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SEGREGATION OF FAT FACTORS IN MILK PRODUCTION.

BY F. B. HILLS AND E. N. BOLAND.

The need of an investigation into the problem of inheritance of fat in milk, has long been recognized by the practical milk producer and the physiologist. For the former, a solution of the problem would simplify, very markedly, his breeding operations, as well as increase the certainty of his results. For the latter, a knowledge of the fat producing possibilities of the animal genetically would give an index to the physiological limits of fat formation, and its relation to metabolism.

The title of this paper might indicate that the problem has been solved, but in this sense, the title is a misnomer, for the paper can merely throw a little light, perhaps, on some of the work to be done. It records the principal discoveries made in the pursuance of a Master's degree thesis in the breeding laboratory of the Animal Husbandry Department of this college.

With the exception of the data collected from the microscopical examination of many samples of milk in the laboratory, the source of the data studied is the Advanced Registry Official records of the Holstein-Friesian Association. The number of animals listed is large and the field little exploited, although worthy of systematic consideration, since the records have been kept for a sufficient length of time to include the performance of many generations.

The commonly accepted theory of milk secretion, is that first proposed by Langer and since slightly modified by Steinhaus, Brouha and others. Dr. Marshall, in his ''Physiology of Reproduction,'' has outlined this theory somewhat as follows: Some of the cells of the gland lengthen out so that their ends project freely into the lumina of the alveoli, and probably undergo cell division. The projecting portions then disintegrate, before or after becoming detached, and the cell substance passes into solution to form the albuminous and carbohydrate constituents of the milk. The fat droplets, which collect in the disintegrating part of the cell, give rise to the milk fat. The basal portions of the cells remain in position, without being detached, and subsequently develop fresh processes, which in turn are disintegrated. It is believed, however, that some cells, possibly the largest number, simply discharge their fat droplets and other contents into the lumina, while otherwise remaining intact. To support the first mentioned idea, Steinhaus and Szabo report actual evidence of mitotic cell division in the actively secreting glands, the daughter nuclei taking part in the general disintegration.

The precise method of the formation of fat in milk is not known. It occurs in the milk in the form of innumerable globules, covered with a thin layer of casein. These vary in diameter from .001 to .005 mm. and give color to the emulsion by the reflection of light. The relative numbers of larger and smaller globules in milk is somewhat affected by the breed to which the producing animal belongs. It is commonly recognized that there is a higher percentage of large globules in Jersey and Guernsey milk than in Ayrshire and Holstein milk, since the emulsive power of the former is less than that of the latter, permitting the cream to rise more rapidly. This fact might suggest a factor in inheritance similar to the intensity factors found in color inheritance.

In a microscopical examination of a large number of samples of milk of various composition, it was found convenient for comparison to divide the globules into three classes, as regards size. All under .0016 mm. in diameter were in the first class, those ranging from .0016 to .0032 mm. in diameter fell into the second group, and all over .0032 mm. were placed in the third class.

Numerous counts of the globules were made in samples of milk of the following fat content: 2.8%, 3.2%, 4.2%, 5.2%, 6.2%, and 7.2%. There was found to be a positive correlation between the percentage fat composition of the milk and the number of fat globules of different sizes, the co-efficient being .19. From an inspection of the counts, the relation is evident,—for instance in the sample of 2.8% fat content, 66% of the number of globules were in the first division, 28% in the second and 6% in the third division. In the 7.2% milk there were only 47% of the total number of fat globules in the first division, while there were 40% in the second and 16% in the third,—showing at a glance the large increase in the proportion of large globules, with the increased fat composition of the milk.

The grouping of the globules according to the system mentioned, was purely arbitrary. Under a different grouping the correlation might be even more evident. But the results were positive enough to warrant the conclusions drawn. Continued investigation along this line should reveal some facts of great value to the practical producer.

