DOI : 10.5958/2277-8934.2021.00001.1 *Vol 28 No 1, p 1-9*

A NEW MILKING TECHNOLOGY: "STIMULACTOR" FOR LACTATING CAMELS

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ABSTRACT

The aim of this study was to develop a new milking machine for camels that guarantees high milk yield and quality whilst maintaining udder health. After a great effort, the new milking machine "StimuLactor for Camels" has been developed by Siliconform Germany. All the requirements of camels were tested on 5 dromedary camels over a period of one year. Our development was based on two main aspects: first, on the technical basis of the milking machine (type of machine, with or without a claw piece, kind of pulsation, vacuum level, type of teat cup liner and pulsation rate and ratio) which have to be adapted to the requirements of a camel's udder and teats. The second important aspect was the calf's suckling behaviour. The first results with the new milking technology have clearly shown that the system milks as the calf sucks. It can be used without the presence of the calf during the course of milk removal. Furthermore, the results proved that milk ejection reflex was induced and the milk was let down during the milking process. In conclusion, the new milking technology "StimuLactor for Camels" was adapted to the physiological, morphological and anatomical requirements of lactating camels.

Key words: Camel, dromedary, lactation, milking technology, stimulactor

Despite the importance of the milking machine for milk removal in camels, it is common only in a few farms in the world. There are several reasons hindering the use of milking machines for camels. First, differences in milk yield and lactation length. The daily milk yield varies between 0.5 and 35 kg and the length of lactation varies between 6 and 18 months or more (Khan and Iqbal, 2001; Wernery, 2006; Razig *et al,* 2008; Nagy *et al,* 2013; Zayed *et al,* 2014; Kaskous and Fadlelmoula, 2014; Dowelmadina *et al,* 2015; Jemmali *et al,* 2016; Hadef *et al,* 2018; Gebremichael *et al,* 2019; Boujenane, 2020). Second, there are very strong differences with regard to udder and teat shapes as well as udder measurements between the camels, including within the herd in the same farm (Kaskous and Fadlelmoula, 2014; Kaskous, 2018a). The third challenge is that most camels milking necessitate the presence of calves beside their mothers to stimulate the udder and for the induction of the milk ejection reflex and milk let-down (Kaskous, 2018b). But to increase the milk yield for each camel and to improve the quality as well as the safety of raw camel milk, machine milking must be used instead of hand milking. However, the daily milk yield was 38% higher in machine compared with hand milking of camels (Hammadi *et al,* 2010). Saleh *et al* (2013) reported that the use of milking machines can reduce the contamination of camel's milk as compared with hand milking. Currently, milking machines are limited to intensive dairy camel farms in a few countries (Nagy and Juhasz, 2016; Ayadi *et al,* 2018; Kaskous, 2018b). The amount of residual milk after machine milking was found high and up to 30% or even more of the stored milk (Ayadi *et al,* 2014; 2018). Milking machine used, therefore, needed to be improved to fit the camel's udder, hence improving milk ejection reflex (Nagy and Juhasz, 2016) and avoiding the problems with the use of the milking machine (Aljumaah *et al,* 2012).

Many studies have shown the impact of teat cup liners on milk performance and udder health in cows (Schmidt *et al,* 1963; Gleeson *et al,* 2004; Zwertvaegher *et al,* 2012). Marnet *et al* (2016) recommended that setting the optimal vacuum level is necessary before definition of the best liner shape and quality for camels.

The pulsation ratio of the milking machine affects milk flow rate and milking time (Thomas *et al,* 1991; Pfeilsticker *et al,* 1995; Hamann and Mein, 1996; Ambord and Bruckmaier, 2009). Bade *et al* (2009) found that increasing the vacuum and b-phase duration increased peak milk flow rate. Hamann and Mein (1996) observed that a d-phase duration of at least 150 ms was enough to relieve congestion and keep the teat healthy.

