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The Influence of Age at First Calving on Milk Secretion

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ABSTRACT

A study is reported on the effect of the age at first calving (up to 36 months) on the official yearly milk and fat production of purebred cows of the four dairy breeds. It was observed in all the breeds studied that there was an increase in the yearly milk and fat production as the age at first calving increased. When these data were plotted it was observed that the curve of increase in production was similar to the growth curve, i.e., of exponential form. It was concluded that the most efficient milk and fat production (utilization of nutrients) will be obtained by breeding animals to calve at from 20 to 24 months of age, maximum production at about 30 months of age, and within 5 to 10 per cent of the maximum production at from 23 to 28 months, depending upon the breed.

The Influence of Age at First Calving on Milk Secretion

C. W. TURNER

The fact that production of milk and fat increases gradually with increasing age until about eight years and then gradually decreases with the onset of old age has been demonstrated by a large number of studies with many breeds of dairy cattle. These studies have served as a basis for "conversion factors" designed to convert records of production made at various ages to a comparable basis.

In these studies, however, no mention is made of the underlying factors involved. The question arises, Why do cows increase in production with age up to about eight years?

There are two obvious changes in the dairy cow with the advance in age. There is an increase in size and body weight and also development in the size of the udder as a result of recurring pregnancy. In a study of the growth of lactating dairy cattle Eckles (1920) observed an increase in weight during the first five lactation periods. Turner, Ragsdale, and Brody (1923) studied the change in weight with age of Jersey Register of Merit cattle. These data show that the animals included reached the mature weight of 960 pounds at about 8 years of age.

Similarly Turner (1928) studied the growth of 2700 Guernsey A. R. cattle. It was observed that Guernsey cattle increase in weight with age reaching a weight of 1130 pounds at about eight years.

Recently Johansson (1928), Kapazinsky (1928) and Dawidow (1930) have presented similar data on other breeds of cattle in which growth in weight was observed to increase until approximately the same age.

In connection with the studies of Jersey and Guernsey official records made at this Station, it was found that the increase in body weight and yearly fat production followed the same curve up until the eighth year. From these observations it might be inferred that the increase in milk secretion with age was chiefly due to the increase in body weight (Figs. 1 and 2).

If the increase in body weight is entirely responsible for the increase in milk secretion with age, the influence of body weight on milk secretion may be determined by plotting the yearly fat production at each age interval against the corresponding body weight. Turner, Ragsdale, and Brody (1924) observed that in the case of the Jersey R. of M. data the relation was represented by a straight line (Fig. 3).

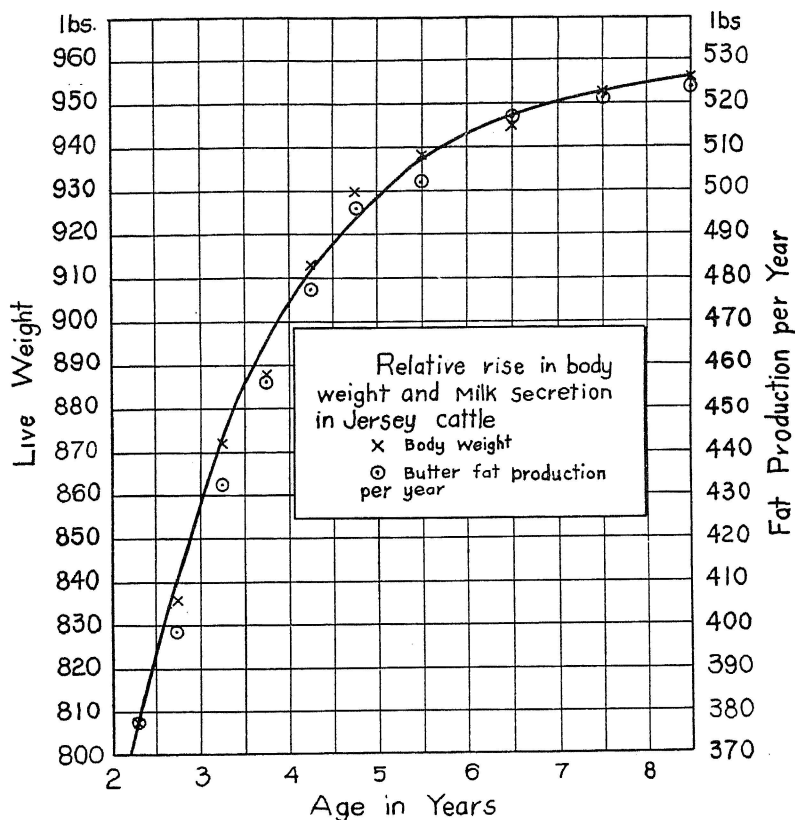


Fig. 1.—Relative Increase in Weight and Fat Production in Jersey Cattle. The increase of body weight with age is indicated by the crosses and the fat production indicated by the circles. It will be noted that both follow the same course.

By fitting an equation to the data, the following results were obtained:

Yearly fat production (lbs.) = $1.04 \text{ weight} - 472.32$. This equation was taken to indicate that after the Jersey cow reaches the body weight of 472 pounds there is an increase of 1.04 pounds in fat production per year for each increase of one pound in body weight.

A similar study of the Guernsey cattle data by Turner (1929) revealed a similar relation (Fig. 4). The equation obtained was of the form: Yearly fat production = $0.77 \text{ weight} - 304.74$. This equation indicates that with an increase of 100 pounds in body weight accompanying growth there is an increase of about 77 pounds in yearly fat production after the cow reaches the body weight of 305 pounds.

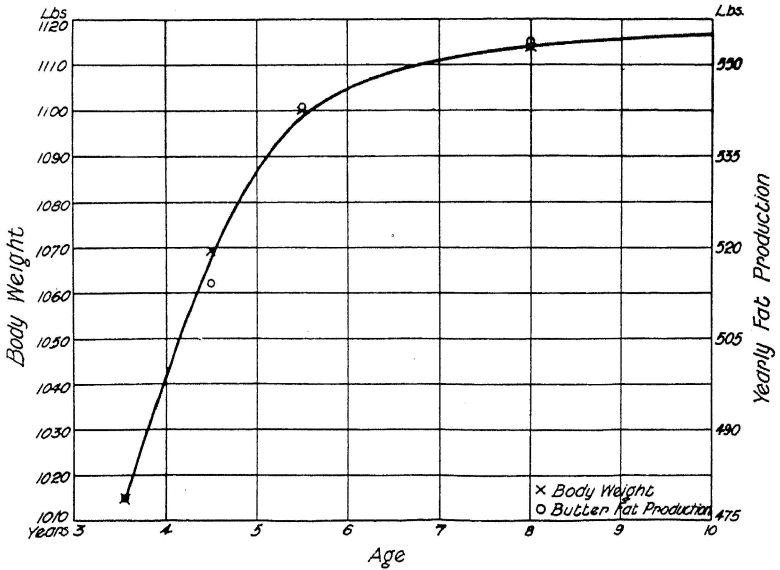


Fig. 2.—Relative increase in body weight and yearly fat production in Guernsey cattle.

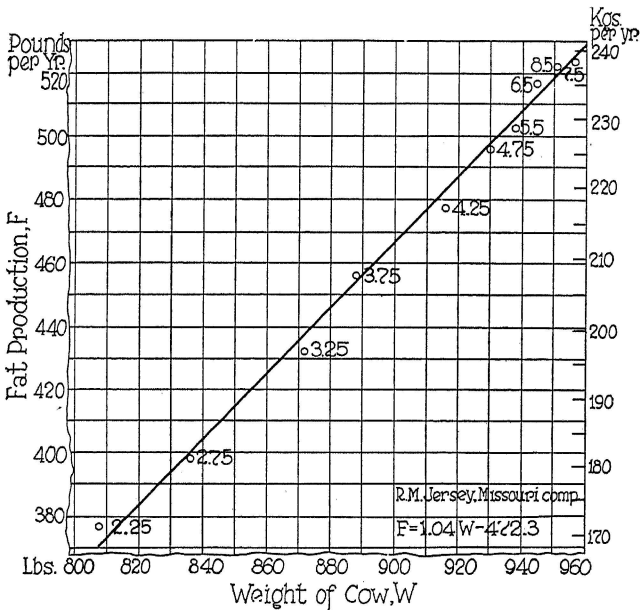


Fig. 3.—The increase of milk secretion with increasing body weight with age in Jersey cattle. The smooth line passing through the observed values was plotted from the equation $F = 1.0423W - 472.32$ in which F is the yearly milk fat production for any body weight (W). From this equation an increase of 100 pounds in the weight of the body with age is accompanied by an increase of about 104 pounds of milk fat per year. The numerals on the curve represent the ages of the animals in years.

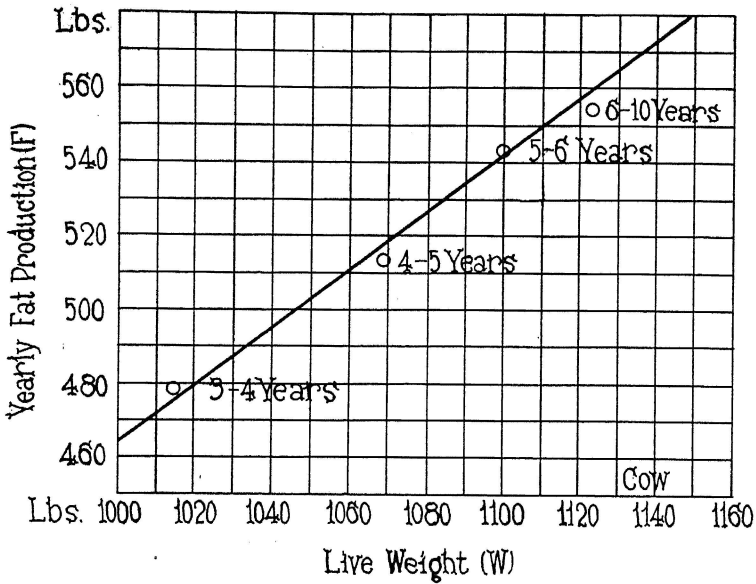


Fig. 4.—The Increase of Yearly Fat Secretion with Increase in Age and Live Weight in Guernsey Cattle. The line passing through the observed values was fitted by the method of least squares. With the determinations of the parameters, the equation takes the form $F = 0.77W - 304.73$, in which F is the yearly fat production for any live weight W . This equation indicates that with an increase of 100 pounds in live weight accompanying age there is an increase of 77 pounds of fat per year above 304.73 pounds. The corresponding equation for the Jersey breed was $F = 1.042W - 472.32$.

However, with increasing age and the recurrence of pregnancy there is an increase in the size of the udder. The growth of the udder is not dependent upon age directly but rather upon the recurrence of pregnancy. The growth of the udder remains very rudimentary even at advanced age without the occurrence of pregnancy. Milk secretion is thus dependent upon the hormonal stimulus of the mammary gland accompanying pregnancy.

The influence of recurring pregnancy on the yield of milk and fat has not been measured directly. It would require that records of production be classified according to the number of pregnancies (or lactations) at constant age and weight.

It is possible, however, to indirectly measure these two factors. This is accomplished by separating the records of production into year age groups and then measuring the relation between body weight and fat production. Thus practically all of the animals in the two-year-old age group would have an udder developed by a single pregnancy, those

in the three-year-old group would be further developed by two pregnancies, etc. The relation between increasing body weight and yearly fat production in any age group, i. e., the two-year-old animals etc., would measure the influence of weight alone. Or considered in another way, the comparison of cows of similar weight, i. e., 900 pounds, at each succeeding age interval would measure the influence of recurring pregnancy alone.