For a study of inheritance of fat production, as shown by the relation of the production of dams to that of their offspring, 3,700 pairs of variates were taken from the 1910-1911 Official Year book of the Advanced Registry of the Holstein-Friesian Association. The mean fat production of the offspring was 16.952±.039, while that of the dams was 15.971±.034. The standard deviation and co-efficient of variability of the offspring were also greater than those of the dams, showing the tendency of the individuals of the F_1 generation to reach the extremes of the parental generations. The correlation coefficient of .29 would, according to the statistical method of study of Biparental Inheritance, show evidence of prepotency on the part of the dams as opposed to the sires. This fact may indicate a sex-linkage of the factors controlling inheritance of fat production.

A rearrangement of the data, used in the work just discussed, in classes representing three generations, shows the following coefficients of variability,—parental generation, 21.686, F_1 generation 18.737, and F_2 generation 21.824. This is typically Mendelian, although the fact that there is an artilcial selection which leaves the poorer producers out of the Advanced Registry and also out of the breeding herd, lowers the coefficient. With as large numbers as are under consideration here the effect is probably equal in each generation.

Any attempt to distinguish the unit of inheritance is somewhat futile, when one depends entirely on written records. An attempt was made to find such a unit however, and a dividing point, that separated into two classes was readily recognized. The breeding records of the granddams, classified into different groups with the pound as the unit, were tabulated and compared. For example the granddams producing 12 lbs., (the lowest production allowed in Advanced Registry for a mature animal) were grouped together, their daughters forming the relative class, and their granddaughters the subject class. All the granddams of different productions were grouped in the same way. By inspection of the result, it was found that the granddams producing up to 21 lbs., bred qualitatively the same. At this point appeared a sharp line of demarkation, above which the production in the granddaughters averaged about 21 lbs., while below the production was 17 lbs. The figures for these groups are as follows:

12 lb. granddams—mean production of granddaughters 17.41 lbs.
13 lb. granddams—mean production of granddaughters 16.89 lbs.
14 lb. granddams—mean production of granddaughters 17.68 lbs.
15 lb. granddams—mean production of granddaughters 17.5 lbs.
16 lb. granddams—mean production of granddaughters 17.66 lbs.
17 lb. granddams—mean production of granddaughters 17.2 lbs.
18 lb. granddams—mean production of granddaughters 18.48 lbs.
19 lb. granddams—mean production of granddaughters 17.69 lbs.
20 lb. granddams—mean production of granddaughters 16.32 lbs.
21 lb. granddams—mean production of granddaughters 15.5 lbs.
22 lb. granddams—mean production of granddaughters 25.0 lbs.
23 lb. granddams—mean production of granddaughters 20.44 lbs.
24 lb. granddams—mean production of granddaughters 20.66 lbs.
25 lb. granddams—mean production of granddaughters 23.0 lbs.
26 lb. granddams—mean production of granddaughters 23.5 lbs.
27 lb. granddams—mean production of granddaughters 20.0 lbs.
28 lb. granddams—mean production of granddaughters 20.33 lbs.

A tabulation of the variates within these limits reveals the fact that the granddams having records above 21 lbs. produced F_2 descendants, as follows: 54 above 21 lbs. and 60 below. The granddams below 21 lbs. produced 764 below 21 lbs. and 104 above. The latter appears to be a 7:1 ratio, indicating a linkage of two factors,—one a pure dominant, the other probably sex-linked acting in a simple 3:1 ratio.

These facts, it is true, go but a very short way in the solution of this problem, but it is hoped that they may afford an indication of the means for further investigations.

In the work just reviewed, the points to be noted are:

1st. The relation between the percentage fat composition of milk, and the proportion of fat globules of different sizes.

2d. The prepotency of dams in transmission of fat production to their offspring as evidenced by the correlation coefficient .29 indicating sex-linkage of some of the factors of fat inheritance, and,

3d. The segregation of fat factors in a 7:1 ratio showing further evidence of linkage of factors in the inheritance of fat content of milk.