5-1962

Influence of Age on Milk Production of Holstein Cows in Utah

Marvin R. Green
Utah State University

INFLUENCE OF AGE ON MILK PRODUCTION

OF HOLSTEIN COWS IN UTAH

by

Marvin R Green

A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Dairy Production

Approved:

UTAH STATE UNIVERSITY
Logan, Utah

1962

ACKNOWLEDGMENT

I am grateful to Dr. George E. Stoddard for his encouragement and assistance in the completion of this study. My sincere thanks to Dr. Rex Hurst for his counsel in the organization and solution of the statistical data. I express appreciation to the staff and members of the Dairy Department and Department of Applied Statistics for their cooperation and assistance. I am especially appreciative for the encouragement and assistance of my wife, Gayla.

Marvin R Green

LIST OF ILLUSTRATIONS

LIST OF TABLES

TABLE OF CONTENTS

INTRODUCTION

Production of dairy cows is influenced by many factors, among which are: genetics, nutrition, management, disease and age. Most of these factors can be modified to maintain a high level of production. Age, however, is beyond the influence of mankind; therefore, it is important to understand the effect of age on milk and butterfat production.

Age is an important influence in comparing the records of individual animals. Realizing this influence, the United States Department of Agriculture (U.S.D.A.) made a study of the individual Dairy Herd Improvement Association (D.H.I.A.) 305 day lactation records. These D.H.I.A. records were used to compute factors for correcting lactation records to their mature equivalent.

A study has been made to determine the influence of age on milk and butterfat production. This study was accomplished by utilizing Utah D.H.I.A. records. These records represent approximately 15 per cent of the total cow population of Utah and represent a wide variation in management and environmental conditions.

The objective of this study is two-fold: (1) To determine the influence of age on milk production of Holstein cows in the state of Utah, and (2) To develop and compare the age conversion factors of dairy cows on D.H.I.A. testing within the state of Utah, with factors developed by the U.S.D.A. on D.H.I.A. tested cows throughout the nation, and those factors developed for cows of the Utah State University Dairy Herd.

LITERATURE REVIEW

An understanding of the factors influencing milk production has been the objective of dairymen for many years. Some of the early studies were made in an effort to determine the effect of age as a factor of milk production.

Turner and Ragsdale (1924) found that while the per cent of fat in cow's milk was fixed by inheritance, there appeared to be a tendency for the percentage of butterfat to decline slightly with age. However, the total decline was very slight and of no practical importance.

Ludwick and Peterson (1943) indicated the variation in total milk production is influenced principally by three factors: (1) maximum inital production, (2) the persistency with which such yields are maintained, and (3) the length of the production period. In general, cows having the highest degree of persistency are the most economical producers. After reaching maturity their average decrease in production is approximately nine per cent per month.

<u>Age milk production curves</u>

Mahadevan (1951) found age in lactations to be closely related to milk and butterfat production. He also found that by the fifth lactation, milk yield was practically independent of age at calving. In twelve different dairy herds a study was made of milk production as affected by the age of calving. The results of the study indicated there were significant differences between levels of production of animals within each herd, and there was large variation in the average milk production between the various herds. Mahadevan decided these factors could not be merely lumped together in studying interrelationships. Because of this condition, it was decided to express yields as deviations from respective herd averages.

Mahadevan (1951) further indicated that the regression equation included not only the effect of age, but also the effect of environmental changes which would occur during the lifetime of the cow. He suggested the most important environmental effects upon milk production were those due to age and different management practices. His results showed greater progress can be made in dairy cattle improvement by concentrating more on environment rather than heredity. This was especially true with the low producing herds.

Age conversion factors

It is often desirable to compare the approximate mature production of one cow with that of another. Mature production is that peak of production obtained when all or most all of the body processes reach maturity. Ordinarily, a dairy cow will produce more milk at this stage of her life than at any other period. Kay and McCandlish (1929) found this period to be approximately eight years of age. In order to compare the mature production of one animal with that of another, factors have been developed which, when applied to the individual animal, will give the estimated mature production.

Turner and Ragsdale (1924) developed some of the earliest factors for comparing the production of one animal with another.

Ward and Campbell (1938) suggested there was a lack of information demonstrating the practical application of standardized methods under normal herd conditions. However, we know age conversion factors are of considerable importance at the present time, as they have become important in sire proving. In summarizing their work, Ward and Campbell said,

> Care must be taken to assure that factors will be applicable to ordinary herd conditions. The addition of a percentage factor as an age conversion factor assumes that two-year old production is in perfect relationship with normal producing ability. This is highly improbable in actual practice.
>
> Increase in age strongly suggests that the increase in production can not be summarized by a percentage addition or a constant addition, but most nearly correct by a regression formula.

Hickman and Henderson (1954) in their work at Cornell, said that the present use of progeny testing, as a basis for the selection of good sires, had resulted in selection based almost entirely on first lactation records. Their studies seemed to indicate that genetic variation of increase in production from first to second lactation was only about one third as great as genetic variation for the first lactation level of production. A positive correlation between first lactation production and the increase from first and second lactation was also noted. However, they could not substantiate the oft stated hypothesis that first lactation records automatically selected bulls whose daughters will do poorly in subsequent lactations.

Sanders (1928) calculated age conversion factors on a ratio basis. He concluded they are not too accurate at high and low levels of production.

Kay and McCandlish (1929) calculated age conversion factors on the basis of population averages with animals of at least five consecutive lactations.

Edwards (1950) pointed out that generalization was worth little where differences in management and practice may cause great exception to the rule. One must be careful in assessing the quality of dairy bulls using age correction factors.

Kendrick (1953) demonstrated that age correction factors applied to individual lactations of an animal exhibited greater error than when applied to the average of cumulated lactation periods. Factors determined for cumulative lactation periods showed little difference between the first and any one of the following lactation periods. A similar condition existed when applied to the individual months of a lactation period. Greater error was noted when factors were applied to the center months of the lactation period.

Gaines et al. (1947) in studying the within-cow regression of milk energy yield on age and live weight, concluded that it was biologically unsound to correct yield for age, because age had no effect on yield independent of live weight. However, correction on either basis would accomplish part of that done by the other.

With all the debate as to the value of age correction factors in predicting the average mature equivalent production of dairy cows, they still remain our most easily applied and reliable factors for estimating the mature yield of an individual or group of animals. Harrison (1952) pointed out how misleading the factors can be.

