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FACTORS AFFECTING THE PHYSICAL AND ECONOMIC COST OF BUTTERFAT PRODUCTION IN PINE COUNTY, MINNESOTA

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UNIVERSITY FARM, ST. PAUL

CONTENTS

	Page
Introduction	3
Variation in butterfat production	5
Influence of individual factors on butterfat production	5
Economic application of results	15
Time of freshening	15
Fat test of milk	16
Importance of protein in the ration	17
The relative economy of hay and silage in the ration	20
Management as a factor in profitable dairying	22
Technical appendix	27
I. Source of data	27
II. Methods of analysis	29
Reliability and importance of individual factors	31

ILLUSTRATIONS

	Page
Fig. 1. Differences in butterfat production with differences in nutrients in ration, other factors constant at average values	9
2. Differences in butterfat production with differences in nutritive ratio	11
3. Differences in butterfat production with differences in fat test of milk	13
4. Differences in butterfat production with differences in extent of fall freshening	14

FACTORS AFFECTING THE PHYSICAL AND ECONOMIC COSTS OF BUTTERFAT PRODUCTION IN PINE COUNTY, MINNESOTA

By George A. Pond and Mordecai Ezekiel[1]

INTRODUCTION

All studies of dairy production reveal a wide range in physical and economic efficiency among different farms. This variation occurs even among farms in a given community where systems of farming, types of feed available, climatic conditions, and other factors that might influence production are fairly uniform. The causes of this wide range may be classified under two general heads—(1) variations in the inherent capacity and efficiency of individual cows in converting feed into milk and butterfat; and (2) differences in the feeding and management practices of individual farmers in handling their herds. In this second class are differences in such factors as kinds and amounts of feeds, seasonal feeding practices, and the time of freshening, all of which are within the control of the farmer and regulated according to his judgment.

The variations in feeding practices among individual farms in the same community in a particular year are shown in Table 1. The feeds reported are those fed during the months from November to May, inclusive, a period of the year when the cows are almost entirely on dry feed. These data reveal a rather uniform daily ration of roughage in terms of dry roughage equivalent, but a wide range in the kinds of hay and other roughages composing the total. The daily grain ration varies much more widely than does the roughage. In order to give some relative picture of the total daily rations fed to the several herds, the roughage and grain feeds have been added together in terms of the total digestible nutrients in each. Some herds received almost twice as much total nutrients per day as did others. On Farm 210 the feed per day is the least of any and the product of butterfat is also the least in the group. Ordinarily one would assume that more liberal feeding would make possible higher production. However, the herd on Farm 607 received 74 per cent more nutrients daily than the herd on Farm 210, but produced only 4½ per cent more butterfat and less total milk. It should be remembered in this connection that this feed ration is only for the non-pasture season, whereas

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Table 1

Rations Used During Non-Pasture Season (June 1 to Oct. 31, inc.) on Dairy Farms in Pine County in 1925

Farm No.	Pounds of roughage per day during feeding season							Pounds of grain per day, feeding season				Total digestible nutrients per day in all feeds†	Total production for year	
	Timothy and clover hay	Wild hay and millet	Corn fodder	Straw and stover	Corn silage	Ruta-bagas and other succulent roughage	Total dry roughage equivalent*	Low protein grains	Wheat mill-feeds	Oil-meal	Total grain		Butter-fat	Milk
210	12.8	0.4	0.5	...	....	20.6	20.6	1.1	0.8	...	1.9	10.0	176	5,269
214	8.1	...	...	...	28.6	4.3	19.0	3.2	2.5	1.1	6.8	12.7	276	8,379
122	14.1	...	...	...	16.4	19.9	26.2	2.5	0.7	0.5	3.7	12.7	228	5,087
519	12.7	...	1.1	2.4	15.9	5.7	23.4	3.5	...	0.3	3.8	13.1	216	6,189
812	9.8	4.3	...	...	24.7	16.2	27.7	1.5	1.8	0.7	4.0	14.6	211	5,731
618	10.2	3.7	1.0	...	36.9	...	27.2	1.7	2.1	0.4	4.2	15.0	216	5,377
120	17.7	...	0.4	...	23.2	4.1	27.2	2.1	1.2	0.4	3.7	15.6	220	6,253
208	13.1	1.4	...	...	30.2	1.3	25.0	3.8	2.2	1.3	7.3	15.7	315	9,067
113	14.7	...	...	0.3	36.6	....	27.2	3.0	1.6	1.2	5.8	16.2	288	7,847
419	14.5	0.5	0.7	0.8	32.2	4.2	28.6	3.6	2.3	1.1	7.0	17.3	310	8,812
607	10.1	6.5	4.6	1.8	29.9	23.2	40.7	2.0	0.3	0.4	2.7	17.4	184	3,948
108	25.6	0.3	...	...	....	6.0	27.9	4.1	3.4	0.7	8.2	19.1	259	6,306

* Pounds succulent roughage divided by 3 and added to dry roughage.

† Tables for computing the digestible nutrients and the digestible protein in the different feeds are given in Technical Appendix III, page 41.

the production is for the entire calendar year. In all cases these herds received some additional grain or roughage or both during the pasture season but in widely differing amounts. On the other hand, the herd on Farm 208 received 57 per cent more feed than that on Farm 210 but produced nearly 80 per cent more butterfat. These illustrations seem to emphasize the wide range in feeding practices and in the resulting production on different farms. In the following pages are presented some analyses of the effect of quantity and quality of ration and of variations in management on the production of a dairy herd.

VARIATION IN BUTTERFAT PRODUCTION

There were wide differences in average butterfat production among the 77 herd-year records included in this study. Table 2 shows the distribution of herds according to average production, and indicates just how wide this variation was. Some of the herds averaged less than 200 pounds of butterfat per cow, while others averaged over 320.

Table 2

Herds Classified According to Butterfat Production per Cow

Butterfat production per cow, lb.	No. of herds in group
140-159	1
160-179	4
180-199	9
200-219	8
220-239	8
240-259	12
260-279	10
280-299	4
300-319	11
320-339	6
340-359	3
360-379	1

Statistical study of the relation of the production in various herds to the ways the cows were fed and handled showed that nearly three-quarters of this variation in production could be explained by differences in these various factors.[2] The average way in which differences in cost of these factors affect production is shown in the following discussion.

Influence of Individual Factors on Butterfat Production

Total digestible nutrients.—The basic factor affecting the amount of butterfat a cow or a herd produces is the quantity and quality of feed consumed. With no record of the quantity of feed obtained from pasturage, this study was restricted to measuring the

[2] See the technical appendix, pages 29 to 37, for the detailed statement of the way in which these results were obtained.

relation between the other feeds received and the production. The digestible nutrients available in the ration were determined according to the tables given in Feeds and Feeding, by Henry and Morrison. The amount of these nutrients in protein and in succulent roughage also was computed.

The pounds of nutrients fed per cow varied widely from herd to herd. This is evident from Table 3.

Table 3

Herds Classified According to Quantity of Digestible Nutrients per Cow

Digestible nutrients fed per cow, in addition to pasturage, lb.	No. of herds in group
2,000-2,499	3
2,500-2,999	6
3,000-3,499	20
3,500-3,999	28
4,000-4,499	14
4,500-4,999	6

The average difference in butterfat production with the differences in the quantity of digestible nutrients fed is shown in Table 4. The production indicated is for herds receiving the pounds of digestible nutrients stated, with a nutritive ratio of 1:7.2, with 43 per cent of the cows freshening in the fall; and producing milk with a fat test averaging 3.86 per cent for the herd. The production is also shown for herds averaging 3.4 per cent fat, and for herds averaging 4.0 per cent fat, to indicate roughly how the production for different rates of feeding varies between Holstein and Guernsey herds.

Table 4

Average Differences in Butterfat Production with Differences in Nutrients in Ration

Total digestible nutrients in addition to pasture, lb.	Annual butterfat production with other factors at average*		
	Average test milk, lb. (3.86% fat)	Low test milk, lb. (3.4% fat)	Higher test milk, lb. (4.0% fat)
2,500	239.5	231.0	240.8
3,000	244.9	236.2	246.2
3,500	249.6	240.7	250.9
4,000	253.7	244.7	255.1
4,500	257.4	248.2	258.8

* For feed of nutritive ratio 1:7.2, with 43 per cent of the herd freshening in the fall months.

This table indicates that, on the average, the production does not increase quite so rapidly as does the feed the cows are fed, and that the higher the production goes, the more feed must be added to secure further increases of production. These conclusions are based on the herd averages included in this study, and may indicate that some of the cows are being fed beyond their ability to use the feed efficiently. Apparently, most of the herds are being fed well, since, according to Table 3, few herds were receiving less than 3,000 pounds of digestible nutrients per cow.

That the fat production did not go up more rapidly with additional feed might be due to the cows not all having the same amount of pasture available, or not obtaining the same quantity of nutrients from pasture. If the cows fed the heaviest ate the least on pasturage, and vice versa, that would explain the results.

According to the Morrison feeding standards, it would take 5,283 pounds of digestible nutrients with a nutritive ratio of 1:6.93, to produce 245 pounds of fat in 3.5 per cent milk.[3] Table 4 shows that the cows fed 4,000 pounds of digestible nutrients in this area, with nearly the same nutritive ratio, produced 244.7 pounds of fat. Apparently such cows secured the remaining 1,300 pounds of digestible nutrients from pasture. On the other hand, cows fed less heavily secured more of the required nutrients from pasture, to judge from the results in the table.[3]

Nutritive ratio.—The proportion of the protein in feed, as well as the total quantity of nutrients, affects the milk production. The variation in the nutritive ratio between different herds is even greater than is the variation in total nutrients.

Table 5
Herds Classified According to the Nutritive Ratio of the Feed

Nutritive ratio	No. of herds in group
1:5.0-1:5.49	1
1:5.5-1:5.99	7
1:6.0-1:6.49	4
1:6.5-1:6.99	19
1:7.0-1:7.49	17
1:7.5-1:7.99	15
1:8.0-1:8.49	4
1:8.5-1:8.99	7
1:9.0-1:9.49	0
1:9.5-1:9.99	3

The changes in butterfat production with changes in nutritive ratio are shown in Table 6. This table shows the corrections to be applied to the estimated production shown in Table 4, for cases where the nutritive ratio differs from the averages assumed in Table 4. Thus for a herd fed a ration with a nutritive ratio of 1:9.0, the most probable production would be 6.2 per cent below that shown in Table 4.

[3] Computed from Henry and Morrison, Feeds and Feeding. Given in Wisconsin Research Bull. 79, p. 35.

Table 6
Average Differences in Butterfat Production with Differences in Nutritive Ratio

Nutritive ratio	Butterfat produced per unit of feed — In per cent of production expected*
1:6.0	101.6
1:6.5	101.1
1:7.0	100.5
1:7.5	99.3
1:8.0	98.0
1:8.5	96.2
1:9.0	93.8

* Expected production is the amount of butterfat that, on the basis of the influence of each factor as brought out in this study, would result from any given combination of these factors if nutritive ratio had no effect on production.

