these measurements, which the internal evidence shows are untrustworthy, are thrown out, the inversion gives a constant coefficient (see column five), showing that the inversion of cane sugar by acids is of the unimolecular order even in its first stages, as it has always been considered to be. The other similar tables of Meyer contain the same error, and when the erroneous readings are excluded from them by the above unbiased method, they give satisfactory constancy for the inversion coefficient.

A complete discussion of Meyer's results is deferred to a later article which will present a detailed study that is now in progress of the inversion of cane sugar by invertase and acids. The present article is only a preliminary communication but it is thought that its immediate publication may be of service to investigators in this field, because the data that are here given are quite sufficient to show, first, that the inversion of cane sugar by acids follows, even in its first stages, the unimolecular order, and second, that the polarimetric measurement of the inversion of cane sugar by invertase involves a large source of error which can be avoided by adding alkali to the inverting solution before each reading of the polariscope. When this source of error is eliminated, as was done by O'Sullivan and Tompson in their inversion measurements, the rate follows the unimolecular order. The inversion of cane sugar by invertase is the most thoroughly studied of the numerous enzyme actions; in view of the foregoing proof of its unimolecular order may it not be that the other enzyme actions are, after all, quite similar to the usual types of chemical catalysis and that they do not constitute a group that has unique laws of catalytic action, as is now generally believed?

[CONTRIBUTION FROM THE NEW YORK AGRICULTURAL EXPERIMENT STATION.]

CONDITIONS AFFECTING THE PROPORTIONS OF FAT AND PROTEINS IN COW'S MILK.

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The interesting article of Mr. E. B. Hart on "Variations in the Amount of Casein in Cow's Milk" in THIS JOURNAL, 30, 281 has suggested that the subject is capable of much more extended treatment than was attempted and that its practical applications concern wider and more varied interests than those indicated. Thus, among these practical applications, we may mention the following: (1) The relation of fat and casein in milk to yield of cheese. (2) The relation of fat and casein in milk to composition and quality of cheese. (3) The relation of fat to proteins in milk as a basis for detecting skimmed milk. (4) The relation of fat to proteins in cheese as a basis for detecting cheese made from skimmed milk.

The accumulation of extensive data in the records of this station, bearing on the subject of this paper, furnishes abundant material for a somewhat detailed discussion. Briefly stated, these records include the following data: (1) Analyses of the mixed milk of numerous herds of cows, as obtained at cheese-factories in this state. We have over 300 such analyses, representing results of work done during several different factory seasons (April to November). (2) Analyses of the milk of each of 50 different herds of cows, whose milk was taken to one cheese-factory, analysis being made every other week from April through October. This work furnishes about 650 analyses of herd milk, such as is common in the dairy regions of this state. (3) Analyses of milk of individual cows, representing a systematic investigation covering entire periods of lactation. Seven different breeds of cows are represented, each with three to six individuals, the results covering for each individual one to eight periods of lactation and an aggregate of nearly 100 periods of lactation. This work furnished several thousand analyses of milk. The extent of our data is such that in the limits of this article they can be used only in the digested form of summaries or in illustration of specific details.

It is a matter of historical interest that up to 1892 very few determinations of casein in cow's milk had been made in America. In reality, casein, as such, was generally ignored, as is well evidenced by the fact that, in practically all analyses published up to that time, the term, casein, was used as synonymous with proteins or total nitrogen compounds of milk. In most cases, no attempt was made to determine casein and albumin separately in milk. Thus, in the article published by Cooke in the Fourth Annual Report of the Vermont Experiment Station (1890) "On the Relation of Fat and Casein in Milk," the word, casein, as used by him, is not casein proper but includes the entire protein content of the milk. In connection with this investigation of the relations between milk and cheese, begun at this station in 1891, it was appreciated that casein must be determined separately; and the details of the method, which was later adopted as "Official" by the Association of Official Agricultural Chemists, were worked out in this laboratory early in 1892.

It is the purpose of this article to present data, showing: (1) The range of variation in the amounts of fat and proteins in milk; (2) the conditions which influence variation of these constituents; (3) the variations in the relation of fat to proteins; and (4) some of the practical applications of the facts presented.

General Range of Variation in the Percentages of Fat and Proteins in Milk.

The extreme variation possible in cow's milk is a matter of general rather than practical interest. As such, we first present the results furnished by our records. As would be expected and as is well known, the variations in the percentages of constituents are much greater in the case of single milkings of individual cows than in the case of averages for entire periods of lactation, or than in the case of the mixed milk of a herd of cows, or than in the case where the milk of several different herds is mixed. Of course, practically all the milk handled in commerce is either the milk of individual herds or the mixed milk of numerous herds.

(1) *Fat.*—Taking all the results in our records for the single, complete milkings of individual cows, the lowest percentage of fat found is 2.25, and the highest 9, the minimum amount being found in the milk of a Holstein-Friesian cow, and the maximum, in that of a Jersey cow that was far along in lactation. During a period of lactation (usually 10 to 12 months), the fat in the milk of an individual cow may vary, in the case of single milkings, more than 3 per cent, from lowest to highest. The extreme variation of fat between two successive milkings (night and morning) may be as much as 2 per cent. in the case of the same animal.

The percentage of fat in the milk of individual cows for an entire period of lactation, according to our records, is a minimum of 2.79 (Holstein-Friesian) and a maximum of 6.30 (Jersey).

In the case of individual herds of cows, such as are common in the dairy regions of this state, the minimum percentage of fat on any one day was found to be 2.90; the maximum, 5.50, which occurred late in the season (October). The lowest season average for any one herd was 3.31 per cent.; the highest 4.31 per cent.

In the case of milk consisting of a mixture of the milk of different herds, the lowest percentage of fat found was 3.04 and the highest 4.60.

Proteins.—In the single milkings of individual cows, we have found as low as 2.19 per cent. of total proteins and as high as 8.56 per cent., the casein varying from 1.59 to 4.49 per cent., and albumin from 0.31 to 5.32 per cent. The highest percentages were found in the case of cows far along in lactation and giving only small amounts of milk. Such milk is, of course, not normal from a commercial standpoint and possesses interest mainly in showing what the secretion may become under certain known conditions. Our results do not appear to support the statement of Blyth ("Foods," p. 244, 4th ed.), who says: "The amount of albumin in milk is really fairly constant." The percentage of proteins in the milk of individual cows for an entire period of lactation varies from 2.37 to 4.44; of casein, from 1.90 to 3.55; and of albumin, from 0.47 to 1.00.

In the case of individual herds of cows, the percentage of proteins ranged from 2.31 to 3.71; of casein, from 1.79 to 3.02; and of albumin, from 0.41 to 0.97.