METHOD OF PROCEDURE

Source of data

Data in this study were taken from the Dairy Herd Improvement Association records of the state of Utah. D.H.I.A. is a state wide organization of milk producers who cooperate in a program of monthly testing for milk and butterfat production of each dairy cow in their herd. About 15 per cent of the total dairy cow population of Utah are included in D.H.I.A.

In 1952 the D.H.I.A. changed from a hand computing system to the I.B.M. system of record keeping. At the time of this study only those records from January, 1954 to June, 1956, had been transferred to I.B.M. cards and were available for study.

Organization of experimental data

Animals were grouped by age for analysis by arbitrarily selecting two month intervals, beginning at 19 months of age and continuing through 142 months. The animals calving under 18 months of age were so few in numbers, they were combined with the 18-19 month old group. Cows calving over 142 months in age were all grouped in age group 63. Due to small numbers this oldest age group was not considered in the analysis. Elimination of this group left a total of 12,696 completed Holstein lactation records for analysis (Table 1).

The average milk and butterfat production of each of the 62 age groups was treated as an individual statistic for the regression analysis (Tables 4 and 5).

Statistical methods

Polynomial regression, involving the method of least squares is

Table 1. Distribution of animals by number and age

Age group	Age (month)	No. of animals	% of total	Age (years)	No. of animals	% of total
1	18–19	210	1.60	less		
2	20–21	438	3.45	than	1648	13.00
3	22–23	1000	7.88	2		
4	24–25	870	6.85			
5	26–27	592	4.66			
6	28–29	412	3.24	2	3246	25.57
7	30–31	332	2.61			
8	32–33	452	3.56			
9	34–35	588	4.63			
10	36–37	560	4.41			
11	38–39	432	3.40			
12	40–41	385	3.03	3	2437	19.19
13	42–43	295	2.32			
14	44–45	357	2.81			
15	46–47	408	3.21			
16	48–49	384	3.02			
17	50–51	307	2.41			
18	52–53	249	1.96	4	1768	13.92
19	54–55	246	1.93			
20	56–57	268	2.11			
21	58–59	314	2.47			
22	60–61	239	1.88			
23	62–63	217	1.71			
24	64–65	219	1.72	5	1278	10.07
25	66–67	184	1.45			
26	68–69	202	1.59			
27	70–71	217	1.70			
28	72–73	197	1.55			
29	74–75	161	1.27			
30	76–77	133	1.05	6	929	7.32
31	78–79	151	1.19			
32	80–81	152	1.20			
33	82–83	135	1.06			
34	84–85	126	.99			
35	86–87	107	.84			
36	88–89	82	.64	7	592	4.66
37	90–91	82	.64			
38	92–93	108	.85			
39	94–95	87	.68			

Table 1. Continued

Age group	Age (month)	No. of animals	% of total	Age (years)	No. of animals	% of total
40	96-97	69	.54			
41	98-99	89	.70			
42	100-101	56	.44	8	379	2.98
43	102-103	62	.49			
44	104-105	50	.39			
45	106-107	53	.42			
46	108-109	33	.26			
47	110-111	35	.27			
48	112-113	40	.31	9	226	1.78
49	114-115	37	.29			
50	116-117	40	.31			
51	118-119	41	.32			
52	120-121	22	.17			
53	122-123	33	.26			
54	124-125	27	.21			
55	126-127	14	.11	10	130	1.02
56	128-129	22	.17			
57	130-131	12	.09			
58	132-133	19	.15			
59	134-135	11	.09			
60	136-137	9	.07	11	63	.50
61	138-139	15	.12			
62	140-141	9	.07			
63	All above	80			80	.63

a procedure commonly used for expressing the relationship existing between two variables X(age) and Y(milk or butterfat production). As the values of X are equally spaced, this problem lends itself to solution by the method of orthogonal polynomials. Orthogonality enables one to compute each regression coefficient independently of all others. Orthogonal polynomial regression is valuable in readily evaluating each step of the fitting process and testing the significance of each of the regression coefficients to determine which is applicable to the particular situation.

The regression coefficients were calculated through the fifth degree for 62 points using constant values for orthogonal polynomials as determined by Fisher and Yates, 1949. This procedure gave the following regression equation:

$$\hat{Y} = A_0 + A_1 \xi_1 + A_2 \xi_2 + A_3 \xi_3 + A_4 \xi_4 + A_5 \xi_5$$

Direct substitution was made of the regression function in terms of X instead of ξ_s'.

At each point to evaluate the upper, middle and lower producers, the mean as well as the mean plus and minus one standard deviation was determined.

Age conversion factors were calculated for converting the production of an animal of one age to its mature equivalent. If one so desires, he may convert production of any age to that of another age. The relationship of factors developed by Kendrick (1953) for the U.S.D.A., and Patterson (1955) for the U.S.U. Dairy herd, and those obtained from this study are shown in Table 2.

A maturity of six to eight and a half years of age, was used as the base period for factors by Kendrick and also for this study. A slightly different base period was used by Patterson. However, the relationship is adequately shown between these three sets of conversion factors.

For convenience of working, the actual values in the analysis of variance were coded in the following manner.

Milk—Actual value ÷ by 1,000,000

Butterfat—Actual value ÷ by 1,000

Table 2. Milk and butterfat age conversion factors for Utah State D.H.I.A., U.S.D.A.-D.H.I.A. and the Utah State University Dairy Herd