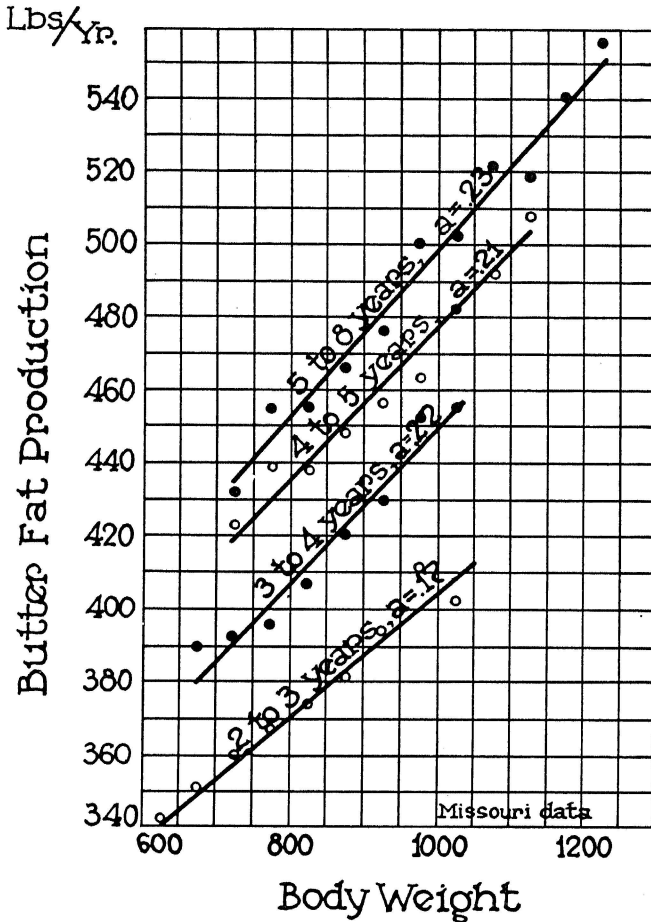
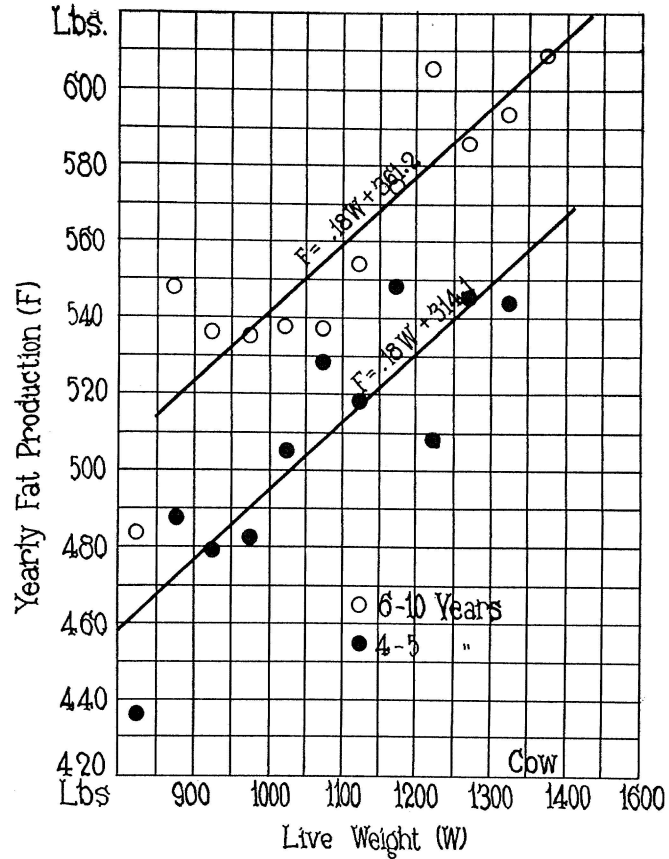
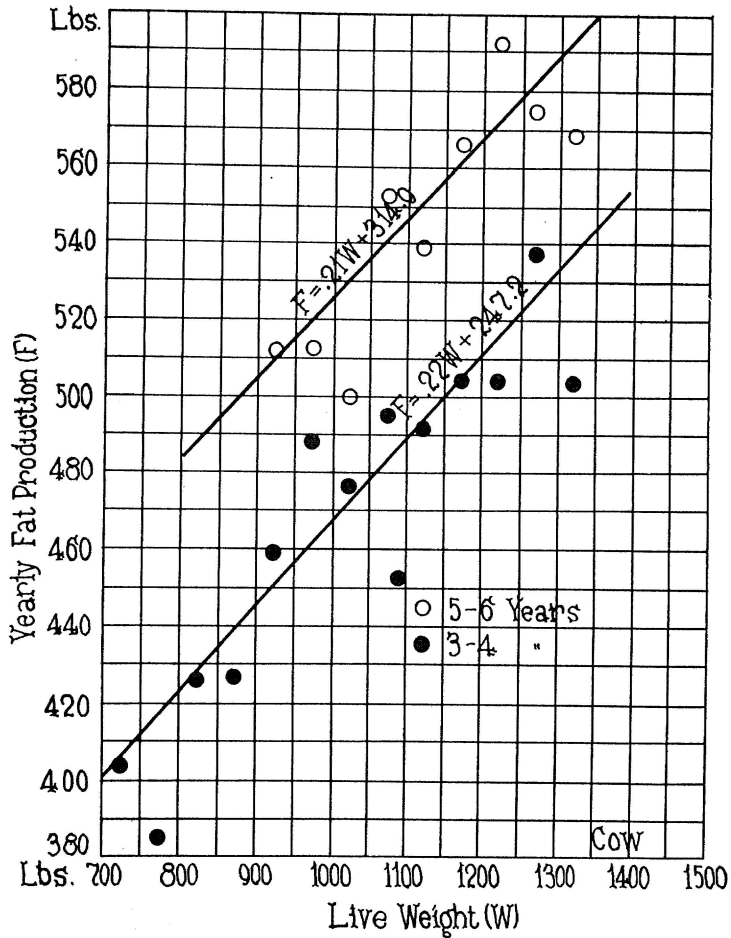


Fig. 5.—The increase of milk secretion with increasing body weight at constant age. The smooth lines passing through the observed values were plotted from the equation $F = aW + b$, in which F is the yearly milk fat production for the body weight (W) at the constant ages indicated on the curves; a is the constant increase of yearly fat production for each added pound of body weight. From the values of a indicated on the curves, an increase of 100 pounds in the weight of the body is accompanied by an increase of 20 pounds of milk fat production per year.



Figs. 6 and 7.—Presenting the Increase in Fat Secretion with Increasing Body Weight for Various Age Groups (Age Held Constant). The straight lines passing through the observed values were fitted by the method of least squares from the equation of the form $F = aW + b$, in which F is the yearly fat production for the body weight W; a is the constant increase of yearly fat production for each added pound of body weight. From the values of a indicated on the lines, it will be noted that an increase of 100 pounds in the weight of the body is accompanied by an increase, on the average, of 20 pounds of fat production per year.

When the production data for the Jersey and Guernsey breeds were analyzed by this method, the striking observation was made that *body weight is a minor influence on the production of fat as compared with recurring pregnancy* (Figs. 5, 6 and 7). The relative value of an increase of body weight as compared to the development of the mammary gland with pregnancy may be estimated from a comparison of the curves. The Jersey records show that instead of an increase of 104 pounds of fat for an increase of 100 pounds of body weight, when the age is constant, there is an increase of about 20 pounds of fat for each 100 pounds of body weight.

On the other hand, at a constant body weight (900 pounds for example) the two-year-old cows average 387 pounds, the three-year-olds 427 pounds, the four-year-olds 455 pounds, and the 5- to 8-year-old group 475 pounds of fat.

It appears that the increase of body weight contributes about 20 per cent to the total increased fat production with age, while 80 per cent of increased fat production with age is due to the development of the mammary glands with recurring pregnancy.

In the case of the Guernsey data the results are quite similar. Instead of an increase of 77 pounds of fat per 100 pounds increase in the body weight with age, at constant age the average increase in fat production was only 20 pounds per 100 pounds increase in body weight. From these figures it would appear that about 25 per cent ($\frac{20}{77}$) of the total increase of fat secretion with age is due to the increase of the body weight of the animals concerned, while the other 75 per cent of the increase in fat secretion with age is due to the development of the udder by recurring pregnancies.

Assuming the above relation exists between the influence of body weight and recurring pregnancy on the yearly fat production, it is pos-

TABLE 1.—FAT PRODUCTION DUE TO BODY WEIGHT CHANGES AND UDDER DEVELOPMENT WITH AGE

Age	Yearly Fat Production (calculated)		Yearly Increase in Fat Production		Yearly Increase in Fat Due to Body Weight		Yearly Increase in Fat Due to Udder Development	
	Jersey	Guernsey	Jersey	Guernsey	Jersey	Guernsey	Jersey	Guernsey
	<i>lbs.</i>	<i>lbs.</i>	<i>lbs.</i>	<i>lbs.</i>	<i>lbs.</i>	<i>lbs.</i>	<i>lbs.</i>	<i>lbs.</i>
2.5	383	410	----	----	----	----	----	----
3.5	443	461	60	51	12.0	13.0	48.0	38.0
4.5	486	491	43	30	8.6	7.5	34.4	22.5
5.5	502	511	16	20	3.2	5.0	12.8	15.0
6.5	516	521	14	10	2.8	2.5	11.2	7.5
7.5	521	528	5	7	1.0	2.0	4.0	5.0
			138	118	27.6	30.0	110.4	88.0

sible to determine at each age, the relative contribution of the two factors toward the increased production observed. (Table 1). It will be noted that the increase in yearly fat production at 3.5 years for Jersey cattle over the 2.5 year's production is 60 pounds. Of this production 12 pounds may be considered as due to increasing weight with age and 48 pounds due to the development resulting from a second pregnancy.

For comparison with these data on milk and fat production produced under official test conditions, there are available the records of all the dairy breeds made under cow testing association conditions tabulated by McDowell (1930). The study included only mature cows (5-9 years of age). The relation between the increase in body weight and yearly fat production for all breeds was studied by the writer. It was found that under cow testing conditions there was an increase of from 10 to 15 pounds in yearly fat production for an increase of 100 pounds in body weight.

In comparison with official records, it will be noted that these data indicate a significantly lower return in yearly fat production with increasing body weight. This would be expected, considering the lower level of production of these animals.

Considering these data from the standpoint of the economical production of milk and fat, attention is called to the factors involved in the feed cost. The feed cost of milk and fat production is dependent upon two factors, the cost of maintenance of the animal body and the cost of producing milk. The feed cost of maintenance increases with the body weight of the cow, while the feed cost of milk production varies with the yield. It is upon these facts that the feeding standards are based.

Knowing the feed cost of maintenance for increases in the body weight of the cow it is possible to determine whether the increase in yearly fat production pays the increased maintenance cost of the greater size. Using the Morrison feeding standard for dairy cattle, it was observed (Turner 1930) that only when total digestible nutrients are relatively cheap and the price of butterfat is relatively high is there a fair spread between the feed cost of maintenance and the value of the butterfat produced.

Gaines (1931) has recently reported the results of a study of the records of production, and body weight of Cow Testing Association cows tabulated by McDowell. He applied an efficiency formula based on the relation between the digestible nutrients consumed by the cow and the digestible nutrients in the milk produced as indicated by the Haecker feeding standard. The formula is further based on the production of a uniform 4 per cent milk (Gaines 1928).

$$\text{Coefficient of efficiency} = 52.6 \frac{\text{Pounds of 4\% milk}}{\text{Pounds of 4\% milk} + 8.847 \text{ weight}}$$

Using this formula Gaines found that *the average efficiency of all breeds of dairy cattle on Cow Testing Association test declined as the body weight increased*. In other words, from the standpoint of transforming the digestible nutrients in the feed into milk the smaller cows were, on the average, more efficient than the larger.