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Present study was, therefore, aimed to develop a milking machine for camels that is suitable for all teat shapes and measurements, needs a low vacuum to open the teat effectively, have the right kind of pulsation for a stable vacuum on the teat area during milking, have the right type of teat cup liner to quickly and completely extract the milk from the udder, can form the milk ejection reflex without the presence of the calf during milking and can provide the right pulsation rate and right pulsation ratio to achieve an ideal milking process for an increasing milk production with high quality standards.

Materials and Methods

This experimental work was carried out by the Department of Research and Development of Siliconform Company located in Türkheim, Germany on 5 dromedary she-camels with their calves, in different parity and stage of lactation. The animals were kept out on the pasture most of the time. At night and during the cold winter season the camels were kept in the barn in a loose housing system. Camels were fed primarily pasture grass and were also provided with grass hay and supplements of vitamins and minerals. Drinking water was given *ad lib*. The camels were milked once a day (11:00 a.m.) with a unit milking machine-StimuLactor for camels over a period of one year.

Study parameters

This project was done to achieve the right milking technology for camels and to answer the target questions: first, on the technical basis of the milking machine (type of machine, with or without a claw piece, vacuum level, kind of pulsation, type of teat cup liner and pulsation rate and ratio) adapted to the requirements of a camel's udder and teats. Second, on the basis of the suckling behaviour of the calf. The following phases were carried out for the development of the milking machine for camels:

1st phase: A milking machine for camels was made analogous to "MultiLactor" milking machine for cows, which was based on a claw-free quarter separation. The quarter-individual milking system is particularly suitable for different udder and teat shapes, which is of great importance in the case of camels. The claw piece centre was omitted. There was an even distribution of the forces acting on the teat. However, a quarter individual adaptation to each udder quarter was possible*. The developed milking machine was called "StimuLactor" for camels.

2nd phase: Determination of the vacuum in the milking machine:

A low vacuum (36 kPa) was tested on lactating camels and was found sufficient for the teat opening and for the milking process as well as without the teat cups dropping during milking.

3rd phase: Determination of the kind of pulsation:

In order to achieve a stable vacuum in the teat cup and a regular milk flow as well as to take into account observations of the calf while sucking, sequential pulsation was used in the new milking machine, which proved to be ideal here.

4th phase: Testing the best teat cup liner for the camel teat:

Seven teat cup liners (1 to 7) were tested with constant vacuum (36 kPa) and pulse rate (90 cycles/min) and pulsation ratio (60:40).

5th phase: Establishment of the pulsation rate and pulsation ratio. Two pulsation rates (60 and 90 cycles/minute) and two pulsation ratios (50:50 and 65:35) were tested.

Characteristics of the new milking technology

StimuLactor for camels (ST-C) was found an easily handled and animal- as well as person-friendly semiautomatic milking system. It was based on a quarter-individual milking system and milking cups worked completely independently from each other (without a claw). Furthermore, the system provided periodic air inlet into the teat cups and was equipped with silicone liners (Figs 1A, B).

The working vacuum level was set to 36 kPa and sequential pulsation (25% each quarter) was adopted. The pulsation rate was 90 cycles/min with a 65:35 pulsation ratio during the milking time. In addition, the system included a very special pre-stimulation program and an excellent cleaning and sanitary process.

The milking routine

First, the animals were gradually trained to the new milking machine technology with the presence of calves for a month, to avoid the physiological-psychological effects at the beginning of machine milking with new technology, since the lactating camels had never been milked either by hand or by machine. Subsequently, the system was successfully installed and the camels became fully acclimatised to it. After the training phase, milking was started without the presence of calves during the milking

* (ST-C), Siliconfom company, Türkheim Germany (2018) (www.siliconform.com).