Age by months	Milk			Butterfat	
	Utah	U.S.D.A.[a]	U.S.U.[b]	Utah	U.S.U.[b]
24-25	1.27	1.31	1.22	1.24	1.24
26-27	1.25	1.29	1.21	1.22	1.22
28-29	1.23	1.26		1.20	
30-31	1.21	1.24	1.19	1.19	1.20
32-33	1.20	1.22	1.17	1.17	1.18
34-35	1.18	1.20		1.16	
36-37	1.17	1.18	1.16	1.15	1.16
38-39	1.15	1.16	1.14	1.13	1.15
40-41	1.14	1.14		1.12	
42-43	1.13	1.12	1.13	1.11	1.13
44-45	1.13	1.11	1.12	1.10	1.12
46-47	1.11	1.10		1.09	
48-49	1.10	1.08	1.11	1.08	1.10
50-51	1.09	1.06	1.09	1.07	1.09
52-53	1.08	1.05		1.06	
54-55	1.07	1.04	1.08	1.06	1.08
56-57	1.06	1.03	1.07	1.05	1.07
58-59	1.06	1.03		1.04	
60-61	1.05	1.02	1.07	1.04	1.06
62-63	1.04	1.02	1.06	1.03	1.05
64-65	1.04	1.02		1.03	
66-67	1.03	1.02	1.05	1.02	1.04
68-69	1.03	1.01	1.04	1.02	1.04
70-71	1.02	1.01		1.02	
72-73	1.00	1.00	1.04	1.01	1.03
74-75	1.00	1.00	1.03	1.01	1.02
76-77	1.00	1.00		1.01	
78-79	1.00	1.00	1.03	1.01	1.02
80-81	1.00	1.00	1.02	1.01	1.01
82-83	1.00	1.00		1.01	
84-85	1.00	1.00	1.02	1.01	1.01
86-87	1.00	1.00	1.01	1.00	1.01
88-89	1.00	1.00		1.00	
90-91	1.00	1.00	1.01	1.00	1.00
92-93	1.00	1.00	1.01	1.00	1.00
94-95	1.00	1.00		1.00	
96-97	1.00	1.00	1.01	1.00	1.00
98-99	1.00	1.00	1.00	1.00	1.00
100-101	1.00	1.00		1.00	
102-103	.98	1.01	1.00	.99	1.00
104-105	.98	1.01	1.00	.99	1.00
106-107	.98	1.02		.99	
108-109	.98	1.02	1.00	.99	1.00
110-111	.98	1.02	1.00	.99	1.00
112-113	.98	1.03		.99	

Table 2. Continued

Age by months	Milk			Butterfat	
	Utah	U.S.D.A.[a]	U.S.U.[b]	Utah	U.S.U.[b]
114-115	.98	1.03	1.00	.99	1.00
116-117	.97	1.03	1.00	.99	1.01
118-119	.97	1.04		.99	
120-121	.97	1.04	1.00	.99	1.01
122-123	.97	1.04	1.01	.99	1.01
124-125	.97	1.05		.99	
126-127	.97	1.05	1.01	.98	1.02
128-129	.97	1.06	1.01	.98	1.02
130-131	.97	1.06		.98	
132-133	.96	1.06	1.01	.98	1.03
134-135	.96	1.07	1.02	.98	1.04
136-137	.96	1.07		.98	
138-139	.96	1.08	1.02	.98	1.04
140-141	.96	1.08	1.03	.98	1.05

[a]Kendrick (1953)
[b]Patterson (1955)

RESULTS AND DISCUSSION

Observed results

The result of grouping the cow population of Utah by age gave considerable variation in the number of animals within each age group. This variation ranged from nine animals in groups 60 and 62 to 1000 animals in group three.

Table 1 consists of the various age groups, the age in months represented by each group, the number of animals in each group, the per cent of the total represented within that age, the age in years, number of animals by year, and the per cent of the total number of animals by years.

Holstein heifers which freshen under two years of age are often not fully developed. Table 1 shows that 13 per cent of the D.H.I.A. dairy cows calved under two years of age. Brody (1927) illustrated from his experimental work that better fed animals, and those coming into lactation nearing two and one half years of age, reach their mature production earlier than those with less care and younger in age at first calving. Gaines et al (1947) found that both age and size have substantially equal effect upon yield. He found that it is biologically unsound to correct yield for age because it has no effect independent of live weight.

There was an increase of approximately 30 per cent in milk production from first calving (18 months of age) through maturity (78 months of age). Many factors are responsible for a variation frequently as high as 30 per cent from the mean milk production.

Shrode (1945) lists these and many other factors.

The trend in the state of Utah is for fairly early calving with the largest single group, eight per cent at 22-23 months of age. (Table 1) Of the 12,696 animals studied, 2462, or one out of five, (20 per cent) entered lactation between 22 and 27 months of age. Plum and Lush (1934) reported that approximately one half of their grade and purebred heifers from the state of Iowa calved slightly under 24 months of age.

Information in Table 1 shows that 81.23 per cent of all animals were five years of age and under. Approximately 14 per cent of the group is represented by the mature age group, six to eight and one half years of age, while only one half of one per cent of the cows reached 11 years of age. The total number of animals exceeding this age was only 143 of 12,776 or .63 per cent of the total.

Age milk production curves

Age production curves determined by the cubic regression equation have been plotted in Figures 1 and 2 respectively.

As may be noted from the above indicated figures, the production curves continue upward from 19 months of age through 11 years of age. The possible exception is the mean minus one standard deviation of milk production (Figure 1). The mean milk production minus one standard deviation indicated a tendency for a decrease in milk production in animals approximately 10 years of age and older. Of particular interest is the mean milk production curve (Figure 1) which continues its upward trend through the mature period, with no indication of leveling off. If we accept the previously given definition for

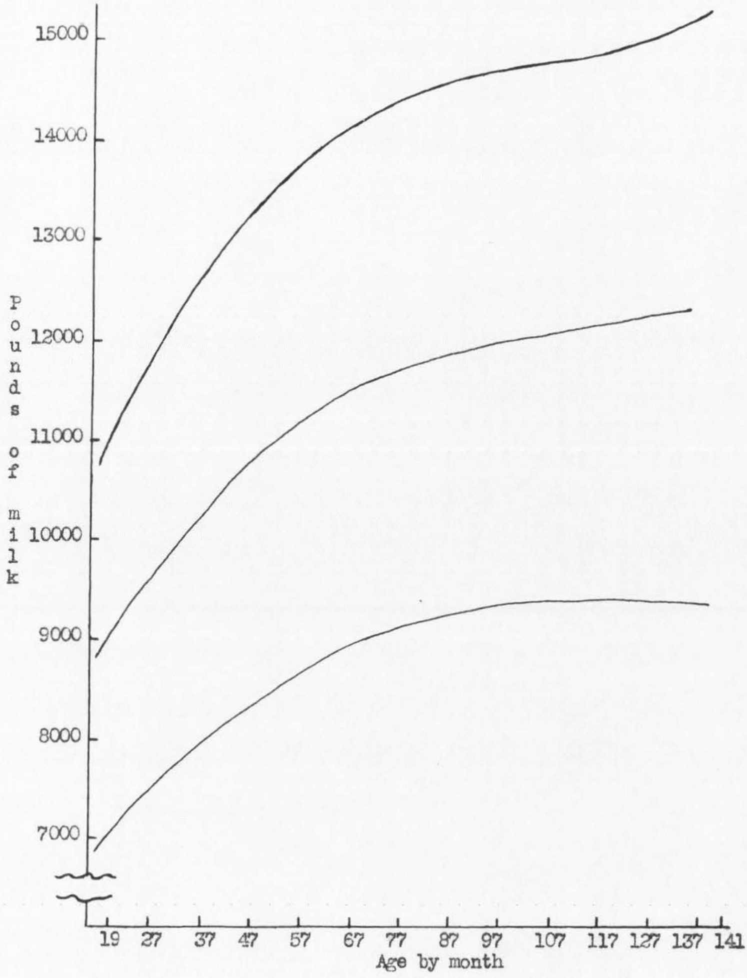

Figure 1. Age curves showing the effect of age on milk production, expressed as a cubic equation with the mean plus and minus one standard deviation

