase in the average flow rate was 7%, whereas the lowest reduced milking-on time was 40.2 second/milking after the pulsation ratio changed from 60:40 to 65:35. These results depend on the amount of harvested milk yield per milking and show that milking efficiency could be increased by increasing the pulsation ratio up to 65:35 without negative effects on udder health.

In conclusion, it is possible that an increased pulsation ratio up to 65:35 can be used to increase milking efficiency in conventional milking parlor with ML milking system.

Keywords – **Dairy Cows, Milk Flow Rate, Milking-On Time, Multilactor, Pulsation Ratio.**

I. Introduction

The goal of milking is to harvest the total quantity of milk fast, completely and to maintain good udder health. Herewith the milking machine plays a big role. Due to this reason, attention should focus on the settings of the milking machines in order to increase milk flow rate, reduce milk harvesting time and reduce labor costs. Many scholars have demonstrated that the milking machine settings determine the course of the milk removal during milking [1], [2], [3], [4]. Technically, it is possible to determine the perfect setting of the pulsation number, pulsation ratio and the vacuum level of the milking machine. But milking equipment and routine need to be adjusted according to the animals' physiological mechanism in order to achieve optimal milk removal [5], [6] and must not to be uncomfortable to the cow [7].

The pulsation ratio of the milking machine affects milk flow rate and milking time [8], [9], [10], [11]. The 70:30 and 75:25 ratios increased peak and average milk flows and the machine-on time was shorter, whereas both peak and average milk flows were lower and machine-on time was longer with the 60:40 ratio in automatic milking system [12]. Thomas et al. [8] reported similar results but in conventional milking system and they found that the 70:30 ratio yielded more milk per milking than 50:50 and needed lower machine-on time than 50:50 and 60:40. However, the results of Gleeson et al. [13] observed that widening the pulsation ratio from 60:40 to 67:33 had a positive effect on milk yield and milking time as well as did not have negative effects on changes in teat tissue. O'Callaghan [14] has shown similar results in his experiments and that a wide pulsation ratio leads to faster milking time than a narrow pulsation ratio. A new study investigated that milking efficiency could be increased by increasing the pulsation ratio, without negative effects on milk yield or milk composition [15].

The objective of the present study was to examine the pulsation ratio in order to find the optimization of the opening to closing phase of a teat cup when a quarter individual milking system ML was used.

II. Material and Methods

A. Animals

The research was carried out in two commercial cattle farms.

First Farm (F1): 50 dairy cows of the breed Brown cattle in Southern Germany (Bavaria) were examined after the using of ML milking system. At the beginning of the experiments, the average milk production was 7900 kg in 305 d, the mean lactation number was 2.13 ± 0.08, fat and protein were 4.40 ± 0.07% and 3.42 ± 0.12%, respectively. The cows were kept in loose housing and they were fed ad libitum with a partial mixed ration (grass-and corn-silage, hay) and received concentrate according to the production level. Twice daily at 6:30 and 16:30 o'clock, the cows were milked in a tandem milking parlor (2 x 5) with ML milking system.

Second Farm (F2): 120 dairy cows of the breed Holstein-Friesian in north-eastern France were used. At the beginning of the experiments, the average milk production was 10200 kg in 305 d, the mean lactation number was 2.45 ± 0.09 and fat and protein were 4.25 ± 0.03% and 3.44 ± 0.02%, respectively. The cows were kept in loose housing and were fed ad libitum with a partial mixed ration (grass-and corn-silage, sugar beet pulp, hay) and received concentrate according to the production level. Twice daily at 7:00 and 18:00 o'clock, the cows were milked in a tandem milking parlor (2 x 8) with ML milking system (Fig. 1).

Fig. 1. Tandem milking parlor (2 x 8) with ML milking system in Farm 2.

B. The used Milking System

The used Milking system, ML was developed and has been used in the field for a couple of years now (Siliconform, Germany). It is a well-handled and animal- as well as personal-friendly semi-automatic milking system that differs technically and spectacularly from conventional milking machines. It is based on a quarter-individual milking system. That means that milking cups work completely independently from each other (without a claw). Furthermore, the system provides periodic air inlet into the teat cups (BioMilker) (Fig. 2).