Table 6 indicates the necessity of feeding a ration containing an ample supply of protein. A ration with 4,000 pounds of digestible nutrients, only 400 pounds of which were protein (a nutritive ration of 1:9) produced only about 238 pounds of butterfat, on the average; whereas a ration of 4,000 pounds of digestible nutrients, with 570 pounds of protein (a nutritive ratio of 1:6), produced about 258 pounds. Substituting 170 pounds of protein for 170 pounds of other digestible nutrients added 20 pounds to butterfat production.

Fat test of the milk.—It has already been noted that allowance must be made for differences in the fat test of the milk, in studying the quantity of fat that is produced from a given quantity of feed. There were wide differences in fat test in this area, since some of the herds were all Holstein cows, some were all Guernseys, while some had other breeds or representatives of two or more. The differences in average fat tests for the year, for the 77 herds, are shown in Table 7.

Table 7
Herds Classified According to Fat Test of the Milk

Fat test, %	No. of herds in group
3.00-3.24	3
3.25-3.49	19
3.50-3.74	16
3.75-3.99	10
4.00-4.24	10
4.25-4.49	6
4.50-4.74	7
4.75-4.99	3
5.00 and over	3

Table 8 shows the relation of production to fat test in the area.

Table 8
Average Differences in Butterfat Production with Differences in Fat Test of the Milk

Fat test, %	Butterfat produced per unit of feed — Percentage of production expected*
3.25	94.7
3.50	97.4
3.75	99.4
4.00 and over†	100.5

* In percentage of expected production of 3.86 per cent milk (the average of all herds studied) with other factors remaning the same.

† The number of cases of over 4¼ per cent fat was not sufficient to determine the relation accurately beyond this limit.

Figure 3 shows the relation of milk production to fat test.

It is only natural that, with other conditions the same, a high-testing cow can produce more fat from the same feed than can the low-testing cow. While she produces more fat, she produces less skimmilk and less of the solids other than fat. Where a farmer sells only the fat, and makes no use of the skimmilk, it is obviously to his advantage to keep the high-testing cows, if he can get cows of as good producing

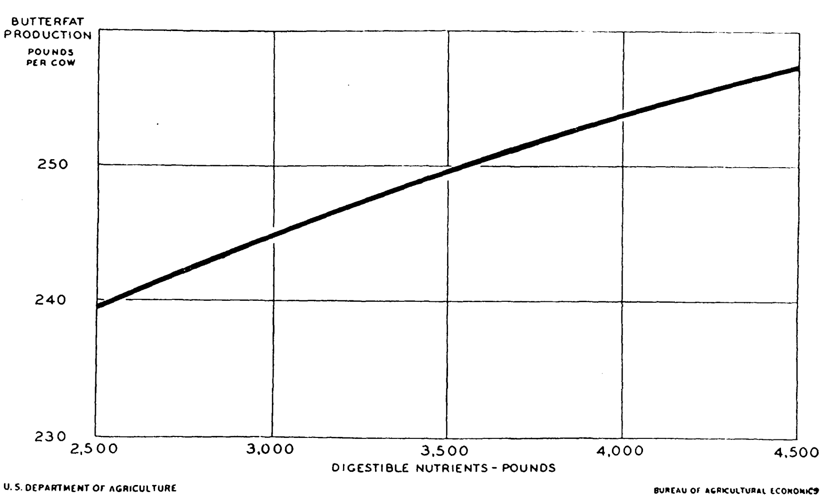

Fig. 1. Differences in Butterfat Production with Differences in Nutrients in Ration, Other Factors Constant at Average Values

ability as low-testing cows. However, if he can use the skimmilk in feeding hogs or for some other purpose, the question becomes whether the additional skimmilk from low-testing cows is worth enough to offset the loss in fat production. That point will be developed subsequently, in connection with the economic application of these results.

Fall freshening.—In addition to the three important factors that have been discussed, the analysis showed that the time of year the cows freshen has a definite influence upon the milk produced from a given quantity of feed. Since the study was based upon herd averages rather than upon individual cows, it was not possible to consider separately the influence of freshening in individual months; instead, the proportion of all the cows in each herd freshening during the period from September to December was used as the basis for studying the influence of the time of freshening. There were wide differences in the proportion of the herd freshening in this period; as shown in Table 9, in some herds nearly all the cows freshened in the fall; in others only a few or none.

Table 9

Herds Classified According to the Proportion of the Cows Freshening in the Fall

Proportion of cows in herd freshening from September to December, inclusive	No. of herds in group
0- 9.9	4
10- 19.9	6
20- 29.9	5
30- 39.9	3
40- 49.9	9
50- 59.9	8
60- 69.9	10
70- 79.9	15
80- 89.9	9
90-100.0	8

It is evident that the most common practice is to have from 60 to 80 per cent of the herd freshen in the fall. Table 10 indicates that there is a good reason for this practice; the herds freshening in the fall produce more butterfat from the same feed than do the herds freshening in the spring.

Table 10

Average Differences in Production wtih Differences in Fall Freshening

Proportion of cows in herd freshening from September to December, inclusive	Butterfat production per unit of feed
	Per cent of production expected*
0	94.8
20	97.3
40	99.5
60	102.3
80	104.5
100	106.4

* In per cent of expected production for a herd with 43 per cent of cows freshening in the fall (the average of all herds in this study) the influence of other factors being held constant.

The herds in which all the cows freshened in the fall produced about 12 per cent more butterfat per unit of feed than did the herds in which none of the cows freshened in the fall.

Use of silage.—The influence of silage on production was studied by determining what proportion of all the total digestible nutrients was in the form of succulent roughages, including beets and green corn as well as silage. As is shown in Table 11, practically all of the herds received some green roughage, and for most of them the roughage contributed about one-quarter of the total digestible nutrients in the ration.

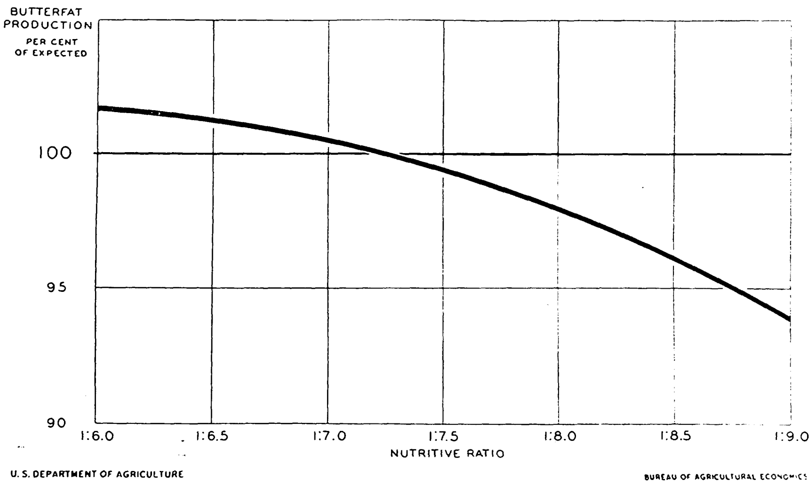

Fig. 2. Differences in Butterfat Production with Differences in Nutritive Ratio

Table 11
Herds Classified According to Proportion of Total Nutrients Fed as Succulent Roughage

Total nutrients fed as succulent roughage, per cent	No. of herds in group
0- 9.9	4
10-19.9	13
20-29.9	40
30-39.9	17
40-49.9	2
50-59.9	1

There were no significant differences in production with differences in the proportion of nutrients in succulent roughage. The silage added as much to the production as would be expected for the digestible nutrients contained, but no more. If more feed can be saved from the same area in the form of silage than in the form of fodder, or otherwise, it is a valuable feed; but the water in silage appears to make it no more effective in producing butterfat than an equal quantity of nutrients in any other form.

Quality of management.—In addition to the way in which the cows are fed and handled, many elements in dairying can not be subjected so readily to exact measurement. These include the selecting and breeding of the herd to high production; feeding each cow to her own capacity, providing the cows adequate water and shelter, and providing sufficient pasturage. All these elements may be lumped together under "quality of management."

A rough measure of the extent to which quality of management may influence production was secured by classifying the herds into four groups according to the quality of the dairy management, as judged by the men who worked with the farmers in taking the farm records. After allowing for the differences in production which would be explained by differences in quantity and quality of feed, in fat test, and in time of freshening, it was still found that the men who had been classified as the "best" dairymen had higher production per cow than would be expected for the feed, and those who were classified as "poor" dairymen had less production than would be expected for the feed. Table 12 summarizes these results.

Table 12

Herds Classified According to the Quality of Management and Average Production for Each Group

Quality of management	No. of herds	Butterfat production per unit of feed: Per cent of production expected
Good	25	117
Fair	19	100
Unsatisfactory	18	93
Poor	15	82

Table 12 illustrates strikingly how important is the dairyman himself for success in dairying. The best dairymen secured 17 per cent more fat from the same feed than did the next group, whereas the poorest dairymen obtained only 70 per cent as much fat from the same feed as did the best men. In this area, differences in quality of management accounted for more differences in production than did all other factors combined.

The specific practices followed by the best dairymen are discussed on pages 22 to 26.

Estimating milk production.—Now that the relation of production to the several individual factors has been considered, the several influences can be combined to indicate the most probable butterfat production for any given combination of feeds and practices. This may be illustrated by taking the figures for Farm No. 1, as shown in Table A, and estimating the most probable average milk production for such a herd.[4] The record shows the cows were fed 4,134 pounds of digestible nutrients with a nutritive ratio of 1:7.9, producing milk of 4.59 fat test; that 60 per cent of the cows freshen in the fall, and that the dairyman was of first-rate ability. Tables 4, 6, 8, 10, and 12 give the data needed to estimate production from these factors; but with one exception the values given fall at points between those for which values are given in the tables. Figures 1 to 4 show the same data graphically, however, so the required interpolations can be readily made by reference to these figures.