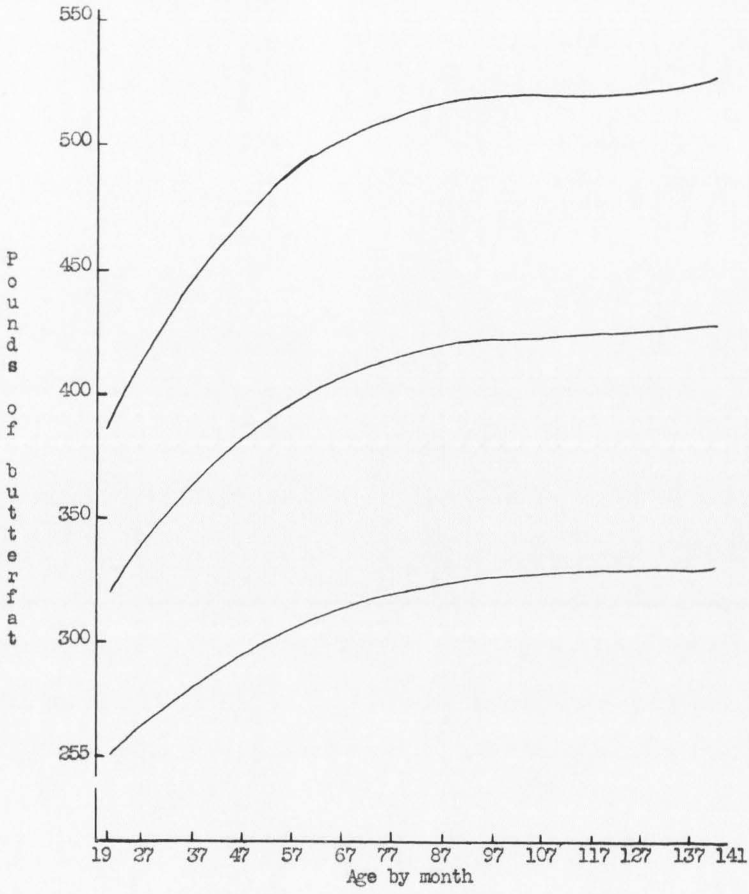

Figure 2. Age curves showing the effect of age on butterfat production expressed as cubic equation with the mean plus and minus one standard deviation

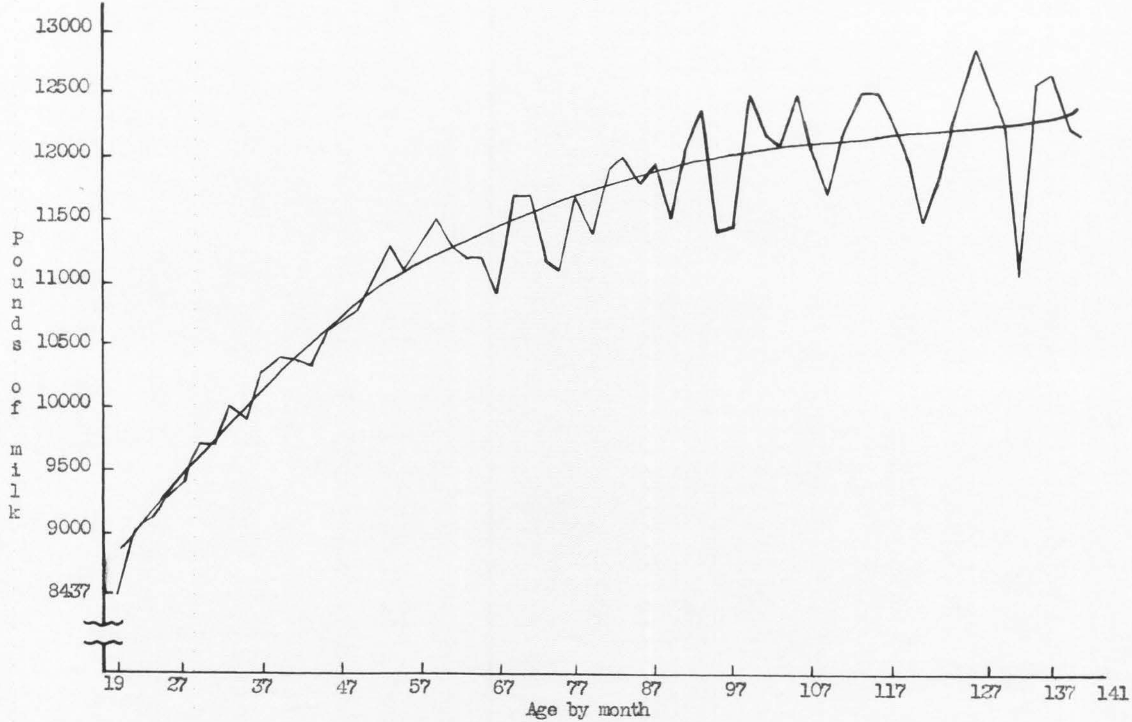

Figure 3. Actual mean production by age group showing cubic regression

mature production, we might expect the lactation curve to continue upward until maturity is reached, level off during this period of mature production and then decrease during the remainder of the life span.

In Figure 3 the mean milk production as determined by the cubic regression equation is plotted over the actual mean milk production for the various age groups. It is evident that where population numbers are large, the average milk production of each age group is centered closely about the age production curve. As population numbers decrease the mean production becomes more widely dispersed about the production curve. This tendency is due to the greater influence which individual lactations have upon the mean of small groups as compared to the mean of large populations. Table 1 shows the rapid decrease in population numbers of each age group as age increases. Many of the groups represent less than 1 per cent of the total population.