From these observations certain conclusions of great practical importance may be drawn. It would appear, first, that dairymen concerned chiefly with the problem of producing milk economically should not try to breed animals above the average weight of the breed unless the animals concerned are exceptional producers.

Second, dairy cattle should not be selected on the basis of size alone. The cow above the average size of the breed will, on the average, be less efficient in transforming digestible nutrients in the feed into milk than the smaller animal.

While in general the above statement appears to represent the physiological relation, it should be clearly understood that in individual cases it is quite possible for large animals to be economical producers of milk and fat. The converse is also true, that small individuals may in many cases be uneconomical producers.

A middle course is open to progressive breeders of dairy cattle. It consists in the selection of breeding animals not only on the basis of milk and fat production or for large body weight but upon the efficiency of production considering both production and body weight.

REVIEW OF EXPERIMENTS ON AGE AT FIRST CALVING

The observation that the recurrence of pregnancy is responsible for the major portion of the increase in production with age and further that the average efficiency of dairy cattle declines with the increase in body weight, is believed by the writer to make desirable a re-examination of the factors to be considered in determining the most satisfactory age for first calving in dairy cattle.

Eckles (1915) appears to be one of the first to have made a study of the influence of early and late calving on the production of dairy heifers. The early calving group, consisting of six Jerseys and two Holsteins, was bred to calve at 20 to 24 months of age and the late calving group, consisting of four Jerseys and five Holsteins, was bred to calve at 30 to 34 months of age. Slightly more milk and fat were produced by the late calving group. However, the number of animals in each group is very small. The question of light and heavy feeding was also considered.

In addition to the above study, the records of the Holstein and Jersey cows in the Station Herd were tabulated as to the age of first

calving. The average milk and fat production for these various groups was then determined for the first, second, and third lactation periods.

From the standpoint of securing the greatest development as a dairy animal, Eckles believes it is decidedly disadvantageous for a Jersey cow to calve under 24 months of age, while nothing seems to be gained by allowing her to reach an age more than 30 months. The smaller number of Holsteins give less basis for such a statement, but it also indicates that the best milk producers are on the average found among those which are well matured before coming into milk for the first time.

At the Pennsylvania Station, Beam (1918) compared the average production of the first calf heifers calving at various age intervals. The following table shows little advantage in late calving. (Table 2).

TABLE 2.—EFFECT OF AGE OF CALVING ON FAT PRODUCTION
(Beam 1918)

Age at Calving	Number of Cows	Percentage of Cows	Average Fat Production
<i>months</i>			<i>lbs.</i>
18-24	21	12	261
24-30	75	43	268
30-36	52	30	278
36-40	27	15	252
Total	175		

In addition to these studies White (1917) compared two groups of Holstein cows. The five early calvers (ave. age 2 years, 1 month) averaged 7691 pounds of milk and 273 pounds of fat in 356 days. The five late calvers (ave. age 3 years, 1 month) averaged 13128 pounds of milk and 443 pounds of fat in 349 days. Of this latter group two cows were exceptional producers.

Towles (1918) also studied the production of 15 Ayrshire heifers, but the groups of four, five, and six animals in a lot can scarcely be relied upon to eliminate individual variation.

Considering these several studies based upon rather limited data, it appears that the average milk and fat production increases with the delay in calving, but not to any great extent. The weights of the animals were not included, neither were the economic aspects of the question considered.

Due to the great savings that might be realized by earlier calving it seemed desirable to extend the study to the Advanced Registry data of the dairy breeds in order to obtain larger numbers of animals in each age group. The object of this bulletin is to report the results of that study.

PRESENTATION OF DATA

The Source of The Data.—The Advanced Registry and Register of Merit records of the four breeds of dairy cattle served as the source of the data. All first-entry records from the earliest age available up to and including three years were divided into groups by monthly intervals.

Two objections to the use of these records should be noted. All records are subject to the minimum entrance requirements. As a result all records below the fat production specified for the age in question are eliminated. As will be noted later methods of correction for the progressive elimination due to this factor are outlined.

A second factor which must be considered in the use of these data are the recent changes (increase) in the minimum entrance requirements. Whenever possible there has been included only those records completed previous to the change in the entrance requirements:

The Ayrshire Advanced Registry records included in Vols. 1 to 4 inclusive were tabulated for this study. These volumes include all records reported up to January 31, 1924. The records in Vol. 1 are subject to the minimum entrance requirements beginning at 214.3 pounds of fat and 6000 pounds of milk at two years. Beginning January 1, 1919, the minimum entrance requirements were increased to 250.5 pounds of fat.

All records published up to Dec. 31, 1924, included in the Guernsey Advanced Registry were tabulated for this study.

The study of Holstein-Friesian A. R. S. O. records includes the reports in Vol. 18 to 34, ending March 31, 1923.

The Jersey R. of M. records included in the present study were those found in the consolidated volume which included all records completed to May 15, 1924. As the minimum entrance requirements were raised to 290.5 pounds on July 1, 1921, this study included some records under both requirements.

The Age at First Calving.—Under ordinary conditions, cows to be placed on official test would not be bred as early as those in herds in which official testing is not being conducted. As a consequence it might be expected that the animals included in this study would, on the average, calve at a later date than animals kept under average herd conditions. It should be pointed out, therefore, that the age at first calving observed in these data apply to purebred cows subject to an official test.

These data are subject to the further arbitrary restriction as to the upper age limit of three years. It is reasonably certain that most of the animals included were calving for the first time, however, it is possible that in the older age classes, i. e., 32 to 36 months, a few may be calving

for the second time. This would be possible if they had calved at an early age the first time and were not placed upon test. In fact, there appears to be some indication that such was the case. (In several breeds the frequency increased in the 35 month old class). For the above reason it seemed better to restrict the study to original entry cows not over three years (36 months) even though by so doing part of the population of first-calf animals would be eliminated.

TABLE 3.—AGE AT FIRST CALVING OF COWS ON OFFICIAL TEST

Age at First Calving (months)	Ayrshire A. R. records		Guernsey A. R. records		Holstein A. R. S. O. records		Jersey R. of M. records	
	Fre- quency	Per- centage	Fre- quency	Per- centage	Fre- quency	Per- centage	Fre- quency	Per- centage
13	---	---	---	---	---	---	2	.02
14	---	---	---	---	---	---	1	.01
15	---	---	---	---	---	---	2	.02
16	---	---	1	.01	---	---	14	.14
17	2	.12	3	.04	3	.09	33	.33
18	2	.12	6	.08	9	.26	57	.57
19	3	.18	12	.16	6	.18	63	.63
20	5	.30	22	.30	14	.41	134	1.33
21	11	.66	49	.67	19	.56	240	2.38
22	16	.96	110	1.50	51	1.49	453	4.50
23	34	2.04	250	3.41	147	4.60	873	8.67
24	74	4.44	558	7.61	244	7.15	1035	10.28
25	88	5.28	689	9.40	301	8.82	1035	10.28
26	98	5.88	778	10.61	357	10.46	1036	10.29
27	106	6.36	750	10.23	281	8.23	913	9.07
28	164	9.84	737	10.05	275	8.06	696	6.91
29	159	9.54	747	10.19	265	7.76	628	6.24
30	185	11.10	557	7.60	245	7.18	504	5.01
31	155	9.30	467	6.37	231	6.77	421	4.18
32	129	7.74	385	5.25	210	6.15	349	3.47
33	134	8.04	346	4.72	187	5.48	375	3.72
34	105	6.30	282	3.85	167	4.89	394	3.91
35	110	6.60	310	4.23	219	6.41	422	4.19
36	86	5.16	274	3.74	183	5.36	389	3.86
Total	1666		7333		3414		10069	
Mean	29.8 ± 0.609		28.5 ± 0.029		28.8 ± 0.046		27.3 ± 0.029	
S. D.	3.68 ± 0.043		3.66 ± 0.020		4.01 ± 0.033		4.27 ± 0.020	
C. V.	12.37 ± 0.147		12.88 ± 0.073		13.89 ± 0.101		15.64 ± 0.076	

The youngest heifers to calve were of the Jersey breed, two of which calved at 13 months of age. If pregnancy was of normal duration this would indicate that successful conception took place at four months of age. The number of animals calving during each succeeding month increased until the 24th month. The same number calved during the two following months. Thus it would appear that over 30 per cent of the Jersey cows on test calve for the first time between the 24th and

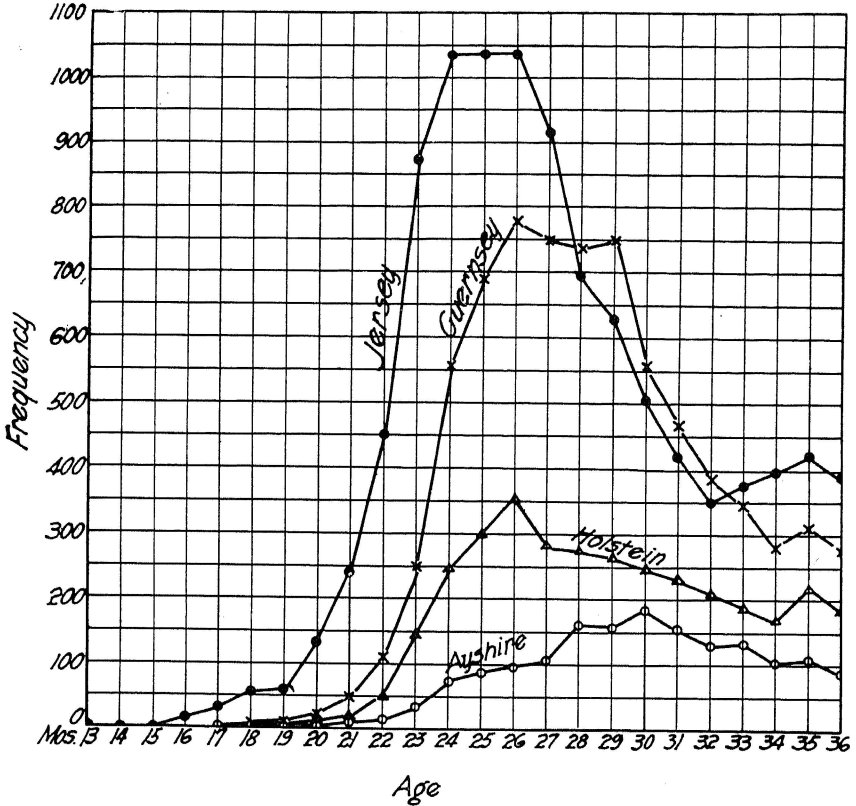


Fig. 8.—The age frequency of purebred cows on official test calving for the first time. The mean age of calving was as follows: Jersey 27.3 months, Guernsey 28.5 months, Holstein 28.8 months, and Ayrshire 29.8 months.

26th months. The mean age of first calving of these animals was 27.3 months. (Table 3 and Fig. 8).

The youngest Guernsey cow placed on test was 16 months old at the time of parturition. The greatest number calved during the 26th month although the number calving during the following three months was only slightly smaller. From the 26th to the 29th month over 40 per cent of the entire number calved. The mean calving age of these Guernsey cattle was 28.5 months, 1.2 months older than the Jerseys.

The Holstein-Friesian heifers increase in their frequency of calving until the 26th month and then gradually decline. The mean age of calving for the first time was 28.8 months, 0.3 months older than the Guernsey heifers, and 1.5 months older than the Jersey heifers.

The Ayrshire heifers reach the age of 30 months before the mode is reached. About 40 per cent of the population calve between 28 and 31 months of age. The mean age at first calving, 29.8 months, is about a month older than that of the Holstein and Guernsey cattle and 2.5 months older than the Jersey.

