Some Factors Influencing Milk Ejection in Mechanical Milking

(Summary)

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Most of the work done on the study of let-down and milk ejection has been carried out by physiologists and their approach to the problem has been from the physiological side. Even though the most readily observable phenomena and also those of greatest practical importance are the physical changes in the udder, there has been no systematic physical study of the problem.

These physical changes although controlled from outside, are confined to the udder, so that the udder behaves as a partially isolated mechanical system which is readily available for study. The systematic analysis of this mechanical system is, therefore, a good starting point for the study of let-down and milk ejection, since the physical quantities involved are readily observed and measured with the necessary degree of accuracy. If the physical changes in the udder can be understood and interpretated in terms of muscular changes, then these muscular (or mechanical) changes can be used as indicators in the study of the physiological processes which give rise to them.

In the following paper, the preliminary results of such an analysis are discussed. The methods and techniques being varied and numerous, are not discussed in detail and only the essential conclusions are given. The subject is discussed under the following headings:—

1. Removal of Milk from the Milk Cistern of the Udder.

The factors affecting the removal of milk from the udder during milking are discussed and a physical explanation of the shape of the ejection curve is given. It is shown that the relation between the applied vacuum (in mechanical milking) and milking rate, predicted from the physics of the teat and udder, agree quite well with the experimental results.

The vacuum at which the milk starts to stream from the teat varies from cow to cow and is a function of the initial tension of the sphincter muscle. The subsequent increase in the milking rate with increasing vacuum is very rapid, showing that milking rate is directly influenced by vacuum level when this is near the "opening vacuum." This curve is similar in shape for most cows, and as the vacuum is increased the milking rate increases less rapidly until finally the elastic limit of the teat sphincter is reached.

It is shown that during the part of milking when the removal of milk is not obstructed by the "crawling" of the cups, the rate of milking is a function of the following factors:

(a) Tension in the sphincter muscle and the manner in which its elasticity varies on stretching.
(b) Milk pressure in the cistern and teat.
(c) Vacuum applied to the outside of the teat.

An important practical result is mentioned here in connection with the so-called "hard" and "easy" milkers. These cows differ in the vacuum level necessary to open the teat orifice, i.e., the "opening vacuum" is much higher for the "hard" cow.

This is very important in practice in that a reduction in vacuum of a fixed amount (say 15in. mercury to 12in. mercury) will affect both cows by a similar change in milking rate (say 2lb./minute), but this may amount to a 50% reduction in the rate for the "hard" cow and only a 15% reduction in rate for the "easy" cow.

2. Study of Pressure Changes in the Milk Cistern of the Udder and Its Significance in the Study of Ejection and Let-down.

Several methods of measuring and recording the milk cistern pressure are discussed briefly, and the information provided by these measurements is considered.

Some recordings of the rise in milk cistern pressure on let-down are given and differences between cows are indicated in conjunction with their effects on the milk ejection curve.

3. Persistence of Let-down and Distribution of Milk in the Udder.

Some experiments are discussed in which the distribution of milk in the udders of several cows was studied under different conditions. These experiments suggest the following mechanism in the let-down process:—

Summary of Physical Evidence:

The results of this work can be summarised thus:—

(1) Before let down the upper and lower portions of the udder are disconnected and the milk cistern contains only a small proportion of the milk which is variable in quantity (being usually greater for the morning milking).

(2) On let-down the upper and lower portions of the udder are connected together and the milk is transferred from the upper portion under constant pressure, to the cistern. This flow continues until equilibrium is reached and the pressure is the same in both portions. (Unless the connecting ducts are closed before this point is reached.)

(3) The udder remains in this state of relatively constant pressure until a point is reached where the two sections of the udder are again disconnected. After this point the pressure can be varied by outside pressure due to the disconnection of the constant pressure source. The time from the initial pressure rise to this point is called the "persistence time" of the let-down.

(4) The milk retained in the upper part of the udder after this point can be obtained only after further stimulation and let-down.

Interpretation of the Results:

These results would be explained by a muscular mechanism in which the alveoli are squeezed by muscle contraction at the same time as the connecting ducts are opened. The muscular squeezing of the alveoli being of constant tension thus producing a constant milk pressure, the tension varying slightly with the degree of contraction of the muscles, i.e., with the quantity of milk in the alveoli.

4. Characteristics of Double Let-down.

Some results are given of a study of a number of cases in which a second let-down was obtained, and the relation between cistern pressure rise and milk ejection found. The results indicate that a "double let-down" can give rise to a great variety of ejection curves and also that "double let-down" is somewhat more common than previously supposed, especially at the end of lactation.

Some factors affecting the "persistence" (or duration) of the let-down action, are discussed. Results suggest that the "persistence" of the let-down becomes shorter as the lactation progresses and also increasingly susceptible to external stimuli.

In conclusion it is pointed out that these results were obtained during the last three months of lactation and in some cases only suggested results can be given. Further work will be necessary to study the various factors throughout lactation before these points can be fully understood.

Discussion on Mr. Phillips's Paper

Prof. CAMPBELL: What is the association between the crawling of the cup and the shape of the gland?

Mr. PHILLIPS: It is more pronounced when the lower part of the cistern is conical rather than rounded.

Mr. MacFARLANE: Improved design of milking machines and better milking procedures require a thorough knowledge of the let-down process and of the second let-down. Might one not breed for a mechanism such as satisfactory let-down?

Mr. CARTER: Does the data from identical twins suggest that there is a possibility of breeding for such a trait?

Mr. PHILLIPS: The twin data are incomplete but one set had very similar pressure changes and second let-down. The production of this set was halved when they were removed to another dairy where the changed routine resulted in a loss of the second let-down.

Mr. STEWART: Would selection on milking time and selection on production not give the same result?

Mr. PHILLIPS: Slow milking and a second let-down both give long milking time. Some high producers are slow milkers and are retained in the herd in spite of it.

Dr. WALLACE: Is persistence likely to be longer than normal milking time and if not could a higher vacuum be used to shorten the milking time?

Mr. PHILLIPS: Persistence may be 3-7 minutes so the cups should be put on fairly soon. Later in the season it may be shorter than normal milking time. With a vacuum of over 15in. teat cups tend to crawl. There must be a compromise between the milking time and the crawling of the cups.