A decrease in milk production in the years following maturity is reported by Turner and Ragsdale (1924) and Ludwick and Peterson (1943). These authors further suggest that a quadratic curve would be a good expression of the trend in milk production.

The polynomial curve best fitted to the data was determined by the analysis of variance in Table 3. The analysis of variance was carried through the fifth (quintic) degree and the significance of each degree was determined by the F test. The results were summarized in Table 3. In the analysis the 90 per cent level was established as the significant level. Those values falling below the 90 per cent level are not considered to be significant. It will be noted from Table 3 that the linear and quadratic regression for the mean plus and minus one standard deviation were significant for both milk and butterfat. In the cubic

Table 3. Analysis of variance for milk and butterfat including the mean and mean plus and minus one standard deviation

		Mean square for milk			Mean square for butterfat		
Source	D.F.	Mean	-S	S	Mean	-S	S
Total	61						
Linear	1	10.1502 *	5.9830 *	15.4122 *	8.4472 *	4.8125 *	13.0977 *
From	60	.0498	.0590	.0749	.0712	.0628	.0121
Quadratic	1	1.6250 *	1.1256 *	2.2158 *	2.1796 *	.9980 *	3.8170 *
From	59	.0231	.0409	.0386	.0355	.0470	.0584
Cubic	1	.1387 **	.0014 ***	.3934 *	.2156 **	.0485	.5019 *
From	58	.0211	.0413	.0325	.0324	.0470	.0508
Quartic	1	.0321	.0959	.0024	.1097 ***	.0118	.0989
From	57	.0209	.0404	.0330	.0310	.0457	.0500
Quintic	1	.0063	.0035	.0475	.0002	.0020	.0099
From	56	.0212	.0410	.0327	.0316	.0415	.0506

* Significant (P .005)
** Significant (P .025)
*** Significant (P .10)

regression the mean and the mean plus one standard deviation were significant for both milk and butterfat, while the mean minus one standard deviation was significant (P .10) for milk, and was not significant for butterfat (Table 3). From the analysis of variance it was determined that plotting the cubic equation would represent sufficiently the data contained herein (Figure 3).

The effect of age

The lactation curves rise sharply from first lactation to maturity (Figure 1). At maturity they tend to level off, then maintain a gradual increase until nearly 11 years of age. This upward trend beyond maturity is not in keeping with the national and U.S.U. trends. It might be due to such factors as the following: (1) small numbers of select individuals and (2) the rapid elimination of poor producers from the herd. The number of producing animals steadily decreases until at the age of 11 years there are only 60 animals remaining in the herds of the state (Table 1). Note that in the last three age groups there is a slight recession of milk production from 12, 728 to 12,252 pounds of milk (Table 5). This trend downward is also noted for butterfat production (Table 6).

It is evident from this study that the age curves do not follow the expected course and decrease following maturity. This is due to heavy culling practices followed throughout the state on low producing animals, and because of the inclusion of as many as three lactation records from each high producing cow. Generally no more than one and possibly two lactation records of low producers are included in the study. No correction was attempted for this condition.

Table 4. Mean milk production in pounds for each age group

Age by month	Actual production Mean	Actual production Mean −S	Actual production Mean S	Due to cubic regression Mean	Due to cubic regression Mean −S	Due to cubic regression Mean S
18–19	8537	6458	10,616	8816.9	6890.5	10743.2
20–21	9005	7087	10,923	8993.3	7008.1	10978.3
22–23	9159	7191	11,127	9163.0	7122.6	11203.3
24–25	9333	7234	11,432	9326.2	7233.5	11418.7
26–27	9418	7301	11,535	9482.8	7341.1	11624.5
28–29	9783	7539	12,027	9633.3	7445.4	11821.1
30–31	9773	7208	12,338	9777.7	7546.5	12008.7
32–33	10083	7371	12,295	9916.0	7644.4	12187.5
34–35	9908	7748	12,068	10048.5	7739.2	12357.8
36–37	10302	8150	12,454	10175.3	7830.8	12519.8
38–39	10441	7966	12,916	10296.5	7919.4	12673.7
40–41	10428	8010	12,846	10412.2	8004.9	12819.7
42–43	10375	8081	12,669	10522.8	8087.4	12958.2
44–45	10688	8258	13,118	10628.3	8167.0	13089.4
46–47	10724	8394	13,054	10728.6	8243.8	13213.4
48–49	10771	8240	13,302	10824.1	8317.8	13330.5
50–51	11099	8629	13,569	10914.9	8388.9	13441.1
52–53	11303	8489	14,117	11001.2	8457.2	13545.1
54–55	11108	8750	13,466	11082.9	8522.9	13643.1
56–57	11312	8699	13,925	11160.5	8585.8	13735.2
58–59	11501	9186	13,816	11233.9	8646.3	13821.5
60–61	11375	8653	14,097	11303.2	8704.1	13902.4
62–63	11233	8435	14,031	11368.8	8759.4	13978.0
64–65	11293	8836	13,750	11430.4	8812.2	14048.8
66–67	10997	8462	13,532	11488.7	8862.5	14114.7
68–69	11718	8861	14,575	11543.3	8910.5	14176.2
70–71	11736	8923	14,549	11594.8	8956.1	14233.4
72–73	11290	8525	14,055	11643.0	8999.4	14286.6
74–75	11150	8414	13,886	11688.2	9040.5	14336.1
76–77	11715	9100	14,330	11730.7	9079.3	14381.9
78–79	11495	8910	14,080	11770.2	9115.9	14424.4
80–81	11918	9527	14,309	11807.2	9150.5	14463.8
82–83	12089	9363	14,815	11841.7	9182.9	14500.5
84–85	11841	9179	14,503	11874.0	9213.3	14534.5
86–87	11990	9236	14,744	11904.0	9241.8	14566.2
88–89	11592	9041	14,143	11932.0	9268.3	14595.8
90–91	12108	9492	14,724	11958.3	9292.9	14623.4
92–93	12424	9723	15,125	11982.5	9315.5	14649.5
94–95	11479	8735	14,223	12005.4	9336.4	14674.2
96–97	11450	8425	14,475	12026.6	9355.6	14697.6
98–99	12525	9377	15,173	12046.6	9372.9	14720.2
100–101	12239	9902	14,576	12065.3	9388.7	14741.9
102–103	12152	9632	14,672	12083.1	9402.8	14763.4
104–105	12531	10070	14,992	12099.9	9415.3	14784.5
106–107	12112	8946	15,278	12116.0	9426.2	14805.7
108–109	11705	8977	14,433	12131.5	9435.7	14827.1
110–111	12230	9742	14,718	12146.3	9443.6	14849.1

