PHYSIOLOGIC FACTORS THAT MODIFY THE EFFICIENCY OF MACHINE MILKING IN DAIRY EWES

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Introduction

Machine milking efficiency can be summarized as the recuperation of the maximum amount of milk in the shortest amount of time without causing harm to the udder and without any intervention by the milker. This is to say that once the teat cups have been placed on the dairy ewe, the milking machine should be able to quickly remove all of the secreted milk that has accumulated in the udder. Failure of the machine to remove all of the milk on its own in a timely manner increases financial loss due to less commercial milk yield, increases in parlor throughput time, and potentially more udder health problems due to over-milking. Moreover, when large amounts of milk are not removed at milking and are left behind in the udder, lactation lengths and total commercial milk yield are reduced. Finally, machine milking efficiency can also be influenced by other physiological events that occur in early lactation, as well as during the interval between milkings.

For the past year, the University of Wisconsin-Madison dairy sheep research team has been collaborating with a French lactation physiology laboratory (UMR Production du lait, Institut National de la Recherche Agronomique, Rennes, France). This paper will present some preliminary results of work done both at the Spooner Agricultural Research Station with our flock of East Friesian crossbred dairy ewes, and in France with the Lacaune breed. The objectives of this paper are to discuss the physiologic parameters which can be modified during early lactation in response to different weaning systems, as well as the physiologic parameters that allow the ewe to better store milk between milkings, and that permit the ewe to efficiently release milk at the time of milking.

Physiologic factors which are important during the first 30 days of lactation

In dairy ewes, 25% of the total milk yield for the entire lactation is produced during the first month. This is primarily due to the fact that milk production is increasing from parturition to about 24 days in lactation when peak milk production is attained. To complicate matters, ruminants have the highest probability of mastitis during the first 45 days post-partum. Therefore, early lactation management of the dairy ewe is critical to overall financial returns and udder health. A wide variety of weaning systems exist for dairy ewes that allow for either optimization of lamb growth, commercial milk production, or a combination of the two. The weaning system that favors lamb growth is the 30-day exclusive suckling system (DY30) where ewes are not machine milked during the first month of lactation and the lambs are weaned at about one month of age. The weaning system that favors maximum commercial milk yield is the day one system (DY1) where lambs are weaned within 24 hours after birth and raised on artificial milk replacer; the ewes are machine milked twice daily for the entire lactation. Finally, a weaning system that
attempts to find a compromise between acceptable lamb growth and commercial milk production is the mixed system (MIX). The MIX system allows for lambs to suckle their dams for 8 to 12 hours per day, after which they are separated for the night, and the ewes are machine milked the following morning. For the past three years, one of the primary research goals at the Spooner Agricultural Research Station has been to evaluate these three weaning systems in terms of commercial milk yield, milk quality, and lamb growth. More recently, we have been trying to characterize the physiologic changes in the udder during early lactation which explain the differences in milk yield and milk quality between weaning systems in early lactation and which also might better prepare the ewe for machine milking later in lactation.

**Maximum milk production potential.** Because dairy animals have been genetically selected for high milk production potential, milk production during early lactation often exceeds what is required to raise two or even three offspring. This surplus of milk, if not removed from the udder, causes a gradual cessation of milk secretion and greatly reduces the ewe’s capacity to maintain her maximum milk production potential. There are two important physiological reasons for the reduction in milk yield. The first reason is due simply to the fact that as milk accumulates in the udder, the pressure exerted on the milk secretion cells increases. Eventually this pressure will reach high enough levels to cause either damage or “discomfort” to the milk secretion cells, and milk secretion will be slowed if not stopped. In addition to the effects of pressure on these cells, is the presence of a hormone in milk called feedback inhibitor of lactation (FIL). This hormone has been studied extensively in goats and has been shown to directly inhibit milk secretion in a dose-dependent manner. This is to say that as more milk accumulates in the udder, especially around the secretory cells, the amount of FIL increases and milk secretion is slowed. Therefore, for a dairy ewe to maintain her maximum milk production potential, frequent and complete evacuation of the udder is imperative, especially in early lactation when milk production is highest.

