

mal of 5% to less than 1% for milk retained 120 hours. Total solids diminished with retention mainly because of the decrease in fat and lactose.

Total ash increased, reaching the maximum in 36 hours. Calcium and phosphorus, however, decreased, reaching the minimum after 120 hours, which was slightly more than one-half of the normal. There was a large increase in chlorides, presumably sodium chloride. This increase in chloride content and decrease in lactose is taken as an indication that the milk is coming into equilibrium with the blood as far as the solutes are concerned.

The pH increased from 6.4 to over 7.3 for milk retained 120 hours. Just why the pH should be higher for retained milk than for the blood is problematical.

Conclusions. After milk has been permitted to accumulate in the udder to reach the maximum pressure, resorption takes place, which greatly alters the composition of the udder contents. Lactose and fats first diminish with an increase in total protein. Ash increases due to an increase in chlorides, taken to be sodium chloride, and there is a decrease in both calcium and phosphorus. The pH is increased to above that of normal blood. The character of the protein is also changed.

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Osmotic Pressure and Milk Secretion.*

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Previous work^{1, 2} has shown that physical pressure exerts a marked influence upon the rate and character of milk secretion and indicates that osmotic pressure may play an important rôle in milk secretion. It is well known that milk is isotonic, but that it is not

* The data used in this paper are taken mainly from a thesis presented by T. V. Rigor in partial fulfillment of the Ph.D. degree.

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¹ Petersen, W. E., and Rigor, T. V., *PROC. SOC. EXP. BIOL. AND MED.*, 1932, **30**, 254.

² Petersen, W. E., and Rigor, T. V., *PROC. SOC. EXP. BIOL. AND MED.*, 1932, **30**, 257.

in equilibrium with the blood is definitely known. Davidson³ has reported on the effect of injection into the duct system of isotonic lactose and salt solutions. No reference has been found as to the effects of hypo- and hypertonic solutions on milk secretion or as to whether or not ions exert specific influence.

This report deals with a study of the effect upon the character of the secretions of the following: 1. Isotonic solutions: lactose, saline, and Ringer's solution. 2. Hypotonic solutions: (three-fourths concentration of isotonic) lactose, saline, and Ringer's solution. 3. Hypertonic saline ($1\frac{1}{4}$ concentration of isotonic). 4. Distilled water.

These various solutions were introduced into the duct system of one quarter of the udder through a teat cannula. The amount of the solution introduced was equal to the quantity of milk withdrawn. The solution was introduced immediately following a milking and left in the gland for 12 hours. The milkings were analyzed for 4 days following the injection, the same analytic technique being used as in a previous paper.² Comparisons are made to the secretions of a 5-day preliminary period and to the milk produced simultaneously in the corresponding normal quarter.

Figure 1 presents graphically the effect of isotonic saline solution. Protein, ash, and pH are significantly increased with a decrease in lactose. Changes in fat and total solids are not significant. Milk yield dropped to less than one-third normal for the first milking following injection of the saline solution. All constituents as well as yield returned to normal in 2 to 4 days. Calcium and phosphorus contents were unaffected.

Figure 2 shows the effect of Ringer's solution. A marked depression of fat, lactose, and total solids is noted, reaching the minimum for the first milking following injection and becoming normal in 4 days. Protein and ash were markedly increased, reaching the maximum in second day after injection and becoming normal in 4 days. Yield of milk was reduced to less than a tenth normal and both calcium and phosphorus increased significantly. All returned to normal in 4 days.

Figure 3. With the exception of fat, isotonic lactose had the same effect upon the character of secretion as did the saline solution. The yield was not depressed to the extent it was with Ringer's and recovery to normal was effected in less than half the time.

The effect of hypotonic solutions is shown in Figures 4, 5, and 6. The variations on fat content are not significant. Protein increases

³ Davidson, F. A., *J. Agr. Research*, 1926, **33**, 873.