Table 4. Continued

Age by month	Actual production			Due to cubic regression		
	Mean	Mean -S	Mean S	Mean	Mean -S	Mean S
112-113	12568	9475	15,661	12161.0	9450.2	14871.8
114-115	12572	9764	15,380	12175.3	9455.4	14895.4
116-117	12342	9123	15,561	12189.8	9459.2	14920.2
118-119	12012	9628	14,396	12204.2	9461.9	14946.5
120-121	11574	8574	14,574	12218.9	9463.2	14974.5
122-123	11918	9203	14,633	12233.9	9463.4	15004.4
124-125	12402	9757	15,047	12249.3	9462.4	15036.4
126-127	12946	10211	15,681	12265.6	9460.4	15070.9
128-129	12659	10695	14,623	12282.5	9457.3	15107.9
130-131	12305	9334	15,276	12300.5	9453.0	15147.9
132-133	11135	8270	14,000	12319.4	9447.9	15190.9
134-135	12673	9979	15,367	12339.6	9441.9	15237.3
136-137	12728	9541	15,915	12361.2	9435.0	15287.3
138-139	12293	10143	14,443	12384.1	9427.3	15341.1
140-141	12252	8214	16,290	12408.9	9418.7	15399.0

Table 5. Mean butterfat production in pounds for each age group

Age by month	Actual production: Mean	Actual production: Mean −S	Actual production: Mean S	Due to cubic regression: Mean	Due to cubic regression: Mean −S	Due to cubic regression: Mean S
18–19	311.0	243.3	378.7	321.03	254.97	387.08
20–21	325.3	257.8	392.8	327.23	258.88	395.58
22–23	331.7	263.0	400.4	333.18	262.66	403.70
24–25	335.7	262.6	408.8	338.88	266.30	411.47
26–27	341.2	268.3	414.1	344.33	269.80	418.87
28–29	357.3	279.1	435.5	349.55	273.17	425.93
30–31	356.5	274.0	439.0	354.52	276.41	432.65
32–33	365.1	288.3	441.9	359.28	279.52	439.03
34–35	359.8	281.9	437.7	363.80	282.50	445.10
36–37	373.9	294.8	453.0	368.10	285.37	450.85
38–39	377.4	289.6	465.2	372.21	288.12	456.30
40–41	377.0	287.9	466.1	376.09	290.74	461.45
42–43	377.2	291.1	463.3	379.79	293.25	466.31
44–45	386.9	297.6	476.2	383.28	295.67	470.90
46–47	386.3	303.5	469.1	386.57	297.96	475.20
48–49	389.8	296.3	483.3	389.69	300.15	479.25
50–51	397.5	309.5	485.5	392.63	302.23	483.05
52–53	406.3	309.4	503.2	395.40	304.21	486.60
54–55	403.2	313.1	493.3	398.00	306.10	489.91
56–57	406.4	313.1	499.7	400.45	307.89	492.99
58–59	410.2	325.2	495.2	402.72	309.58	495.85
60–61	410.6	313.3	507.9	404.84	311.19	498.50
62–63	398.7	296.7	500.7	406.82	312.70	500.95
64–65	401.9	314.2	489.6	408.67	314.14	503.21
66–67	391.9	303.4	480.4	410.38	315.49	505.27
68–69	420.5	321.3	519.7	411.97	316.77	507.16
70–71	419.7	319.3	520.1	413.42	317.96	508.88
72–73	399.5	300.8	498.2	414.76	319.08	510.43
74–75	398.0	297.0	499.0	415.98	320.13	511.85
76–77	415.2	317.8	512.6	417.10	321.10	513.12
78–79	412.0	321.4	502.6	418.13	322.02	514.24
80–81	421.0	335.2	506.8	419.05	322.86	515.24
82–83	429.1	331.5	526.7	419.88	323.64	516.12
84–85	414.4	322.8	506.0	420.64	324.37	516.89
86–87	416.1	316.0	516.2	421.30	325.04	517.57
88–89	406.6	311.5	501.7	421.90	325.66	518.14
90–91	428.2	339.6	516.8	422.43	326.75	519.05
92–93	444.2	345.6	542.8	422.90	326.75	519.05
94–95	408.6	306.7	510.5	423.31	327.22	519.41
96–97	397.6	289.3	505.9	423.68	327.66	519.71
98–99	441.8	347.0	536.6	424.00	328.05	519.94
100–101	425.4	344.7	506.1	424.26	328.40	520.15
102–103	431.8	339.5	524.1	424.51	328.71	520.31
104–105	434.0	339.0	529.0	424.72	329.00	520.45
106–107	423.9	317.6	530.2	424.92	329.25	520.58
108–109	415.3	322.7	507.9	425.09	329.49	520.69
110–111	427.3	342.0	512.6	425.25	329.69	520.81

Table 5. Continued

Age by month	Actual production			Due to cubic regression		
	Mean	Mean -S	Mean S	Mean	Mean -S	Mean S
112-113	434.6	323.5	545.7	425.41	329.86	520.94
114-115	448.9	348.9	548.9	425.56	330.03	521.08
116-117	423.8	306.9	540.7	425.71	330.19	521.25
118-119	430.2	345.1	515.3	425.89	330.32	521.45
120-121	405.6	302.2	509.0	426.07	330.44	521.70
122-123	406.5	325.9	487.1	426.28	330.55	522.01
124-125	433.7	351.0	516.4	426.52	330.66	522.36
126-127	457.7	348.0	567.4	426.78	330.76	522.79
128-129	438.1	361.3	514.9	427.08	330.37	523.29
130-131	433.7	334.2	533.2	427.43	330.97	523.89
132-133	386.3	286.4	486.2	427.83	331.08	524.57
134-135	456.0	347.2	564.8	428.28	331.20	525.35
136-137	428.2	333.9	522.5	428.80	331.32	526.26
138-139	421.0	351.4	490.6	429.37	331.48	527.28
140-141	420.4	298.3	542.5	430.01	331.63	528.42