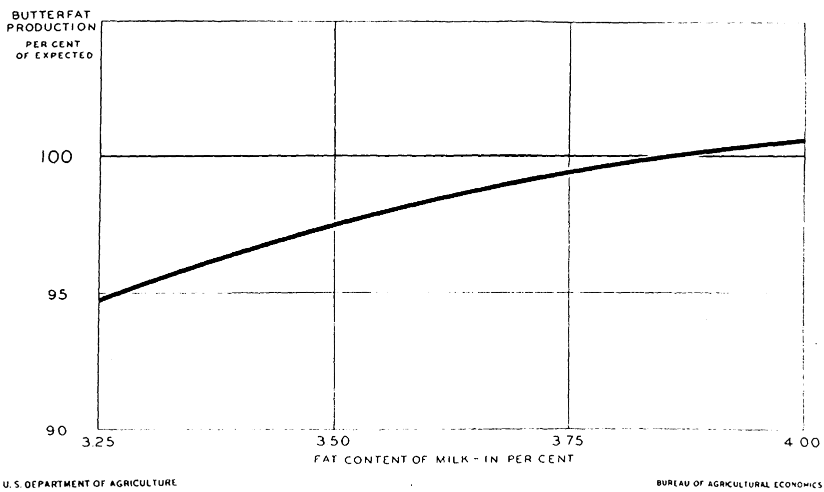

Fig. 3. Differences in Butterfat Production with Differences in Fat Test of the Milk

Table 13
Computation of Probable Butterfat Production

Variable	Average for herd	Estimated production	Accumulated estimate
Total dig. nutrients ..	4,134 lb.	255 lb. (Fig. 1)	255 lb.
Nutritive ratio	1:7.9	98.3% of above (Fig. 2)	250.6 "
Fat test	4.59%	100.5% of above (Fig. 3)	251.8 "
Fall freshening	60% of cows	102.3% of above (Fig. 4)	257.6 "
Quality of management	Good	117% of above (Fig. 5)	291.4 "

The third column shows the probable effect of each factor on production, as read from the curves. The last column shows the estimated production as each additional variable is taken into account. Thus

[4] See Technical appendix II, page 28.

a herd fed 4,134 pounds of digestible nutrients with a nutritive ratio of 1:7.9, but average in all other respects, probably would produce about 98.3 per cent of 255 pounds of fat, or 250.6 pounds. For a herd producing milk of 4.59 per cent fat test, however, 0.5 per cent more butterfat would be expected, increasing the estimated production to 251.8 pounds. Then taking account of the two remaining factors, the estimate is increased to 291.4 pounds. The actual production for this herd was 281 pounds, or 0.4 per cent less than that estimated. This is well within the average error of estimate of 18.2 per cent, and indicates that other conditions affecting production for this particular herd, such as quality of cows and food value of the pasturage, was nearer average than on many of the herds included in the study.

In the same way that probable production has been worked out for this combination of conditions, it may be worked out for any other combination. If it is desired to test the relative economy of different rations or different practices, the probable production can be estimated for

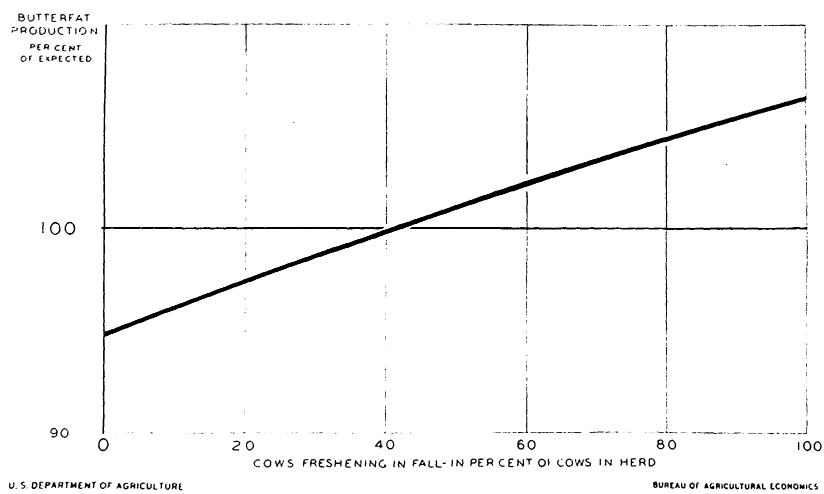

Fig. 4. Differences in Butterfat Production with Differences in Extent of Fall Freshening

each combination. Then the prices or costs for the prevailing economic conditions can be taken into account, and the most profitable practices for the particular economic conditions can be determined. The estimated butterfat production may also be used for comparing the feed fed by farmers in this area, in addition to pasture, with quantities which would be required for their production, as determined from feeding standards established on the basis of experimental investigation.

ECONOMIC APPLICATION OF RESULTS

Time of Freshening

Forty-three per cent of all cows included in this study freshened during the months of September, October, November, and December. The figures presented in Table 10 indicate, as already noted, that these cows freshening in the fall produced more butterfat from a given quantity of feed in addition to pasture than did those freshening during the other months of the year. When all the cows in the herd freshened in the fall months, the production of butterfat per cow with a given quantity of feed was 106.4 per cent of what would have been expected with only 43 per cent freshening in the fall, the average of all herds. On the other hand, when none of the cows freshened during the fall months, the production was only 94.8 per cent of what would have been expected with average fall freshening. Herd 56 is an example of a herd with no cows freshening in the fall.[5] The average total digestible nutrients per cow in addition to pasture was 3,332 pounds, and the average butterfat production per cow, 260 pounds. Had 43 per cent of these cows freshened in the fall, a production of 274.3 pounds of butterfat might have been expected and with 100 per cent fall freshening, 291.9 pounds of fat with the same feed. A further advantage of fall freshening is that a large proportion of the butterfat is produced during the months of higher prices. The average selling price of butterfat during the period of this study was 50 cents per pound and ranged from 46 cents in June, July, and August to 55 cents in December. If the monthly prices are weighted by the production by months of the fall-freshening cows, the average price for the year is 50.7 cents. A similar weighting for spring-freshening cows gives a yearly average price of 48.7 cents. The combined advantage of higher production and a higher price for this herd is shown in Table 14.

Table 14

Comparison of Returns Over Feed per Cow with Spring and Fall Freshening

Per cent fall freshening	Butterfat production, lb.	Value of butterfat	Feed cost	Return over feed
0	260.0*	$126.62	$51.98	$74.64
43	274.3†	137.15	51.98	85.17
100	291.9†	147.99	51.98	96.01

* Actual production.
† Expected production.

This advantage of $21.37 in return over feed per cow for the fall-freshening herd indicates that an increase in the practice of having the cows freshen in the fall would add materially to the net returns

[5] See Table C, page 40.

from dairy herds in this area. Another advantage not shown by these figures is the fact that fall-freshening cows are dry in late summer and early fall when the farmer is busiest with field work and the peak load of dairy labor does not come till after the rush of harvest time. Spring freshening, on the other hand, involves the heaviest load of milking and calf-rearing during the rush of the crop season.

Fat Test of Milk

The herds giving milk with a high fat content produced more butterfat from a given quantity of feed than did those giving milk of a low fat content. This is indicated in Table 8. The low-test herds, however, produced more milk in proportion to the feed received. The relative advantage of low- or high-testing cows, therefore, depends on the relative value of butterfat and skimmilk. In the area studied, as well as in most of Minnesota, the only market outlet for dairy products is as cream for butter manufacture. The skimmilk is only worth what it can be made to return in livestock production. On the farms studied, the skimmilk is fed largely to hogs and poultry. During the period of the study, these classes of livestock returned slightly less than 20 cents per 100 pounds above all other costs for the skimmilk they received. If the increased amount of skimmilk produced by the low-testing herds, valued at 20 cents per pound, amounts to more than the value of the increased production of butterfat of the high-testing herds, it is obvious that it would be more profitable to maintain low-testing herds. On the other hand, if the value of the increased butterfat production of the high-testing cows more than offsets the loss in value of skimmilk produced, the high-testing cows are more profitable.

In Table 15 is presented a comparison of the value of product of cows giving milk of differing fat content produced from a given quantity of feed. This is based on the data presented in Table 8.

Table 15

Value of Product of a Given Quantity of Feed from Cows Producing Milk with Varying Butterfat Content

Fat test, per cent	Butterfat		Skimmilk		Total value of product	Price for skimmilk necessary to make return equal to that of 4 per cent milk
	Pounds	Value at 50 cents per lb.	Pounds*	Value at 20 cents per 100 lb.		
3.25	94.7	$47.35	2,598	$5.20	$52.55	$0.64
3.5	97.4	48.70	2,458	4.92	53.62	0.55
3.75	99.4	49.70	2,320	4.64	54.34	0.39
4	100.5	50.25	2,178	4.36	54.61	....

* Assuming 30 per cent cream marketed.

These computations are based on the assumption that other factors such as quality of ration and time of freshening are equal and that each group of cows is fed the same quantity and quality of feed. On this basis, it is apparent that in an area where skimmilk can not be made to yield a return greater than 20 cents per 100 pounds, the net return from the high-testing cows is greater than that from low-testing cows. The disadvantage of the low-testing cows shown in Table 15 mght be offset if the low-testing cows used more feed and had a higher production per cow then high-testing cows, since only feed costs increase directly with production, and the other costs, including labor, shelter,, interest, and depreciation, would decrease per pound of butterfat as the total production increased. In case the product was marketed as whole milk, the larger production of the low-test cows might prove an advantage, provided the price of milk was not adjusted to compensate for differences in fat content. However, within the limits of production found in this study and with price conditions as they existed in this area, on the average the cows producing milk of high fat content produced butterfat more economically than did those producing low-test milk.

Importance of Protein in the Ration

From a physical standpoint, a high-protein ration for a dairy cow is more efficient than a low-protein ration. This is indicated in Table 6. The most profitable proportions of the protein and non-protein elements of the ration, however, depend on the relative price of high and low protein feeds. This is indicated in Table 6. The most profitable proportions of the protein and non-protein elements of the ration, however, depend on the relative price of high- and low-protein feeds and on the price of the product. In order to illustrate this point, rations varying in protein content have been suggested and the probable production of milk and butterfat from each computed. These rations are shown in Table 16. Each ration provides approximately 4,000 pounds of digestible nutrients to be fed in addition to pasture. The probable production is computed from the data presented in Table 6. In comparing the relative returns from these four rations, two sets of prices have been used. The first set is based on the farm market price of feeds in the Askov community, as reported monthly by the fieldman during the years of this study, 1925-1927, inclusive. The second set is based on the monthly farm price of feeds in Minnesota as reported by the Bureau of Agricultural Economics, of the United States Department of Agriculture, for the same three years. As there is no regular market for silage, hence no market price, the average cost of producing silage for the three years on the farms studied has been used in the first series of prices and the average cost of producing silage on farms in southern Minnesota in the second. Prices for commercial feeds at Askov are the actual prices paid. The same prices for commercial feeds have been used in the second set of prices, as these prices were based on the Minneapolis market and were not affected materially by local conditions. To the regular market price of farm grains has been added a charge for grinding at the rate of 10 cents per 100 pounds. These two sets of prices are represented in Table 17.