In the case of milk consisting of a mixture of the milk of different herds of cows, the percentage of proteins varied from 2.53 to 3.76; of casein, from 1.93 to 3.00; and of albumin, from 0.47 to 0.88.

In this connection, it may be stated that under the term albumin we include the protein content of the milk other than casein. While this is not absolutely correct, it is sufficiently so for all practical purposes.

Conditions Affecting Variations of Fat and Proteins in Milk.

The conditions of the marked variations observed in the amounts of constituents in cow's milk have received considerable study, and many of our data are available with special reference to this phase of the subject, which will be discussed under the following headings: (1) Individuality, (2) Breed, (3) Stage of Lactation, (4) Food, (5) Season, (6) Manner and Time of Milking.

(1) *Individuality.*—In examining the results of analysis of single milkings in the case of two or more individual cows, one is first impressed with the marked differences usually existing. If one carries on the study of individuals for prolonged periods of time, as for entire periods of lactation, it wi 1 be not'ced that, while the composition of the milk of each may vary quite widely in single milkings at different times, each possesses certain characteristics that serve to distinguish it in a manner more or less marked. To change the composition of the milk of a cow to such an extent that it loses its individual characteristics requires extreme and abnormal conditions and, even when such changes are effected, they are usually only temporary. Probably no question in animal nutrition has attracted so much attention along practical lines as that of changing the percentage of fat in milk by means of feeding, or, to state it in another form, the problem of overcoming through food the influence of individuality. The problem has not yet been solved, at least not in an economical form, and it is generally regarded by students of animal nutrition as a dairyman's will-o'-the-wisp. A few analyses are given in Table II, illustrating individuality in a general way.

(2) *Breed.*—The influence of what is known as breed upon the composition of cow's milk has been long recognized and extensively studied. The following figures, representing in the case of each of seven different breeds averages of three to six individuals of each breed for an aggregate of four to twenty lactation periods, well illustrate the point under consideration.

TABLE I.—FAT AND PROTEINS IN MILK OF DIFFERENT BREEDS OF COWS.

Name of breed.	Fat. Per cent.	Proteins. Per cent.	Casein. Per cent.	Albumin. Per cent.
1. Holstein Friesian	3.26	2.84	2.20	0.64
2. Ayrshire	3.76	3.07	2.46	0.61
3. American Holderness	4.01	3.32	2.63	0.69
4. Shorthorn	4.28	3.43	2.79	0.64
5. Devon	4.89	3.93	3.10	0.83
6. Guernsey	5.38	3.56	2.91	0.65
7. Jersey	5.78	3.68	3.03	0.65

These averages, though based upon more extensive data, agree well with results obtained at the New Jersey and Maine Experiment Stations, in so far as the same breeds were studied. The characteristics of a breed are, of course, more or less modified in the case of individuals, so that we may have quite wide variations in the percentages of fat and proteins in the milk of different individuals of the same breed; but it is extremely rare that the individual characteristics overcome those of breed to such an extent that we should, for example, not be able readily to distinguish normal Guernsey or Jersey milk from Holstein or Ayrshire milk, even in the case of single milkings. While extreme variations in the case of individuals of the same breed can be thoroughly studied only with single milkings, the average differences for entire periods of lactation are very marked, as is illustrated in the case of two breeds by the following figures:

TABLE II.—DIFFERENCES IN PERCENTAGE OF FAT AND PROTEINS IN MILK OF INDIVIDUALS.

Individual Jerseys.	Fat. Per cent.	Proteins. Per cent.	Casein. Per cent.	Albumin. Per cent.
1	5.49	3.57	2.91	0.66
2	5.61	3.44	2.83	0.61
3	5.77	3.69	2.91	0.78
4	6.04	3.87	3.19	0.68
5	6.15	3.96	3.42	0.54
Individual Holstein-Friesians.				
1	3.05	2.97	2.29	0.68
2	3.11	2.60	2.11	0.49
3	3.16	2.96	2.41	0.55
4	3.19	2.92	2.27	0.65
5	3.53	3.34	2.70	0.64

(3) *Stage of Lactation.*—From the time a cow "comes fresh in milk" up to the time she becomes "dry," the composition of the milk undergoes a gradual process of change, quite independent of other conditions. The period of lactation varies in length with different individual cows but, for practical purposes, lasts about 10 to 12 months. The changes in the percentages of fat and of proteins observed during the progress of the lactation period are quite marked and fairly regular, without reference to individual or breed. The colostrum, the secretion produced by a cow soon after calving, is very different in composition from normal milk and is not considered at all in our discussion. The figures presented in the following table represent the monthly averages of nearly 100 different lactation periods.

In studying this table, we notice that the percentages of fat and proteins drop in the second month of lactation, as compared with the first, and then begin to increase, continuing to increase from month to month during the entire period of lactation. Such behavior appears to be the

TABLE III.—INFLUENCE OF LACTATION ON PERCENTAGES OF FAT AND OF PROTEINS IN MILK.

Month of lactation.	Fat. Per cent.	Proteins. Per cent.	Casein. Per cent.	Albumin. Per cent.
1	4.30	3.16	2.54	0.62
2	4.11	2.99	2.42	0.57
3	4.21	3.04	2.46	0.58
4	4.25	3.13	2.52	0.61
5	4.38	3.25	2.61	0.64
6	4.53	3.33	2.68	0.65
7	4.57	3.40	2.74	0.66
8	4.59	3.47	2.80	0.67
9	4.67	3.57	2.90	0.67
10	4.90	3.79	3.01	0.78
11	5.07	4.04	3.13	0.91

general rule. Occasionally, an individual may, for a single period of lactation, depart quite widely from the general tendency. Individuals usually, but not always, show much of the uniformity observed in the results shown in Table III. The decrease may continue longer than one month, before the increase begins; or the increase may be very slow, or more or less irregular; or there may be an increase during the second month, followed by a decrease and then by the usual increase; or, in some cases, the percentages may not drop at all but increase each month after the first. These occasional variations, from the general tendency, are due to special, temporary causes in each case, usually connected with such conditions as weather, health, care, etc.

In the tenth and eleventh months of lactation, the increase of fat and of proteins is more marked than during the preceding months. In the case of cows whose lactation period is prolonged for one and a half to two years, with a good flow of milk, the percentages of fat and of proteins may not continue to increase but may even decrease.

It will be a matter of interest, in this connection, to consider the influence of advancing lactation upon the percentages of fat and of proteins, as observed by us in the case of milk used at cheese-factories in this state. In general, dairymen have their cows "come fresh in milk" in March and April, so that the milk taken to a cheese-factory represents, during the season, stages of the lactation period extending from about the second to the eighth months. Cows kept under ordinary farm conditions are subject to greater variation of external influences than in the case of the cows used in our station investigation. The following figures give the results of our work.