Table 6. Standard error of mean $S_{\bar{x}}$

	Milk		Butterfat	
Age by month	S	Standard error of mean $S_{\bar{x}}$	S	Standard error of mean $S_{\bar{x}}$
18–19	2079.24	14.3	67.73	4.7
20–21	1917.90	9.2	67.50	3.2
22–23	1967.54	2.0	68.72	2.2
24–25	2099.31	7.1	73.10	2.5
26–27	2117.45	9.7	72.90	2.9
28–29	2244.22	11.0	78.21	3.9
30–31	2564.87	14.0	82.46	4.5
32–33	2211.88	10.4	76.79	3.6
34–35	2160.32	8.9	77.93	3.6
36–37	2152.05	9.1	79.09	3.3
38–39	2474.97	11.9	87.79	4.2
40–41	2417.91	12.3	89.07	4.5
42–43	2294.32	13.3	86.11	5.0
44–45	2429.70	12.8	89.34	4.7
46–47	2329.67	11.5	82.75	4.1
48–49	2531.01	12.9	93.45	4.8
50–51	2469.95	14.1	87.99	5.0
52–53	2813.76	17.8	96.87	6.1
54–55	2358.28	15.0	90.08	5.7
56–57	2613.26	15.9	93.25	5.7
58–59	2314.73	13.1	85.02	4.8
60–61	2721.51	17.6	97.33	6.3
62–63	2797.96	18.9	102.00	6.9
64–65	2456.78	16.6	87.70	5.9
66–67	2534.50	18.6	88.51	6.5
68–69	2856.92	20.1	99.24	6.9
70–71	2813.37	19.1	100.41	6.8
72–73	2765.35	19.7	98.74	7.0
74–75	2736.15	21.6	101.02	7.9
76–77	2615.41	22.7	97.36	8.4
78–79	2584.88	21.0	90.59	7.3
80–81	2390.94	19.4	85.82	7.0
82–83	2726.44	23.5	97.61	8.4
84–85	2661.59	23.7	91.63	8.2
86–87	2753.53	26.6	100.05	9.7
88–89	2551.29	28.2	95.11	10.5
90–91	2616.09	28.9	88.55	9.8
92–93	2700.58	26.0	98.62	9.5
94–95	2744.44	29.4	101.94	13.9
96–97	3024.97	30.6	108.34	13.9
98–99	2648.08	28.1	94.79	10.0
100–101	2337.36	31.2	80.69	10.8
102–103	2519.52	30.2	92.32	11.7
104–105	2460.69	30.5	95.00	13.4
106–107	3166.00	40.3	106.32	14.6

Table 6. Continued

Age by month	Milk S	Milk Standard error of mean $S_{\bar{x}}$	Butterfat S	Butterfat Standard error of mean $S_{\bar{x}}$
108-109	2728.41	40.8	92.61	16.1
110-111	2487.57	30.2	85.26	14.3
112-113	3092.89	40.9	111.06	17.5
114-115	2807.91	40.0	100.00	16.4
116-117	3219.12	40.1	116.94	18.5
118-119	2384.08	30.7	85.09	13.5
120-121	2999.73	60.4	103.37	2.2
122-123	2714.83	40.7	80.64	14.0
124-125	2644.83	40.0	82.67	15.9
126-127	2734.55	70.3	109.68	29.0
128-129	1963.98	30.1	76.83	16.7
130-131	2971.31	80.6	99.48	28.7
132-133	2864.61	60.6	99.90	22.9
134-135	2694.09	80.1	108.79	31.8
136-137	3186.68	100.6	94.28	31.4
138-139	2149.54	50.5	69.63	18.0
140-141	4038.00	103.4	122.10	40.7
142.143	2465.74	27.6	92.94	10.6

A rather serious limitation to studies made on commercial dairy herds is the lack of large numbers of life time production records. A few records are available for top producing cows. Because of economic necessity and popular custom, heifers are selected from better bred animals. During the first lactation and almost always by the end of the second lactation, a large percentage of the total population has been eliminated because the animal's production has not reached the desired level. As this culling effect continues, the slope of the age curve is strongly influenced by the remaining few high producers.

It would seem that much of the bias appearing in this and similar studies might be eliminated if we were to categorize all animals by the number of completed lactations, the various production levels, and the relation shown between individual lactations and the relation between various production levels.

It is highly probable that many first calf heifers with high productive capacity are eliminated from herds because the management and environmental factors are not conducive to maximum production. There is good indication that the inherent productive range of an animal is quite broad, but because of inferior management practices the animal never reaches its potential.

<u>Fitting orthogonal polynomials</u>

In fitting orthogonal polynomials the type of equation obtained is expressed in terms of ξ'_s as they are orthogonal functions of X(age). The regression equations obtained were as follows:

Milk:

Mean $\hat{Y} = 11,384.14 + 25.28\,\xi_1 - 2.53\,\xi_2 + .0706\,\xi_3$

+ S $\hat{Y} = 13,971.74 + 31.15\,\xi_1 - 2.95\,\xi_2 + .1188\,\xi_3$

- S $\hat{Y} = 8,796.55 + 19.41\,\xi_1 - 2.10\,\xi_2 + .0223\,\xi_3$

Butterfat: Mean $\hat{Y} = 403.77 + .7292\,\xi_1 - .0926\,\xi_2 + .0028\,\xi_3$

$+S$ $\hat{Y} = 495.12 + .9080\,\xi_1 - .1225\,\xi_2 + .0042\,\xi_3$

$-S$ $\hat{Y} = 312.41 + .5504\,\xi_1 - .0627\,\xi_2 + .0013\,\xi_3$

It is very often desirable to obtain these equations in terms of X rather than in terms of ξ_s. A transformation from ξ_s to X resulted in the following regression equation.

Milk: Mean $\hat{Y} = 8{,}607.02 + 217.85X - 3.98X^2 + .0235X^3$

$+S$ $\hat{Y} = 10{,}495.81 + 250.60X - 5.22X^2 + .0396X^3$

$-S$ $\hat{Y} = 6{,}771.15 + 122.73X - 1.75X^2 + .0074X^3$

Butterfat: Mean $\hat{Y} = 314.49 + 6.54X - .1313X^2 + .0009X^3$

$+S$ $\hat{Y} = 378.27 + 9.04X - .193X^2 + .0014X^3$

$-S$ $\hat{Y} = 251.49 + 4.03X - .0693X^2 + .0004X^3$

Age conversion factors

Factors for converting the production of an animal of one age to that of another age have been determined for both milk and fat. These factors are compared with Kendrick and also those of Patterson (Table 2). Factors in column 1 of Table 2 were determined by using a similar age base, (six to eight and one half years of age) as the U.S.D.A.