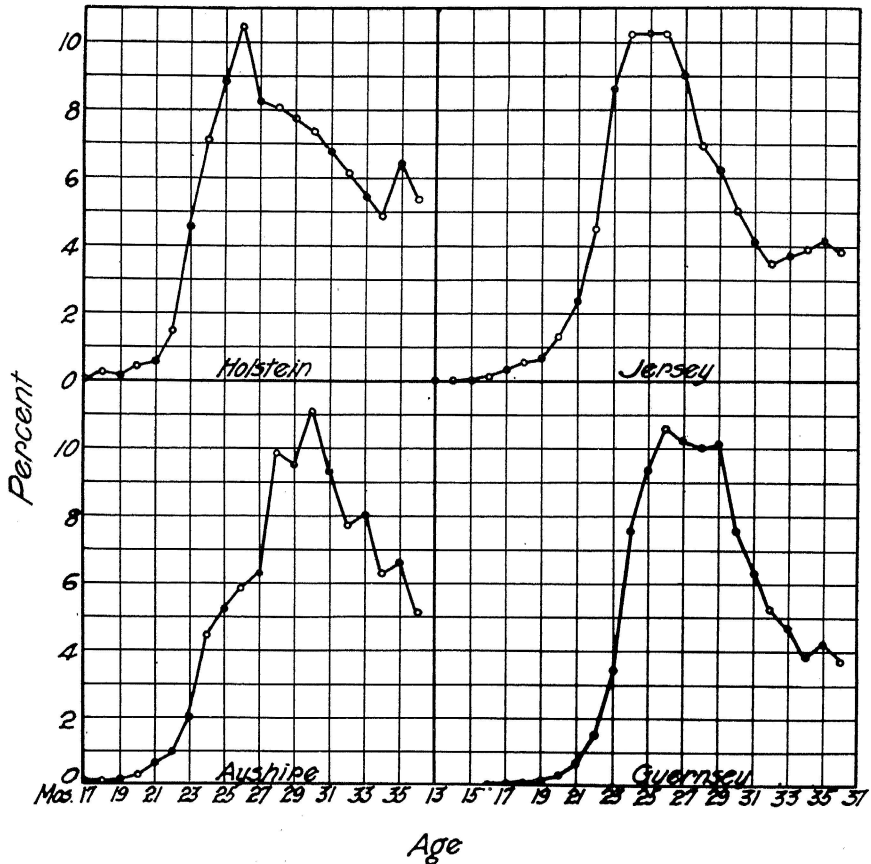


Fig. 9.—Percentage frequency in the age at first calving of cows on official test. The increase in the frequency at the 35th month in several breeds may indicate the inclusion of a few cows calving for the second time. This would be possible if the first lactation was not official.

Factors Affecting the Yield of Milk Secretion During the First Lactation.—During the first gestation period, the growth of the mammary gland is very rapid. At the approach of parturition, the growth stage is superseded by active lactation. After parturition milk secretion increases for a time and then gradually declines. The active growth and

increase in size of the mammary gland does not occur to any extent again until the following pregnancy as only slight development occurs with recurring estrus cycles (Turner 1931).

This being true, the difference in the average productive ability of dairy heifers during their first lactation period must lie in the differences in inheritance for milk secretion, differences in the environment, differences in the body weight at calving time, differences in the age of the heifers aside from weight, differences in the minimum entrance requirements, etc.

The variation in milk secretion of heifers due to genetic and environmental differences cannot be measured easily. With large numbers of animals in each age group the importance of these factors as disturbing influences in the study can be reduced to a minimum although there may still remain some bias in that breeders with the better prospective animals may delay breeding unduly, thus tending to throw the genetically better and those under the most favorable environment into the older age classes.

The increase in body weight during the period under consideration (from about 18 to 36 months) is very rapid. Animals calving at about 18 months would be considerably lighter than those calving at 36 months. The average body weight change during this period for each breed will be considered in detail shortly. It is sufficient here to point out that this factor is believed to be the fundamental cause of the difference in the productive ability of heifers during the first lactation period when other factors are held constant.

The influence of age aside from the accompanying increase in body weight may be a factor of importance. Just how the increase in age would influence milk secretion is not clear, however. It has been shown that young animals are more persistent in lactation than older animals (Turner 1927). If this same relation holds true within the group of animals considered, it would favor the younger animals rather than those calving for the first time at a more advanced age.

The influence of the minimum entrance requirements in causing a slight artificial increase in the fat production especially requires more detailed treatment.

Correction for the Minimum Entrance Requirement.—The minimum entrance requirements for the Advanced Registry are 250.5 pounds of butterfat at two years of age and under, except for the early Ayrshire records. Above two years, the requirements increase at the rate of 0.1 pounds per day or 3.0 pounds for each 30 day month. The gradual increase in the requirements each month eliminates an increasing number of cows in the first frequency class, namely that from 250

to 274 pounds of fat. (In tabulating these data, a class interval of 25 pounds of fat and 500 pounds of milk was used for all breeds). Thus in the 2 year, 0 month class, the requirements would vary from 250.5 pounds to 253.5 pounds or an average of 1.5 pounds above the minimum of 250.5 pounds or 252 pounds.

As a consequence, the 2 year, 0 month age class would include only $\frac{23}{25}$ of the normal population, in the 250 to 274 pound fat class. The

2-1 class would contain only $\frac{20}{25}$ of the normal population, etc., until the

2-7 group would contain only $\frac{2}{25}$ of the normal population.

TABLE 4.—CORRECTION FACTORS FOR THE ELIMINATION DUE TO THE MINIMUM ENTRANCE REQUIREMENTS

Age Years-months	Minimum Entrance Requirements Ave.	Relation to Upper Class Limit (274 lbs.)	Relation to Upper Class Limit (299 lbs.)	Conversion Factors
	<i>lbs.</i>			
2-0	252	23	--	1.0869
2-1	255	20	--	1.2500
2-2	258	17	--	1.4705
2-3	261	14	--	1.7854
2-4	264	11	--	2.2727
2-5	267	8	--	3.1250
2-6	270	5	--	5.0000
2-7	273	2	--	12.5000
2-8	276	--	24	1.0416
2-9	279	--	21	1.1904
2-10	282	--	18	1.3888
2-11	285	--	15	1.6666
3-0	288	--	13	1.9230

Knowing the actual population in the 250 to 274 pound group, the population which might have been present had not the entrance requirements increased, can be computed by simple proportion, or by the determination of the appropriate conversion factor to use. (Table 4.)

The entire population in the 250 to 274 pound fat class is eliminated in the age classes 2 years, 8 months and above. The above method can then be applied to compute the estimated population in the 275 to 299 pound class. To estimate the population in the first fat class (250 to 274 pounds) the ratio of the population in the first class to the population

in the second class (275 to 299 pounds) for the ages from 2 years, 0 months to 2 years, 7 months, was used as a basis in computing the probable frequency in the first class. Thus the computed frequency in the first class totaled 508, and the actual frequency in the second class totaled 681. The ratio $\frac{508}{681} = 0.746$. The computed frequency in the 275-299 pound fat class for the 2 year, 8 month group equaled 22. This frequency was multiplied by 0.746, giving 16 as the computed frequency in the 250-274 pound fat class (Table 5).

TABLE 5.—CORRECTIONS OF FREQUENCY DISTRIBUTIONS

Age Years-months	Actual Frequency Distribution Class 250-274	Computed Fre- quency Distribu- tion Class 250-274	Actual Frequency Distribution Class 275-299	Computed Fre- quency Distribu- tion Class 275-299
2 0	94	102	113	--
2 1	62	78	123	--
2 2	59	69	114	--
2 3	53	95	102	--
2 4	17	39	71	--
2 5	16	50	68	--
2 6	10	50	55	--
2 7	2	25	35	--
Total --	--	508	681	--
2 8	0	16	21	22
2 9	0	29	33	39
2 10	0	38	37	51
2 11	0	28	23	38
3 0	0	30	21	40

$$\text{Ratio } \frac{508}{681} = 0.746$$

By the methods described, it is believed that the population either partially or entirely eliminated by the gradual increase in the minimum entrance requirement may be equitably corrected.

This method can only be used when the minimum entrance requirements are uniform. Due to the fact that the standards in the Ayrshire breed had been changed, no correction was attempted. While the same is true of a part of the Jersey records, they were such a small proportion of the total that the correction was made.

As would be expected the computed production at each age class is either the same or slightly less than the actual production under the minimum entrance requirements. As the age increases there is a tendency for the difference in the computed average yearly fat production to increase slightly (Table 6).

TABLE 6.—INFLUENCE OF THE MINIMUM ENTRANCE REQUIREMENTS ON THE AVERAGE FAT PRODUCTION

Age (mo.)	Guernsey				Holstein-Friesian				Jersey			
	Frequency		Average Yearly Fat Production		Frequency		Average Yearly Fat Production		Frequency		Average Yearly Fat Production	
	Actual	Computed	Actual	Computed	Actual	Computed	Actual	Computed	Actual	Computed	Actual	Computed
24	558	560	393.7	393.3	244	244	460.9	460.9	1034	1042	375.8	365.8
25	689	694	407.4	406.3	301	302	483.0	482.3	1035	1066	376.3	372.9
26	778	786	420.8	419.2	357	359	481.2	479.9	1036	1064	374.5	371.7
27	750	765	425.7	422.4	281	283	490.5	490.2	913	955	374.7	368.8
28	737	746	433.9	431.8	275	277	493.6	491.9	696	717	383.5	379.8
29	747	760	437.1	434.1	265	267	505.5	503.7	628	662	382.6	377.3
30	557	565	440.9	438.4	245	249	484.1	480.5	504	545	381.6	372.8
31	467	479	443.3	438.7	231	242	508.4	497.2	420	444	395.3	388.4
32	385	392	441.7	438.5	210	214	517.0	512.2	349	366	408.3	401.6
33	346	357	442.1	436.6	189	191	507.5	504.9	375	410	391.4	380.7
34	282	297	441.6	433.0	167	168	511.4	509.9	399	451	396.4	381.6
35	310	323	444.7	437.8	219	223	525.1	520.5	423	466	405.0	388.8
36	274	279	438.2	435.3	183	188	511.3	504.9	389	438	399.4	385.1

While it is clear that the minimum entrance requirements increase the average yearly fat production in the records studied, the increase is not believed to be sufficiently large to invalidate the conclusions which can be drawn from the analysis of the actual records. It therefore seemed better to study the actual records since by so doing both milk and fat production records could be included.

WHAT THE STUDY SHOWS

It will be recalled that in the present study, the actual records for each monthly age group rather than computed records were used even though a slight error is introduced thereby due to the gradual increase in the minimum entrance requirements. As a consequence the records increase slightly more rapidly than they otherwise would with the advance in age after two years.

Ayrshire cattle.—The number of records in the age groups below 24 months is too limited to indicate the true trend in the production of milk and fat at this time. The production of the young animals is rather irregular but usually considerably higher than that which would be expected considering the average production of the older age groups. It would appear as though these early records were made by a highly selected group of animals. Only the very best animals, i. e., those coming into a good flow of milk, would be placed on test when calving extremely early.

From 24 to 36 months of age the number of records seem adequate to give an indication of the change in production which might be ascribed to the age changes prior to the first calving. (Table 7 and 8.)

The change in milk and fat production with age, when plotted, is observed to be similar to that of the curve of growth of dairy cattle. The increase in production per month is at first fairly large but gradually declines up to about 36 months of age.