These results show, in general, an increase in the percentages of fat and of proteins similar to that observed in Table III. The irregularities shown in July and August, especially by a decrease of proteins, will be considered later.

TABLE IV.—INFLUENCE OF LACTATION ON PERCENTAGES OF FAT AND PROTEINS IN CASE OF CHEESE-FACTORY MILK.

Month.	Fat. Per cent.	Proteins. Per cent.	Casein. Per cent.	Albumin. Per cent.
April	3.43	2.81	2.29	0.52
May	3.58	3.02	2.34	0.68
June	3.64	3.24	2.47	0.77
July	3.62	3.07	2.43	0.64
August	3.84	3.02	2.39	0.63
September	3.92	3.20	2.55	0.65
October	4.23	3.55	2.81	0.74

(4) *Food.*—It has been stated already that, under normal conditions, the percentage composition of milk is little influenced by variations in food. In the course of our studies of cheese-factory milk, it was noticed that, under certain conditions, marked changes in composition take place. Each year of our studies it was observed that about the middle of May there was a marked increase of fat and proteins. Thus, the difference in composition of milk between the first half and the last half of May in one season is shown by the following figures:

	Fat. Per cent.	Proteins. Per cent.	Casein. Per cent.	Albumin. Per cent.
First half of May	3.46	2.85	2.25	0.60
Second half of May	3.70	3.17	2.45	0.72

A careful study of all the available facts justifies the explanation that these changes were largely due to a marked change in the character of the food and environment of the cows, since they were turned into pasture about the middle of May. Under the known existing conditions, there was thus a change from dry food of an indifferent character, mainly straw or poor hay without grain, to a highly succulent food of a most palatable and nutritious character. It is probable that the change of the environment of the cows from confinement in barn and yard to the freedom of the pasture exercised a beneficial physiological influence.

In Table IV it is noticed that there is a marked decrease of proteins in July and August. Similar changes were always observed in the case of cows kept at pasture without supplementary sources of food, whenever there was a period of drouth sufficiently severe to cause a drying up of pastures. Under such circumstances, the main food supply was seriously affected. The changes in composition of milk were accompanied by severe shrinkage in yield of milk. Accompanying this impaired condition of food supply, the animals were subjected to the unfavorable effects coming from excessive heat combined with annoyance of flies. Such changes in composition and yield of milk do not occur in times of drouth in the case of cows which are protected from the effects of extreme weather and whose food supply is kept normal.

(5) *Season.*—The influence of season upon variations in the compo-

sition of milk, apart from the effect of advancing lactation, is, to a considerable extent, associated with that of food supply, as indicated by the discussion preceding. When conditions are normal, or when cows are properly protected from the effects of abnormal weather conditions, variations in the composition of milk appear to be quite independent of seasonal influences.

(6) *Time and Manner of Milking.*—The composition of the milk given by an individual cow may be much influenced by the conditions under which milking is done. We shall consider three conditions: (*a*) Time between milkings; (*b*) fractional milking of the whole udder; and (*c*) milking different quarters of udder separately.

(*a*) *Time between Milkings.*—In general, when the time between successive milkings is the same, the composition of the milk varies little in the absence of any special, disturbing influence. Averaging about 500 analyses, each, of morning's and evening's milk representing 15 cows, we find the morning's milk to contain 100 parts of fat as compared with 99.06 parts in the evening's milk, and 100 parts of proteins for 98.34, the time between milkings being as nearly uniform as possible. However, if we consider single milkings of an individual cow, we may in special instances find considerable variation, in illustration of which the following figures are given:

TABLE V.—PERCENTAGES OF FAT AND PROTEINS IN MORNING'S AND EVENING'S MILK.

Date.	Fat. Per cent.	Proteins. Per cent.	Casein. Pet cent.	Albumin. Per cent.
December 13, A.M.	5.60	4.16	3.52	0.64
December 13, P.M.	6.00	4.23	3.55	0.68
December 20, A.M.	6.00	4.11	3.26	0.85
December 20, P.M.	6.00	3.93	3.19	0.74
December 28, A.M.	5.80	4.19	3.51	0.68
December 28, P.M.	6.45	3.98	3.30	0.68
January 4, A.M.	6.20	4.37	3.52	0.85
January 4, P.M.	6.40	4.23	3.38	0.85

(*b*) *Fractional Milkings of Whole Udder.*—The first portions of milk drawn from a cow's udder are very unlike normal milk in composition, showing a marked deficiency of fat. Each successive portion of milk drawn increases in fat content and the last portions drawn usually contain twice as much fat as normal milk. In illustration of these statements, we give analyses of the milk of a Guernsey cow, representing milk drawn successively from the whole udder in four fractions:

TABLE VI.—VARIATION OF FAT AND PROTEINS OF MILK IN FRACTIONAL MILKINGS.

Fraction drawn.	Pounds of milk.	Fat. Per cent.	Proteins. Per cent.	Casein. Per cent.	Albumin. Per cent.
First	3.2	0.76	3.29	2.67	0.62
Second	4.1	2.60	3.21	2.57	0.64
Third	4.6	5.35	3.10	2.49	0.61
Fourth	5.8	9.80	2.97	2.39	0.58
Whole milk of same cow	...	5.34	3.12	2.51	0.61

While the fat increases rapidly with each successive portion of milk drawn from the udder, the proteins decrease slightly, as would be expected from the mere presence of increase of fat. The work was repeated by us with several different cows and the several sets of corresponding analyses show similar results.

(*c*) *Milking Different Quarters of Udder.*—As the result of a large number of analyses of milk drawn separately from each quarter of the udder, it appears that the milk in each quarter possesses individual characteristics of composition, the extent of difference between the quarters varying in the case of different cows. The following figures illustrate this:

TABLE VII.—PERCENTAGES OF FAT AND PROTEINS IN MILK FROM DIFFERENT QUARTERS OF UDDER.

Quarter of udder.	Fat. Per cent.	Proteins. Per cent.	Casein. Per cent.	Albumin. Per cent.
Left hind quarter.............	4.15	2.97	2.33	0.64
Left forward quarter...........	4.60	2.94	2.32	0.62
Right hind quarter............	5.05	2.89	2.31	0.58
Right forward quarter..........	5.20	2.96	2.38	0.58

The variations in percentage of fat are much greater than in the case of proteins.

Not only does the composition of the milk in one quarter of the udder differ from that in other quarters, but the composition in the same quarter varies according to the order, relative to the other quarters, in which the milk is drawn, as shown by the following example:

TABLE VIII.—PERCENTAGES OF FAT AND PROTEINS IN MILK OF SAME QUARTER OF UDDER WHEN DRAWN IN DIFFERENT ORDER RELATIVE TO OTHER QUARTERS.