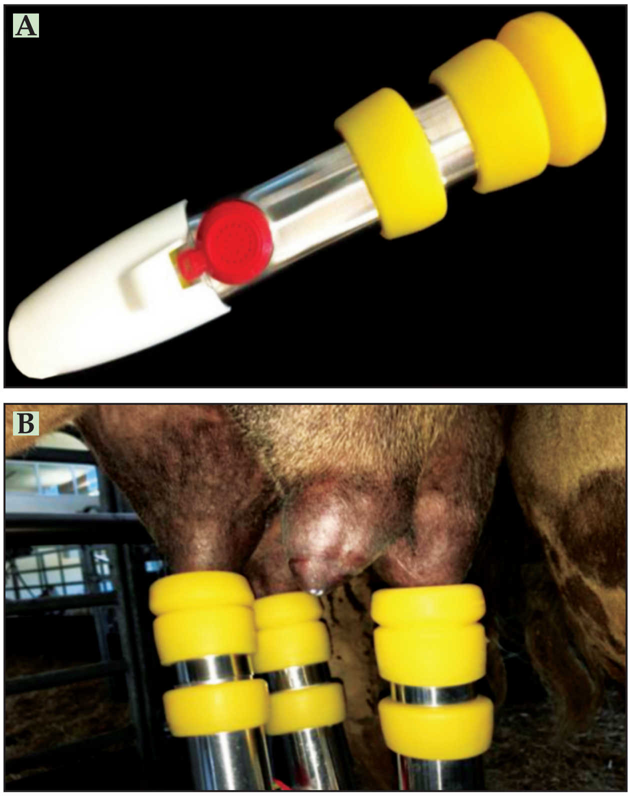

Fig 1. A) Teat cup with periodic air inlet for camels, **B)** The StimuLactor during attachment.

process. At the beginning, the milking routine started with pre-milking preparations, in which the teats were cleaned with a wet udder tissue and afterwards dried with another tissue. Then, each teat cup was individually or in pairs manually attached to the teats. Subsequent to this step, the system was started on the control display and the pre-stimulation began. The pre-stimulation is programmed to be intensively stimulated with a normal pulse rate (90 cycles/min) and reduces the milking phase (b-phase) to 10 % over a period of 90 s. Simultaneously, intensive movement of the teat cups is regulated as an additional stimulation by an actuator. This is an arm on which four milk tubes are placed. With this methods, the liners apply a gentle vibratory massage to the teats, similar to the tongue of a calf. During the pre-stimulation and the milking phases this arm moves up and down. This movement is transferred to the teat cups and make the teats erect. After stimulation the main milk phase begins and the milk flow is observed on the display. When the milk flow has decreased to a certain level, the milking process is automatically stopped by detaching the milking unit. After all animals have been milked, the milking system is cleaned.

Statistical analyses

The received data were processed with Excel and evaluated using statistics program SAS (SAS, 1999). The data were checked for normal distribution. Then, the data were analysed by ANOVA. Significant differences ($P<0.05$) of the study parameters were localised by F-Test.

Results and Discussion

The goal of a camel milking machine is to harvest the total quantity of milk fast and completely whilst maintaining good udder health. However, the characteristics of the milking machine play a crucial role. But camel milking machine and routine needed to be adjusted according to the animals' physiological mechanism in order to achieve optimal milk removal and minimise stress factors during the course of milking (Bruckmaier and Blum, 1998; Marnet *et al*, 2016; Kaskous, 2018b). Although camels are known to be difficult to milk using the existing milking machine (Wernery, 2006; Nagy and Juhasz, 2016). Atigui *et al* (2015) emphasised that the cow's liner used in camels was not adapted to a large basis and short teats. The machine used in present study was improved to fit the camel's udder. Thus, milking machine design and function are critical for rapid and efficient removal of milk without damage to the teat and with minimal risk for transmitting pathogenic microorganisms that might cause mastitis.The new milking machine thus developed was "StimuLactor for Camel" and had many merits when used for camels.

An optimal seat of the milking equipment on the camel udder with an even distribution of the vertical forces acting on the four teats by the milking machine is an important factor for good milking technology. The new milking system used in present study had a cluster-free milking unit, i.e. the teat cups work completely independently of each other. This ensured an even weight distribution per quarter over the entire milking period. There were no disruptions in milk let down due to uncontrolled penetration of air into the teat cup. It offered advantage of no cross contamination with StimuLactor for camels since the milking cups were not connected to each other.