The three weaning systems studied at Spooner have distinctly different effects on milk production potential during early lactation. The weaning system most appropriate in terms of maintaining maximum milk production potential during the first 30 days of lactation is the MIX system. This system allows for frequent udder evacuation during the day (lamb suckling), and one large evacuation every morning (machine milking). Because the MIX system permits the sale of at least some commercial milk during the first 30 days of lactation and requires no artificial rearing of the lambs, it is a more financially advantageous system compared to both traditional 30-day weaning and the DY1 system. The DY1 system is probably the least efficient in maintaining maximum milk production potential due to the fact that the udder is being emptied only twice per day. We have recently shown that when milking frequency is increased to three times per day for DY1 ewes, we see a significant increase in commercial milk yield. This confirms our hypothesis that ewes which are selected for high milk production do not meet their maximal production potential when they are machine milked only twice per day in early lactation. An economic analysis will need to be performed to determine if three times a day milking is financially advantageous compared to twice daily milking or to the MIX system. The traditional DY30 system relies uniquely on the lamb to maintain milk production during early lactation. It is only when milk requirements of the lambs are great that maximal milk production potential is met in DY30 ewes. Thus, the DY30 system is not appropriate for ewes that rear only single lambs. In some parts of the world where the DY30 system is required by law (such as the Roquefort region in France), many dairy sheep producers are obliged to milk their ewes once per
day and discard the milk because the ewes’ milk production exceeds what twin or even triplet lambs can suckle. One can appreciate that the DY30 system is the least financially attractive in terms of commercial milk sales. Although we see marked differences between the three weaning systems during the first 30 days of lactation in terms of milk production potential, these differences become non-existent after about 45 days in lactation. This is to say that DY1, DY30, and MIX ewes have similar milk yield and lactation lengths from 45 days onward. Other management factors, such as milking practices, become more important in allowing ewes to maintain their maximum milk production potential following weaning (when twice daily milking has been established for all ewes). These factors are discussed later in this paper.

**Milk composition and milk quality.** In addition to the significant differences in milk production observed for the three weaning systems, there are also marked differences in milk fat content and somatic cell count during the first 30 days of lactation. Compared to DY1 ewes, the commercial milk (total milk extracted with the machine) of MIX ewes has significantly less milk fat content for as long as the ewes remain in contact with their lambs. The reasons for this are not yet completely clear. We know that this phenomenon is not due to nutritional insufficiencies because we have demonstrated that when MIX ewes receive daily fat supplements there are no increase in their milk fat content, however, there was a significant increase in fat content of DY1 ewe when they received the fat supplements. In France, it has been demonstrated that MIX ewes never have a release of oxytocin during machine milking until after their lambs have been weaned. Oxytocin is a hormone released from the brain of mammals as a result of teat and udder stimulation, usually at the time of suckling. Oxytocin is an integral part of “milk ejection”: the contraction of the alveoli (groups of milk secreting cells) within the udder which causes secreted milk to flow down a system of ducts and canals into the storage part of the udder known as the cistern. During machine milking, if there is no release of oxytocin, secreted milk remains in the area of the alveoli along with large quantities of milk fat. This results in an incomplete evacuation of the udder as well as a less rich commercial milk. Many researchers feel that the low fat content of MIX ewes’ commercial milk is simply due to a failure of milk ejection. However, we have recently shown that injections of oxytocin during machine milking of MIX ewes only increases milk fat content to that of normal DY1 ewe milk fat content. Furthermore, when DY1 ewes are given a drug that blocks oxytocin and inhibits milk ejection, milk fat content is reduced to the same level of normal DY1 milk fat content. This experiment will be repeated to verify these findings, however our preliminary conclusion is that the low fat content of MIX ewe commercial milk is not entirely due to a failure of the milk ejection reflex and might be due to other factors, such as stress, which further disrupts milk ejection and/or fat synthesis in the udder.