Left forward quarter of udder.	Fat. Per cent.	Proteins. Per cent.	Casein. Per cent.	Albumin. Per cent.
When milked first..................	5.10	2.85	2.30	0.55
When milked second...............	4.85	3.00	2.40	0.60
When milked third.................	4.60	2.96	2.36	0.60
When milked fourth...............	3.95	2.91	2.35	0.56

Variations in the Relation of Fat to Proteins in Cow's Milk.

We have thus far considered the conditions that affect the percentages of fat and of proteins in milk, without paying attention to the relative variations of these constituents. It now remains to study the effect of various conditions upon (1) the relation of fat to total proteins, (2) the relation of fat to casein, and (3) the relation of casein to albumin.

Conditions Affecting the Relation of Fat to Total Proteins and to Casein in Milk.

This phase of our subject will be briefly considered under the headings already used in discussing the general subject preceding, and the figures already presented in the foregoing tables will be utilized in furnishing desired data.

(*a*) *Breed.*—The influence of breed in affecting the relation of fat to proteins is shown in the following table, the data of which are derived from Table I:

TABLE IX.—SHOWING INFLUENCE OF BREED UPON RELATION OF FAT TO PROTEINS.

Name of breed.	Fat. Per cent.	Proteins. Per cent.	Parts of proteins for 1 part of fat. Fat : Proteins.	Casein. Per cent.	Parts of casein for 1 part of fat. Fat : Casein.
1. Holstein-Friesian	3.26	2.84	1 : 0.87	2.20	1 : 0.67
2. Ayrshire	3.76	3.07	1 : 0.82	2.46	1 : 0.65
3. American Holderness	4.01	3.32	1 : 0.83	2.63	1 : 0.66
4. Shorthorn	4.28	3.43	1 : 0.80	2.79	1 : 0.65
5. Devon	4.89	3.93	1 : 0.80	3.10	1 : 0.63
6. Guernesy	5.38	3.56	1 : 0.66	2.91	1 : 0.54
7. Jersey	5.78	3.68	1 : 0.64	3.03	1 : 0.52

It is seen that the different breeds represented separate into two general groups in relation to the ratio of fat to total proteins and to casein in milk. In the case of the first five breeds, the ratio of fat to proteins or to casein does not vary widely. The milk of the Holstein-Friesian breed contains least fat and most proteins in relation to fat. In the case of the next four breeds in the list, the fat varies from 3.76 to 4.89 per cent. but the proteins also vary in very nearly the same ratio as the fat. The Guernsey and Jersey breeds constitute the second group, the fat being high in amount but the proteins relatively low. These two breeds vary comparatively little in reference to the ratio of fat either to total proteins or to casein.

(*b*) *Individuality.*—We will notice briefly the variations that occur in case of different individuals of the same breed. The figures in the following table are derived from Table II and represent the averages for an entire period of lactation in the case of several different individuals of two breeds. More marked differences could be obtained, of course, by taking single milkings or monthly averages:

TABLE X.—INFLUENCE OF INDIVIDUALITY UPON THE RELATION OF FAT TO PROTEINS.

Individual Jerseys.	Fat. Per cent.	Proteins. Per cent.	Parts of proteins for 1 part of fat. Fat : Proteins.	Casein. Per cent.	Parts of casein for 1 part of fat. Fat : Casein.
1	5.49	3.57	1 : 0.64	2.91	1 : 0.56
2	5.61	3.44	1 : 0.64	2.83	1 : 0.53
3	5.77	3.69	1 : 0.64	2.91	1 : 0.50
4	6.04	3.87	1 : 0.61	3.19	1 : 0.50
5	6.15	3.96	1 : 0.65	3.43	1 : 0.53
Individual Holstein-Friesians.					
1	3.05	2.97	1 : 0.97	2.29	1 : 0.75
2	3.11	2.60	1 : 0.84	2.11	1 : 0.68
3	3.16	2.96	1 : 0.94	2.41	1 : 0.76
4	3.19	2.92	1 : 0.91	2.27	1 : 0.71
5	3.53	3.34	1 : 0.95	2.70	1 : 0.77

Whether we take the ratio of fat to proteins or of fat to casein, there would be very little difficulty in identifying any individual in the list with its proper breed, even though there is some range of variation between the individuals of each breed.

(*c*) *Stage of Lactation.*—We have previously noticed that during the period of lactation the fat and proteins increase gradually and quite regularly. We will now consider the question as to whether these constituents increase in the same ratio. The data in the following table are derived from the figures given in Table III.:

TABLE XI.—INFLUENCE OF STAGE OF LACTATION UPON THE RELATION OF FAT AND PROTEINS.

Month of lactation.	Fat. Per cent.	Proteins. Per cent.	Parts of proteins for 1 part of fat. Fat : Proteins.	Casein. Per cent	Parts of casein for 1 part of fat. Fat : Casein.
1	4.30	3.16	1 : 0.74	2.54	1 : 0.59
2	4.11	2.99	1 : 0.73	2.42	1 : 0.59
3	4.21	3.04	1 : 0.72	2.46	1 : 0.58
4	4.25	3.13	1 : 0.74	2.52	1 : 0.59
5	4.38	3.25	1 : 0.74	2.61	1 : 0.60
6	4.53	3.33	1 : 0.74	2.68	1 : 0.59
7	4.57	3.40	1 : 0.74	2.74	1 : 0.60
8	4.59	3.47	1 : 0.75	2.84	1 : 0.61
9	4.67	3.57	1 : 0.76	2.90	1 : 0.62
10	4.90	3.79	1 : 0.77	3.01	1 : 0.62
11	5.07	4.04	1 : 0.80	3.13	1 : 0.62

An examination of the fourth and the last columns shows a remarkable uniformity in the ratio of fat to total proteins and to casein throughout most of the period of lactation. During the first three months a very slight tendency appears for the fat to increase with reference to proteins or, stated another way, for the proteins to decrease in proportion to fat. After this there is very close uniformity up to the eighth month, after which the total proteins increase gradually in relation to fat to the end of the lactation period. During the last three months of lactation, the fat increases quite rapidly but the proteins increase even more rapidly in relation to fat. During this period the casein increases in exact proportion to fat, maintaining a uniform ratio that is very striking. The close uniformity observed in Table XI is not always so marked, of course, in every individual case, but the tendency shown is a very general one.

In this connection we will use the data embodied in Table IV to illustrate the relations under consideration in the case of the mixed milk of many herds of cows, as obtained at cheese-factories.

The amount of total proteins shows a tendency to increase relative to fat for a few months, when a decrease occurs, which is followed by a later increase. The casein maintains a fairly uniform relation to fat during the whole season, except during August, when a decrease was caused by the effect of drouth upon pasturage and attendant unfavorable conditions.

TABLE XII.—INFLUENCE OF STAGE OF LACTATION UPON THE RELATION OF FAT TO PROTEINS IN CASE OF CHEESE-FACTORY MILK.