Table 16

Suggested Dairy Rations Containing Varying Proportions of Protein and the Probable Product of Milk and Butterfat to be Expected from Them

(Amount of feed per cow per year in addition to pasture)

Feeds	Ration 1	Ration 2	Ration 3	Ration 4
Corn, ground, lb.	600	...	600	600
Oats, ground, lb.	600	800	600	700
Barley, ground, lb.	100	...	...	575
Bran, wheat, lb.	300	500	600	...
Middlings, standard, lb.	300	400	...	...
Oilmeal, lb.	...	310	185	...
Clover and timothy hay, lb.	3,500	3,500	...	...
Clover (alsike) hay, lb.	...	...	3,500	...
Alfalfa hay, lb.	...	...	...	3,200
Silage, lb.	7,000	7,000	7,000	7,000
Total digestible nutrients	4,000	4,002	4,003	4,002
Nutritive ratio	1:9	1:7	1:6	1:6
Probable production				
Milk, lb.	6,166	6,606	6,684	6,684
Butterfat, lb.	238	255	258	258

Table 17

Prices Used in Comparing Returns from Suggested Dairy Rations

Kind of feed	Unit	Local farm prices	
		Askov	Minnesota
Corn, ground	Bushel	$ 1.00	$ 0.76
Oats, ground	"	0.56	0.39
Barley, ground	"	0.85	0.65
Bran, wheat	100 lb.	1.55	1.55
Middlings, standard	"	1.60	1.60
Oilmeal	"	2.70	2.70
Clover and timothy hay	Ton	13.00	12.75
Clover (alsike) hay	"	14.00	13.00
Alfalfa hay	"	20.00	15.75
Corn silage	"	6.65	4.00

The return over feed for each ration for both sets of prices is shown in Table 18. With each set of prices, the wide ration is least profitable. The returns from the other rations vary according to the prices used. Ration 4 is at a disadvantage in the area studied because the low-lime content of the soil makes it difficult, if not impossible, to grow alfalfa. Since the alfalfa must be shipped in, the price is relatively high. On the basis of state farm prices, the alfalfa ration has the advantage. On the high-lime soils of southern and western Minnesota, alfalfa can be produced at a cost of approximately $8.00 per ton. If alfalfa is charged at this rate, the return over feed cost for Ration 4 would be $89.38 instead of $76.98 and the advantage of this ration over Ration 1 would be $22.50. Wherever alfalfa can be grown successfully, it is one of the cheapest sources of digestible nutrients and especially of digestible protein. In the Askov community, alsike clover is the principal legume roughage. Usually it is grown in a mixture with timothy in order to insure a fuller stand and make the crop easier to cut and cure. Clear stands of alsike usually outyield either timothy or the timothy and alsike mixture. A comparison of the returns from Ration 2 and Ration 3 indicates the desirability of clear alsike hay for cows as compared with a mixture of alsike and timothy. It appears to be a wise policy to reduce the proportion of timothy in the mixture and, if possible, even to eliminate it altogether.

Table 18

Comparison of Returns from Rations with the Same Total Digestible Nutrients but Varying in the Protein Content and in the Price at Which Feeds Are Charged

Ration	Feed cost except pasture	Value of product*	Returns over feed cost	Additional returns over Ration 1
		Askov Farm Prices		
1	$78.47	$129.75	$51.28	....
2	82.55	139.01	56.46	$5.18
3	83.30	140.65	57.35	6.07
4	88.43	140.65	52.22	0.94
		Minnesota Farm Prices		
1	62.57	129.75	67.18	....
2	68.59	139.01	70.42	3.24
3	66.51	140.65	74.14	6.96
4	63.67	140.65	76.98	9.80

* Butterfat valued at 50 cents a pound and skimmilk at 20 cents per 100 pounds; assuming butterfat is sold in 30 per cent cream.

Another factor affecting the relative economic efficiency of the suggested rations is the price of dairy products. In these computations butterfat is valued at 50 cents a pound. If, instead, a price of 40 cents a pound is used, the returns are reduced but not in the same proportions as shown in Table 18. On the basis of Askov farm prices, the additional return of feed cost as compared with Ration 1 is $3.18 for Ration 2, and $4.08 for Ration 3. For Ration 4, the return over feed cost is $1.06 less than for Ration 1 instead of 94 cents greater, as was the case when butterfat was charged at the higher price. With lower prices for the product, lower cost rations become more profitable even tho they may involve some decrease in production. On the basis of average state farm prices for feeds, the different rations have the same relative ranking in returns over feed with a 40-cent price for butterfat as with a 50-cent price.

Relative Economy of Hay and Silage in the Ration

The cows included in this study received about two pounds of succulent roughage for each pound of dry roughage fed. Eighty-one per cent of the succulent roughage was corn silage, 15.5 per cent was rutabagas, and the balance was rutabaga tops and potatoes. Seventy-three and one-half per cent of the dry roughage was composed of clover, principally alsike, and mixtures of clover with timothy and to some extent with native grasses. Nine per cent was alfalfa, practically all of which was shipped in from other sections of the state; and the balance was wild hay, millet, corn fodder, corn stover, and straw. As has already been noted, succulent roughage contributed no more to the production than did the same quantity and quality of digestible nutrients in other feeds. Unless the cost of digestible nutrients in succulent roughage is less than that of the same nutrients in other feeds, there appears to be no advantage in the use of succulent feeds. On the other hand, the lower cost of digestible nutrients in non-succulent roughages may make the use of succulent feeds highly unprofitable.

Corn silage is the principal succulent feed in this area. Because of the relatively cool summers, the short growing season, and the physical character of the soil, this section is not well adapted to corn growing. The average yield of silage was only 5.5 tons per acre and the cost $6.55 per ton. The same land would produce 1½ tons of clover or mixed clover and timothy hay at a cost not exceeding $10 per ton with the factors of production charged at the same rate as in case of the silage crop. Alfalfa—altho, as already noted, it can not be successfully grown locally—could have been purchased during the period of this study at an average price of $20 per ton. The cost of 100 pounds of digestible nutrients in these four roughages is shown in Table 19. Corn silage is an expensive feed from this standpoint. If the costs of producing silage and alfalfa in southern Minnesota are used instead, the comparison is still strongly in favor of alfalfa. With corn silage costing $4.00 per ton and alfalfa $8.00, the cost of 100 pounds of digestible nutrients in silage would be $1.50 and in alfalfa 78 cents. Both clover and alfalfa have another advantage over silage for feeding dairy cows, in that protein constitutes a larger percentage of the total digestible nutrients. Protein constitutes 20.8 per cent of the total digestible nutrients in alfalfa, 16.7 per cent in alsike clover, and only 7.5 per cent in corn silage.

Table 19

Cost of 100 Pounds Digestible Nutrients in Principal Roughages Fed to Herds Studied

Kind	Local cost per ton	Digestible nutrients per ton	Cost per 100 lb. digestible nutrients
Clover (alsike) and timothy	$10.00	962	$1.04
Clover (alsike)	10.00	946	1.06
Alfalfa	20.00	1,020	1.96
Corn silage	6.65	266	2.50

The combined effect of the lower cost of nutrients in these hays, as compared with corn silage, and the increased production due to the higher protein content of the hay, is shown in Table 20. Herd 47 has been used for this illustration.[6] This herd received 3,622 pounds of total digestible nutrients, of which 381.2 pounds was digestible protein. The ration included 9,963 pounds of corn silage containing 1,285.2 pounds of digestible nutrients. To replace this with the same amount of digestible nutrients in the form of hay would require 2,672 pounds of timothy and clover hay, 2,717 pounds of clover hay, or 2,520 pounds of alfalfa hay. This would provide a total dry roughage ration per cow of 2½ tons or slightly less. The nutritive ratio, probable production, decrease in feed cost, and increase in return over feed have been computed for each substitution. On the basis of the findings of this study, corn silage is an expensive feed for dairy cows and apparently could be profitably replaced to a considerable extent, if not altogether, by legume hay. It is possible than in this area some corn may be necessary to provide a cultivated crop for a good rotation system. The silo offers the best means of utilizing the crop, as the growing season is too short to mature corn for grain satisfactorily. It seems hardly likely that this consideration is important

Table 20

Probable Effect on Production, Feed Cost, and Return Over Feed of Substituting Different Hays for Corn Silage in a Given Dairy Ration

Ration	Nutritive ratio	Probable production of butterfat, lb.	Value of increased butterfat production over silage ration*	Decreased cost of feet as compared to silage ration†	Increase in return over feed as compared to silage ration
Ration, including silage	1:8.5	217.0	....	.....	.....
Silage replaced with timothy and alsike hay	1:7.5	224.0	$3.50	$18.77	$22.27
Silage replaced with alsike hay	1:6.3	228.5	5.75	18.54	24.29
Silage replaced with alfalfa hay	1:5.6	230.0	6.50	6.93	13.43

* Butterfat valued at 50 cents per pound.

† Silage at $6.65 per ton, clover and timothy and clover at $10 per ton, and alfalfa at $20 per ton.

[6] See Table 3, page 6.

enough to continue the use of such an expensive feed as silage on the scale now practiced in this region.

Management as a Factor in Profitable Dairying

The quality of management is the most important factor affecting production considered in this study. The effect of management on efficiency of production is indicated in Table 12. Management is a rather intangible factor. It does not lend itself to objective measurement as readily as do the other factors considered. The dairymen whose records are used in this study were rated on this factor as good, fair, unsatisfactory, or poor, according to the judgment of the men who supervised the field work and were in fairly regular contact with the farmers for the three years. The original ratings were based on a general appraisal of each individual, as to his methods and practices. Later the whole factor of management was analyzed and classified in a score card containing the following points.[7]

1. Providing suitable barn conditions
   a. Warmth
   b. Light
   c. Ventilation
   d. Sanitation
2. Supplying an abundance of water, readily available.
3. Providing a variety in ration—at least three concentrates.
4. Keeping production records and culling low producers.
5. Using precautions to keep herd free from disease.
6. Practicing regularity in care and attention given cows.
7. Displaying interest in dairy cows as shown by attendance at dairy extension meetings, reading dairy papers, careful attention to details in handling and feeding cows, questions asked fieldman about dairying, and similar evidences of personal liking for the business.

The factors included in this score card are in addition to such evidences of management as are shown in the balancing of the ration and the adjustment of it to production, which have already been considered in the correlation analysis.

Suitable barn conditions.—Some of the points mentioned above are capable of direct objective measurement, whereas the rating on others is largely a matter of individual judgment. The first point comes in the latter class. Barns were divided into three classes—

[7] The authors wish to express their indebtedness to Dr. C. H. Eckles, Chief of the Division of Dairy Husbandry, Minn. Agr. Expt. Station for his assistance in analyzing the management factor in dairying; and to F. H. Tomlinson, route man in charge of the field work in Pine County, for his services in scoring the farmers on the basis of the factors selected.

good, fair, and poor—on the basis of each of the four subheads under the heading of suitable barn conditions. All the barns belonging to the dairymen classed as good, rated at least fair, and more than half rated good. In the group of fair dairymen, there was a lower proportion of factors rated as good and one was classed as poor. As far as barn conditions were concerned, there was little difference between the groups listed as unsatisfactory and poor, altho as groups they rated materially below the previous two groups. In general it might be said that most of the barns on these farms were good enough not to be an important factor in limiting production.