A low vacuum (36 kPa) was sufficient to successfully carry out the milking process in camels to milk gently and to avoid strain on the udder. Since it was a quarter individual milking machine, no loss of vacuum was shown on the teat area during milking. On the other hand, low vacuum was enough to open the teat during milking. Conversely, high vacuum levels were recommended to ensure efficient machine milking for Tunisian Maghrebi camels (Atigui *et al,* 2011). Similar results were shown by Ayadi *et al* (2014; 2018) and milk yield was increased significantly by using higher vacuum (50 kPa). However, these technical settings of the milking machine were not sufficient to empty the udder completely. The amount of residual milk remaining in the udder after milking by injection of oxytocin (20 UI/camel) was estimated to be 30%. It is known that the level of the operating vacuum in machine milking is one of the principal factors which influence the integrity of the tissues and the milk quality (Caria *et al,* 2013). Therefore, Marnet *et al* (2016) recommended that setting the optimal vacuum level is necessary before definition of the best liner shape and quality for camels. Due to the slower induction of milk ejection in camels and a short milking time, many authors use high vacuum levels of machine milking to increase their efficiency (Ayadi *et al,* 2014; 2015; Atigui *et al,* 2014). However, they emphasised that camels can readily be milked efficiently at 50 kPa and 60 pulsations/min without negatively affecting teat condition or udder health (Ayadi *et al,* 2018). The effect of using higher vacuum on udder health and teat condition need to be examined for a long period (not just 10 or 12 weeks). Gleeson *et al* (2003) reported that reducing the vacuum level minimised teat tissue reaction, but extended the cluster-on time and reduced the peak flow rate without affecting milk yield or milk composition. Furthermore, scientists have tried to reduce the vacuum level in the milking machine used on sheep, goats and buffaloes in order to avoid the problems with higher vacuum. The results of present study showed that a low vacuum level modifies the kinetics of milk removal. However, the milk yield was satisfactory at any level tested, showing that low vacuums can be adequate to completely empty the udder (Caria *et al,* 2013).

It is noteworthy that the vacuum level in the range of 37 to 52 kPa did not significantly affect the individual milk production per milking in Mediterranean Italian buffalo cows (Caria *et al,* 2012). Conversely, with increasing vacuum level and wider ratio, the average and peak milk flow rates increased, whereas milking duration decreased (Spencer *et al,* 2007). Atigui *et al* (2015) showed the same results and the best combination of settings for camel milking machines was high vacuum and low pulsation rate (48 kPa/60 cycles per min). A lower vacuum level extended the milking time by more than 100% and was not enough to extract the milk completely from the udder. These results do not agree with our results possibly due to differences in the machine technology. High vacuum levels and vacuum fluctuations that occurred in cows during the milking process had a negative impact on teat conditions and udder health (Hamann, 1990; Hamann *et al,* 1993; Neijenhuis *et al,* 2001; Gleeson *et al,* 2004; Besier *et al,* 2016). High vacuum levels can also lead to increased teat wall thickness (Hamann *et al,* 1993), tissue damage and the development of hyperkeratosis (Bade *et al,* 2007, 2009).

Penry *et al* (2018) reported that increasing teat-end vacuum and suction phase time in the milking machine increased the milk flow rate, but reduced cross sectional area of the teat canal (indicates an increased congestion at the teat-end).

Using a high milking vacuum for camels could lead to udder health problems, which is reflected in a high somatic cell count in the produced milk and a negative impact on the health status of the teats. A positive relationship between increasing working vacuum and somatic cell counts in the milk has been found in buffalo (Pazzona and Murgia, 1992) and other dairy species (Hamann, 1990; Sinapis and Vlachos, 1999; Rasmussen and Madsen, 2000; Mein *et al,* 2003). In addition, it must also be noted that our milking machine used in present study works with a quarter-individual milking system and always provide a constant vacuum on the teats during the suction phase, and there are no fluctuations in the vacuum, as in the case with claw piece milking machines. The investigations by Ströbel *et al* (2016) confirm this statement and the authors observed that a sequential pulsation regime leads to a lower range of vacuum reductions during the suction phase. As a result, these settings can help to improve the udder health of a dairy herd.