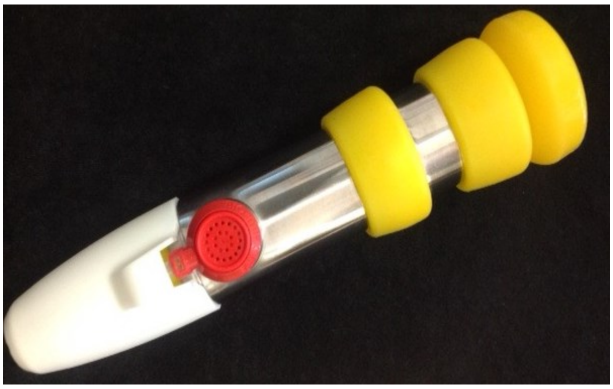

Fig. 2. Teat cup with periodic air inlet (BioMilker)

The working vacuum level was set to 34 KPa and sequential pulsation was adopted. The pulsation rate was 60 cycles/min with a 60:40 pulsation ratio as standard during the milking time. In addition ML has an excellent cleaning and sanitary process. After each milking, the teat cups are completely pre-cleaned with water from outside and inside, in order to remove milk residues and dirt particles. Subsequently, the teat cups are sprayed inside with a 0.5% per acetic acid solution and after a contact time of at least 35 seconds, they are again rinsed with water in order to rule out the contamination of the food milk by foreign substances such as chemicals (Fig. 3).

Pre-cleaning with water | Disinfection with a 0.5% per acetic acid | Rinse with water

Fig. 3. Cleaning process of the MultiLactor milking system

The system is equipped with silicone liners. In the two examined farms, the milk line in the milking parlor was installed in low-level. For certain treatments the changes of pulsation ratio settings were done manually directly on the screen.

C. The Milking Routine

At the time of milking with ML in the investigated farms, the milking routine started with pre-milking preparations, which consisted of fore-stripping of one or two squirts of milk from each teat and cleaning udder and teats. After that, the milking unit swing directly in front of the cow's udder. The teat cups were pulled out of the magazine individually or in pairs and manually attached to the teats. Subsequently, the system is started on the control display and the pre-stimulation begins. The pre-stimulation consists of intensive activation with a normal pulse rate (60 cycles/min) and reduction the milking phase (b-phase) by 10% over a period of 50 s. At the same time, intensive movement of the teat cups are regulated as an additional stimulation by an actuator. This is an arm on which four milk tubes situate. During the pre-stimulation and the milking time (main and post-milking), this arm was moving up and down. This movement is transferred to the teat cups and makes the teats erecting. When the milk flow reached 250g/min, the milking process is automatically stopped by detaching the milking unit and each teat is dipped with a solution containing Chlorhexidine. At the same time, teat

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cups were cleaned and disinfected automatically as mentioned above after each cow and milking (Fig. 4).

Fig. 4. MultiLactor milking system during the milking process on the farm 1 in Southern Germany.

D. Experimental Design

The experimental study was carried out in two phases:

In the first phase, all cows in the two farms were milked over 7 days with the following settings of the ML system: Vacuum 34 kPa, pulsation rate 60 cycles/min and pulsation ratio 60:40.

In the second phase, all cows were milked as in the first phase and directly after that with the same settings of the ML system with only pulsation ratio changed to 65:35.

E. Recording the Milking Parameters and Statistical Analysis

Milk yield per milking, milk flow rate and milking-on time were recorded through a special program for ML milking system (Production and development of the Siliconform Company, 2013). Data were taken daily from all cows (two farms) and milking times (morning and evening) over a period of 14 days. The total data for each parameter over the experimental period were 4760. That is, 2380 data before the change and 2380 data after the change of the pulsation ratio.

In order to determine the influence of the amount of harvested milk per milking on the milk flow rate and milking-on time regardless of farm and milking time, the amount was divided into the following levels: <10 kg of milk/milking = 1, from 10 to 15 kg of milk/milking = 2, from 15.01 to 20 kg of milk/milking = 3 and >20 kg of milk/milking = 4.

The primary data were edited with Excel and evaluated using the statistics program SAS (SAS.1999). The data were analyzed by ANOVA. Significant differences (P<0.05) of the tested parameters were localized by using Bonferroni's t test. The results were presented as least square means with standard errors (LSM ± SE).