	Fat. Per cent.	Proteins. Per cent.	Parts of proteins for 1 part of fat. Fat : Proteins.	Casein. Per cent.	Parts of casein for 1 part of fat. Fat : Casein.
April	3.43	2.81	1 : 0.82	2.29	1 : 0.67
May	3.58	3.02	1 : 0.84	2.34	1 : 0.65
June	3.64	3.24	1 : 0.89	2.47	1 : 0.68
July	3.62	3.07	1 : 0.85	2.43	1 : 0.67
August	3.84	3.02	1 : 0.79	2.39	1 : 0.62
September	3.92	3.20	1 : 0.82	2.55	1 : 0.65
October	4.23	3.55	1 : 0.84	2.81	1 : 0.66

(*d*) *Food and Season.*—Attention has previously been called to the effect of turning cows into pasture, as manifested by changes in the composition of milk in the first and second half of May. We will now notice whether the relation of fat and proteins is changed.

	Fat. Per cent.	Proteins. Per cent.	Parts of proteins for 1 part of fat. Fat : Protein.	Casein. Per cent.	Parts of casein for 1 part of fat. Fat : Casein.
First half of May	3.46	2.85	1 : 0.82	2.25	1 : 0.65
Second half of May	3.70	3.17	1 : 0.86	2.45	1 : 0.66

It is seen that while the total proteins increased with reference to fat, the ratio of casein to fat changed only slightly.

(*e*) *Conditions of Milking.*—An inspection of Tables V, VI, VII and VIII indicates that the total proteins and the casein also remain fairly uniform while the fat may vary greatly in the case of milk drawn from the udder in fractional portions, in the case of milk drawn from different quarters of the udder, etc.

Conditions Affecting the Relation of Casein to Albumin in Milk.

The general statement has peen prominently current in literature to the effect that casein and albumin are present in cow's milk in very constant relative proportions, the amount of casein being five times that of albumin. Taking herd milks, we have found the casein varying all the way from 2.6 to 5.6 parts for one part of albumin. In single milkings of individual cows, the variations are considerably wider.

The data already presented enable us to study this question under a variety of conditions.

(*a*) *Breed.*—The variation of albumin in relation to casein in the case of different breeds of cows is shown in the following table, the data of which are derived from Table I.

In studying the results embodied in Table XII, it is noticeable that the casein and albumin vary more or less in their relative proportions in the case of different breeds of cows, and in no case is the propor-

TABLE XIII.—INFLUENCE OF BREED UPON RELATION OF CASEIN TO ALBUMIN.

Name of breed.	Proteins. Per cent.	Casein. Per cent.	Albumin. Per cent.	Parts of casein for 1 part of albumin Albumin : Casein.	Per cent. of total proteins in form of casein.	Per cent. of total proteins in form of albumin.
1. Holstein-Friesian	2.84	2.20	0.64	1 : 3.4	77.5	22.5
2. Ayrshire	3.07	2.46	0.61	1 : 4.0	80.1	19.9
3. American Holderness	3.32	2.63	0.69	1 : 3.8	79.2	20.8
4. Shorthorn	3.43	2.79	0.64	1 : 4.5	81.3	18.7
5. Devon	3.93	3.10	0.83	1 : 3.7	78.9	21.1
6. Guernsey	3.56	2.91	0.65	1 : 4.5	81.7	18.3
7. Jersey	3.68	3.03	0.65	1 : 4.7	82.3	17.7

tion of casein to albumin as high as the average commonly given (1:5). It is also noticeable that, in general, the albumin forms a larger proportion, and the casein a smaller proportion, of the proteins in milk which contains a low percentage of fat than in case of milk which contains a high percentage of fat, when we compare the milk of different breeds of cows. Thus, in the milk of Holstein-Friesian cows, we have the least amount of fat, and the albumin forms a larger part (22.5 per cent.) of the proteins than in case of any other breed under discussion. In the case of Guernsey and Jersey milk, in which the fat content is highest, the proportion of albumin with reference to total proteins or to casein is least (17.7 and 18.3 per cent. of total proteins).

(*b*) *Individuality.*—For illustration of the relative proportions of casein and albumin in the case of the milk of different individuals of the same breed, we take the data embodied in the following table from Table II:

TABLE XIV.—INFLUENCE OF INDIVIDUALITY UPON RELATION OF CASEIN TO ALBUMIN IN MILK.

Individual Jerseys:	Proteins. Per cent.	Casein. Per cent.	Albumin. Per cent.	Parts of casein for 1 part of albumin Albumin : Casein.	Percentage of total proteins in form of casein.	Percentage of total proteins in form of albumin.
1	3.57	2.91	0.66	1 : 4.4	81.5	18.5
2	3.44	2.83	0.61	1 : 4.6	82.3	17.7
3	3.69	2.91	0.78	1 : 3.7	78.8	21.2
4	3.87	3.19	0.68	1 : 4.7	82.4	17.6
5	3.96	3.42	0.54	1 : 6.3	86.4	13.6
Individual Holstein Friesians:						
1	2.97	2.29	0.68	1 : 3.2	77.1	22.9
2	2.60	2.11	0.49	1 : 4.3	81.2	18.8
3	2.96	2.41	0.55	1 : 4.4	81.4	18.6
4	2.92	2.27	0.65	1 : 3.5	77.7	22.3
5	3.34	2.70	0.64	1 : 4.2	80.9	19.1

We see marked variation in the relation of casein to albumin in the case of the milk of different individuals of the same breed, the ratio varying in case of the Jerseys from 3.7 to 6.3 parts of casein for one of albumin, and in case of the Holstein-Friesians from 3.2 to 4.4.

(*c*) *Stage of Lactation.*—The figures given below are derived from the data contained in Table III:

TABLE XV.—INFLUENCE OF LACTATION UPON RELATION OF CASEIN TO ALBUMIN.

Month of lactation.	Proteins. Per cent.	Casein. Per cent.	Albumin. Per cent.	Parts of casein for 1 part of albumin. Albumin : Casein.	Percentage of total proteins in form of casein.	Percentage of total proteins in form of albumin.
1	3.16	2.54	0.62	1 : 4.1	80.4	19.6
2	2.99	2.42	0.57	1 : 4.2	80.9	19.1
3	3.04	2.46	0.58	1 : 4.2	80.9	19.1
4	3.13	2.52	0.61	1 : 4.1	80.5	19.5
5	3.25	2.51	0.64	1 : 4.1	80.3	19.7
6	3.33	2.68	0.65	1 : 4.1	80.5	19.5
7	3.40	2.74	0.66	1 : 4.2	80.6	19.4
8	3.47	2.80	0.67	1 : 4.2	80.7	19.3
9	3.57	2.90	0.67	1 : 4.3	81.2	18.8
10	3.79	3.01	0.78	1 : 3.9	79.4	20.6
11	4.04	3.13	0.91	1 : 3.4	77.5	22.5

The relation of casein and albumin, as shown by the foregoing data, is remarkably uniform during the first eight months of lactation, varying between 4.1 and 4.2 parts of casein for one of albumin; or, stated in another way, the percentage of total proteins in the form of albumin varied from 19.1 to 19.7 and, in the form of casein, from 80.3 to 80.9. After the ninth month, the casein decreases relative to albumin, or the albumin increases in relation to casein; and the change is quite marked and rapid during the tenth and eleventh months, constituting the close of the lactation period studied.

