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Influence of Plane of Nutrition of the Cow Upon the Composition and Properties of Milk and Butter Fat

Influence of Overfeeding

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[1]In the service of the U. S. Department of Agriculture.

The Influence of the Plane of Nutrition of the Cow upon the Composition and Properties of Milk and Butter Fat

C. H. Eckles and L. S. Palmer[1]

INTRODUCTION

The normal composition of cow's milk and the variations in composition to which it is subject are questions of very great importance. This is true, both from the standpoint of physiology, and from the standpoint of its use as human food, particularly, for infants. It is for this reason that the composition of milk has for a long time been the subject of careful investigation. Such studies have grown in importance from time to time as additional factors influencing the composition of milk have been discovered, and data regarding the character and extent of the variations have accumulated. A number of these factors are now well defined, and the facts regarding them fairly well established.

Other factors are known, but further investigation is necessary before their importance and limitations are fully established. A number of these factors concerned with the normal variations in the composition of milk have been studied by the Missouri Agricultural Experiment Station and the results published.[2] Investigations of other factors of importance are still in progress.

[1]This investigation was begun by the Missouri Agricultural Experiment Station in cooperation with the Dairy Division, Bureau of Animal Industry, U. S. Department of Agriculture. During its progress the cooperative character of the work was modified and the responsibility for its continuation and completion was assumed by the Missouri Experiment Station.

C. H. Eckles is responsible for the original plan of the investigation and for the selection and control of the animals, and has served in an advisory capacity thruout the progress of the work and in the interpretation of the data secured.

R. H. Shaw represented the Bureau of Animal Industry in the planning of the investigation and was responsible for the chemical data taken in the early stages of the work.

L. S. Palmer has been responsible for the greater portion of the chemical data, for the preparation of the material for publication, and, in conjunction with C. H. Eckles, for the interpretation of the data.

[2](a) Eckles, C. H. Influence of fatness of cow at parturition on per cent of fat in milk. Mo. Agr. Exp. Sta. Bull. 100, 1912.

(b) Eckles, C. H. and Shaw, R. H. The influence of the stage of lactation on the composition and properties of milk. U. S. Dept. of Agr. Bull. 155, 1913.

The investigation reported in the present paper is in regard to an additional factor found to influence the composition and properties of milk and butter, namely, the plane of nutrition of the cow. During lactation a cow fed a normal ration, that is, on a normal plane of nutrition, uses the food for two general purposes, (1) for maintaining her body and (2) for producing milk. If less food is given than the cow requires for these two purposes the animal would be regarded as underfed, or on a subnormal plane of nutrition; similarly, if more food is given than the cow requires for maintenance and milk production, such a condition would be regarded as overfeeding, or a supernormal plane of nutrition. It is to be expected that a cow on a normal plane of nutrition will produce normal milk, provided there are no other influencing factors. The question arises, however, as to what the effect will be, both on the animal and on the milk, particularly the composition and properties of the latter, of inducing either a supernormal or subnormal plane of nutrition upon the cow. This question has not heretofore been subjected to careful study.

The results of our investigation of this question show clearly that at least one of these conditions, namely a subnormal plane of nutrition, may exert a very great influence on the composition of milk, particularly the milk fat. In fact, it has been found that greater abnormalities in the composition of milk and milk fat may at times be caused by this factor than by any factor yet found normally[3] exerting an influence on the general composition and properties of milk.

As will be pointed out later, the plane of nutrition of the cow has an important bearing on nearly all questions involving the composition and properties of milk and butter. It seems especially important to raise the question as to what extent the adaptability of milk or butter as human food, especially in connection with infant feeding, is influenced by this factor. Our investigation unfortunately offers no data concerning this particular point. It has been possible, however, to point out the importance of taking the plane of nutrition of the animal into account in interpreting data relative to the influence of specific feeds, or changes in feed, on the composition of milk and

(c) Eckles, C. H. and Shaw, R. H. The influence of breed and individuality on the composition and properties of milk. U. S. Dept. of Agr. Bull. 156, 1913.

(d) Eckles, C. H. and Shaw, R. H. Variations in the composition and properties of milk from the individual cow. U. S. Dept. of Agr., Bull. 157, 1913.

(e) Palmer, L. S. and Eckles, C. H. Carotin: The principal natural yellow pigment of milk fat. Jour. of Biol. Chem. 1914, v. XVII, No. 2, pp. 191–249; Mo. Agr. Sta., Res. Bull. 9, 10, 11 and 12, pp. 313–450, 1914.

[3]Very abnormal butter has been produced by feeding a cow large quantities of vegetable oils, such as cottonseed oil, linseed oil, and sesame oil, but such feeding conditions cannot be regarded as normal.

butter. Examples of a misinterpretation of data of this character because of variations in the plane of nutrition of the cow will be given in a subsequent bulletin. Again, the results of our experiments appear to offer an explanation of certain of the heretofore unexplained cases of abnormal butter to which reference is frequently made in agricultural literature. Examples of such an application of the plane of nutrition studies will also be given in the subsequent bulletin.