Somatic cell count (SCC) is often used in monitoring udder health in dairy animals. Although the probability of infection is higher as the number of SCC increases, it should be noted that SCC is not a direct indicator of infection, but moreover of inflammation. Weaning systems can have marked effects on SCC in dairy ewes. Our observations at Spooner indicate that MIX ewes maintain significantly lower SCC during the first 30 days of lactation compared to DY1 ewes. We feel that this is related again to more frequent udder evacuation during the time when milk production is the highest in lactation. When the udder is heavily distended and under high intramammary pressures, the small junctions between cells in the mammary gland begin to open which permit an influx of SCC (white blood cells and other cell types) into the mammary gland. Furthermore, if the mammary gland does get infected (for example via entry of bacteria through the teat canal), more frequent evacuation of the udder decreases the chances of
those bacteria from colonizing the udder and establishing an infection. Thus, it is to be expected that a weaning system that provides a period of partial or exclusive suckling would have less SCC and less incidence of mastitis compared to ewes that are exclusively machine milked immediately following parturition. While our observations at Spooner demonstrated this to be true for a partial suckling system (MIX system) during early and mid-lactation, we found contradictory results for the exclusive suckling system (DY30 system). DY30 ewes tend to have significantly higher SCC compared to both MIX and DY1 ewes around the time of weaning and during mid-lactation. In another experiment conducted in France where the DY1 and DY30 systems were compared within the same ewe, we again found that the DY30 udder halves had consistently and significantly higher SCC, this time during a three-week suckling period and again during the three weeks following weaning. Because bacteriological analyses were not performed in the experiments, it is difficult to comment on whether or not any of the weaning systems are beneficial in reducing the mastitis incidence in dairy ewes. However, if in fact DY30 ewes were able to maintain high SCC without any increase in infection rate, we might conclude that suckling may actually be beneficial in the recruitment of white blood cells during early lactation which could be responsible in preventing mastitis. This hypothesis will be one of our primary research objectives for the next lactation season.

Local changes at the level of the teat. The idea of suckling prior to machine milking is currently receiving more and more discussion in the literature, not only for dairy ewes but also for dairy cows. Researchers have already reported lower mastitis incidence in cattle that are suckled for a brief period prior to machine milking. In France, we hypothesized that sucking may actually induce some physical changes at the level of the teat end, teat canal, or teat cistern which might facilitate a lower incidence of mastitis in suckled animals and thus would be beneficial to machine milking later in lactation. Using a half-udder comparison technique whereby one udder-half of a ewe was machine milked twice daily (DY1) and the other udder-half was exclusively suckled (DY30) for the first 3 weeks of lactation, we demonstrated significant local modification of the suckled teat and udder-half. The DY30 teat ends were less congested at the time of suckling as well as during machine milking following weaning. Researchers have reported that increases in congestion of the teat during machine milking are one of the predisposing factors to new intramammary infection in cattle. Additionally, we demonstrated that the teat end itself was tougher and more durable when suckled during early lactation compared to teat ends that are only machine milked. One of the more important barriers to infection within the teat is the teat sphincter. This is a muscular layer of tissue that opens in response to suckling or machine milking when a vacuum is applied to the teat end. If the teat sphincter is naturally too relaxed, the entry of bacteria into the mammary gland is facilitated. If the sphincter is too tight, milk flow is impeded during machine milking. Thus there exists a delicate balance in teat sphincter tightness or “resistance”. In the half-udder experiment, we observed that although the suckled teat ends had no change in teat-sphincter resistance, they were able to achieve significantly higher milk flow rates compared to the machine-milked teat ends. Although the above experimental findings remain to be confirmed in partially suckled ewes (MIX system) and in conjunction with bacteriological analyses, we conclude that suckling does have some beneficial effects at the level of the teat in terms of physically preparing itself for machine milking.
Physiologic factors which are important between milkings