III. The Results

Total milk yield per milking, average flow rate and machine-on time differed significantly (P<0.001) after the change the pulsation ratio from 60:40 to 65:35 (see Table I). However, the total milk yield per milking and average flow rate increased, whereas milking–on time decreased.

Table I. Least square means by pulsation ratio

Pulsation Ratio	Total yield per milking (kg)	Average flow rate (kg/min)	Machine-on time (min)
60:40	13.67 ± 0.33^{a}	1.75 ± 0.05^{a}	8.36 ± 0.25^{a}
65:35	14.00 ± 0.33^{b}	1.86 ± 0.05^{b}	8.03 ± 0.25^{b}

^{a,b} Means with different superscripts on the same column differ (P<0.001)

According to milking time the tested parameters before and after the change of the pulsation ratio in farm (1) were presented in table (II). There was a significant increase in average milk yield whether in the morning or in the evening milking after the change in the pulsation ratio from 60:40 to 65:35. A similar tendency for milk flow rate was shown and the values increases significantly in the morning milking from 1.62 ± 0.08 kg/min to 1.69 ± 0.08 kg/min and in the evening milking from 1.53 ± 0.08 kg/min to 1.63 ± 0.08 kg/min after the change in the pulsation ratio from 60:40 to 65:35. Conversely, it was shown that the milking-on time did not change significantly (P>0.05) neither in the morning nor in the evening milking after the change of pulsation ratio from 60:40 to 65:35.

Table II. Least square means by morning and evening milking time, before and after the change of the pulsation ratio in farm 1.

Milking time	Pul-sation ratio	Total yield per milking (kg)	Average flow rate (kg/min)	Milking-on time (min)
Morning	60:40	12.19 ± 0.53^{a}	1.62 ± 0.08^{a}	8.01 ± 0.41^{a}
Morning	65:35	12.50 ± 0.53^{b}	1.69 ± 0.08^{b}	7.89 ± 0.41^{a}
Evening	60:40	10.12 ± 0.53^{a}	1.53 ± 0.08^{a}	7.05 ± 0.41^{a}
Evening	65:35	10.79 ± 0.53^{b}	1.63 ± 0.08^{b}	7.02 ± 0.41^{a}

^{a,b} Means with different superscripts on the same column and milking times differ (P<0.05)

On farm 2 (Table III), there was a significant increase (P<0.05) in the average milk yield per milking in the morning milking from 17.92 ± 0.38 kg/milking to 18.13 ± 0.38 kg/milking after changing the pulsation ratio from 60:40 to 65:35. However, in the evening milking, the average milk yield per milking did not change significantly (P>0.05). But the average milk flow rate increased significantly in the morning (2.02 ± 0.06 vs. 2.16 ± 0.06 kg/min, P<0.001) as well as in the evening milking (1.83 ± 0.06 vs. 1.96 ± 0.06 kg/min, P<0.001). Moreover, there was a significant decrease in the average of milking-on time in the morning as well as in the evening milking after changing the pulsation ratio from 60:40 to 65:35.

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Table III. Least square means by morning and evening milking time, before and after the change of the pulsation ratio at farm 2

Milking time	Pul-sation ratio	Total yield per milking (kg)	Average flow rate (kg/min)	Milking-on time (min)
Morning	60:40	17.92 ± 0.38[a]	2.02 ± 0.06[a]	9.65 ± 0.30[a]
Morning	65:35	18.13 ± 0.38[b]	2.16 ± 0.06[b]	9.07 ± 0.30[b]
Evening	60:40	14.44 ± 0.38[a]	1.83 ± 0.06[a]	8.71 ± 0.30[a]
Evening	65:35	14.59 ± 0.38[a]	1.96 ± 0.06[b]	8.13 ± 0.30[b]

[a,b] Means with different superscripts on the same column and milking times difference (P<0.05)

As recorded in Table IV, no significant differences (P>0.05) were observed in milk flow rate and milking-on time after changing the pulsation ratio from 60:40 to 65:35, when the harvested milk yield was <10 kg/milking. However, a significant increase in milk flow rate and a reduction of milking–on time were clearly shown when the harvested milk yield was more than 10 kg/milking after changing the pulsation ratio from 60:40 to 65:35.