Using the same base period as the U.S.D.A., column 1 indicates that cows in Utah are not as close to their mature production when calving as are those of the U.S.U. Dairy Herd. However, they are closer than those of the national D.H.I.A. This trend is in keeping with the work of Brody (1927) and others when they suggest that animals in controlled herds are better cared for as heifers, and as a result are heavier producers during the first lactation, and subsequently reach mature production at an earlier age. Another factor possible involved in this trend, is the varied culling procedures practiced by different individuals.

Factors computed for butterfat closely agree with those developed for the U.S.U. Dairy Herd. A relationship is shown in Table 2.

<u>Mean error</u>

The standard error of the mean was computed and is shown in Table 6. Though this is of no particular significance statistically, it does show an interesting trend. In view of the large numbers involved and the extreme variation in the number of animals in each age group, it suggests the large error involved when using these small groups to make predictions for the total population. The range of the standard error of the mean is 2.10 for the 22-23 month old group and 100 for those in the 136-137 month old group. The error increases as the number in each group grows smaller with relation to the total population.

<u>The effect of age on the standard deviation</u>

The standard deviation is a form of the average deviation from the mean. A small standard deviation means the population has small variability, and is homogeneous in nature, while a large standard deviation means considerable variability exists in the population and they are heterogeneous in nature. This is well illustrated by the dairy cow and milk production. At an early age and in large numbers the standard deviation is closely clustered about the mean milk production. As population numbers decrease the effect of the individual production characteristics has more effect upon the mean of the group and we have a wider dispersion of the standard deviation about the mean.

SUMMARY

Grouping cow populations by age gave considerable variation in the number of animals in each freshening age group of two months. These numbers ranged from nine to 1000 in each age group.

It is evident from the rapid decrease in animals within each age group that extensive culling is carried on between the first and third lactations. More than 81 per cent of the animals are represented in this two through five year old group. Thirteen per cent of the animals studied came into production under two years of age.

An increase of approximately 30 per cent in milk production was noted between heifers calving at 18–19 months of age and mature cows.

The trend in Utah is for fairly early calving at approximately 22–23 months of age. Fourteen per cent of all animals are represented by the mature age group.

To evaluate the effect of age on the upper, middle and lower producers, the standard deviation, which includes a minimum of 68 per cent of the total population in each determination, was used. Age curves determined by the cubic regression equation were plotted for the mean and the mean plus and minus one standard deviation. They show a continual rise in milk and butterfat production from first calving through the end of the productive life of the animal. Age effected the curve of the mean plus one standard deviation more than it did the mean minus one standard deviation. The rapid and continual rise of the age curve throughout the life of the dairy cow studied is strongly influenced by the severe culling during the early lactations.

The rapid elimination of medium and low producers by culling leaves few high producing animals in each of the age groups for which the age curves were determined.

Factors for converting the production of an animal of one age to that of another age were determined. A close relationship was noted between factors computed in this study and those computed on cows in D.H.I.A. throughout the United States and for cows in the Utah State University Dairy Herd.

The severe culling problem would also strongly affect age conversion factors. There would be a tendency for the computed factors to over estimate the actual yield at older ages.

The mean error showed the large error involved when using a few select animals to predict large population trends. This was also evidenced with the standard deviation. Age showed little effect upon the standard deviation when population numbers were large, but considerable effect was noted when population numbers were small in relation to the total population.

LITERATURE CITED

Brody, S. 1927. The relation between the course of growth and the course of senescence with special reference to age changes in milk secretion. Mo. Agri. Exp. Bul. 105.

Cannon, C. Y., Frye, J. B., Jr., and Sims, John A. 1942. Predicting 305-day yields from short time records. Jour. Dairy Sci. 25(12):991.

Edwards, Joseph. 1950. Relationship between the secretion on milk and butterfat. Jour. Agri. Sci. 40(1&2):100-123.

Fisher, Ronald A., and Yates, Frank. 1949. Statistical tables for biological, agricultural, and medical research. 3rd ed. New York: Hafner Publishing Co.,

Gaines, W. L., Davis, H. P., and Morgan, R. F. 1947. Within-cow regression of milk-energy on age and liveweight. Jour. Dairy Sci. 30(5):273-278.

Harrison, E. W. 1952. How valuable is a herd sire index. Holstein-Friesian World 49(3):242-243.

Hickman, C. B., and Henderson, C. R. 1954. Genetic variation and covariation in rate of maturity and level of production in dairy cattle. Jour. Dairy Sci. 37(6):668.

Kay, R. R. and McCandlish, A. C. 1929. Factors affecting the yield and quality of milk. Jour. Agri. Sci. 19(2):342-372.

Kendrick, J. F. 1953. Standardizing Dairy-Herd-Improvement-Association records in proving sires. BDI-Inf-162.

Ludwick, T. M., and Peterson, W. E. 1943. A measure of persistency of lactation in Dairy Cattle. Jour. Dairy Sci. 26(5):439-445.

Madden, D. E., Lush, J. L., and McGilliard, L. D. 1955. Relation between parts of lactations and producing ability of Holstein cows. Jour. Dairy Sci. 38(11):1264. pt. 2.

Mahadevan, P. 1951. The effect of environment and heredity on lactation. Jour. Agri. Sci. 41(1):80-97.

Ostle, Bernard, 1953. Statistics in research. Iowa State College Press, Ames, Iowa.

Patterson, George E. 1955. Lactation curves of Holstein cows as influenced by age, gestation, and season of freshening. Master of Science Thesis. Utah State University, Logan, Utah.

Pearl, R. 1914. On the law relating milk flow to age in dairy cattle. Proc. Soc. Exp. Biol. Med. 12(1):18-19.

Plum, M., and Lush, J. L. 1934. Freshening age of purebred cows in Iowa cow testing association. Jour. Dairy Sci. 17:625-638.

Sanders, H. G. 1928. The variations in milk yields caused by season of the year, age, dry period and their elimination. Jour. Agri. Sci. 18(1):46-67.

Shrode, R. R. 1945. Milk production as related to age in Holstein-Friesian dairy cows. Master of Science Thesis. Iowa State College Library, Ames, Iowa.

Turner, C. W. and Ragsdale, A. C. 1924. A comparison of Holstein-Friesian sires based on the average "Mature Equivalent" fat production of the daughters. Mo. Agri. Exp. Sta. Bul. 217.

Word, A. H., and Campbell, J. T. 1938. The practical application of age conversion factors to dairy cattle production (butterfat) records. Jour. Agri, Sci. 28(4):509-522.