In order to determine whether the rate of increase in production was of exponential form, the increments in monthly production were plotted on semi-logarithmic paper. These points were observed to fall quite well along a straight line. As a consequence, an equation of the form $M = A - Be^{-kt}$ used by Brody (1927) to describe the course of growth following the inflection in dairy cattle was fitted to the data. A satisfactory fit of the data is shown in Fig. 10. In this equation M (or F) is the yearly milk (or fat) production, A the maximum yearly production of milk or fat produced as the result of the first pregnancy, B "an age-parameter employed to correct for the fact that while age is counted from birth, the equation fits the data during the phase of growth following the inflection only" (see discussion by Brody for further de-

TABLE 7.—EFFECT OF AGE AT FIRST CALVING ON YEARLY MILK PRODUCTION
AYRSHIRE BREED

Age Months	Number of Cows Included	Yearly Milk Production Calculated from Equation. (lbs.)	Yearly Milk Production (lbs.)	Standard Deviation (lbs.)	Coefficient of Variation	Yearly Milk Production F. C. M.** (lbs.)
17	2	----	7118.0	----	----	7055
18	2	----	7107.0	----	----	7305
19	3	----	6911.7	----	----	6894
20	5	----	7796.8	----	----	7748
21	11	----	7999.1	----	----	8051
22	16	----	6812.0	----	----	6842
23	34	----	7807.7	----	----	7793
24	74	7527	7506.5 ± 103.35	1318.1 ± 73.07	17.56 ± 1.00	7540
25	88	7884	7868.2 ± 101.27	1408.5 ± 71.61	17.90 ± .94	7908
26	98	8156	8081.5 ± 88.51	1299.0 ± 62.58	16.07 ± .79	8085
27	106	8371	8409.9 ± 109.41	1670.0 ± 77.36	19.86 ± .96	8533
28	164	8533	8611.5 ± 105.01	1993.7 ± 74.25	23.15 ± .91	8675
29	159	8663	8347.0 ± 87.08	1628.0 ± 61.57	19.50 ± .76	8485
30	185	8760	8577.0 ± 83.06	1675.0 ± 58.73	19.53 ± .71	8682
31	155	8838	8859.2 ± 100.50	1855.0 ± 71.06	20.94 ± .84	8923
32	129	8896	8962.7 ± 92.38	1555.6 ± 65.32	17.36 ± .75	9093
33	134	8943	8843.5 ± 99.35	1705.0 ± 70.24	19.28 ± .82	8970
34	105	8977	9064.0 ± 113.05	1717.5 ± 79.93	18.95 ± .91	9087
35	110	9006	9186.0 ± 118.98	1850.0 ± 84.12	20.15 ± .95	9271
36	86	9026	8686.0 ± 104.45	1436.0 ± 73.85	16.53 ± .81	8804

*Milk = $9100 - 715000e^{-.255t}$ **F. C. M. = $15 F. + 4M$ TABLE 8.—EFFECT OF AGE AT FIRST CALVING ON YEARLY FAT PRODUCTION
AYRSHIRE BREED

Age Months	Number of Cows Included	Yearly Fat Production Calculated from Equations* (lbs.)	Yearly Milk Production (lbs.)	Standard Deviation (lbs.)	Coefficient of Variation	Average Fat Percentage
17	2	----	280.5	----	----	3.94
18	2	----	279.5	----	----	3.93
19	3	----	275.3	----	----	3.98
20	5	----	308.6	----	----	3.96
21	11	----	323.4	----	----	4.04
22	16	----	274.5	----	----	4.03
23	34	----	311.3	----	----	3.99
24	74	300.3	302.5 ± 45.87	58.5 ± 3.24	19.34 ± 1.11	4.03
25	88	316.0	317.4 ± 41.06	57.1 ± 2.90	18.01 ± .94	4.03
26	98	327.7	323.5 ± 40.13	58.9 ± 2.84	18.21 ± .91	4.00
27	106	336.8	344.6 ± 48.41	73.9 ± 3.42	21.47 ± 1.04	4.10
28	164	343.9	348.7 ± 40.50	76.9 ± 2.86	22.05 ± .86	4.05
29	159	349.1	343.1 ± 34.50	64.5 ± 2.44	18.82 ± .74	4.11
30	185	353.1	350.1 ± 38.98	78.6 ± 2.76	22.46 ± .83	4.08
31	155	356.2	358.6 ± 40.90	75.5 ± 2.89	21.05 ± .84	4.05
32	129	358.5	367.2 ± 38.36	64.6 ± 2.71	17.60 ± .76	4.10
33	134	360.3	362.2 ± 45.92	78.8 ± 3.25	21.78 ± .93	4.10
34	105	361.7	364.1 ± 49.43	75.1 ± 3.50	20.63 ± 1.00	4.02
35	110	362.7	373.1 ± 49.33	76.7 ± 3.49	20.57 ± .97	4.06
36	86	363.5	355.3 ± 46.33	63.7 ± 3.28	17.93 ± .94	4.09

*Fat = $366 - 45000e^{-.272t}$

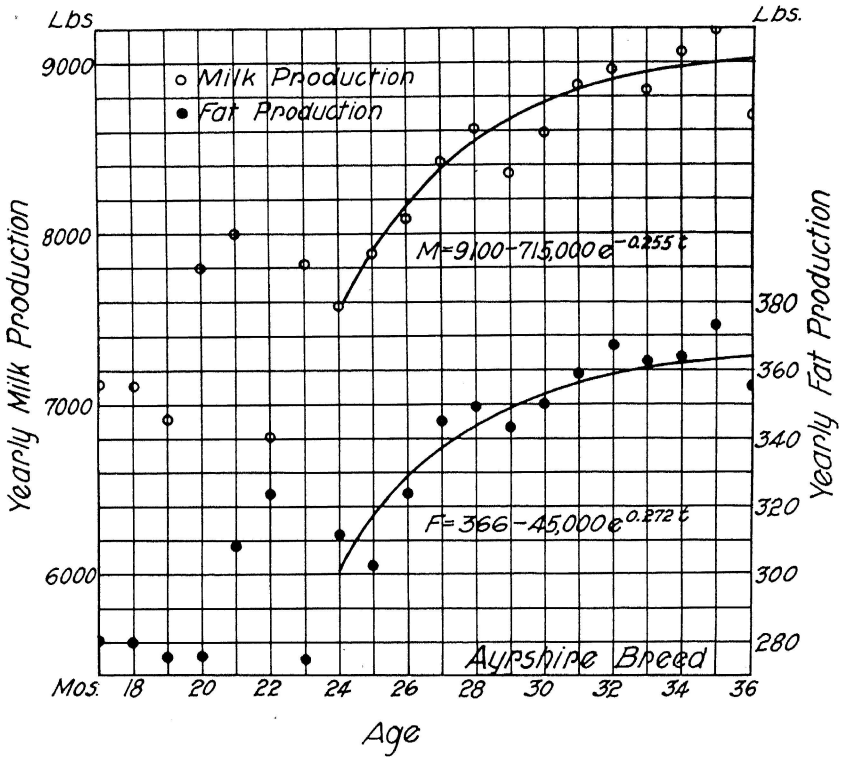


Fig. 10.—The change in the milk and fat production of Ayrshire cows on test with advance in the age at first calving is presented graphically. Equations of the form

$$M = A - Be^{-kt}$$

were fitted to the data. It will be noted that the fit is quite satisfactory where the data are sufficient to give a reliable mean production.

tails), k the rate of increase in milk or fat production, and t the age in months from birth.

It appears from these data that little is to be gained in the way of increased milk and fat production by delaying the first calving of Ayrshire cattle beyond 30 months of age. These data do indicate an average increase of approximately 50 pounds of butterfat and 1200 pounds of milk by delaying the calving from 24 to 30 months of age. It should be noted, however, that with each month's advance in age to 30 months, the benefit of further delay rapidly decreases.

Guernsey cattle.—The early Guernsey records were observed to be similar to the Ayrshire records in that a large proportion of the exceptional producers were tested giving higher averages than would be

TABLE 9.—EFFECT OF AGE AT FIRST CALVING ON YEARLY MILK YIELD
GUERNSEY BREED

Age Months	Number of Cows Included	Yearly Milk Production Calculated from Equation*	Yearly Milk Production Mean	Standard Deviation	Coefficient of Variation	Yearly Milk Production F. C. M.**
		(lbs.)	(lbs.)	(lbs.)		(lbs.)
16	1	----	5203.0	----	----	6476.2
17	3	----	7273.7	----	----	8594.5
18	6	----	7177.5	----	----	7945.5
19	12	----	7499.5	----	----	8305.3
20	22	----	7544.9	----	----	8702.9
21	49	----	7443.3	----	----	8545.3
22	110	6898	7472.2 ± 98.90	1537.9 ± 69.93	20.58 ± .97	8609.4
23	250	7481	7537.5 ± 70.42	1650.8 ± 49.79	21.91 ± .69	8601.0
24	558	7880	7805.1 ± 49.46	1732.1 ± 34.97	22.19 ± .47	9027.5
25	689	8153	8122.6 ± 35.72	1390.0 ± 25.25	17.11 ± .32	9360.0
26	778	8344	8332.4 ± 43.53	1800.0 ± 30.78	21.60 ± .39	9645.0
27	750	8479	8408.8 ± 44.70	1815.0 ± 31.61	21.58 ± .39	9749.0
28	737	8570	8585.3 ± 52.55	2115.0 ± 37.15	24.63 ± .46	9526.0
29	747	8635	8618.3 ± 44.92	1820.0 ± 31.76	21.11 ± .37	10003.8
30	557	8679	8678.6 ± 52.53	1838.0 ± 37.14	21.14 ± .45	10084.9
31	467	8709	8745.2 ± 55.18	1767.8 ± 39.01	20.21 ± .46	10147.6
32	385	8731	8782.0 ± 60.77	1767.8 ± 42.97	20.13 ± .51	10138.3
33	346	8746	8629.6 ± 71.80	1980.0 ± 50.76	22.94 ± .62	10083.3
34	282	8756	8783.2 ± 81.07	2018.5 ± 57.32	22.98 ± .69	10137.3
35	310	8764	8839.8 ± 73.94	1930.0 ± 52.28	21.83 ± .62	10206.4
36	274	8769	8671.0 ± 75.14	1843.9 ± 53.12	21.26 ± .64	10041.4

*Milk = 8780 - 5,600,000e^{-384t}

**F. C. M. = 15 F + .4 M

TABLE 10.—EFFECT OF AGE AT FIRST CALVING ON YEARLY FAT PRODUCTION
GUERNSEY BREED

Age Months	Number of Cows Included	Yearly Fat Production Calculated from Equation*	Yearly Fat Production Mean	Standard Deviation	Coefficient of Variation	Average Fat Percentage
		(lbs.)	(lbs.)	(lbs.)		
16	1	----	293.0	----	----	5.63
17	3	----	379.0	----	----	5.21
18	6	----	338.3	----	----	4.71
19	12	----	353.7	----	----	4.72
20	22	----	379.0	----	----	5.02
21	49	----	371.2	----	----	4.99
22	110	333.0	374.7 ± 50.48	78.5 ± 3.57	20.93 ± .99	5.01
23	250	370.6	372.4 ± 33.23	77.9 ± 2.35	20.92 ± .66	4.94
24	558	395.8	393.7 ± 26.98	94.5 ± 1.91	24.00 ± .51	5.04
25	689	412.0	407.4 ± 23.08	89.8 ± 1.63	22.03 ± .42	5.01
26	778	422.8	420.8 ± 21.96	90.8 ± 1.55	21.58 ± .39	5.05
27	750	430.0	425.7 ± 22.36	90.8 ± 1.58	21.33 ± .39	5.06
28	737	434.7	433.9 ± 23.48	94.5 ± 1.66	21.78 ± .40	5.05
29	747	437.9	437.1 ± 22.58	91.5 ± 1.60	20.93 ± .38	5.07
30	557	440.0	440.9 ± 25.81	90.3 ± 1.82	20.46 ± .43	5.08
31	467	441.3	443.3 ± 28.87	92.5 ± 2.04	20.86 ± .48	5.07
32	385	442.0	441.7 ± 31.69	92.2 ± 2.24	20.86 ± .53	5.03
33	346	442.8	442.1 ± 37.28	102.8 ± 2.64	23.24 ± .63	5.12
34	282	443.2	441.6 ± 38.88	96.8 ± 2.75	21.92 ± .65	5.03
35	310	443.5	444.7 ± 34.59	90.3 ± 2.45	20.29 ± .57	5.03
36	274	443.7	438.2 ± 35.57	87.3 ± 2.52	19.91 ± .60	5.05