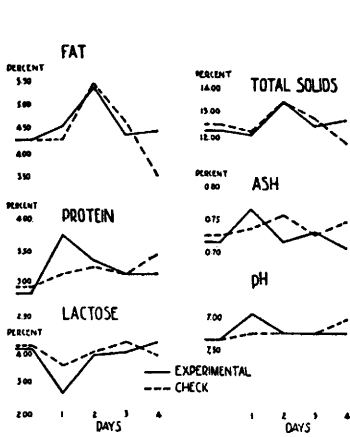


FIG. 1

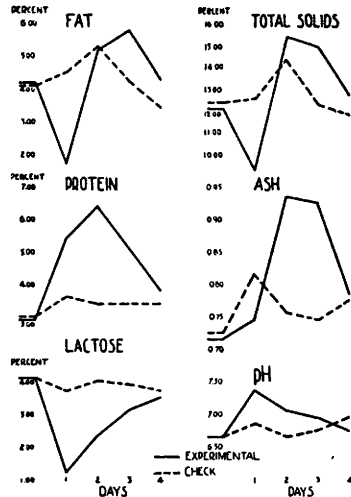


FIG. 2

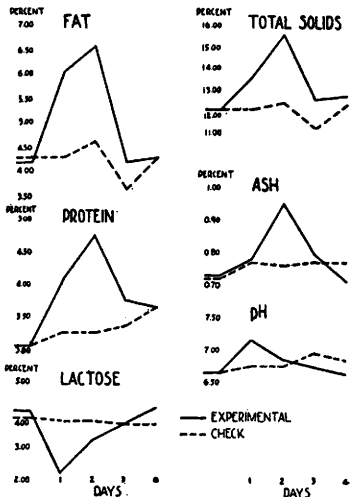


FIG. 3

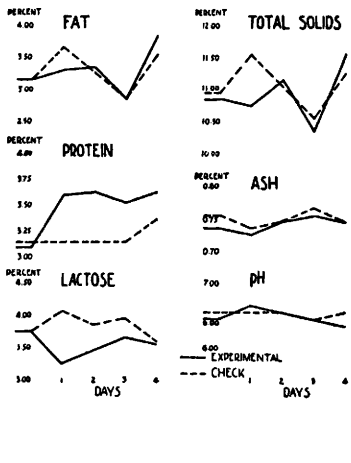


FIG. 4

FIG. 1. *Effect of isotonic saline solution upon milk secretion.* The short line on the left is the average of a 4-day preliminary period. The points following are for the subsequent milkings expressed in daily averages.

FIG. 2. *Effect of Ringer's solution upon milk secretion.* The short line on the left is the average of a 5-day preliminary period. The points following are for the subsequent milkings expressed in daily averages.

FIG. 3. *Effect of isotonic lactose solution upon milk secretion.* The short line on the left is the average of a 5-day preliminary period. The points following are for the subsequent milkings expressed in daily averages.

FIG. 4. *Effect of hypotonic saline solution upon milk secretion.* The short line on the left is the average of a 4-day preliminary period. The points following are for the subsequent milkings expressed in daily averages.