Table IV. Least square means before and after the change of the pulsation ratio based on the milk yield level (kg/milking) in both farms.

Milk yield level	Pulsation ratio	Average flow rate (kg/min)	Milking-on time (min)
<10	60:40	1.37 ±0.03[a]	6.74 ± 0.18[a]
	65:35	1.41 ± 0.03[a]	6.60 ± 0.19[a]
10-15	60:40	1.72 ± 0.03[a]	8.33 ± 0.15[a]
	65:35	1.84 ± 0.03[b]	7.85 ± 0.15[b]
15,1-20	60:40	2.04 ± 0.03[a]	9.62 ± 0.15[a]
	65:35	2.16 ± 0.03[b]	8.95 ± 0.15[b]
>20	60:40	2.37 ± 0.03[a]	10.80 ± 0.19[a]
	65:35	2.50 ± 0.03[b]	10.15 ± 0.20[b]

[a,b] Means with different superscripts on the same column and same milk yield level differ (P<0.05)

The results in table (V) show, that the highest increase in milk flow rate was 7% after the pulsation ratio being changed from 60:40 to 65:35 when the milk yield per milking was between 10 and 15 kg, whereas the lowest reduced milking-on time was 40.2 second/milking after changing the pulsation ratio and when the milk yield was between 15 and 20 kg/milking.

Table V. Increase in the milk flow rate and reduction of milking-on time after changing the pulsation ratio from 60:40 to 65:35 based on the milk yield level (kg/milking)

Milk yield level (kg)	Increase in the milk flow rate (%)	Reduction of milking-on time (second/animal)
<10	3	8.4
10 -15	7	28.8
15.01-20	6	40.2
>20	5	39

IV. Discussion

Pulsation is defined as the cyclic opening and closing of a teat cup liner. Pulsation, in addition to vacuum and the pulsation ratio, are major operating parameters that affect milking performance. The development of pulsation was a major turning point in the adoption of mechanical milk harvesting systems. Field experience and research have shown that a relatively narrow range of pulsation rates and ratios is required to ensure good teat-end health, good udder health and also to optimize milking speed [16]. In this study, our goal was to optimize the pulsation ratio when using MultiLactor milking system. Therefore, we only tested one new pulsation ratio (65:35) in addition to the standard pulsation ratio (60:40). The results in Table (I) show that increasing the pulsation ratio from 60:40 to 65:35 increased daily milk yield, indicating better udder emptying. Similar results found Thomas et al. [8]. Furthermore, the results show a significantly better milk flow rate after changing the pulsation ratio from 60:40 to 65:35 on both farms. These results match with numerous previous studies [8], [13], [17], [11], [12]. However, it is well-known that the pulsation ratio has a big effect on the milk flow rate [18], [2]. Moreover, Spencer et al. [2] reported that average and peak milk flow rates increased at each increasing wider ratio (from 60:40 to 65:35, and to 70:30). As expected, when pulsation ratios were widened, milking flow rate increased. In our results, when the pulsation ratio was widened from 60:40 to 65:35, average flow rates increased by up to 7%. Thus, in both milking times and normal pulsation rates (60 cycles/min), widened ratios resulted in greater milk flow rate and shorter milking-on time. However, changing the pulsation ratio during the milking process (after 1.5 min from beginning of milking) did neither affect the total amount of produced milk, nor the total milking time [19].

As shown in Table (V), the increase in the milk flow rate depends on the amount of harvested milk yield per milking. The highest percentage increase in milk flow rate was 7% after the pulsation ratio changed from 60:40 to 65:35 when the milk yield per milking was between 10 and 15 kg, whereas the lowest milking-on time was 40.2 second/milking when the milk yield was between 15 and 20 kg/milking. Therefore, the amount of harvested milk yield plays a major role in the milk flow rate and milking-on time.