Among testing of seven different teat cup liners made from silicon, the best type of liner for camels was number 7 (Fig 2). The amount of harvested milk is essential parameter for camel breeders as it reflects the state of the milking process.

The examined teat cup liners are significantly different from each other, especially as regards structure, density, hardness, elasticity, and head structure and dimensions.

The liner is the only component of the milking machine that comes into direct contact with the camel's teat. However, the liner has the greatest impact on milking efficiency, hygiene and camel comfort in comparison with any other milking machine component. Hence, the use of unsuitable milking liners leads to the occurrence of oedema and enhances colonisation of *Staphylococcus aureus* during the period of machine milking in camels (Juhasz and Nagy, 2008). Model and Rudovsky (1999) observed that bad application of teat cup liner in the milking machine with claw, the germs can be transferred to the next 6-8 cows after milking a cow infected with streptococci. Thus, the kink point of the liner is generally situated in the middle of its barrel (Marnet *et al,* 2016). The shape of the liner barrel (conical or tubular), the diameter of the mouthpiece and softness of the lip, the quality of rubber used are some of the liner's parameters to adapt to avoid too much elongation of the teat or compression ring at the teat base, leading to retention of milk in cisterns (Marnet *et al,* 2015). Silicone teat cup liners used in present study harmonised due to their outstanding milk physiological properties. Many studies have shown the impact of teat cup liners on milk performance and udder health in cows (Schmidt *et al,* 1963; Gleeson *et al,* 2004; Zwertvaegher *et al,* 2012). However, studies on camels have been lacking. Badly slipping teat cup liners may increase new mastitis infection rate by 10-15%, therefore, teat cup liner slip appears to have a most significant impact on udder health (Tranel, 2018). Results from Spencer and Rogers (1991) indicated that machine liner design and construction as well as operating vacuum influence the occurrence of liner slips. Therefore, optimisation of vacuum setting and liner design improved machine milking in present study. An interaction between liner slippage and the mean machine yield per cow and milking was detected; the amount of slippage increased significantly as milk yield increased (O'Callaghan and Harrington, 2000). It is important that teats penetrate into the liner barrel to provide for relief of the teats during the rest phase. In some liners, teats less than two inches may not be massaged adequately (Tranel, 2018). Finally, the following point must be considered: depending on the teats shape of the majority of the herd, the appropriate size and shape of the liner should be selected. The opening of the teat cup liner head should only be large as big as necessary, but never too small.

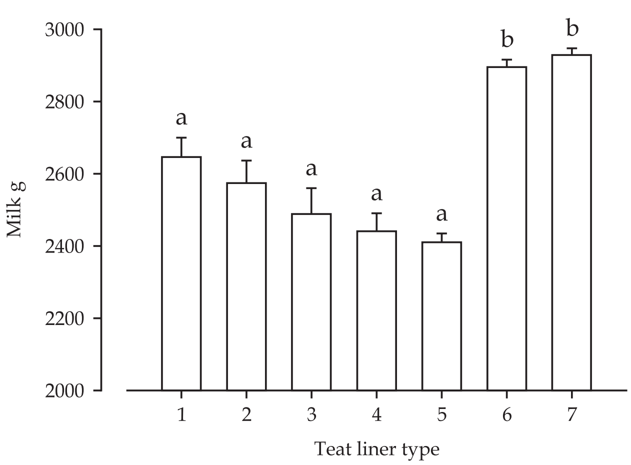

Fig 2. Average daily milk yield (LSM±SE) in examined camels after the application of various teat cup liners in the new milking technology.