One can think about the inside of the udder as having two compartments. One compartment is responsible for producing and secreting milk (the alveoli), and the other compartment is responsible for storing milk (the cistern). In ewes, there exists a dynamic relationship between these two compartments that greatly affects milk yield. Immediately following evacuation of the udder, either by suckling or the machine, the pressure within the udder (intramammary pressure) decreases significantly. The removal of milk combined with the drop in pressure allows new secreted milk to quickly accumulate in the alveoli. The alveoli begin to stretch as they accumulate newly secreted milk, and eventually they spontaneously contract in response to the tension within the alveoli. Milk then flows into a long system of small ducts, eventually traveling through a system of larger ducts, to finally arrive in the cistern. The whole process is repeated. Eventually, because of the large volume of milk that accumulates in the cistern, the intramammary pressure of the cistern becomes great enough to slow down the flow of milk from the small and large ducts. Milk begins to over-distend the alveoli because it can no longer be expelled into the small ducts. In response to the increased pressure within the alveoli, the neighboring secretory cells begin to shut down the production of milk. Additionally, the feedback inhibitor of lactation hormone (FIL) concentration increases when there are large volumes of milk that stay within the alveoli. This hormone essentially tells the secretory cells that there is too much milk being produced and that milk synthesis should be slowed down. Thus when the interval between milkings (or sucklings) surpasses 16 hours, milk secretion is essentially stopped and the secretory cells begin to “dry up”, a cellular process known as “programmed cell death”.

In order to maintain maximum milk production potential following peak milk production and weaning, optimal milking frequency is actually determined by the ewe’s ability to store milk between milkings. As it turns out, the ewe can store between 40 and 60% of her total secreted milk in the cistern; the rest being stored in the ducts and alveoli, further up in the mammary gland. For a given level of milk production, the more milk the ewe is able to store in the cistern, the less often she would have to be milked. Provided that the ewe has correct udder morphology, these ewes would be in fact more efficient milkers. In fact, in France during the early 1970’s, a fair amount of research was conducted to determine if one could omit the Sunday evening milking in order for the family to enjoy a long Sunday dinner. Unfortunately, with the given genetic potential of dairy ewes at that time, there were too great of losses in milk yield for it to be financially viable. Thirty years later, there is renewed interest in the ability of lactating animals to support the omission of one or more weekly milkings, or the omission of part of a milking (i.e. machine stripping). By the same token, ewes which are better adept at storing milk between milkings might also better support the abrupt switch in udder evacuation frequency (suckling to machine milking) at weaning. The capacity to store milk can be discussed as a function of two criteria: the ewe’s udder anatomy and morphology, and the secondly, the ability of the ewe’s udder to stretch between milkings. The latter criteria is referred to as compliance.