Water supply.—What has just been said of barn conditions is also true of the water supply. Eighty per cent of the barns were supplied with individual drinking cups and in the rest either an inside tank was available or the cows were watered with a pail.

Variety in the ration.—Variety in the ration, likewise, was a relatively minor limitation, as much of the concentrates fed on these farms was purchased and it was easy to provide the variety. The average number of concentrates fed by the dairymen rated good was 4.6; by those rated fair, 4.5; by those rated unsatisfactory, 4.3; and by those rated poor, only 3.2. Only in the last group was there a marked falling off in variety and this was because of lighter total feeding and the more limited use of commercial feeds. These first three points on the score card, while evidences of management, in general, were of little significance in this study because the ratings were uiformly good on nearly all the farms studied.

Production records and culling.—The keeping of production records and the culling out of low producers proved to be an important factor of management. This was capable of direct measurement from the records available. The farmers were divided into four classes as follows:

1. Those who weighed each milking from each cow and tested a sample from each cow for butterfat content each month.
2. Those who weighed one day's production of each cow each month and tested a sample from each cow for butterfat content.
3. Those who weighed a day's production of each cow at intervals of more than once a month and tested a sample from each cow occasionally.
4. Those who kept no records of the production of individual cows.

The extent to which dairymen of the different grades followed these different practices as to production records is shown in Table 21. Nearly 75 per cent of all the dairymen whose records are used kept some record of the production of each cow in their herds. The advantage of the practice of weighing the milk daily is that it enables the dairyman to observe the production of each individual in his herd more accurately and to adjust feed more closely to production. Some production record for each cow in the herd is essential as a basis for breeding and selection. The extent to which records were used as a basis for culling by the dairymen of different grades is shown in Table 22. In the first group, the cows sold are largely low producers, as shown by the production records. In the second group a lower percentage of the cows culled out are low producers. In the third group there is either little relation between production and culling or no records are available to serve as a basis for checking the culling. The use of production records as a basis for culling the dairy herd is an important factor in successful management.

Table 21

Quality of Dairy Management as Related to the Keeping of Production Records

Production records kept	Quality of management			
	Good	Fair	Unsatisfactory	Poor
Individual daily weights and monthly tests	10	9	6	1
Individual monthly weights and tests	14	3	5	3
Occasional individual weights and tests	1	3	2	..
No individual records	..	4	5	11

Table 22

Quality of Dairy Management and the Use of Production Records as the Basis for Culling the Dairy Herd

Extent of relation between low production and culling	Quality of management			
	Good	Fair	Unsatisfactory	Poor
Close relation between low production of cows and culling	22	7	..	..
Moderate relation between low production of cows and culling	3	6	12	3
Little relation between low production of cows and culling	..	6	6	12

Disease control.—The use of preventive measures in keeping a dairy herd free from disease is difficult to measure objectively. It includes such factors as general sanitation, timely treatment of diseases and injuries, testing for tuberculosis, the isolation or sale of diseased animals, the practice of keeping the herd out of contact with other herds and of not bringing into the herd individuals untested for tuberculosis or individuals from herds not known to be free from disease, and similar precautions against disease. On the basis of these factors, the dairymen studied have been divided into three groups according to their attention to disease control in their herds. This rating is based on observations of the field man rather than on direct measurement, as was possible with the factor of production records and culling. The relation between the rating on quality of management and the rating on disease control is shown in Table 23. Apparently disease control is of considerable importance as a factor in dairy herd management.

Table 23
Quality of Dairy Management and Disease Control Practices

Rating on disease control practices	Quality of management			
	Good	Fair	Unsatisfactory	Poor
1	18	1	3	..
2	7	15	10	11
3	..	3	5	4

Regularity of care.—The sixth factor of good management to be considered is regularity in the care and attention given the dairy herd. It was possible to check this rather closely by means of detailed labor records. All the men were divided into three groups according to the regularity with which they milked and fed their cows. The time records were supplemented with personal observations, in arriving at these ratings. The relation between these ratings and the general rating on management is shown in Table 24.

Table 24
Quality of Dairy Management and Regularity of Care and Attention Given the Dairy Herd

Rating on regularity of care given cows	Quality of management			
	Good	Fair	Unsatisfactory	Poor
1	21	1	..	..
2	4	18	12	5
3	..	..	6	9

General interest.—The seventh factor of management—general interest of the farmer in the dairy business—is, to a certain extent, possible of objective measurement. In making the ratings used, these measurements have been supplemented with the observation and judgment of the field men. Three grades, or degrees, of interest have been used in this study. The relation between degree of interest and quality of management is shown in Table 25.

Summary of management factors.—No attempt was made to combine these various factors representing good management into a single measure on a purely mathematical basis. The classification of management as good, fair, unsatisfactory, and poor, was the product of judgment based on consideration of all seven factors but without a definite weight being assigned to each. A few farmers excelled in each of the seven points, but many of the best managers had their faults and some of the least successful followed at least a few good practices. In general, this analysis indicates the importance of the human factor in determining physical and economic efficiency in dairying. Kind and quality of the ration, time of freshening, and the fat content of the milk all have a definite measurable effect on the economy of butterfat production, but of even greater importance are the factors listed here under quality of management. A cow must be comfortably housed and supplied with drinking water readily available. In addition to sufficient protein in the ration, a variety of concentrates is also important. No direct measure of the quality of the cows in this study is available other than their production of milk and butterfat.

Table 25
Quality of Dairy Management and Degree of Interest of the Farmer in the Dairy Business

Rating on degree of interest	Quality of management			
	Good	Fair	Unsatisfactory	Poor
1	19	3	..	..
2	6	13	2	4
3	..	3	10	11

The dairyman, however, who recorded each individual cow's production and weeded out the low producers was increasing the quality of his herd. Doubtless this accounts in some measure for the more economical production of those practicing good management. Daily weights of milk from individual cows make possible a more accurate adjustment of feed to production. Disease is an important limiting factor in any livestock production. The best managers gave the most attention to disease control. Attention to maintaining a definite time schedule for milking and feeding is important. With no class of stock is regularity of care more important than with dairy cattle. Above all, the farmer must be interested personally in dairy cows to attain the highest degree of success in handling them. He must be studying his business constantly and drawing information from the experiences of others. Also he must observe closely the individuals in his own herd. Without a real personal liking for dairy cows on the part of the operator, no dairy business can achieve a full measure of physical and economic efficiency, regardless of how carefully the rations are compounded or the mechanical organization perfected.

TECHNICAL APPENDIX

I. Source of Data

Method of collection.—The data used in this study were obtained by the detailed farm accounting route method.[1] They were collected over a three-year period—from January 1, 1925, to December 31, 1927. Twenty-eight farms were included the first year. Four of these were dropped at the end of the first year and three at the end of the second. Four additional farms were added the third year. Seventy-seven herd-year records are used in this study. The farms studied were visited twice a week by a field man who supervised and checked all records kept. Each farmer kept a complete record of all cash receipts and expenses. At least once a month, and as much oftener as the ration was changed, a careful record was made of all feed fed to each class of livestock. These ration reports were checked with the aid of periodic inventories, records of purchases of feed, sales of feed crops, and yields of crops harvested. A considerable part of the concentrates used were purchased and charged directly to the cows. As a result of this, and the careful system of checking used, the percentage of error in the feed records has been reduced to a minimum. It would hardly be possible to obtain feed records of greater accuracy under farm conditions without actually weighing every pound of feed used.

The production records are based on reports of butterfat marketed as indicated by the monthly cream checks received. To this has been added the butterfat in milk and cream used in the house and in any whole milk fed to calves. The total production of butterfat as computed in this way is somewhat lower than that shown by cow-testing association records for the same farms. Since the price received is based on the actual pounds of butterfat reported by the creamery, this production figure is more useful for studies involving price and cost comparisons than the usual type of cow-testing record. All these data have been computed on a herd basis. Accurate feed and production records for individual cows could not be obtained under farm conditions as they prevailed in this locality.

Location and description of farms.—The farms from which the data used in this study were obtained are located in north central Pine County. They are grouped about the town of Askov. This area was originally covered with a heavy stand of white pine timber. The soil is a red clay loam, rather low in humus, with some peat in low spots. The land is quite stony and the rock must be hauled off before the land can be cultivated.

The average size of the farms studied was 115 acres. Of this, 56½ acres were in crops as follows: Hay 26 acres, small grain 14 acres,

[1] The authors wish to thank the farmers of Pine County for their co-operation in furnishing the records on which this study is based.

corn 8 acres, potatoes and rutabagas 8½ acres. This crop acreage was not all tillable, as considerable of the hay land is still encumbered with rocks and stumps. About forty acres of land on each farm was used as pasture, tho much of this was still covered with stumps and brush. The remainder of the farms consisted of roads, farmsteads, headlands, brush not pastured, and other waste land. The size of farms varied from 46 to 282 acres and the crop acreages from 12 to 125. Eighty-acre farms were most common. The proportion of crop land was much lower on the large farms.

Dairy cattle were the principal kind of livestock. The average number per farm was a little more than 11. The range was from 4 to 24. Sixty-six of the 77 herd-year records are for herds of dairy breeding—either Holstein or Guernsey, and eight for herds of such dual purpose breeds as Red Polled and milking Shorthorns or mixtures of these two. Most of the cattle were grades, altho purebred sires were used almost exclusively. The herds were maintained primarily for butterfat production and the principal product sold was cream for manufacture into butter. Only enough young cattle were raised, in most cases, to maintain the herds.

Climate and weather.—The region in which the farms studied are located has a comparatively short growing season. The average length of the frost-free period during the three years was 103 days. The springs are usually late and cool. The average annual mean temperature is about 40 degrees F., and the average annual precipitation 26 inches. The climate is well adapted to grass, small grains, and root crops, but not corn. Practically all the corn grown is put into silos. The first year of this study, 1925, was a dry season. Pastures were poor almost throughout the season and the hay crop was quite short. The next year the early part of the season was dry and pastures made a very poor start. The drouth of the previous season had resulted in a poor catch of clover. Even where the stock was turned on to meadows for additional feed, there was little for them. In 1927 the spring was cold, wet, and late. Pasture started slowly because of the late season. Even in a favorable year there is little more than four months of good pasture (June to September, inclusive) that can be depended on. Usually cows are stabled and on full winter feed by the first of November and remain indoors until well into April.