Each pulsation cycle contains two phases, the suction phase and the rest phase. During the suction phase of the pulsation cycle the liner is open and milk flows through the teat. During the rest phase, the liner collapses, preventing milk flow. The timing of these two phases is determined by the pulsator's pulsation rate and pulsation ratio settings. However, 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 animal farm productivity and profit (Spencer *et al,* 2007; Kaskous, 2018c). Hamann (1987) concluded that mastitis could be caused by improper milking techniques, such as inappropriate pulsation settings. In our study, 2 pulsation rates (60 and 90 cycles/min) and 2 pulsation ratios (50:50 and 65:35) were tested. Figs 4 and 5 show the effect of the pulsation rate and the ratio on the daily milk yield after using new milking technology for camels in present study. As shown in Fig (4), a pulsation rate of 90 cycles/min produced a higher daily milk yield compared to 60 cycles/min and the difference was significant ($P<0.05$). The investigations of Atigui *et al* (2015) showed different results. Higher pulsation rate did not improve stimulation of the camel's udder during milking, on the contrary, it induced more bimodality and lower milk flow rate, and the best combination of setting the milking machine for camels was high vacuum and low pulsation rate (48 kPa/60 cycles per min). In our study, the better milk yield after applying the pulsation rate of 90 cycles/min compared to 60 cycles/min is due to two factors, namely using a quarter-individual pulsation system and sequential pulsation (25% each quarter) (Fig 3).

Neijenhuis *et al* (2000) reported that quarter-individual pulsation systems might prevent over-milking and improve the tissue of the teatend. However, the use of a quarter-individual pulsation system led to a positive trend (Sterrett *et al,* 2013), but the author did not find a significant effect on the teat-end condition.

The pulsation ratio is the percentage of time in each cycle spent in the suction phase versus the rest phase. As shown in Fig 5, the pulsation ratio 65:35

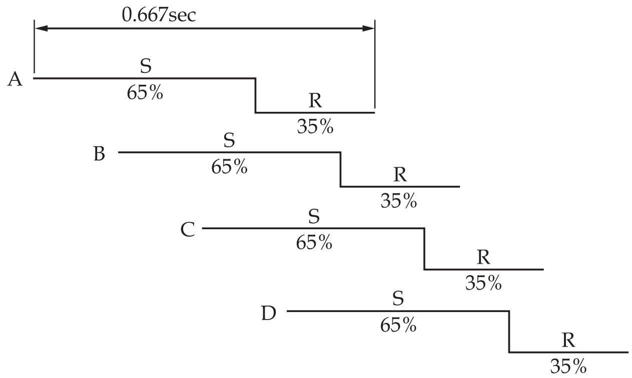

Fig 3. Sequential pulsation in the new milking technology for camels. (0.667 sec.: each cycle in the pulsation rate 90 cycles/min; S: suction phase 65%: R: rest phase 35% and A, B, C and D are four quarters with sequential pulsation 25%).

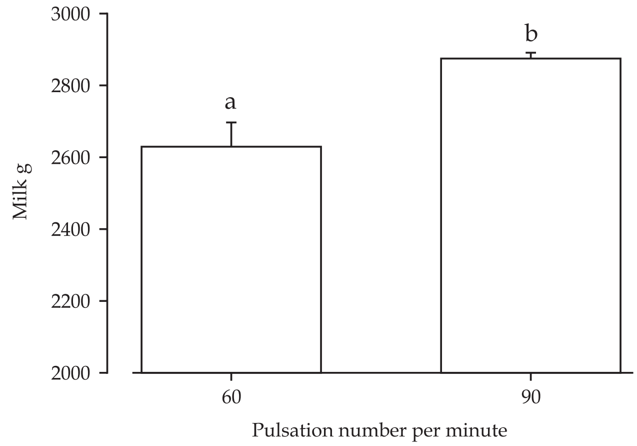

Fig 4. Daily milk yield (LSM±SE) of tested camels after using 2 pulsation rates (60 and 90 cycles/min) in the new milking technology.

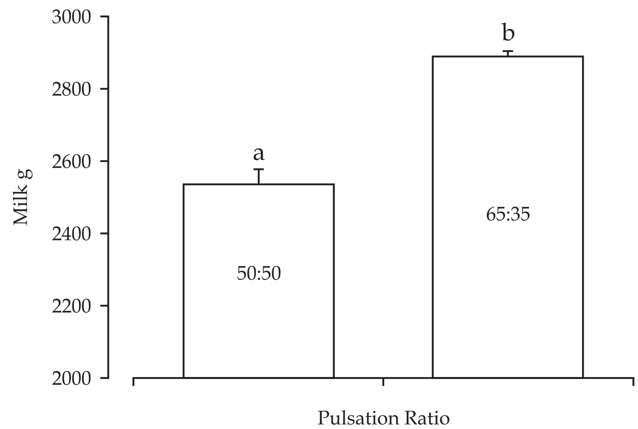

Fig 5. Daily milk yield (LSM±SE) in camels after the application of 2 pulsation ratios (50:50 and 65:35) in the new milking technology.