Despite the use of low levelled vacuum (34 kPa) in the milking machine in this study, the results after changing the pulsation ratio from 60:40 to 65:35 were better, which is due to our usage of special silicone teat cup liners (Stimulor liner). These results match with those of some researchers. Mein et al., [20] reported that peak milk flow rate probably reaches a maximum level at a pulsation ratio within the range of 60:40 to 70:30, depending on the characteristics of the liners used. Hillerton [21] recognized the variation in liners with regard to milking performance, cow behavior, udder health, and teat responses. The interaction of liner characteristics with milking machine settings may be important. Furthermore, Spencer and Rogers [22] found an interaction of vacuum and ratio with two conventional liner types. Gleeson et al. [13] showed that milk liner design has a bigger effect on teat tissue changes and milking characteristics than pulsation settings. Finally, we can say that the optimal settings for milking system vacuum and ratio highly depend on liner characteristics.

It was also stated that milking-on time could be reduced with a pulsation ratio setting of 65:35 as compared to a ratio of 60:40. This result would match with the findings of Thomas et al. [8], O'Callaghan [14], Gleeson et al. [13], Gleeson et al., [1] and Spencer et al. [2], that milk machines with a wide pulsation ratio would milk faster than those with a narrow pulsation ratio. Rosen et al. [23] reported that increasing pulsation ratio leads to increased peak and average milking rates and decreased machine and total milking times. However, Thomas et al. [24] investigated the effects of 50:50 or 70:30 pulsation ratios on milk parlor performance, milk production and udder health. The results indicated that milking with a 70:30 pulsation ratio increased cows milked by 4.1 cows per hours, increased milk harvested by 38.3 kg/h, increased parlor turns by 0.2 turns per hours and decreased parlor cycle time by 0.4 min compared to the 50:50 pulsation ratio.

Furthermore, in this study, no negative impact on the teat could be detected, despite an increase in milk flow rate and a reduction of milking-on time was shown. However, our milking system works with low vacuum (34 KPa), silicon liner and a quarter individual milking unit. So that no teat reaction could be seen after changing the pulsation ratio. Thus, it is possible that increased pulsation ratio (up to 65:35) can be used to increase milking efficiency in a conventional milking system with MultiLactor. In addition, this result matches with the finding of Gleeson et al. [13] that widening pulsation ratio from 60:40 to 67:33 did not have negative effects on changes in teat tissue. However, it was found that reduced d-phase (too short) would result in congestion of teat-end tissue [25], [13]. Upton et al. [26] observed that there was a significant reduction in the estimated cross-sectional area of the teat canal with d-phase duration of 50 and 100 millisecond (ms) when compared with d-phase duration of 150, 175, 225, 250, and 300 ms. Similar results were shown by Ferneborg and Svennersten-Sjauja [12] that no negative effects on teat condition or milk somatic cell counts were observed with any of the pulsation ratios applied (60:40, 65:35, 70:30, 75:25) during the study.

V. Conclusion

The results of this study confirms that widening pulsator ratio from 60:40 to 65:35 had a positive effect on daily milk yield, milk flow rate and milking–on time. Thus, it is possible that increased pulsation ratio (up to 65:35) can be used to increase milking efficiency in conventional milking parlor with ML milking system. Furthermore, it was shown that with 65:35 pulsation ratio no negative effect on the teat condition were established.

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Conflict of Interest

The author declared that there is no conflict of interest.

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AUTHORS' PROFILES

Shehadeh Kaskous

Professional Experience

Since 2012 Head of Department of Research and development of Siliconform Company GmbH, Germany.

1989- 2012 Staff member for Animal physiology (Physiology of Lactation), Department of Animal Science, Faculty of Agriculture Damascus university, Damascus, Syria.

Education

I. 2000 Professor of Animal Physiology at the Department of Animal Science, Faculty of Agriculture Damascus university, Damascus, Syria.
II. 1994-2000 Docent of Animal Physiology at the Department of Animal Science, Faculty of Agriculture Damascus university, Damascus, Syria.
III. 1989-1994 Ordinary doctor of Animal physiology at the Department of Animal Science, Faculty of Agriculture Damascus university, Damascus, Syria.
IV. 1984- 1989 Assistant at the institute of Physiology, veterinary Medicine, Leipzig university, Germany, ph. Dr. Agrar Doctor Agriculturarum.
V. 1981-1983 Diploma Higher Study (Animal Science) at the Faculty of Agriculture, Damascus university, Syria.
VI. 1977-1981 Study at the Faculty of Agriculture (Animal Science), Damascus university, Syria.