*Fat = 444 - 1,000,000e^{-414t}

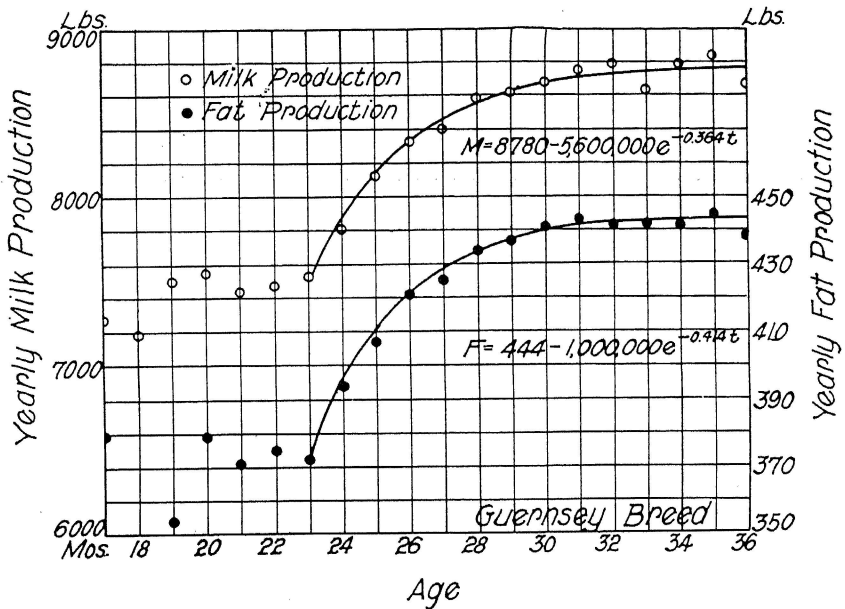


Fig. 11.—The change in the milk and fat production of Guernsey cows on test with advance in the age at first calving is presented. The continuous lines represent equations fitted to the data. The increase in milk secretion is negligible after 30 months of age.

predicted on the basis of the later production. (Tables 9 and 10). From about 23 months on, the equation fits the observed points exceptionally well. (Fig. 11.) It will be noted that the curve increases rapidly until 30 months. One hardly need comment that nothing is gained by delaying the parturition of Guernsey cows beyond that age.

From 24 to 30 months, however, there is an increase of almost 45 pounds of fat and 800 pounds of milk.

Holstein-Friesian cattle.—The records of the Holstein-Friesian heifers calving for the first time are quite similar to those of the breeds already mentioned. In this case the early records fall more nearly in line with the records made after 24 months. (Tables 11 and 12.) The calculated curve appears to fit the actual data very satisfactorily although there is considerable fluctuation in the records between 30 and 36 months of age (Fig. 12). While the data is not quite as definite, it would appear that no material increase in the production of Holsteins is gained by delaying calving beyond 30 months.

Between 24 and 30 months, the increase in average yearly fat production increases about 45 pounds and the milk yield about 1400 pounds.

TABLE 11.—EFFECT OF AGE AT FIRST CALVING ON YEARLY MILK PRODUCTION
HOLSTEIN BREED

Age Months	Number of Cows Included	Yearly Milk Production Calculated from Equation*	Yearly Milk Production Mean	Standard Deviation	Coefficient of Variation	Yearly Milk Production F. C. M.**
17	3	(lbs.)	(lbs.)	(lbs.)		(lbs.)
18	9	-----	11,155.0	-----	-----	9832
19	6	-----	10,618.0	-----	-----	9985
20	14	-----	8,999.5	-----	-----	8467
21	19	-----	12,464.0	-----	-----	10085
22	51	-----	11,197.0	-----	-----	10816
23	147	13068	12,250.0	-----	-----	11257
24	244	13626	12,824 ± 185.35	3331.7 ± 131.09	25.98 ± 1.09	11649
25	301	14060	13,619 ± 128.09	2966.5 ± 90.57	21.78 ± .70	12361
26	357	14371	14,223 ± 120.29	3094.0 ± 85.05	21.75 ± .63	12934
27	281	14605	14,266 ± 118.27	3312.9 ± 83.62	23.22 ± .62	12921
28	275	14780	14,609 ± 130.53	3244.0 ± 92.29	22.20 ± .66	13201
29	265	14911	14,648 ± 133.51	3282.5 ± 94.40	22.41 ± .68	13263
30	245	15012	14,890 ± 129.88	3134.5 ± 91.83	21.05 ± .64	13539
31	231	15082	15,276 ± 137.57	3192.4 ± 97.27	20.90 ± .66	13370
32	210	15137	15,770 ± 152.66	3440.0 ± 107.94	21.81 ± .72	13928
33	189	15178	15,266 ± 160.39	3446.0 ± 113.41	22.57 ± .78	13861
34	167	15209	14,734 ± 158.41	3228.8 ± 112.01	21.98 ± .80	12899
35	219	15232	15,028 ± 173.03	3315.0 ± 122.34	22.06 ± .85	13346
36	183	15250	15,466 ± 150.12	3293.9 ± 106.15	21.30 ± .72	14061
			15,296 ± 150.00	3008.3 ± 106.05	19.67 ± .72	13783

*Milk = 15300 - 1,800,000e⁻²⁹¹

**F. C. M. = 15 F + .4 M

TABLE 12.—EFFECT OF AGE AT FIRST CALVING ON YEARLY FAT PRODUCTION
HOLSTEIN BREED

Age Months	Number of Cows Included	Yearly Fat Production Calculated from Equation*	Yearly Fat Production Mean	Standard Deviation	Coefficient of Variation	Average Fat Percentage
17	3	(lbs.)	(lbs.)	(lbs.)		
18	9	-----	358.0	-----	-----	3.21
19	6	-----	382.5	-----	-----	3.60
20	14	-----	324.5	-----	-----	3.61
21	19	-----	340.0	-----	-----	2.73
22	51	-----	422.5	-----	-----	3.77
23	147	438.3	423.8	-----	-----	3.46
24	244	438.3	434.6 ± 58.52	105.2 ± 4.14	24.19 ± 1.50	3.39
25	301	473.4	460.9 ± 44.52	103.1 ± 3.15	22.36 ± .72	3.38
26	357	483.6	483.0 ± 40.74	104.8 ± 2.88	21.68 ± .62	3.40
27	281	491.3	481.0 ± 39.91	111.8 ± 2.82	23.23 ± .62	3.37
28	275	496.5	490.5 ± 43.46	108.0 ± 3.07	22.02 ± .66	3.36
29	265	500.4	493.6 ± 45.47	111.8 ± 3.22	22.64 ± .68	3.37
30	245	503.1	505.5 ± 43.34	104.6 ± 3.06	20.68 ± .63	3.39
31	231	505.1	484.0 ± 46.45	107.8 ± 3.28	22.25 ± .71	3.17
32	210	506.5	508.0 ± 51.88	116.9 ± 3.67	23.01 ± .76	3.22
33	189	507.5	517.0 ± 55.67	119.6 ± 3.94	23.14 ± .80	3.39
34	167	508.2	507.5 ± 57.70	118.0 ± 4.08	23.25 ± .85	3.17
35	219	508.7	489.0 ± 59.24	113.5 ± 4.19	23.18 ± .90	3.25
36	183	509.1	525.0 ± 52.60	115.4 ± 3.72	21.97 ± .74	3.39
			511.0 ± 52.85	106.0 ± 3.74	20.73 ± .76	3.34

*Fat = 510 - 160,000e^{-335t}

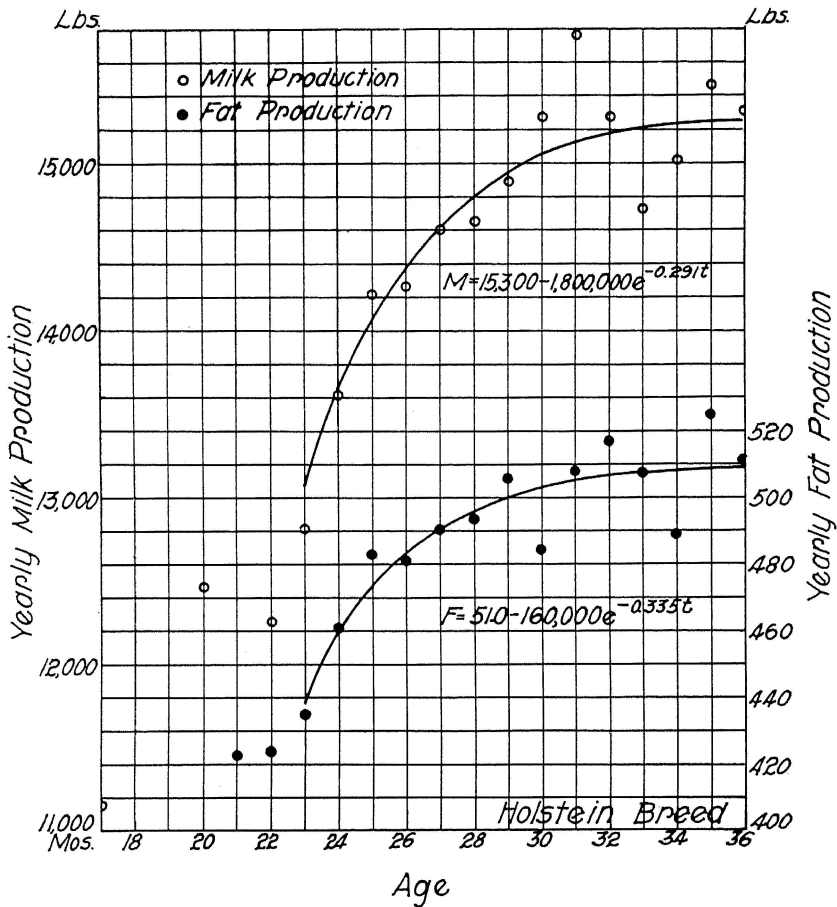


Fig. 12.—The change in the milk secretion of Holstein-Friesian cows on test with advance in the age at first calving is presented. The continuous lines represent equations fitted to the data.

Jersey cattle.—As the age of calving increases, the average production rises gradually. It will be noted, however, that the rise is not only less rapid but also less in total amount. It would not pay to delay calving beyond 30 months for the increase in milk or fat production after that age. (Tables 13 and 14.)

From 24 to 30 months the average increase in production was less than 25 pounds of fat and 400 pounds of milk. (Fig. 13.)