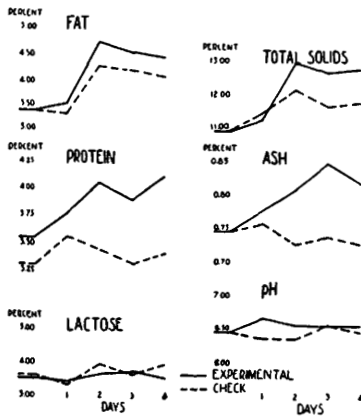


FIG. 5

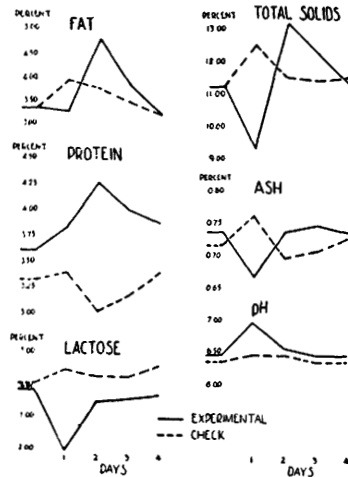


FIG. 6

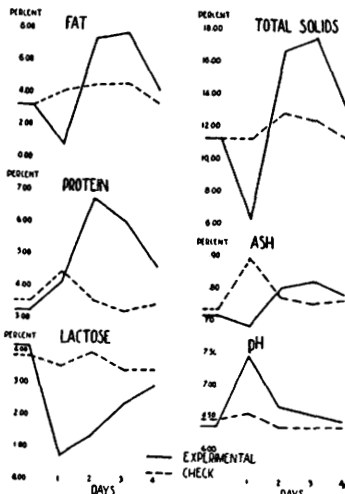


FIG. 7

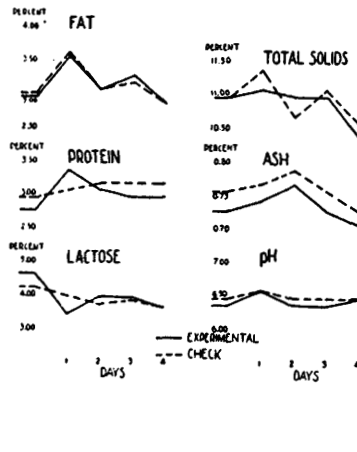


FIG. 8

FIG. 5. *Effect of hypotonic Ringer's solution upon milk secretion.* The short line on the left is the average of a 4-day preliminary period. The points following are for the subsequent milkings expressed in daily averages.

FIG. 6. *Effect of hypotonic lactose solution upon milk secretion.* The short line on the left is the average of a 4-day preliminary period. The points following are for the subsequent milkings expressed in daily averages.

FIG. 7. *Effect of hypertonic saline solution upon milk secretion.* The short line on the left is the average of a 5-day preliminary period. The points following are for the subsequent milkings expressed in daily averages.

FIG. 8. *Effect of distilled water upon milk secretion.* The short line on the left is the average of a 5-day preliminary period. The points following are for the subsequent milkings expressed in daily averages.

and does not return to normal in 4 days following the injection. Lactose slightly depressed except for "hypotonic" Ringer's solution where it is unaffected. Ash is increased for Ringer's and unaffected for the others. The pH increased for all 3. The hypotonic solutions depressed the milk yield to a much less extent than the isotonic solutions. In order of depression they were lactose most, Ringer's and saline least, although differences are not significant. The calcium and phosphorus content was unaffected except for the lactose injection when they were about three-fourths normal for the first milking following injection.

Effects upon the composition of milk following the injection of hypertonic saline solution ($1\frac{1}{4}$ normal) are given in Figure 7. The effects are in the same direction only much more marked, except for ash, which increased in the milk from the corresponding normal quarter. Protein more than doubled while lactose dropped to one-fifth normal. The yield dropped from a normal of 2,000 cc. to less than 100 cc. and returned to less than one-half normal after 4 days. Both calcium and phosphorus dropped to about one-third normal for the first day following injection and normal on the second day. The milk appeared very abnormal, being watery with the proteins precipitating out immediately after milking.

The effect of distilled water is shown in Figure 8. Comparatively minor effects are to be noted for lactose (slightly depressed) and protein (slightly increased) other ingredients including calcium and phosphorus are not significantly effected. Yield dropped about 20% on first milking following injection and returned to normal on the second day.

Conclusions. From the above it becomes evident that the concentration of solutes affects both the character and amount of secretion. The depressing effect upon the amount of secretion is in direct proportion to the concentration of solutes. The amount of secretion produced following hypertonic solution is about $1/20$ normal; isotonic about one-fifth normal; hypotonic one-half normal, and water four-fifths normal. This clearly indicates a selective absorption of the solutes and not a simple equilibrium phenomenon through a semi-permeable membrane. If the latter were true, water should pass into the gland from the blood and increase the amount of secretion.

As there is no significant difference between the effects of saline solution, Ringer's solution, and lactose it may be concluded that electrolytes exert no greater effect than non-electrolytes or a more balanced mixture of electrolytes such as Ringer's solution.

That the effect of an injection lasted for more than one day indicates a disturbance in secreting cell, requiring a little time to overcome. It is significant that protein in the secretion increased in the order of increase of solutes in the injected solution which is reverse to the amount of secretion.

The picture of the character of the secretion following an injections of solution approximates that of milk retained in the udder, indicating that normal milk secretion depends upon a complex selective equilibrium.