

THE RELATION BETWEEN THE INITIAL RISE AND THE
SUBSEQUENT DECLINE OF MILK SECRETION
FOLLOWING PARTURITION.

By SAMUEL BRODY, CHARLES W. TURNER, AND ARTHUR C. RAGSDALE.

(From the Department of Dairy Husbandry, University of Missouri, Columbia.)

(Received for publication, January 28, 1924.)

It is a common observation of dairymen that the milk flow of the dairy cow rises for some time after calving and then declines steadily. In preceding papers¹ we have presented data and have offered an interpretation for the declining segment of the curve of milk secretion. Having found that after the first month of lactation the curve of milk secretion with the advance of the period of lactation may be represented by the exponential law representing the course of monomolecular change in chemistry, we suggested the interpretation that the course of milk secretion is probably limited by a monomolecular chemical reaction. This interpretation seemed reasonable in view of the fact that milk secretion must be a chemical or physicochemical process since certain substances typical of blood are converted into other different substances typical of milk. The initial rise of milk secretion, on which no data were available at that time, was explained as due to the improving condition of the animal and to the increasing food consumption due to the improved condition. However, a comparison of the curve of food consumption with the curve of milk secretion does not show the expected parallelism,² and the condition of the animal appears to become normal within a short time after calving which is long before maximum milk secretion is reached. These facts suggest that under favorable conditions of food and management the factors limiting or controlling the characteristic rise and

¹ Brody, S., Ragsdale, A. C., and Turner, C. W., *J. Gen. Physiol.*, 1922-23, v, 441, 777.

² Unpublished data of the Missouri Experiment Station compiled by C. W. Turner.

decline in milk secretion are inherent in the mechanism of milk secretion. In other words, milk secretion increases, then decreases, and a superabundant food supply is merely stored as body fat and does not appreciably affect the characteristic course of the curve.

The purpose of this communication is to extend the physico-chemical interpretation employed to explain the mechanism of the declining curve of milk secretion so as to include the first month of the lactation period during which time the curves of milk secretion rise and pass through a maximum as shown in Fig. 1.

There are a number of well known processes in chemistry classed under simultaneous consecutive reactions which show in their velocity curves the characteristic rising and declining course exhibited by the curves of milk secretion of Fig. 1.³ For this purpose we compared the course of the curves of milk secretion with the course of the curves of consecutive reactions in order to interpret the curves of milk secretion from this physicochemical view-point.

As previously pointed out, milk secretion, after the second month, falls off in a geometrical progression with time, and the course of the curve after the second month may, therefore, be represented by the exponential equation

$$M = Ae^{-k_1t} \quad (1)$$

in which M is the milk flow at the time t and k_1 is the constant of decline or the specific reaction rate. This is the integrated form of the equation representing the law of monomolecular change in chemistry. The differentiated form of equation (1) may be written

$$\frac{dm}{dt} = -km$$

which indicates that the amount of milk secreted at any time, t , is directly proportional to the concentration of the substance or factor, or to the intensity of the condition, which controls or limits the velocity of the process of milk secretion at that time.

Similarly, the first part of the rising segment of the curve of milk secretion may likewise be represented by the equation of monomolecular change.

³ Cf. Lewis, W. C. McC., A system of physical chemistry, London and New York, 1920, 3rd edition, 402-6.

$$M = B(1 - e^{-k_2 t}) \quad (2)$$

in which M is the milk flow at the time t and k_2 is the characteristic constant of decline of the rising curve of milk secretion. It will be observed in Fig. 1 that the rise in milk secretion becomes less and less as it approaches the maximum and the decline in this rise is exponential.