TABLE 13.—EFFECT OF AGE AT FIRST CALVING ON YEARLY MILK PRODUCTION

JERSEY BREED

Age Months	Number of Cows Included	Yearly Milk Production Calculated from Equation*	Yearly Milk Production Mean	Standard Deviation	Coefficient of Variation	Yearly Milk Production F. C. M.**
		<i>lbs.</i>	<i>lbs.</i>	<i>lbs.</i>		<i>lbs.</i>
13	2	----	5800	----	----	7585
14	1	----	4048	----	----	5519
15	2	----	6816	----	----	8636
16	14	----	5648	----	----	7143
17	33	----	5700	----	----	6879
18	57	----	6135	----	----	7475
19	63	----	5959	----	----	7241
20	134	6185	6138 ± 70.92	1060.0 ± 43.67	17.27 ± .73	7764
21	240	6340	6275 ± 48.98	1125.0 ± 34.63	17.92 ± .57	7639
22	453	6498	6440 ± 41.63	1313.5 ± 29.43	20.39 ± .48	7826
23	873	6624	6643 ± 29.58	1296.0 ± 20.92	19.51 ± .33	8076
24	1035	6737	6725 ± 31.11	1484.9 ± 22.01	22.08 ± .34	8327
25	1035	6828	6902 ± 32.95	1571.5 ± 24.04	22.76 ± .35	8405
26	1036	6905	6893 ± 30.80	1470.0 ± 21.78	21.32 ± .33	8375
27	913	6975	6423 ± 34.75	1557.0 ± 24.57	24.24 ± .40	8190
28	696	7035	7080 ± 40.20	1572.3 ± 28.42	22.21 ± .42	8585
29	628	7080	7065 ± 41.81	1553.2 ± 29.56	21.98 ± .44	8565
30	504	7120	7085 ± 45.78	1524.0 ± 32.37	21.51 ± .48	8558
31	421	7154	7349 ± 52.04	1583.1 ± 36.79	21.54 ± .52	8869
32	349	7185	7517 ± 58.31	1614.9 ± 41.23	21.48 ± .57	9131
33	375	7209	7166 ± 52.56	1509.0 ± 37.16	21.06 ± .54	8737
34	394	7231	6805 ± 49.48	1456.0 ± 34.98	21.39 ± .54	8668
35	422	7249	7133 ± 53.20	1620.2 ± 37.61	22.71 ± .55	8928
36	389	7264	7354 ± 58.79	1719.2 ± 41.51	23.37 ± .60	8933

*Milk = 7350 - 31500e^{-164t}

**F. C. M. = 15 F + .4 M

TABLE 14.—EFFECT OF AGE AT FIRST CALVING ON YEARLY FAT PRODUCTION
JERSEY BREED

Age Months	Number of Cows Included	Yearly Fat Production Calculated from Equation*	Yearly Fat Production Mean	Standard Deviation	Coefficient of Variation	Average Fat Percentage
		<i>lbs.</i>	<i>lbs.</i>	<i>lbs.</i>		
13	2	-----	351.0	-----	-----	6.05
14	1	-----	260.0	-----	-----	6.42
15	2	-----	394.0	-----	-----	5.78
16	14	-----	325.6	-----	-----	5.76
17	33	-----	306.6	-----	-----	5.38
18	57	-----	334.7	-----	-----	5.45
19	63	-----	323.8	-----	-----	5.43
20	134	326.8	353.9±36.13	62.0±2.55	17.52±.74	5.76
21	240	340.0	341.9±26.43	60.7±1.87	17.74±.56	5.45
22	453	350.8	347.0±21.77	68.7±1.54	19.80±.46	5.39
23	874	359.6	361.5±17.55	76.9±1.24	21.25±.36	5.44
24	1035	367.1	375.8±16.63	79.3±1.18	21.09±.33	5.58
25	1035	373.0	376.3±17.23	82.2±1.22	22.43±.35	5.45
26	1036	377.9	374.5±16.20	77.3±1.15	20.62±.32	5.43
27	913	381.9	374.7±18.08	81.0±1.28	21.62±.36	5.83
28	696	385.2	383.5±21.19	82.9±1.50	21.62±.41	5.42
29	628	387.9	382.6±22.72	84.4±1.61	22.06±.44	5.41
30	504	390.1	381.6±23.49	78.2±1.66	20.49±.45	5.39
31	421	391.9	395.3±26.13	79.5±1.85	20.11±.47	5.38
32	349	393.4	408.3±31.13	87.0±2.22	21.31±.57	5.43
33	375	394.6	391.4±27.10	77.8±1.92	19.88±.51	5.46
34	394	395.6	396.4±28.37	83.5±2.01	21.07±.53	5.82
35	422	396.4	405.0±27.52	83.8±1.95	20.67±.50	5.67
36	389	397.0	399.4±26.16	76.5±1.85	19.16±.48	5.43

* Fat = 400 - 4000e^{-20t}

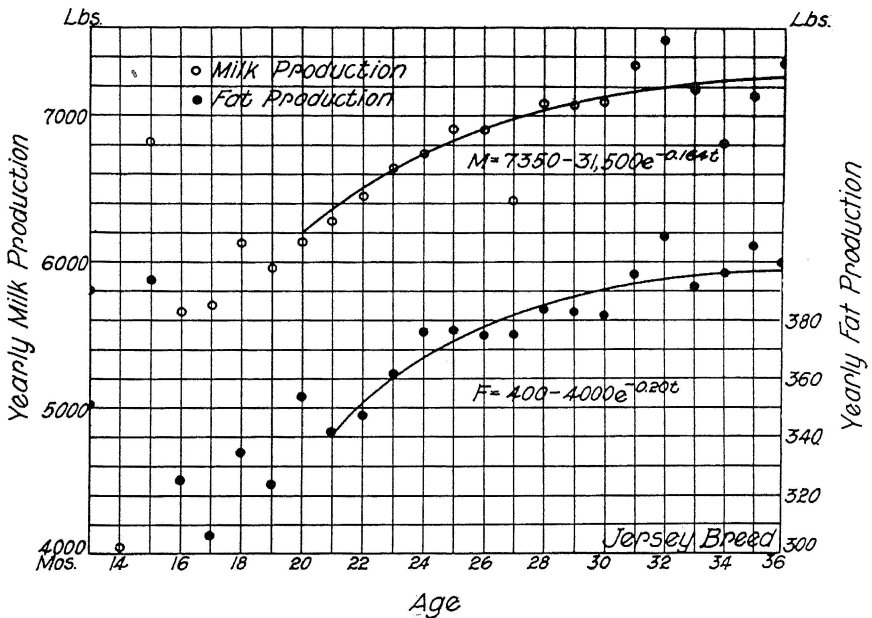


Fig. 13.—The change in the milk secretion of Jersey cows on test with advance in the age at first calving is presented. The continuous lines represent equations fitted to the data.

Relation Between Weight and Production.—The curves indicating the rise in milk and fat production have been shown to be similar to the curves of growth in body weight. This would be expected on the premise that the cause of the increase in the production of cows calving for the first time with increasing age is due to the increase in body weight with age.

In order to prove the point it would be necessary to show that the heifers gained approximately 100 pounds in body weight for each 20 pounds observed increase in fat production. Unfortunately, the body weight of the animals included is not available. However, unpublished data are available from the Missouri Station herd for several breeds of dairy cattle during the period under observation which will give a close approximation of the gains in body weight during this period.

Most studies of the growth of dairy cattle during the period concerned, represents the growth of lactating animals. It is obvious that such data are of little value. What is required is the growth of open and pregnant non-lactating animals. Their growth would be far more rapid as lactation has been shown to inhibit growth. In the following

table the growth in body weight of Holstein and Jersey heifers from 20 to 31 months of age are presented (Table 15). Lactating animals are excluded.

TABLE 15.—GROWTH OF DAIRY HEIFERS PREVIOUS TO THE FIRST LACTATION*

Age months	Holstein-Friesian		Jersey	
	Number of Animals	Average Body Weight	Number of Animals	Average Body Weight
		<i>lbs.</i>		<i>lbs.</i>
20	20	840.8	16	640.7
21	21	872.4	19	668.6
22	20	983.9	18	696.1
23	17	953.0	19	736.6
24	18	1064.1	19	764.4
25	19	1073.8	19	800.5
26	17	1152.1	12	801.5
27	12	1209.7	11	833.7
28	7	1253.6	9	886.1
29	4	1301.5	4	877.2
30	4	1294.4	4	917.2
31	1	1405.0	2	856.5

*The writer is indebted to Prof. A. C. Ragsdale, Chairman of the Department of Dairy Husbandry, Missouri Agricultural Experiment Station, for permission to use the above unpublished data.

The gain in body weight of Holstein heifers from 20 to 30 months of age is approximately 460 pounds, from 24 to 30 months the gain is about 300 pounds. (The weight at 24 months appears about 50 pounds too high in comparison with the weights at 23 and 25 months). Of the 300 pounds gain approximately 100 pounds may be considered as fetal development, leaving about 200 pounds as the net gain in body weight. The increase in fat production during the period from 24 to 30 months would be 40 pounds according to the gain in body weight. As previously noted the actual increase in fat production was about 45 pounds. Thus the growth in body weight of Holstein heifers may be considered as accounting for the increase in yearly fat production due to the delay in the age at first calving from 24 to 30 months.

The gain in body weight of Jersey heifers from 20 to 30 months of age is about 280 pounds and from 24 to 30 months about 155 pounds. If there were a net gain of about 100 pounds in body weight, it would account for the actual increase of about 25 pounds of fat observed in this study.

Data on the growth of the heifers of the Ayrshire and Guernsey

breeds are not available, but the gain in body weight would undoubtedly lie between the figures given above for the Holstein and the Jersey.

While further growth data would be desirable, it seems reasonably certain that the increase in the yearly fat production resulting from a delay in the time of first calving merely indicates the extent of growth during the period which makes possible greater fat production in the ratio of about 20 pounds of fat per year for each 100 pounds increase in body weight.

If the increase in yearly fat production resulting from the delay in calving is due to the prolonged growth of the heifer, the question as to the most satisfactory age to breed dairy heifers turns to the importance of the size or body weight in relation to efficient production. As indicated in the introduction, data has been presented by Gaines (1931) indicating that from the standpoint of transforming the digestible nutrients in the feed to milk, the smaller cows were, on the average, more efficient than the larger animals.

It would appear from these data that nothing is gained in efficiency of production in growing animals out to their maximum size by delaying the time of calving. Further, if the increased production is due to the increase in body weight alone, it would appear feasible to hasten the growth of heifers so as to attain a satisfactory body weight and yet be able to breed them early. In this way a saving of several months in the age of the animal might be effected without any loss in milk and fat production.

The fact that there is considerable growth in body weight between 20 and 30 months and consequently a material increase in milk and fat production, renders it impossible to set any definite age at which all animals of all breeds should calve. Breeders who desire maximum production at the expense of economic production will find it desirable to delay calving until about 30 months of age. At the other extreme, breeders may find it an economically sound practice to breed their heifers to calve at from 20 to 24 months of age. To be sure they will sacrifice varying amounts of milk and fat (Table 16) but the production will be obtained at maximum efficiency insofar as the use of feed is concerned.

To others who would prefer a medium course, that is, obtain an approach to maximum production yet save as much time as possible, an examination of Figures 10 to 13 will be of help. It will be noted that the curve is at first rather steep, then smoothes off without much further increase.

If breeders are willing to sacrifice 10 per cent of the maximum fat production of the first lactation, these data show that Ayrshire heifers may be bred to calve at about 25 months, Guernseys 24.5 months, Holstein-Friesians 24.5 months, and Jerseys 23 months. Only 5 per cent

TABLE 16.—INCREASE IN YEARLY MILK AND FAT PRODUCTION DUE TO DELAYED CALVING

Age	Ayrshire		Guernsey		Holstein-Friesian		Jersey	
	Fat	Milk	Fat	Milk	Fat	Milk	Fat	Milk
<i>Mo.</i>	<i>lbs.</i>	<i>lbs.</i>	<i>lbs.</i>	<i>lbs.</i>	<i>lbs.</i>	<i>lbs.</i>	<i>lbs.</i>	<i>lbs.</i>
21	----	----	----	----	----	----	60.0	1010
22	----	----	----	----	----	----	49.2	852
23	----	----	73.4	1299	71.7	2232	40.4	726
24	65.7	1573	48.2	920	51.7	1674	32.9	613
25	50.0	1216	32.0	627	36.6	1240	27.0	522
26	38.3	944	21.2	436	26.4	929	22.1	445
27	29.2	729	14.0	301	18.7	695	18.1	375
28	22.1	567	9.3	210	13.5	520	14.8	315
29	16.9	437	6.1	145	9.6	389	12.1	270
30	12.9	340	4.0	101	6.9	288	9.9	230
31	9.8	262	2.7	71	4.9	218	8.1	196
32	7.5	204	1.8	49	3.5	163	6.6	165
33	5.7	157	1.2	34	2.5	122	5.4	141
34	4.3	123	0.8	24	1.8	91	4.4	119
35	3.3	94	0.5	16	1.3	68	3.6	101
36	2.5	74	0.3	11	.9	50	3.0	86

of the maximum fat production would be lost by breeding Ayrshires to calve at 28 months, Guernseys at 26 months, Holstein-Friesians at 26 months, and Jerseys at 26 months.