In the case of the mixed milk of numerous herds of cheese-factory cows, we have the following results, derived from Table IV:

TABLE XVI.—INFLUENCE OF LACTATION UPON RELATION OF CASEIN TO ALBUMIN IN CASE OF CHEESE-FACTORY MILK.

Month.	Proteins. Per cent.	Casein. Per cent.	Albumin. Per cent.	Parts of casein for 1 part of albumin. Albumin : Casein.	Percentage of total proteins in form of casein.	Percentage of total proteins in form of albumin.
April	2.81	2.29	0.52	1 : 4.4	81.5	18.5
May	3.02	2.34	0.68	1 : 3.4	77.5	22.5
June	3.24	2.47	0.77	1 : 3.2	76.2	23.8
July	3.07	2.43	0.64	1 : 3.8	79.2	20.8
August	3.02	2.39	0.63	1 : 3.8	79.1	20.9
September	3.20	2.55	0.65	1 : 3.9	79.7	20.3
October	3.55	2.81	0.74	1 : 3.8	79.2	20.8

The proportion of casein in relation to albumin decreases until July, when it makes a marked increase and then remains quite uniform during the remainder of the season, which extends approximately through the seventh or eighth month of lactation.

(*d*) *Time and Manner of Milking.*—Variation in time and manner of milking may, as we have seen, profoundly affect the fat in relation to proteins, the percentage of proteins remaining fairly constant while the fat may vary greatly. It remains now to see whether such variation of conditions of milking affects at all the relation of casein to albumin. The data in the tables following are derived from Tables V, VI, VII and VIII:

(*1*) *Morning's and Evening's Milk.*—The following data are given as a mere illustration:

TABLE XVII.—RELATION OF CASEIN TO ALBUMIN IN MORNING'S AND EVENING'S MILK.

Date.	Proteins. Per cent.	Casein. Per cent.	Albumin. Per cent.	Parts of casein for 1 part of albumin. Albumin : Casein.	Percentage of total proteins in form of casein.	Percentage of total proteins in form of albumin.
Dec. 13, A.M.	4.16	3.52	0.64	1 : 5.5	84.6	15.4
Dec. 13, P.M.	4.23	3.55	0.68	1 : 5.2	83.9	16.1
Dec. 20, A.M.	4.11	3.26	0.85	1 : 3.8	79.3	20.7
Dec. 20, P.M.	3.93	3.19	0.74	1 : 4.3	81.2	18.8
Dec. 28, A.M.	4.19	3.51	0.68	1 : 5.2	83.8	16.2
Dec. 28, P.M.	3.98	3.30	0.68	1 : 4.9	82.9	17.1
Jan. 4, A.M.	4.37	3.52	0.85	1 : 4.1	80.6	19.4
Jan. 4, P.M.	4.23	3.38	0.85	1 : 4.0	80.0	20.0

These data indicate that there may be quite marked variation in the relation of casein and albumin in the milk of morning and of evening in the case of the milk of the same animal.

(*2*) *Fractional Milkings of Whole Udder.*—We have previously seen that the percentage of fat varies greatly in different portions of milk drawn from the same udder, while the total proteins remain fairly constant. Below we present data to illustrate to what extent the casein and albumin may vary relatively under such conditions.

TABLE XVIII.—RELATION OF CASEIN TO ALBUMIN IN DIFFERENT FRACTIONS OF MILKING.

Fraction drawn.	Proteins. Per cent.	Casein. Per cent.	Albumin. Per cent.	Parts of casein for 1 part of albumin. Albumin : Casein.	Per cent. of total proteins in form of casein.	Per cent. of total proteins in form of albumin.
First	3.29	2.67	0.62	1 : 4.3	81.1	18.9
Second	3.21	2.57	0.64	1 : 4.0	80.0	20.0
Third	3.10	2.49	0.61	1 : 4.1	80.3	19.7
Fourth	2.97	2.39	0.58	1 : 4.1	80.5	19.5
Whole milk of same cow.	3.12	2.51	0.61	1 : 4.1	80.4	19.6

These results indicate that, under conditions which may very greatly affect the relation of fat to proteins, the relation of casein to albumin may be influenced very little.

(*3*) *Milking Separately Different Quarters of Udder.*—We have previously seen that milk from different quarters of the udder varies in fat content with little change of percentage of proteins:

TABLE XIX.—RELATION OF CASEIN TO ALBUMIN IN MILK FROM DIFFERENT QUARTERS OF UDDER.

Quarter of udder.	Proteins. Per cent.	Casein. Per cent.	Albumin. Per cent.	Parts of casein for 1 part of albumin. Albumin : Casein.	Percentage of total proteins in form of casein.	Percentage of total proteins in form of albumin.
Left hind quarter.....	2.97	2.33	0.64	1 : 3.6	78.4	21.6
Left forward quarter ..	2.94	2.32	0.68	1 : 3.7	78.9	21.1
Right hind quarter....	2.89	2.31	0.58	1 : 4.0	80.0	20.0
Right forward quarter	2.96	2.38	0.58	1 : 4.1	80.4	19.6

The relation of casein to albumin differs in the left and right halves of the udder but is practically constant in the two quarters of each half in this particular case.

(4) *Milking same Quarter of Udder in Different Orders Relative to Other Quarters.*—The data below illustrate variation of relation of casein to albumin as the effect of milking the same quarter of the udder in different orders with reference to other quarters:

TABLE XX.—RELATION OF CASEIN TO ALBUMIN AS INFLUENCED BY MILKING SAME QUARTER OF UDDER IN DIFFERENT ORDERS.

Left forward quarter of udder.	Proteins. Per cent.	Casein. Per cent.	Albumin. Per cent.	Parts of casein for 1 part of albumin. Albumin : Casein.	Percentage of proteins in form of casein.	Percentage of proteins in form of albumin.
When milked first....	2.85	2.30	0.55	1 : 4.2	80.7	19.3
When milked second.	3.00	2.40	0.60	1 : 4.0	80.0	20.0
When milked third..	2.96	2.36	0.60	1 : 3.9	79.7	20.3
When milked fourth.	2.91	2.35	0.56	1 : 4.2	81.0	19.0

The results show simply that in this particular case there is some slight relative variation of casein in relation to albumin in milk when the same quarter of the udder is milked in different order relative to other quarters.