**Udder anatomy and morphology.** The size, shape, and form of the udder are determined genetically, and play an important role in the storage of milk between milkings and the recuperation of milk at the time of milking. We have studied our East Friesian crossbred ewes at Spooner for two lactations and find a strong positive correlation between udder height, udder circumference and commercial milk yield. This is to say that, in general, ewes with larger udders produce more milk than ewes with smaller udders. We have also found a positive correlation between
milk yield and the height of the cistern. Additionally, we demonstrated that ewe with taller
cisterns (i.e. more udder volume below the teat canal exit) take significantly longer to milk than
ewes with shorter cisterns. It is not surprising that ewes with more cisternal capacity produce
more milk. These ewes have more storage volume which is one of the components which keeps
intramammary pressures low and more easily avoids over distention of the alveoli between
milking. However, during milking, the udders of these ewes often have to be lifted or massaged
during milking to allow all the milk to drain from the udder. This is a process which takes time,
and therefore is a great detriment to the efficiency of machine milking. In Israel, because of the
enormous milk production and large cisterns in Awassi and Assaf dairy ewes, a hook has been
invented which supports the udder at the intramammary groove during milking. Alternatively,
and perhaps more realistically for American dairy sheep producers, genetic selection programs
need to be implemented which allow for increased milk production without concurrent deteriora-
tion of udder morphology. This is not an easy task because as soon as milk production is in-
creased, more physical demands are placed on the suspensory apparatus of the udder. The
suspending apparatus consists of a large sheet of ligaments that descend from the pelvis and
divides the udder into two halves, forming the intramammary groove. There are also lateral
ligaments which descend from the abdominal musculature to the sides of the udder. When milk
production increases (or with age), the middle suspensory ligament becomes stretched and is no
longer able to adequately support the weight of the milk. The result is a contraction of the lateral
suspending ligaments, and a horizontal deviation of the teats. Some researchers feel that the
depth of the intramammary groove might be a good indication of the strength of the middle
suspending ligament: deeper grooves imply stronger ligaments. If this were to be the case, it
would be desirable to select ewes with profound intramammary grooves. In any case, it is of
paramount importance for producers to consider udder morphology as an important criterion
when selecting the flock for the following lactation.

External measurements of the teat, udder, and cistern are cumbersome. Furthermore,
external measurements of the cistern are not reliable indications of actual internal cistern size,
but are moreover a function of teat placement. Therefore, many researchers are now using a
system of subjective udder and teat scores which will be the basis for future genetic selection
programs. In the Roquefort region of France, subjective scores from 1 to 9 are made by trained
technicians in the milking parlor just prior to milking. Three criteria are evaluated: teat place-
ment, depth of the intramammary groove, and udder height. Both the left and right udder halves
are evaluated for teat placement; only one score is assigned to the udder for depth of the
intramammary groove and udder height. Teats that are completely vertical are assigned a score
of 1. Teats that are at a 45° angle are assigned a score of 5, and teats that are completely horizon-
tal are assigned a score of 9. Udders with no intramammary groove are assigned a score of 1,
with a moderate intramammary groove are assigned a score of 5, and with a very strong demar-
cation between udder halves are assigned a score of 9. With respect to udder height, udders that
hang to the level of the point of the hock are assigned a score of 5. Udders that hang to levels
less than the hock are assigned scores from 1 to 4, and udders that surpass the level of the hock
are assigned scores from 6 to 9. This summer at Spooner, we have scored the entire flock with
our traditional system of external measurements as well as with the French subjective system.
We found a significant correlation ($r^2 = .71$) between the subjective teat score and external cistern
height. It appears that a subjective score might be adequate in accurately assessing udder mor-
phology in ewes.
**Udder compliance.** The term compliance is defined as the capacity of an organ to accept dilatation, and can be described mathematically as the change in volume:pressure ratio from when the organ is empty to when the organ is maximally full. Normally, this is a principle observed in many organs of the body which receive, manage, and expel fluids. In France, we had the idea that the storage of milk may function also in terms of compliance. Udders that are capable of holding relatively large volumes of milk at lower pressures are considered to be better adapted for milk storage and could potential better withstand longer intervals between milking and/or the suppression of machine stripping. Furthermore, udders that are more compliant should also remain in lactation longer because they would be more adept at limiting the amount of over-distention of the alveoli.