Suitability of records to type of analysis made.—The records from these farms are especially well adapted to the purposes to which they are put in this analysis. In the first place, they represent as nearly accurate a record of feed consumed as it is possible to get under the most favorable farm conditions. Not only were the methods used and conditions met such as to eliminate many sources of error, but the interest of the co-operating farmers greatly facilitated the work. They were, in general, much better than average dairymen. In most cases rations were compounded rather carefully and fed in some definite relation to production. Since the farms were practically all within the area of a single township, weather and soil conditions were largely constant factors. Feeds were of similar quality on different farms. There was comparatively little variation in the quantity or quality of pasture among different farms. The poor pasture conditions during the period of the study tended to minimize the effect of pasture as a variable. This is especially helpful because of the difficulty of getting any satisfactory physical measure of pasture. Since the herds studied were mostly grade herds, maintained for butterfat production, culling was done rather carefully. Few old cows were maintained for the purpose of raising calves. Feed was higher in price than in most of the dairy sections of the state. The limited area of crop land made it necessary to ship in most of the concentrates, and on account of the drouth in 1926 much of the hay fed during the winter of 1926-27 was also purchased from surplus producing areas. Since the price of butterfat was no higher than in areas of cheaper feed, these farmers were compelled to pay more attention to the quality of their cows and to care in feeding and handling them, in order to compete with dairymen whose feed was less expensive. Practically all feed for the cows was fed for production, as it did not prove profitable to feed high-priced feed to cows culled out in order to get them in better condition for market. There is, therefore, under these conditions, a much closer relation between feed and production than would be true in most sections of the state. Furthermore, with feed so valuable, farmers were keenly aware of the feed they had raised or purchased, and therefore the records of the quantity of feed used are more accurate than ordinarily can be obtained.

II. Methods of Analysis

The conclusions presented were based on detailed cost account records from Pine county, Minnesota. Records were available for three years: 28 farms for 1925, 24 farms for 1926, and 25 farms for 1927. Since the practices on each farm varied from year to year, the record for each year was considered to be an entirely different record. The analysis was therefore based on 77 individual records, each giving the averages for one herd for one year.[2]

[2] Study of the individual records showed that this assumption of complete independence was not entirely justified. The records included 20 farms which were included each of the three years. Eight of these 20 farms showed a definite tendency to have milk production either above or below the production estimated on the basis of these practices. The maximum departures of this type average 15 per cent over the three years, indicating the possible extent to which differences in the quality of the cows, of the pasturage from herd to herd, and in other non-measurable influences, affected production, in addition to the factors directly studied.

The figures for each herd were reduced to a per-cow basis, giving the basic data for each of the 13 variables shown in Table A.

Nine variables were selected from these for correlation study of the change in milk production.

The variables were as follows:

$\overline{X}_2$ —Total digestible nutrients, in pounds.

$\overline{X}_3$ —Nutritive ratio (pounds of nutrients in digestible protein in proportion to pounds of digestible nutrients not protein). Only the figure to the right of the colon used; that is, 6 for 1:6.

$\overline{X}_4$ —Digestible nutrients in succulent roughage (silage, etc.) as percentage of total digestible nutrients.

$\overline{X}_5$ Digestible nutrients fed while on pasturage (June to October, inclusive) as a percentage of total digestible nutrients.

$\overline{X}_6$ —Digestible nutrients fed while on pasturage (June to October, inclusive.

$\overline{X}_7$ —Average age of cows.

$\overline{X}_8$ —Number of cows in herd freshening in fall, September to December inclusive, as a percentage of total number of cows in the herd.

$\overline{X}_9$ —Year of record, coded to represent approximate differences in quality of pasturage each of the three years.

$\overline{X}_{10}$—Number of heifers in their first lactation period, as a percentage of total number of cows in the herd.

$\overline{X}_1$ —Average milk production per cow per year, in pounds.

All factors were stated as logarithms before correlating, so as to put the relations on a relative basis rather than an absolute basis.[3]

The first correlation with all the factors included showed that variables $\overline{X}_5$, $\overline{X}_9$ and $\overline{X}_{10}$ had no significant effect upon production, and they were accordingly dropped. A new factor, $\overline{X}_{11}$, was computed by subtracting the sum of $\overline{X}_9$ and $\overline{X}_5$ from 100. This new factor accordingly measured the proportion of total nutrients fed as concentrates.

The factors in the new correlation, $\overline{X}_6$, $\overline{X}_7$, $\overline{X}_8$, $\overline{X}_3$, $\overline{X}_2$, $\overline{X}_4$, and $\overline{X}_{11}$, gave a multiple correlation with $\overline{X}_1$ of $R = .857$, after adjusting to eliminate the tendency for the computed correlation to be too high with 7 variables and only 77 observations. This indicated that over 73 per cent of the variation in average milk production in these herds could be accounted for by variations in the objective factors mentioned.

[3] Note similar treatment and reasons for it in "Practices Responsible for Variations in Physical Requirements and Economic Costs of Milk Production on Wisconsin Dairy Farms," M. J. B. Ezekiel, P. E. HcNall, and F. B. Morrison, Wisconsin Agr. Expt. Sta. Research Bull. 79, pp. 12-14.

Curvilinear regressions were then determined for such of the independent factors as showed curvilinear relations, and the index of multiple correlation determined after the fit of these new curves had been tested by simultaneous solution. This raised the apparent correlation to P = .904; but after adjusting the number of variables and constants represented in the functional regression equation this was reduced to .864, or slightly higher than the previous linear correlation.

Reliability and Importance of Individual Factors

The importance of each individual factor was then studied with respect to the proportion of variance in milk production which was apparently associated with each factor, and with respect to the reliability of the slope of the regression line from the linear solution. The "part correlation"[4] between each factor and milk production, adjusted to remove the influence of other factors, was also computed.

These several measures of individual significance are shown in Table 26.

Table 26

Measures of the Importance of Individual Factors

Variable	Separate determination: Linear coefficients	Separate determination: Curvilinear indexes	Part correlation: Linear coefficients	Part correlation: Curvilinear indexes	Linear net regression coefficient*	Regression coefficient ÷ its standard error
	per cent	per cent				
$\overline{X}_6$—Fat test	58	48	0.83	0.80	— 1.33 ÷ 0.128	10.4
$\overline{X}_7$—Age of cows	— 4	— 2	0.29	0.18	0.107 ÷ 0.078	1.4
$\overline{X}_8$—% fall freshened	9	10	0.43	0.34	0.209 ÷ 0.070	3.0
$\overline{X}_3$—Nutritive ratio	17	15	0.57	0.51	— 0.637 ÷ 0.157	4.1
$\overline{X}_2$—Total digestible nutrients except pasturage	16	10	0.44	0.51	— 0.474 ÷ 0.098	4.8
$\overline{X}_4$—% of nut. in silage	— 1	— 4	0.41	0.25	0.087 ÷ 0.041	2.1
$\overline{X}_{11}$—% of nut. in conc.	5	4	0.29	0.27	0.176 ÷ 0.103	1.7

* The figure following the regression coefficient is its standard error.

These measures all agree in indicating that the fat test is the most important single factor associated with variations in milk production, and that nutritive ratio and total digestible nutrients follow and are of about equal importance. The proportion of cows freshening in the fall is next in importance, altho these last three factors combined do

[4] Smith, Bradford B., Correlation Theory and Method Applied to Agricultural Research," pp. 55-61, Mimeographed publication, U. S. Dept. of Agr., Bureau of Agricultural Economics, August, 1926.

not explain as much of the variance in production as does fat test alone.

The remaining factors appear to be of neglible significance, except $\overline{X}_4$, the proportion of total nutrients fed in the form of silage or other succulent roughages. The linear regression for this variable is 2.1 times as large as its own standard error, indicating that the probability is at least 98 to 100 that increases in this factor with the other variables constant, really do increase milk production. In the case of age of cows, on the contrary, where the regression coefficient is only 1.4 times its standard error, the corresponding probability is only 92—that is, there are 8 chances out of 100 that milk production does not really increase with increased age, holding amount of feed and other factors constant. This also applies, tho in less degree, to $\overline{X}_{11}$, the proportion of total nutrients in concentrates. With the regression coefficient only 1.7 times the standard error for this variable, there are nearly 5 chances out of 100 that milk production does not increase with a larger proportion of grain in the ration.

The correlation analysis may be said to indicate strongly that increasing the proportion of concentrates in the ration, without changing the total digestible nutrients or the nutritive ratio, will tend to increase milk production slightly, with about 2 per cent increase in milk production for each 10 per cent increase in concentrates; and likewise to indicate that milk production per unit of feed increases with the average age of the cows. Neither conclusion is absolutely proved, however, and it is quite possible that repeating the study might yield conflicting conclusions.

There is practically conclusive evidence that the remaining five variables do affect milk production, with the proportion of nutrients in silage the only one about which any question may be raised. For fall freshening, for example, with the regression coefficient 3 times its own standard error, there are less than 2 chances out of 1,000 that increased fall freshening does not really increase milk production in this area, and the evidence for the other three variables is even more conclusive.

Discarding $\overline{X}_{11}$ and $\overline{X}_7$, nutrients fed as grain, and age of cows, a new multiple correlation was run using only the five independent factors which had shown significant results in the previous correlation. This new computation gave a multiple correlation of $R = .851$, after adjusting for the number of variables. That is, after dropping the two unimportant variables, the significant multiple determination here is still 72.4 per cent, as contrasted to 74.7 per cent for the curvilinear correlation with the larger number of variables. Apparently neither the regression curves nor the additional variables contributed much to the ability to account for milk production.

Tested by the method of coefficients of determination, the relative importance of each of the five factors was as follows:

	Per cent determination
$\overline{X}_6$—Fat test	40.1
$\overline{X}_8$—Fall freshening	6.4
$\overline{X}_3$—Nutritive ratio	15.0
$\overline{X}_2$—Total digestible nutrient	11.6
$\overline{X}_4$—Proportion of silage	—.7
All factors combined	72.3

These results agree with the earlier conclusions, indicating that fat test is the most important single factor in explaining differences in milk production among the herds in this area, that the nutritive ratio and the proportion of total digestible nutrients are next in importance, with fall freshening following, and that the proportion of nutrients fed as silage is of relatively slight importance compared with the other four factors.

The correlation analysis indicated that milk production was so closely related to the five important factors that the average production for a herd could be estimated from the values for each of those five factors, with an average error of 11.6 per cent; and with an error of not over 14.7 per cent for two-thirds of the estimates. With an actual production varying from 3,000 pounds to nearly 10,000 pounds, if the production for a particular herd were estimated at 6,000 pounds, the chances would be 2 out of 3 that it would really be above 5,100 pounds and below 6,900. While this is not perfect agreement, many other factors such as quality of the cows in the individual herds, differences in pasturage on different farms, and differences in the ability of individual dairymen to handle their cows, all affect the production from a given herd. With factors of this type still to be allowed for, the average error of 11.6 per cent in the estimates based on five objective factors is fairly low.