Methods for Calculating Total Proteins and Casein in Normal Milk.

The results of the work done at this station emphasized the fact years ago that the relation of fat to total proteins or to casein is a variable one, the variations being less wide, of course, in the case of herd milk than in that of individual cows and, especially, of single milkings of individuals. But, in the case of averages of several analyses of milk and in the case of milk of herds, especially when the cows are of one general type in respect to breed, a certain degree of uniformity exists in the relation of fat to proteins and to casein. As a result of the writer's study of the milk of each of 50 different herds of cows during one season (May to October, inclusive), a general relation was noticed between the fat and casein content. In general, it was found that when the fat in milk increases 1.0 per cent., casein increases 0.4 per cent. This was found to hold quite satisfactorily when applied in case of ordinary herd milk varying in fat content from 3 to 4.5 per cent. In milk with less than 3 per cent. of fat, the casein content is usually higher in relation to fat than in milk with more than 3 per cent. of fat, while, in the case of milk containing more than 4.5 per cent. of fat, the ratio of casein to fat is less than in milk containing less than 4.5 per cent. of fat. Starting with milk containing an average of 3 per cent. of fat and a casein content of 2.1 per cent., milk with 4 per cent. of fat was found to contain about 2.5 per cent. of casein. On the basis of these observed general relations, the following rule was worked out: From the number representing the per cent. of fat in milk subtract 3, multiply the remainder by 0.4, and to the result add 2.1 Expressed as a formula, we have

$(F-3) \times 0.4 + 2.1 =$ per cent. of casein (F equals number representing per cent. of fat in milk).

This formula is apt to give somewhat low results in case of milk produced after the eighth or ninth month of the lactation period, when the casein is usually greater in relation to fat than during the previous stage of the lactation period.

Applied separately to 50 herds of cows during the factory season, the results are summarized as follows: In 4 cases, the results found by chemical determination were identical with those given by calculation; in 10 cases, the values found by analysis were greater than the calculated values by less than 0.10 per cent.; in 26 cases, the values found by analysis were less than the calculated values by less than 0.10 per cent.; in 8 cases, the values found by analysis were less than the calculated values by an amount between 0.10 and 0.20 per cent.; and in 2 cases, the calculated value exceeded that found by analysis by an amount greater than 0.20 per cent. and less than 0.25 per cent. In relation to ordinary herd milk, we have found that variations between the calculated value and that found by analysis are rarely greater than 0.30 per cent., while most of the differences are less than 0.20 per cent. and, in a majority of cases, the differences are less than 0.10 per cent.

For ordinary purposes, where strict accuracy is not required, the rule can be used quite satisfactorily when applied to herd milks within the limits specified, and comparatively little commercial milk exceeds these limits. The rule has been found especially useful in connection with infant-feeding in cases where it is desired to know approximately the amount of casein in cow's milk.

The above formula can be modified to use in roughly calculating the total proteins in cow's milk by substituting 2.8 for 2.1; the formula then becomes $(F-3) \times 0.4 + 2.8 =$ total proteins in milk.

Of course, it is readily recognized that when strictly accurate results are necessary, only a direct determination of casein or of proteins can suffice for this purpose.

The Relation of Fat and Casein in Milk to Yield of Cheese.

The two constituents of normal milk which largely determine the yield of cheese are fat and casein. The exact relation of these two constituents to cheese production have been worked out very carefully at this station in the case of American cheddar cheese, which is the kind manufactured most extensively in the United States and Canada. Assuming cheese to have the average water content of fresh cheddar cheese, the approximate yield may be easily calculated, if the per cent. of fat in the milk used is known. Thus, to find the yield of fresh cheese from 100 pounds of milk, multiply the number representing the per cent. of fat in milk by 2.7. For example, milk containing 3.6 per cent. of fat should yield from 100 pounds 9.72 pounds of green or fresh cheese; with milk containing 3.8 per cent. of fat, 10.26 pounds. This rule applies closely to normal milk containing 3.6 to 3.8 per cent. of fat. For milk containing fat above 3.8 per cent., the results are usually too high and for milks containing less than 3.6 per cent. of fat, the results are usually low. This is due to the fact that milks low in fat content usually contain a little more casein in relation to fat than do milks high in fat.

The yield of cheese can be ascertained more closely when the per cent. of both fat and casein in milk is known, in the following manner: Multiply the per cent. of casein by 2.5 and to this result add the per cent. of fat multiplied by 1.1. For approximate results, it is necessary to know only the per cent. of fat, for from this the approximate amount of casein can be calculated by the formula given above.

The Relation of Fat and Casein in Milk to Composition and Quality of Cheese.

Milk rich in fat, as compared with milk poor in fat, produces cheese containing more fat in proportion to other constituents. The composition of fresh cheese depends upon the composition of the milk used, provided the process of cheese-making is carried out in a normal manner. The following figures, representing cheese made from Holstein-Friesian milk and from Jersey milk, illustrate this statement clearly.

TABLE XXI.—COMPOSITION OF CHEESE MADE FROM HOLSTEIN-FRIESIAN AND FROM JERSEY MILK.

Kind of milk.	Per cent. of fat in milk.	Per cent. of fat in cheese.	Per cent. of proteins in cheese.	Per cent. of water, salts, etc., in cheese.
Holstein-Friesian........	3.36	35.24	24.50	40.26
Jersey..................	5.60	41.05	21.94	37.06

The cheese made from the richer milk contains relatively more fat and less proteins. Two such cheeses, made with equal skill, would show a marked difference in commercial quality, and the one having the larger amount of fat would be declared to be superior in quality. Improvement or deterioration of quality in cheddar cheese follows more or less closely the relation of fat to proteins in cheese; the larger the proportion of fat, the better the quality of cheese in general and the higher the market value. This position is disputed by those who are especially interested in promoting the sale of cows that produce milk low in fat, but its accuracy has been supported for years by such authorities as Babcock of Wisconsin, and Robertson of Canada. The differences between skim-milk cheese, whole-milk cheese and cream cheese are due to variations in ratio of fat and casein.

The Relation of Fat to Proteins in Milk as a Basis far Detecting Skimmed Milk.—In normal herd milk in the United States, containing over 3 per cent. of fat, the percentage of fat is rarely as low as the percentage of proteins. In 5,550 samples of normal American milks compiled by the writer, with a fat content lying between 3 and 5 per cent., the fat averages 3.92 per cent. and the proteins 3.20 per cent.; that is, for 1 part of proteins there is an average of 1.225 parts of fat. In skimming such milk, the fat may be decreased to 1.0 per cent. or to 0.10 per cent., but the remaining skim-milk contains about 3.20 per cent. of proteins. Milk is strongly open to the suspicion of being skimmed when the percentage of fat falls below that of the proteins.