In France, we conducted a series of compliance experiments with a group of 32 mid-lactation Lacaune dairy ewes. During the first experiment, we measured the intramammary pressure immediately prior to milking, during milking, and after injection of oxytocin along with the volume of milk that was stored in the cistern and alveolar compartments of the udder. A few weeks later in lactation, we conducted a second experiment, this time immediately after machine milking. During this experiment, we gradually filled-up the udders with sterile saline while periodically measuring intramammary pressure. Finally, a third experiment was conducted which involved repeating the first experiment, but after having omitted the previous night’s milking. The experimental analysis has not yet been completely finished, however we have already found a random variation in intramammary pressure as a function of volume of milk in the udder just prior to milking. When we divided the ewes into two groups of 16 ewes (low and high) based on their milk volume:intramammary pressure ratios (v/P ratio), we found that high v/P ewes store up to 65% of their milk in the cistern, compared to low v/P ewes that are only able to store about 50%. When we extended the interval between milking to 24 hours by omitting the previous evening’s milking, we found that the same ewes with low v/P ratios were not able to significantly modify their v/P ratio; in other words, these udders were relatively non-compliant. Conversely, ewes with high v/P ratios showed a significant degree of compliance in their udders because they were able to accommodate an increase in intramammary pressure of 30% when the milking interval was extended to 24 hours. These preliminary results suggest that there exists a population of ewes who are better adept at milk storage between milkings probably due to a higher degree of compliance within their udders.

**Physiologic factors which are important at milking**

Since the onset of mechanized milking of dairy ewes in the 1960’s, it has been the industry’s goal to develop methods for machine milking that completely remove all of the milk from the udder within the shortest amount of time without causing harm to the udder or ewe. Milking machines, along with specific recommendations on vacuum level, pulsation rate and ratio, have been extensively researched and developed for dairy ewes. Genetic selection has been successful in most countries with the average dairy ewe now capable of producing between 250 and 350 liters of commercial milk during a four to five month period. Machine milking efficiency has also improved because milk yields have increased and milking time spent in the parlor has decreased. In the Roquefort region of France, average milking cadence is between 350 to 400 ewes per hour and can be as high as 800 ewes per hour, depending on the type of milking parlor/machine installation. Although we have achieved an acceptable level of milk
production in dairy ewes and a reasonable parlor cadence, there exists a large variation in the way an individual ewe gives her milk to the machine. By further understanding the physiological mechanisms that influence the way a ewe ejects her milk, we can ultimately create new genetic selection criteria which would further improve machine milking efficiency. This summer at Spooner, we initiated an evaluation of the way our ewes give their milk to the machine. We used a piece of equipment which has been loaned to us from our French collaborators that allows us to measure a variety of milk flow criteria during the milking process. After having characterized milk flow in a large number of ewes in the Spooner flock, we began an experiment to assess the impact that suppression of machine stripping would have upon milk production.

The physiologic demands placed upon ewes during machine milking are quite different than those present during suckling. In addition to the beneficial effects of frequent milk removal during the suckling period, the physical presence of the ewe’s own lamb (odor, sight, sound) and the suckling stimulus are extremely important for successful milk ejection in the ewe. As soon as the ewe is weaned and is initiated into the machine milking routine, she no longer receives the usual natural stimuli, but must instead release her milk to a sucking, pulsating piece of silicon. This is initially a stressful event which can result in the immediate drop of 20 to 30% in total milk production. Eventually, usually within 5 to 7 days, ewes adjust to the milking routine. They begin to have normal oxytocin release and subsequent alveolar contraction which enables complete evacuation of milk from the udder. Generally, if the ewe is content during the milking process, she chews her cud. Anecdotally, cud chewing has been correlated to oxytocin release which usually occurs at 30 to 45 seconds after the teat cups have been placed on the ewe. At Spooner, we typically observe 85 to 95% of ewes who chew their cud in the parlor.