produced a higher daily milk yield compared to 50:50 and the difference was significant (P<0.05), with no changes on the teat tissue shown. Similar results have been observed in cows in many studies (Gleeson *et al,* 2004; Kaskous, 2018c). It is known that the pulsation ratio of the milking machine affects milk flow rate and milking time (Thomas *et al,* 1991; Pfeilsticker *et al,* 1995; Hamann and Mein, 1996; Ambord and Bruckmaier, 2009). Thus, Bade *et al* (2009) found that increasing the vacuum and b-phase duration increased peak milk flow rate. Hamann and Mein (1996) observed that a d-phase duration of at least 150 ms was enough to relieve congestion and ensure that teat stays healthy. In this study, the rest phase was 230 ms and the sucking phase was 430 ms. These data are calculated with respect to the pulsation rate (90 cycles/min) and pulsation ratio (65:35) used (Fig 3). That is why the teats stay healthy after milking. However, a rest phase which is too short may not allow enough time for blood to move away from the teat-end, resulting in increased teat damage. Kaskous (2018c) showed in dairy cows that milking efficiency could be increased by raising the pulsation ratio from 60:40 to 65:35 without negative effects on udder health in a conventional milking parlor with MultiLactor milking system. The explanation for higher milk yield after changing the pulsation ratio from 50:50 to 65:35 in this study is due to the rapidly harvested milk yield during the milking process. As we know, camel milking time is short and with increasing suction phase, more milk is harvested from the udder in a shorter time. Of course, the amount of stored milk in the udder before milking plays a significant role in the harvested milk, milk flow rate and milking on-time (Kaskous, 2018c). Furthermore, Spencer *et al,* (2007) observed that pulsation ratio and vacuum level are important operating parameters that affect the performance of milking machines. They tested three different pulsation ratios, 60:40, 65:35 and 70:30, and found that the interaction between vacuum level and pulsation ratio had a significant effect on peak flow rate, average flow rate and milking on-time.

Experience through present study with camels has shown that the function of the milking machine must be modelled on the natural sucking process of the calf and principle of the milking machine should be akin to imitate the suckling of calf. Observations on suckling calves clearly showed that a calf is able to extract the total milk yield of a she-camel, including that from the alveoli (Kaskous, 2018b). However, she-camels are sensitive, respond slowly and have difficulty particularly with machine milking. Consequently, camels must be accustomed to entering the milking parlour and being milked by machine, and the farmer must have a basic knowledge of camel behaviour and field experience in dealing with such animals (Wernery, 2006). Camels need more stimulation (up to 2 minutes) than cows in order to evoke the milk ejection reflex (Kaskous, 2018b). An incorrect application of the milking machine, inappropriate use of the milking technique, or a change in milking routines can inhibit milk let down, thus negatively affecting milk production.

Usually, the suckling is a cyclic process, divided into active and resting phases. During the active phase, the calf produces a vacuum at the teat-end within the oral cavity and creates pressure within the teat cistern. In the rest phase, the mouth of the calf relaxes, and consequently vacuum at the teat-end is relieved and tissue rebound is ensured. These effects are mechanically reproduced by the new milking technology StimuLactor for camels used in present study.

Conclusion

- After analysing the first results of the use of StimuLactor for camels, it was shown that a quarter individual milking technology was adapted to the physiological requirements of dairy camels.
- This new milking machine is easy to use for the milker and it requires less effort when attaching the individual quarters compared to the conventional milking machine.
- This milking machine exhibits optimally positioned milking cups, which are necessary to milk at a high level and to keep the animals healthy.
- The calves do not have to be present during the milking process, because this new milking technology reproduces the way the calf suckles.

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