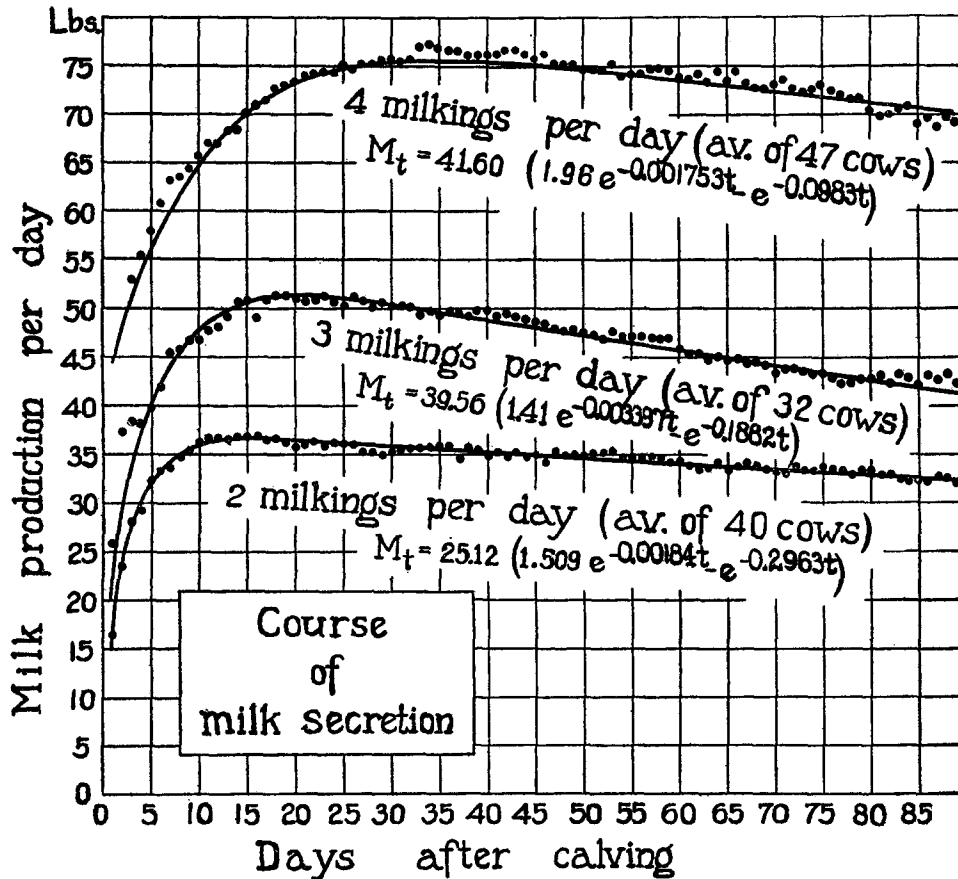
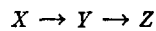


FIG. 1. The course of milk secretion with the advance of the period of lactation of Holstein-Friesian cows. The curves of milk secretion may be extended to any desired time after parturition by the use of the given formulæ.¹ Data bearing on the causes of the differences in the time of maximum production, differences in the slopes of the curves, and differences in the absolute production of the different groups of cows will be presented later.

The curve of equation (1) declines asymptotically, the curve of equation (2) rises asymptotically. Therefore, the milk secretion at any time appears to be the resultant of two processes, a process $X \rightarrow Y$ which follows the curve represented by equation (2) and a process $Y \rightarrow Z$ which follows the course represented by equation (1), and the velocity of milk secretion at any time appears to be proportional to the concentration, or the condition represented by the intermediate substance or state, Y , at that time. The rising and declining course of Y in the processes represented symbolically by



may be represented by the expression combining equations (1) and (2) that is

$$M = Ae^{-kt} - Be^{-kt} \quad (3)$$

in which M is the milk flow at the time t after the beginning of the process.

From Fig. 1, equation (3) fits the data satisfactorily. It is assumed, for convenience, that milk secretion begins on the day of parturition. As a matter of fact in the dairy cow, depending on the individual, the mammary gland shows signs of milk secretion at from 1 to 10 or more days before parturition and this difference between the assumed, and the actual time of the beginning of milk secretion accounts for the differences in the numerical values of A and B shown in Fig. 1.

If the view that the rise and decline of milk secretion is due to the rise and decline of a substance Y as a result of the processes represented by $X \rightarrow Y \rightarrow Z$ is correct, then the following explanation would follow as a consequence. At about the time of parturition the substance X is released and made available for its transformation into Y , and therefore milk secretion begins. Now, remembering that the speed of production of Y is proportional to the concentration of X , and the speed of disappearance of Y is proportional to the concentration of Y , it is clear that since at about the time of parturition there is present, by hypothesis, all of X and no Y , the production of Y is greater than its change to Z , and consequently the amount of Y increases and with it there is an increase of the milk flow. As X de-

creases and Y increases the disappearance of Y becomes greater than the production of Y , and so the initial upward course of Y , and of the milk flow, is changed to a downward course as represented in Fig. 1.⁴

Instead of assuming that X and Y are simple chemical substances it may be assumed that the rise and decline in milk secretion following parturition is due to the development and decline in the number or in the vigor of the milk secreting cells. At first the cells increase in number or in vigor according to equation (2), then they decline according to equation (1) with the result that the number or vigor of the cells, and therefore the milk flow, at any time can be represented by equation (3). But the rise and decline in the number or in the vigor of the secreting cells may in turn be explained as due to limiting chemical processes as explained in the preceding paragraph. We have, indeed, offered such an interpretation for the rising and declining course of vitality of the body as a whole due to the processes of growth and senescence.⁵ It seems quite reasonable to consider the process of rise and decline of milk secretion with the advance of the stage of lactation as a species of growth and senescence possessing, however, the unique property of being renewed with every gestation.

⁴For an enlightening explanation of the mechanism of consecutive processes, cf. Osterhout, W. J. V., Injury, recovery, and death, in relation to conductivity and permeability, Monographs on experimental biology, Philadelphia and London, 1922.

⁵Brody, S., Ragsdale, A. C., and Turner, C. W., *J. Gen. Physiol.*, 1923-24, vi, 31. Brody, S., *J. Gen. Physiol.*, 1923-24, vi, 245.