The equation for estimating milk production from the five factors is as follows:

(Eq. 1) $$\log_{10}\overline{X}_1 = 3.3924 + .4575\ (\log_{10}\overline{X}_2) - .7584\ (\log_{10}\overline{X}_3)$$
$$.0764\ (\log_{10}\overline{X}_4) - 1.2435\ (\log_{10}\overline{X}_6) + .0408\ (\log_{10}\overline{X}_6).$$

As shown in this equation, the symbols have the following meaning:

$\overline{X}_1$ = milk production, in pounds

$\overline{X}_2$ = total digestible nutrients (except pasturage), in pounds

$\overline{X}_3$ = nutritive ratio — number to right of colon only (that is, "8" for 1:8)

$\overline{X}_4$= digestive nutrients in succulent roughage, in percentage of total digestible nutrients

$_6$= fat test, in percentage of fat

$\overline{X}_8$= cows freshening in fall months, in percentage of total number of cows in the herd.

The results may be all stated in terms of fat production instead of milk production. This may be done by multiplying $\overline{X}_1$, milk production, by the mean fat content, and then transforming the regression variable $\overline{X}_6$ to the same terms. The steps are shown in Table 27.

Table 27

Average Differences in Milk and Fat Production with Differences in Fat Test of the Milk

Fat test	Production, feed and other factors held constant			
	Milk production in per cent of production expected	Pounds of fat from a given quantity of feed*	Butterfat in per cent of production expected†	Butterfat in per cent of production expected‡
per cent	per cent	pounds	per cent	per cent
3.25	123.9	4.027	104.32	94.8
3.50	112.9	3.952	102.37	97.0
3.75	103.7	3.889	100.74	99.1
4.00	95.6	3.824	99.07	101.1
4.25	88.7	3.770	97.66	102.9
4.50	82.5	3.713	96.18	104.8

* Test of milk times quantity shown in first column.
† In per cent of fat production in milk of 3.86 per cent test.
‡ From Wis. Tech. Bull. 79, pp. 27, 28.

The effect of differences in fat test upon milk production may be shown in two different ways—as differences in the quantity of milk of different fat tests produced from the same quantity of feed, or as differences in the quantity of feed required to produce a given quantity of milk or fat.

It is evident from Table 27 that the study indicates that the quantity of milk produced from a given quantity of feed is so much lower for herds producing milk of high fat test than for herds producing milk of low fat test that as a consequence the herds producing low-test milk appear to have produced slightly more fat from the same quantity of feed than did herds producing high-test milk. This is contrary to the relations found in other areas.[5]

The difference in milk production with differences in fat test was the most clearly defined relation found in the entire analysis, and was the least subject to statistical errors. Still it may be that the composition of the herds studied was partly responsible for the results. Of the herds included in the study, 29 were of Guernsey cows and 39 of

[5] Wisconsin Tech. Bull. 79, loc. cit., pp. 39-42.

Holstein cows, with the remainder of other breeds or mixed. Correlations computed separately for these two different breeds showed but little influence of fat test on production among the Holstein cows, owing to the uniformity of test from herd to herd; but among the Guernsey herds, where the fat test varied more widely, there was an even more marked influence of fat test on production than in the study for all herds combined. Since the slope of the fat test regression line was largely determined by the Holstein cows at one end, and by the Guernsey cows at the other, any differences in the average quality of the two groups of cows would influence the slope of the line. The Guernsey herds received an average of 3,600 pounds of digestible nutrients, with an average nutritive ratio of 1:7.4, while the Holstein herds received an average of 3,800 pounds of digestible nutrients, with an average nutritive ratio of 1:6.92 (geometric averages). With these relatively slight differences in feed received, the Guernsey herds show an average fat production of only 236 pounds of fat per cow, as compared to an average production of 281 pounds for the Holstein herds (arithmetic average of average fat production per cow). This difference in production is much greater than can be explained by the slightly larger quantity of feed received by the Holstein cows, and can be explained only on one of two bases: either (1) that the Holstein herds in the particular area studied were composed of cows which on the average were of better productive ability than were the cows in the Guernsey herds, and so produced more fat from the same amount of feed; or (2) that cows can produce more total fat from the same feed in low-test milk than in high-test milk. A third explanation also is possible, that the Guernsey herds were on poorer farms with less pasture available, and that the Holstein herds thus received extra nutrients from better pasturage, which are not counted in the digestible nutrients fed.

Examination of the individual herds verifies the first supposition. Of the best 12 dairymen in the area, 9 had Holstein herds, and only 3 had Guernsey herds. Of the poorest 10 dairymen, 6 had Guernseys and 4 had Holsteins. That does not mean that the breeds themselves were responsible, but merely that it happened that a smaller number of the better men kept Guernseys. These differences might be sufficient to account for the unusual relation found between fat test and production, and to justify the use of the relations found in other areas, rather than those found by the analysis of these particular records. As far as could be determined, the pasturage was of about the same quality on all the farms, so the third explanation does not seem valid. Apparently the excessive influence found for fat test was due largely to the accident of the quality of the cows. It was, therefore, decided to take the quality of the dairymen themselves into account as one factor, and determine if, with that held constant, the relation of production to butterfat could be more accurately determined.

Each farmer was scored as to his ability as a dairyman. This scoring was done by a person who had intimate knowledge of each man's farm and of the way he carried on his dairy. No reference was made to the production by each herd in making the scores, but each man's interest, care, and ability as a breeder and handler of dairy cows was considered. There were four classes, the best, those a little better than average, those a little below the average, and the poorest.

Adding the rating of the men as an additional factor, and correlating the six factors—total nutrients, nutritive ratio, use of succulents, fat test, fall freshening, and quality of men with milk production—a multiple correlation of 0.92 was obtained with a standard error of estimate of 10.4 per cent, only two-thirds as large as the standard error where quality of management was not considered.[6] Determining the regression curves raised the correlation very slightly, not enough to change the rounded value after correcting for the number of observations and constants. The regression curves determined in this solution are shown in the body of this report, as Tables 4, 6, 8, 10, and 12.

The relative importance of the several factors after taking quality of men into account was much the same as with the previous analyses. Quality of men was more important than any other factor; next in importance was the fat test, then the nutritive ration, next total digestible nutrients, and finally the proportion of fall freshening. The proportion of nutrients fed as succulent feeds was of negligible importance.

The regression of milk production on fat test, as shown in Table 7 was in excellent agreement with the results secured in other areas. This confirms the assumption that the negative relation of fat production to fat test, observed previously, was really due to the chance association in this area between fat test and quality of management. Now that the association has been eliminated, the usual relation of production to fat test appears.

As a final verification to the results, the production was stated in terms of pounds of butterfat instead of pounds of milk, and the same six factors enumerated above were correlated with the logarithm of butterfat production.

The correlation obtained, R = .87, was not so high as in the previous correlation, but the standard error of estimate in estimating fat production was slightly smaller. The variation in average butter-

[6] For the method used in treating this qualitative factor, see chapter 17 of "Methods of Correlation Analysis," by Modecai Ezekiel, 1930.

fat production between herds is smaller than is the variation in average milk production, owing to the negative correlation between fat test and milk production. Hence a correlation which explains a smaller percentage of the variation in fat production may yet provide a more accurate basis of estimate than a correlation which accounts for a larger percentage of the milk production, which has more variability to begin with.

The relative importance of each variable, as contributing to the variation in fat production, is interesting in contrast to the importance as influencing milk production.

	Determination coefficients	
	of milk production	of butterfat production
	per cent	per cent
X_2—Total digestible nutrients	3.2	5.8
X_3—Nutritive ratio	5.3	12.2
X_4—Proportion of silage	.4	.3
X_6—Fat test	29.9	—.6
X_7—Fall freshening	2.9	3.9
X_{12}—Quality of management	44.2	51.1
Total determination	85.9	77.7
Total adjusted for spurious correlation	84.4	75.5

Fat test has much less influence on total fat production than on milk production. This is to be expected. Fat production from a given quantity of feed varies almost exactly inversely with the fat test.

The relation of production to each of the several variables, as determined in the solution where fat production was taken as the dependent variable, was almost identical with that found in the preceding solution, where milk production was taken as the dependent. For that reason curvilinear regressions were not determined for this last correlation, and the conclusions presented in the body of this bulletin were based on the previous correlation.

Leaving out the unimportant factor, proportion of silage, the regression equation for estimating the logarithm of pounds of fat production is as follows: $\log_{10}X_1 = 1.9953 + .1314 \ (\log_{10}X_2) - .3195 \ (\log_{10}X_3) + .0664 \ (\log_{10}X_6) + .01783 \ (\log_{10}X_7) - .0525 \ (X_{12})$.

As used here, X_{12} uses "1" for the good dairymen, "2" for the fair, "3" for the unsatisfactory, and "4" for the poor. Translating these logarithmic regressions back into the actual numbers of percentages gives results much the same as shown in the earlier tables, based on the previous curvilinear solution.

The basic data used in this investigation are given in the following tables.

Table A

Factors Affecting Butterfat Production, Pine County Farm Accounting Route
Herd Averages for the Calendar Year 1925 (per cow basis)

Record No.	Total digestible nutrients except pasture, lb.	Nutritive ratio of feed	Proportion of total digestible nutrients: In dry roughage	Proportion of total digestible nutrients: In succulent roughage	Proportion of total digestible nutrients: Fed on pasture June to October, incl.	Butterfat test per cent	Production: Butterfat, lb.	Production: Milk, lb.	Average age of cows, years	Proportion first lactation heifers	Proportion fresh September to December	Quality of management
19	4,037	1:8.6	47.4	32.9	13.5	4.95	174	3,515	5.2	14.0	0.0	4
13	3,397	1:8.7	62.3	18.5	10.1	3.46	176	5,087	5.0	35.0	40.0	4
11	2,169	1:8.1	66.2	20.6	2.6	3.34	176	5,269	4.3	39.3	44.0	4
7	4,336	1:9.6	45.9	52.7	15.1	4.69	184	3,984	5.5	23.0	16.7	4
20	4,063	1:6.5	49.4	24.9	5.7	4.69	193	4,120	5.5	7.7	90.0	2
22	2,592	1:8.7	85.7	7.6	16.3	3.02	193	6,395	5.3	16.9	80.0	3
17	3,774	1:8.0	41.6	30.2	3.3	3.16	198	6,276	5.0	23.3	19.1	3
14	3,442	1:7.5	46.4	32.7	9.9	3.68	211	5,731	6.0	9.3	60.0	3
26	2,934	1:8.9	59.8	21.0	5.0	3.49	216	6,189	7.0	1.2	43.8	4
21	3,844	1:8.5	47.5	31.4	17.1	4.02	216	5,377	4.6	21.4	20.0	3
16	4,137	1:7.3	47.6	27.3	14.6	3.43	217	6,323	3.1	36.3	90.9	3
27	3,338	1:8.4	55.3	29.8	.8	3.52	220	6,253	8.0	0.0	70.0	3
28	3,357	1:7.7	49.4	35.4	19.5	4.48	228	5,087	3.1	37.0	33.3	2
3	4,435	1:7.8	65.3	8.4	7.5	4.57	231	5,060	7.1	13.6	57.1	3
2	3,928	1:7.6	52.8	28.7	6.5	3.27	233	7,125	3.9	22.1	44.4	2
4	3,734	1:7.2	51.6	19.0	12.9	3.33	258	7,748	5.1	9.1	14.3	2
8	4,715	1:6.9	67.2	3.6	14.3	4.11	259	6,306	3.9	17.6	85.7	4
24	3,908	1:7.2	42.6	30.3	14.1	3.53	267	7,561	5.8	5.7	50.0	2
23	3,793	1:7.6	47.5	27.6	5.6	3.28	276	8,410	3.9	20.8	72.7	1
18	3,122	1:6.7	32.6	30.3	13.7	3.29	276	8,379	3.5	32.4	100.0	1
1	4,134	1:7.9	43.3	33.4	16.4	4.59	281	6,126	5.8	26.6	60.0	1
12	3,273	1:7.7	40.1	33.9	5.0	4.53	283	6,247	7.5	11.5	66.7	3
15	3,629	1:7.2	44.4	30.9	5.5	3.67	288	7,847	4.1	24.0	81.8	1
25	4,125	1:7.5	47.0	28.1	11.0	3.52	310	8,812	4.2	21.6	50.0	1
5	4,084	1:8.4	41.8	25.1	6.8	3.32	310	9,349	5.2	8.6	100.0	1
9	3,935	1:7.0	45.1	23.1	15.2	3.47	315	9,067	5.4	16.1	69.2	1
10	4,380	1:6.8	49.0	24.0	10.8	3.34	320	9,590	4.0	16.2	75.0	1
6	3,707	1:7.0	36.9	32.1	8.4	3.93	320	8,140	5.5	8.1	66.7	1