The Relation of Fat to Proteins in Cheese as a Basis for Detecting Cheese Made from Skimmed Milk.—The removal of fat from milk reduces the amount of fat in relation to casein, and in cheese made from such milk the amount of fat in the cheese relative to proteins is likewise reduced. In general, it may be said that, in the case of cheese containing more proteins than 1 part for 1.2 parts of fat, skimmed milk has been used. The figures below illustrate the effect of removing fat from milk upon the composition of cheese.

TABLE XXII.—EFFECT OF SKIMMING MILK UPON COMPOSITION OF CHEESE.

	Pounds of fat removed from 100 pounds of milk.	Pounds of fat left in 100 pounds of milk.	Per cent. of fat in cheese.	Per cent. of proteins in cheese.	Parts of fat for 1 part of of proteins. Proteins : Fat.
Normal milk and cheese.	0.00	4.00	37.3	22.5	1 : 1.65
Skim-milk and cheese....	1.00	3.00	31.4	26.2	1 : 1.20
Skim-milk and cheese....	2.50	1.50	19.0	31.6	1 : 0.60
Skim-milk and cheese....	3.50	0.50	7.3	37.0	1 : 0.20

The standard adopted by the United States Department of Agriculture depends essentially upon the principle illustrated here, the only difference being that the relation of fat to total solids rather, than to proteins alone, is utilized.

Summary.

1. *Extent of Data.*—The study of the conditions affecting the proportions of fat and proteins in cow's milk, as embodied in the preceding article, is based upon the following data: (1) 300 analyses of the mixed

milk of numerous herds, obtained at cheese-factories, such as is common in the dairy regions of New York State. (2) 650 analyses of milk of 50 separate herds of cows, covering a period of about six months. (3) Several thousand analyses of milk of individual cows, representing seven different breeds of cows (American Holderness, Ayrshire, Devon, Guernsey, Holstein Friesian, Jersey, Shorthorn), covering for each individual, several lactation periods and an aggregate of about 100 periods of lactation.

2. Up to 1892 very few determinations of casein proper in cow's milk had been made in America, the *term casein having been wrongly used as synonymous with milk proteins.*

3. *General Range of Variation in the Percentages of Fat and Proteins in Milk.*—(1) In single milkings of individual cows, the fat varied from 2.25 to 9.00 per cent.; the total proteins, from 2.19 to 8.56 per cent.; the casein, from 1.59 to 4.49 per cent.; and the albumin, from 0.31 to 5.32 per cent. The highest percentages are found in case of cows far along in lactation. (2) In the case of individual herds of cows, such as are common in dairy regions of New York State, the fat varied from 2.90 to 5.50 per cent.; the total proteins, from 2.31 to 3.71 per cent.; the casein, from 1.79 to 3.02 per cent.; and the albumin from 0.41 to 0.97 per cent. (3) In the case of milk consisting of a mixture of the milk of many different herds of cows, the fat varied from 3.04 to 4.60 per cent.; total proteins, from 2.53 to 3.76 per cent.; casein, from 1.93 to 3.00 per cent.; and albumin, from 0.47 to 0.88 per cent.

4. *Conditions Affecting Variations of Fat and Proteins in Milk.*—The following conditions are discussed as those of special prominence in causing variation of percentages of fat and proteins in milk: (1) Individuality, (2) breed, (3) stage of lactation, (4) food, (5) season, (6) time and manner of milking, including fractional milkings, milk from different quarters of udder and relative order of milking a quarter of udder.

5. *Conditions Affecting the Relation of Fat to Total Proteins and to Casein in Milk.*—(1) The breeds studied fall into two general groups; in one case, the ratio of fat to proteins is relatively high (Guernsey and Jersey); in the other, relatively lower. Individuals of the same breed may vary considerably in this respect. (2) The ratio of fat to proteins is very uniform through the lactation period until about the ninth month, when the total proteins increase quite rapidly in relation to fat. The ratio of fat to casein is very uniform, throughout the entire period of lactation, there being a slight increase of casein in relation to fat about the ninth month. (3) Variations in composition of milk due to manner of milking affect the fat more or less extensively but the proteins very little.

6. *Conditions Affecting the Relation of Casein to Albumin.*—Albumin in milk varies quite widely in relation to casein. The relation varies

(1) with different breeds, (2) with different individuals of the same breed, (3) with time and manner of milking, (4) the relation is quite uniform during the first eight or nine months of lactation, after which the albumin increases relatively more than the casein.

7. *Methods for Calculating Casein and Total Proteins in Normal Milk.*—In the case of herd milk containing 3.00 to 4.50 per cent. of fat, the following formula for calculating the amount of casein has been found to give, in most cases, quite satisfactory results:

$(F - 3) \times 0.4 + 2.1 =$ per cent. of casein in milk (F equals number representing per cent. of fat in milk). Total proteins in milk can be roughly estimated by the following modification of the preceding formula: $(F - 3) \times 0.4 + 2.8 =$ per cent. of proteins in milk.

8. *The Relation of Fat and Casein in Milk to Yield of Cheese.*—In milk of average composition (3.6 to 3.8 per cent. of fat) the yield of fresh cheese from 100 pounds of milk may be ascertained by multiplying the number representing the per cent. of fat in milk by 2.7. The yield of cheese may be calculated more closely for milks containing fat below 3.6 or above 3.8 per cent., when the per cent. of both fat and of casein in milk is known, as follows: $(\text{Casein} \times 2.5) + (\text{Fat} \times 1.1) =$ pounds of fresh cheese made from 100 pounds of milk.

9. *The Relation of Fat and Casein in Milk to Composition and Quality of Cheese.*—Cheese made from milk in which fat is high relative to casein is superior in quality to cheese made from milk in which fat is low relative to casein. Skim-milk cheese, whole-milk cheese and cream cheese owe their differences in quality to the difference in relation of fat to casein in milk.

10. *The Relation of Fat to Proteins in Milk as a Basis for Detecting Skimmed Milk and Skimmed-milk Cheese.*—In the case of herd milk as commonly found in New York State, the milk is open to the suspicion of being skimmed when the percentage of fat is less than that of proteins. Cheese of the cheddar type which contains more than 1 part of proteins for 1.2 parts of fat is made from skimmed milk.

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QUANTITY AND COMPOSITION OF DRAINAGE WATER AND A COMPARISON OF TEMPERATURE, EVAPORATION AND RAINFALL.

BY J. H. NORTON.

Received May 2, 1908.

The time chosen for conducting this experiment was the year of 1906. The drainage water taken was that of Richland creek, which drains a territory of 84,954 acres. This valley is located in the southwestern part of Madison and the eastern part of Washington Counties in the