Conversion Factors for Age at First Calving.—Conversion or correction factors have two important uses. They may be used to convert records made at various ages to a uniform basis for purposes of comparison. This is usually considered the primary purpose of these factors. Another use to which conversion factors may be placed is less seldom recognized. The factors give a quantitative evaluation of the physiological factor under consideration. Thus in the present study of the influence of the age at first calving on the milk and fat production of purebred cattle on official test, the type of conversion factor first developed at this Station, i. e., the ratio of production at a given age to a definite base, serves to indicate quantitatively the influence of delayed calving on yearly milk and fat production. As an example may be cited the conversion factor for fat production in the Ayrshire breed. The factor 1.2105 at 24 months indicates that there is an increase of 21.05 per cent in yearly fat production by delaying calving until 36 months of age. The factor at 30 months, 1.0304 indicates that there is an increase of only 3.04 per cent by delaying the first calving until 36 months of age.

In other words, by eliminating the base one and pointing off two

TABLE 17.—CONVERSION FACTORS FOR AGE AT FIRST CALVING

Age Months	Ayrshire Records				Guernsey Records				Holstein Records				Jersey Records			
	Milk Production		Fat Production		Milk Production		Fat Production		Milk Production		Fat Production		Milk Production		Fat Production	
	To 24 mo.	To 36 mo.	To 24 mo.	To 36 mo.	To 24 mo.	To 36 mo.	To 24 mo.	To 36 mo.	To 24 mo.	To 36 mo.	To 24 mo.	To 36 mo.	To 24 mo.	To 36 mo.	To 24 mo.	To 36 mo.
20	----	----	----	----	----	----	----	----	----	----	----	----	1.0892	1.1745	1.1233	1.2148
21	----	----	----	----	----	----	----	----	----	----	----	----	1.0626	1.1457	1.0797	1.1676
22	----	----	----	----	----	----	----	----	----	----	----	----	1.0368	1.1179	1.0465	1.1317
23	----	----	----	----	1.0533	1.1722	1.0680	1.1972	1.0427	1.1670	1.0461	1.1615	1.0171	1.0966	1.0209	1.1040
24	1.0000	1.1991	1.0000	1.2105	1.0000	1.1128	1.0000	1.1210	1.0000	1.1192	1.0000	1.1104	1.0000	1.0782	1.0000	1.0814
25	0.9547	1.1449	0.9503	1.1503	0.9665	1.0756	0.9607	1.0839	0.9691	1.0846	0.9685	1.0754	0.9867	1.0639	0.9842	1.0643
26	0.9229	1.1067	0.9164	1.1092	0.9444	1.0509	0.9361	1.0494	0.9482	1.0612	0.9481	1.0527	0.9757	1.0520	0.9714	1.0505
27	0.8992	1.0782	0.8916	1.0793	0.9294	1.0342	0.9205	1.0319	0.9330	1.0442	0.9332	1.0362	0.9659	1.0414	0.9612	1.0395
28	0.8821	1.0578	0.8732	1.0570	0.9195	1.0232	0.9105	1.0207	0.9219	1.0318	0.9235	1.0254	0.9576	1.0326	0.9530	1.0306
29	0.8689	1.0419	0.8602	1.0412	0.9126	1.0155	0.9039	1.0132	0.9138	1.0227	0.9163	1.0174	0.9516	1.0260	0.9464	1.0235
30	0.8592	1.0304	0.8505	1.0295	0.9079	1.0104	0.8995	1.0084	0.9077	1.0159	0.9113	1.0119	0.9462	1.0202	0.9410	1.0177
31	0.8517	1.0213	0.8431	1.0205	0.9048	1.0069	0.8969	1.0054	0.9035	1.0111	0.9077	1.0079	0.9417	1.0154	0.9367	1.0130
32	0.8461	1.0146	0.8377	1.0139	0.9025	1.0044	0.8955	1.0038	0.9002	1.0075	0.9052	1.0051	0.9376	1.0110	0.9331	1.0092
33	0.8417	1.0093	0.8335	1.0089	0.9010	1.0026	0.8939	1.0020	0.8977	1.0047	0.9034	1.0032	0.9345	1.0076	0.9303	1.0061
34	0.8385	1.0055	0.8302	1.0050	0.9000	1.0015	0.8931	1.0011	0.8959	1.0027	0.9022	1.0018	0.9317	1.0046	0.9280	1.0035
35	0.8358	1.0022	0.8280	1.0022	0.8991	1.0006	0.8924	1.0005	0.8946	1.0012	0.9013	1.0008	0.9294	1.0021	0.9261	1.0015
36	0.8339	1.0000	0.8261	1.0000	0.8986	1.0000	0.8920	1.0000	0.8935	1.0000	0.9006	1.0000	0.9275	1.0000	0.9247	1.0000
Maximum	0.8271	0.9919	0.8205	0.9932	0.8975	0.9987	0.8914	0.9993	0.8906	0.9967	0.8990	0.9982	0.9166	0.9883	0.9178	0.9925

places, the positive conversion factor is converted into a percentage of the base, a definite quantitative value of the influence or factor being studied.

In the present study, conversion factors were determined using 36 months as the base which is the usual method (Table 17). These factors may be useful as indicated above. Using 24 months as a base, the factors may be found most useful in correcting production to that age. The answer to the following question may be obtained by the use of these factors. If a cow produces 400 pounds of fat calving at 30 months of age, how much would she have produced at 24 months? With that answer one is in a position to determine whether the increase in production is sufficient to justify the loss of 6 months in the productive life of the individual.

DISCUSSION

An examination of these data reveal several important facts which are believed to have a direct bearing upon the economical production of milk and butterfat. The period from birth to the time of first calving in dairy cattle is a non-productive period. The cost of raising heifers to a productive age is an item which cannot be eliminated but is one which should be reduced to a minimum if the enterprise is to show the maximum profit.

In this connection the question arises as to the age at which heifers should calve for the first time. Heifers usually reach sexual maturity by the time they are 12 months old. Should they be bred at this time or allowed to reach a larger size before being bred for the first time? Should heifers calve at 24 months, 30 months or 36 months?

As a result of this study one question can be answered clearly and unequivocally; namely, that the increase in milk and fat production in heifers calving after 30 months of age in all the breeds is practically negligible. It may be concluded, therefore, that nothing is to be gained by allowing heifers to calve for the first time over 30 months of age. In other words, every heifer remaining unproductive at 30 months of age or over is being maintained at a loss not only of the maintenance cost and of the investment in the animal, but in the productive life of the animal. Yet the study shows that 719 Ayrshire cows or 43 per cent freshened after 30 months of age. Of the Guernseys studied 2064 cows or 28 per cent, of the Holsteins 1197 or 35 per cent, and of the Jerseys 2854 or 23 per cent calved between 30 and 36 months of age.

These rather high percentages indicate that many breeders conducting official records are more interested in maximum production than efficient production. As a result there is a tendency to delay breeding as long as possible in the hope that greater production will result.

To such breeders, the present study will clearly show that the delay after 30 months is generally without benefit to the record. They need not, therefore, delay calving beyond 30 months in the hope of greater production.

This conclusion applies only to animals in which normal growth has been made. If animals are seriously stunted up to that age and are capable of making extensive gains in body weight later, the potential production would be increased accordingly.

As indicated in the introduction, the underlying reason for making this study was to determine the influence of age on the yearly milk and fat production during the first period of lactation. The study clearly revealed a significant increase in milk and fat production until the heifers reached an age of about 30 months. Following 30 months, the rise is insignificant.

The determination of the cause of the rise in production is of great interest. Possible causes include the growth in body weight during the period, growth and development of the udder aside from general body growth, and greater efficiency of the animal as maturity is attained.

In previous studies it has been shown that the increase in production with age was due in large part (75 to 80 per cent) to the recurrence of pregnancy and the consequent growth and development of the udder, and to a lesser extent (20 to 25 per cent) to the increase in body weight with age. In officially tested purebred animals, it was observed that there was an increase of about 20 pounds of fat for each 100 pounds increase in body weight.

As the mammary glands of the animals were all uniformly developed by a single gestation, the theory was advanced that the increase in milk and fat production with age during the first lactation was largely if not entirely due to the growth in body weight during the period under consideration.

The results of the study are believed to confirm the theory that the increase in milk and fat production due to the delay in the time of first calving is due to growth in body weight. Further, that the increase in yearly fat production is about 20 pounds per 100 pounds increase in body weight.

It is believed that these data furnish a scientific basis for the determination of the age at which animals should calve for the first time. It is not the writer's wish to infer that all animals under all conditions should calve at any certain time or that any definite age of first calving can be established. Varying conditions and the objectives of breeders must determine the most satisfactory age. The study definitely indicates the production that may be expected when cows calve at various ages.

It is believed that the most efficient milk and fat production will be obtained by breeding animals to calve at from 20 to 24 months of age, maximum production at about 30 months of age, and from 5 to 10 per cent of the maximum production at from 23 to 28 months, depending upon the breed.

SUMMARY AND CONCLUSIONS

1. A study is reported on the effect of the age at first calving (up to 36 months) on the official yearly milk and fat production of purebred cows of the four dairy breeds; Ayrshire, Guernsey, Holstein-Friesian, and Jersey.
2. The youngest heifer included in the study, a Jersey, calved at 13 months of age. The youngest Guernsey calved at 16 months of age, while the youngest Ayrshire and Holstein-Friesian calved at 17 months of age.
3. The frequency curves show that the largest number of Jerseys calve during the 24th to 26th months, the Guernseys during the 26th month, the Holsteins during the 26th month, and the Ayrshires during the 30th month.
4. The mean ages of calving were as follows: Jersey 27.3 months, Guernsey, 28.5 months, Holstein 28.8 months, and Ayrshire 29.8 months.
5. A method of correcting the population in each age group eliminated by the minimum entrance requirements was outlined. However, the increase in the average fat production of the records studied was not believed to be sufficiently large to invalidate the conclusions drawn from the analysis of the actual records.
6. It was observed in all the breeds studied that there was an increase in the yearly milk and fat production as the age at first calving increased. When these data were plotted it was observed that the curve of increase in production was similar to the growth curve, i. e., of exponential form. Equations of the form $M = A - Be^{-kt}$ were found to fit the data very satisfactory.
7. The increase in yearly fat production with the advance in the age at first calving was shown to be largely if not entirely due to the growth in body weight during the period under consideration.
8. Conversion or correction factors were formulated for the purpose of comparing the production records of heifers calving at various ages. These comparisons may be made either at 24 months or 36 months. The later set of factors were also shown to be useful in giving a quantitative measure of the physiological influence being studied.
9. The study clearly indicated that nothing was gained by delaying

the calving of dairy heifers beyond 30 months, yet from 23 to 43 per cent of the heifers included in the study calved after that age.

10. While no definite age of calving will be found satisfactory for all breeds and under varying conditions, a sound scientific basis is provided for the determination of the age best suited to the objectives of individual breeders.

11. It is concluded that the most efficient milk and fat production (utilization of nutrients) will be obtained by breeding animals to calve at from 20 to 24 months of age, maximum production at about 30 months of age, and within 5 to 10 per cent of the maximum production at from 23 to 28 months depending upon the breed.

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