To get an idea of how the dairy ewes at Spooner eject their milk during machine milking, we measured milk flow kinetics of 48 ewes (approximately 50% East Friesian breeding) during the morning milking every two weeks during their fourth and fifth months of lactation. We chose only ewes with symmetrical udders, correct teat placement, and average to above average milk production. The criteria that were evaluated during this two month testing period included: milk flow latency, average milk flow rate, peak milk flow rate, milk yielded to the milking machine (machine milk), stripping milk yield, total commercial milk yield, and milking procedure time. At this point, we have made only a preliminary assessment of the raw data. We observed that the average ewe during mid- to late-lactation gives 0.92 liters of commercial milk in 102 seconds with an average milk flow rate of .5 to .6 L/min. By looking at the milk flow data we are able to further assess what happens to milk flow during that 102 seconds. Milk began to flow (latency) at 11 seconds after placement of the teat cups on the udder. Peak milk flow rate was 1.2 L/min and was usually attained within the first 30 seconds of milking. We found that at 83 seconds, the average ewe no longer gave significant amounts of milk to the machine (a milk flow rate of less than .05 L/min). At this point, she had given only .73 liters of milk and therefore required machine stripping. On average, the milker spent an additional 19 seconds of manual massage (stripping) to remove the final .19 liters of milk, corresponding to about 20% of her total commercial milk yield.

Machine milking efficiency is thus optimized when milking procedure times decrease, the amount of milk given to the machine without intervention increases, and the amount of stripped milk decreases. After looking at all of the milk flow curves and data, we began to appreciate consistent differences between ewes in the way that they give their milk to the ma-
chine. We identified five general types of milk flow patterns. Moreover, these patterns exist independent of total commercial milk yield. In other words, it is possible to find each of the following types of ewes all with a milk production of 1.5 liters, for example.

1. The “fast-milker”: a ewe which attains milk flow almost immediately after the teat cups have been placed on the udder. She achieves one or two very high peak milk flow rates (1.5 to 2 L/min) and has usually emptied her udder by 60 seconds. If the ewe has correct teat placement, she typically has only 5 to 10% stripping volume.

2. The “average-milker”: (see above).

3. The “slow-milker”: a ewe which generally requires a great deal of manual intervention in the parlor. Milk begins to flow 20 to 30 seconds after the teat cups have been placed on the udder. Peak milk flow rates rarely exceed .5 to .6 L/min, the normal milk flow rate for an average ewe. Milking procedure times often exceed 4 minutes, and the milker has a tendency to spend significant amounts of time in udder massage and stripping. It is sufficient to have just one slow-milker in each wave of ewes to greatly slow parlor throughput time.

4. The “poor udder conformation/teat placement ewe”: a ewe with a large amount of udder volume located beneath the teat canal exit. This is more often seen in older ewes with relaxed medial suspensory ligaments. Milk flow rates and milk yields may be acceptable, however, stripping percentages are high (30 to 40%) which significantly increase milking procedure time.

5. The “no milk-ejection ewe”: a ewe that does not release her alveolar milk fraction during milking. This is most often seen during the first 30 days of the MIX weaning system when oxytocin is not released at milking. However, this phenomenon can be seen in some ewes throughout lactation. In high producing ewes, producers may not even be aware of these ewes because milk flow rates can be acceptable and stripping percentages low.

The reasons for the differences in the way a ewe gives her milk to the machine is due to a complex interaction of physiological factors initiated by the machine and the milking parlor environment. I will discuss two of the most important factors: the release of oxytocin and the control of the teat sphincter. Although the teat is the generally the first point of contact with which the ewe appreciates the actual milking process, many times physiological changes within the ewe have already occurred when the ewe hears the milking machine being turned on, or when she sees the milking parlor. These stimuli can all initiate the milk ejection reflex and cause a discharge of oxytocin from the brain. Because oxytocin causes contraction of the alveoli, intramammary pressure increases an average of 1.7 fold as milk is being forced out of the alveoli in the direction of the cistern. Thus oxytocin is responsible for not only eliminating the alveolar fraction of milk (rich in fat) but also for increasing intramammary pressure which could influence milk flow.