Table B

Factors Affecting Butterfat Production, Pine County Farm Accounting Route Herd Averages for the Calendar Year 1926 (per cow basis)

Record No.	Total digestible nutrients except pasture, lb.	Nutritive ratio of feed	Proportion of total digestible nutrients: In dry roughage	Proportion of total digestible nutrients: In succulent roughage	Proportion of total digestible nutrients: Fed on pasture June to October, incl.	Butterfat test per cent	Production: Butterfat, lb.	Production: Milk, lb.	Average age of cows, years	Proportion first lactation heifers	Proportion fresh September to December	Quality of management
39	2,947	1:9.6	43.5	37.2	6.2	3.82	143	3,743	4.3	44.8	25.0	4
37	2,629	1:7.3	37.0	29.2	3.8	3.94	176	4,467	4.3	22.4	18.2	4
45	3,152	1:7.7	41.9	24.5	18.5	5.44	184	3,382	6.2	13.8	6.7	4
52	2,434	1:9.8	34.4	36.9	3.0	3.55	198	5,577	6.4	9.1	40.0	4
30	3,191	1:7.3	45.8	21.8	1.5	4.65	214	4,602	8.0	13.7	73.3	3
43	3,518	1:7.4	48.1	22.6	9.8	3.15	216	6,857	5.6	23.4	17.6	3
47	3,622	1:8.5	30.9	37.2	16.3	4.34	217	5,000	4.7	25.7	21.4	3
50	4,225	1:6.9	42.6	29.7	4.5	3.48	222	6,379	5.0	30.4	44.4	2
29	3,806	1:7.9	60.4	20.1	5.4	3.42	232	6,784	4.2	15.8	45.5	2
42	3,968	1:7.2	42.1	25.1	10.8	3.37	240	7,122	3.5	19.5	71.4	3
40	3,368	1:6.9	44.3	31.3	6.7	4.19	240	5,729	5.2	18.6	53.8	3
31	3,696	1:7.7	47.4	20.8	1.7	3.31	244	7,372	5.4	13.2	12.5	2
34	3,829	1:7.1	55.9	7.6	10.8	4.39	246	5,604	4.3	21.4	100.0	4
48	3,364	1:7.7	62.0	14.0	3.5	3.28	248	7,561	4.2	17.8	57.1	2
49	4,220	1:7.7	39.4	35.2	7.0	3.35	250	7,463	4.1	12.2	73.8	1
38	3,851	1:8.5	50.8	28.0	0.8	4.35	279	6,414	8.6	6.1	66.7	3
46	4,698	1:6.9	48.3	17.1	12.2	4.93	300	6,085	6.6	14.7	90.0	2
32	3,760	1:7.5	35.9	27.9	11.5	3.64	300	8,242	4.4	23.8	88.9	1
33	3,851	1:7.1	42.5	25.5	10.4	4.05	304	7,506	6.5	13.8	75.0	1
36	3,950	1:6.7	37.2	26.0	4.4	3.58	305	8,520	4.0	21.3	88.9	1
44	3,880	1:6.6	46.2	18.2	5.9	3.65	316	8,658	3.9	27.5	90.0	1
35	4,014	1:6.9	42.4	21.9	6.2	3.85	334	8,675	5.8	16.3	84.6	1
41	4,728	1:7.1	30.4	41.9	3.9	3.79	336	8,865	4.4	3.4	70.0	1
51	4,378	1:6.3	42.4	22.4	10.3	3.67	344	9,373	4.0	23.7	60.0	1

Table C

Factors Affecting Butterfat Production, Pine County Farm Accounting Route
Herd Averages for the Calendar Year 1927 (per cow basis)

Record No.	Total digestible nutrients except pasture, lb.	Nutritive ratio of feed	Proportion of total digestible nutrients			Butterfat test per cent	Production		Average age of cows, years	Proportion first lactation heifers	Proportion fresh September to December	Quality of management
			In dry roughage	In succulent roughage	Fed on pasture June to October, incl.		Butterfat, lb.	Milk, lb.				
77	2,602	1:6.9	51.0	22.0	3.5	3.80	186	4,985	7.4	8.2	25.0	4
71	3,423	1:6.4	47.7	21.6	11.9	5.21	195	3,743	7.4	5.3	8.3	4
64	2,573	1.6.7	36.5	19.1	0.6	4.21	198	4,703	4.5	16.4	44.4	4
65	2,189	1:7.9	33.3	40.8	4.3	3.88	219	5,644	3.8	36.2	20.0	4
67	3,078	1:7.4	49.5	23.1	6.8	4.23	225	5,319	5.8	17.0	77.8	3
55	3,043	1:7.0	49.5	19.6	2.1	4.71	232	4,926	6.4	27.1	71.4	3
61	3,592	1:6.9	52.5	19.8	20.6	4.41	241	5,465	6.2	7.0	50.0	2
73	3,394	1:6.5	37.1	22.1	11.0	4.84	244	5,041	5.3	18.5	33.3	3
69	3,944	1:6.6	40.7	26.0	18.0	3.60	250	6,944	4.1	16.2	71.4	3
63	3,473	1:7.3	46.9	22.9	5.7	4.15	251	6,048	5.3	20.5	80.0	2
56	3,332	1:6.8	46.2	22.7	4.7	3.38	260	7,692	5.6	20.8	0.0	2
54	3,472	1:6.7	52.1	23.3	0.8	3.37	261	7,745	4.9	16.3	33.3	2
59	3,947	1:6.6	60.0	29.0	5.7	4.40	266	6,045	5.0	0.0	100.0	2
74	3,359	1:6.8	44.4	28.8	8.8	3.77	266	7,056	4.6	16.0	75.0	2
75	3,800	1:5.9	39.9	18.7	8.4	4.16	274	6,587	6.1	11.3	50.0	2
53	3,761	1:6.3	40.3	24.5	2.0	3.51	274	7,806	5.6	18.7	57.1	2
72	3,489	1:5.7	44.4	27.2	5.7	5.25	287	5,467	6.6	26.6	85.7	2
66	3,006	1:5.8	59.5	27.1	0.6	3.73	305	8,177	5.5	0.0	40.0	1
70	4,511	1:5.4	49.5	14.0	10.5	3.57	306	8,591	4.2	13.7	70.0	1
58	3,546	1:5.9	39.7	24.7	9.9	4.17	317	7,602	5.9	20.3	76.9	1
57	4,509	1:5.5	41.8	16.9	5.0	3.64	328	9,011	4.2	18.6	71.4	1
62	3,798	1:5.7	44.9	18.6	3.0	3.61	328	9,086	4.3	18.6	66.7	1
60	4,027	1:6.0	42.2	24.1	6.7	3.80	345	9,079	6.0	16.2	81.8	1
68	3,687	1:7.2	32.4	38.2	3.4	4.05	348	8,593	4.1	24.7	61.5	1
76	4,643	1:5.5	41.2	17.9	18.8	3.84	368	9,583	4.5	9.7	62.5	1

Appendix 3

Composition of Common Feed Stuffs for Dairy Cows in Pine County, Minnesota (Constituents per 100 pounds)

	Digestible nutrients	Digestible protein	Nutritive ratio
Concentrates			1:0
Barley	79.4*	9.0	7:8
Bran	59.7*	12.0	4:0
Corn, dent	81.7*	7.1	10:5
Cottonseed meal	80.2*	37.6	1:1
Dairy ration, No. 1	76.2†	16.0	3:1
Dairy ration, No. 2	73.4†	13.9	4:3
Middlings, standard	69.3*	13.4	4:2
Oats	70.4*	9.7	6:3
Oilmeal	78.3*	30.2	1:6
Skimmilk	9.1‡	3.6	1:5
Wheat	79.2*	8.8	8:0
Dry roughages			
Alfalfa	51.0*	10.6	3:8
Clover, alsike	47.3*	7.9	5:0
Clover, red	49.6*	7.4	5:7
Corn fodder	48.1*	3.7	12:0
Corn stover	36.4*	2.0	17:2
Millet	55.0‡	5.0	10:0
Oat hay	45.5*	4.7	8:7
Oat straw	45.6*	1.0	44:6
Prairie hay	48.2*	3.0	15:1
Redtop hay	54.1*	4.8	10:3
Swamp hay	45.4*	3.5	12:3
Timothy	48.9*	2.8	16:5
Succulent roughages			
Corn fodder, green	15.6‡	1.0	14:6
Corn silage	13.3‡	1.0	12:3
Mangels	6.5*	1.0	5:5
Potatoes	17.3*	1.1	14:7
Rutabagas	9.5*	1.0	8:5
Rutabaga tops	9.3‡	1.8	4:2
Sunflower silage	12.6*	1.0	11:6

* Eckles, C. H. and Schaefer, O. G., Feeding the Dairy Herd, Minn. Agr. Expt. Sta. Bull. 218, p. 40.

† Guaranteed analysis supplied by manufacturer.

‡ Henry and Morrison, Feeds and Feeding, Ed. 18, pp. 738-743. 1923.