At the other end of the mammary system is the teat sphincter, a ring structure near the teat end composed of smooth muscle fibers which allows milk to flow from the teat canal during suckling or milking, yet which closes firmly soon after the stimulus is over. These smooth
muscles in the teat sphincter are also located higher up in the ducts and canals of the mammary gland and are under strong influences from the nervous system. When animals are disturbed or stressed during milking, adrenaline and other related chemicals began to inhibit milk flow by causing smooth muscle contraction, by interfering with oxytocin release from the brain, or by interfering directly with oxytocin’s effects on alveolar contraction. In France, we demonstrated that ewes with low milk flow rate have significantly “tighter” sphincters, and conversely ewes with high milk flow rate have sphincters that take less vacuum to open. When we injected adrenaline and other related drugs which either inhibit or facilitate milk flow, we were only able to inhibit milk flow. In other words, when we administered drugs that would normally relax the sphincter, we did not necessarily see significant increases in milk flow. From these preliminary observations we conclude, with respect to the teat sphincter, slow-milking ewes have perhaps other physical constraints in their teat tissue itself which prohibit milk flow from increasing. When we measured oxytocin in the blood during milking, we observed that one class of adrenaline-like drugs (α<sub>1</sub>-adrenergic agonists) caused circulating levels of oxytocin to be significantly reduced, which confirms the interaction between “stress” and milk ejection. Finally, another hypothesis that many researchers are working with is that certain ewes have higher densities of receptors in the mammary gland or higher circulating concentrations of certain inhibitory substances and thus are slow to milk.

In approximately 45% of the ewes monitored at Spooner, we observed a “two-peak” milk flow curve during milking. The first peak occurs between 10 and 40 seconds, followed by a sharp decrease in milk flow, finally followed by the second peak. The first peak corresponds to extraction of milk stored within the cistern. If the amount of milk stored in the cistern is small or if the milk flow rate is large, the cisternal milk may be expelled from the mammary gland before oxytocin has a chance to act upon the alveoli. Thus we see a trough in the milk flow curve when cisternal milk has been completely removed. If oxytocin release from the brain has occurred, we see a new sharp increase in the milk flow curve at 30 to 45 seconds which corresponds to alveolar milk flow. In some ewes we could actually externally visualize the impressive “second filling-up” of the udder when the alveolar milk arrived in the cistern. When ewes are in early lactation and/or when milk production is large, we see less “two-peak” ewes because cisternal milk is still being removed when oxytocin begins to cause alveolar contraction.

Machine stripping requires the manual intervention of one or both of the milkers, decreases parlor throughput time, and may eventually habituate ewes to manual massage of the udder. In the Roquefort region of France, producers have abandoned the use of machine stripping in order to gain in parlor throughput time. Average stripping percentages in the INRA laboratory in Rennes are on the order of 8 to 11%, significantly lower than what we found for the Spooner flock. When stripping percentage is low, the small amount of milk gained during machine milking is not worth the labor input to extract it. Instead, flock size can be slightly increased to maintain the same level of production. To evaluate the effects of no machine stripping on milk yield, milk composition and quality, and lactation length, we omitted machine stripping in 24 ewes in the Spooner flock from 90 days in lactation onward. We compared their lactation performance with 24 contemporary ewes which were machine stripped normally. Commercial milk yield for non-stripped ewes was between 13 and 20% less than that of stripped ewes, which corresponded to a loss in commercial milk of .10 to .17 liters. These
results are not surprising given the fact average stripping percentage in the Spooner flock is 20%. Perhaps more surprising were our comparisons between commercial milk yield extracted only by the machine (machine milk = total commercial milk – stripped milk). We found that non-stripped ewes had consistently higher “machine-milk” yield than the stripped ewes. This might imply that stripped ewes are somehow habituated to udder massage and actually give less milk on their own. Furthermore, leaving the small volume of “un-stripped” milk in the udder does not appear to perturb milk synthesis. Analyses of fat and protein content, somatic cell count, and lactation length is currently being conducted along with an economic analysis to further evaluate the effects of omitting machine stripping in dairy ewes.

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