The first suggestion that the plane of nutrition is a factor influencing the composition of milk and butter came in an investigation carried on at this experiment station in regard to the influence of the stage of the lactation period on the composition and properties of milk. It was observed that a cow freshening in good flesh, i. e., with more or less excess fat on her body, almost invariably produced milk of abnormal composition, for a number of days after parturition. The effect of these conditions was especially evident on the physical and chemical constants of the milk fat. It was observed that this result was always accompanied by a loss of weight, due to a tendency on the part of the animal to use the excess nutrients stored in the body for her body needs and milk flow rather than to use the food offerred her for this purpose. The combined results, namely, loss of weight, abnormal milk and milk fat, were usually accentuated in the case of heavy producing cows; and it appeared that a high state of flesh was also an essential factor.[4] The simplest explanation of this condition, especially in the case of high-producing cows, is that more or less time elapses before the appetite is strong enough to meet the greatly increased demands on the organism for nutrients to support a heavy milk flow. We have designated such a condition as a physiological underfeeding, meaning by that a normal physiological result of a specific condition of the organism, in contrast to an underfeeding artificially imposed upon the animal. A direct relation between such an abnormal condition of the animal and the abnormal milk and butter produced at the same time naturally suggests itself. The marked increase in the percentage of fat in the milk accompanying these conditions has been reported in some detail in a previous publication.[5] The data reported there are thus closely connected with the data presented in the present paper.

The studies in regard to the influence of the plane of nutrition were not confined solely to the effects of underfeeding. The influence of a supernormal plane of nutrition was also studied experimentally.

[4]White, G. C. The per cent of fat in milk as influenced by the fatness of the cow and the plane of nutrition. Thesis for the degree of M.A., Univ. of Mo., 1912.

[5]Mo. Agr. Exp. Sta. Bull 100, loc. cit.

Data were also gathered with the view of ascertaining the cause of the influence of the subnormal plane of nutrition. The data from the experiments will be published in two bulletins. The present bulletin states the results of our experiments on the influence of overfeeding. A later bulletin will give the results of our experiments in regard to the influence of underfeeding, and the cause of the influence which is found to be exerted.

HISTORICAL

We have been able to find only two references to previous investigations regarding the influence of the plane of nutrition upon the composition of milk and both dealt with the effect of underfeeding.

Lusk[6] has published the results of a single experiment in which a milk goat receiving a diet of hay, cornmeal, and bran, was starved for two days, and then returned to the former diet. A record was kept of the milk flow, and the percentage of fat in each day's milk. The results are stated in Table 1.

TABLE 1.—THE INFLUENCE OF STARVATION ON PERCENTAGE OF FAT IN GOAT'S MILK[1]

Milk	Fat	Fat
cc.	Grams	Per cent
460	26.50	5.67
470	25.90	5.52
338	23.80	6.23[2]
198	18.35	9.27[2]
232	18.75	8.08
298	16.30	5.47
248	19.40	5.61
362	22.30	6.16
490	27.70	5.66

[1]Lusk.
[2]Starvation.

Henriques and Hansen[7] have reported a single experiment upon the influence of underfeeding on the composition of the milk fat of a cow. The experiment was conducted in connection with a study of the origin of milk fat and body fat, with the view of ascertaining the correctness of Soxhlet's theory in regard to the relations existing between the food fat, body fat and milk fat. According to this well-known theory the fat digested from the food is first deposited in the body, the body fat at the same time being transferred to the milk. As Soxhlet expresses it, "The alimentary fat pushes the body fat into the milk." Henriques and Hansen argued that if the food fat is first laid down as body fat, and from there transferred to the milk, the

[6]Lusk, G.: Über phlorhizin-diabetes. Zeit. f. Biol., 1901. 42, pp. 41–43.
[7]Henriques, V., and Hansen, C. Undersögelser over fedtdannelsen i Organismen ved intensiv Fedtfodring. 1–30. 44 Beretn. f. d. k. Vet. og Landbohöjsk. Laborat. f. landökon. Forsag, Kjobenhavn, 1899.

milk fat should show the same composition during starvation, "when the body fat with great certainty may be said to pass into the milk," as when the animal is subjected to an intense fat diet.[8] "When a lactating animal is starved or its feed reduced to a minimum, the milk ingredients must be produced from the substances of the body, i. e., partly from the proteins and partly from the fat, and few at present doubt that the milk fat during inanition originates from the body fat." The correctness of some of these arguments may be well questioned but this will be reserved until later inasmuch as only the results of the investigation are of importance at this point. The results are given in Table 2.

The authors point out that the data show that "inanition does not cause any considerable change in the amount of volatile acids (Reichert-Meissl number), but, on the other hand, produces a great increase in the iodin number, while, at the same time, the melting point of the butter fat is lowered greatly."

There are some additional features of the results of this experiment that are not pointed out by the authors, but which are of considerable interest. The most important is the marked increase in the percentage of fat in the milk immediately following the second and more intense underfeeding period begun on February 25. It will be seen that the fat increased from an average of 3.41 per cent, during the six days preceding the second underfeeding period, to 4.36 per cent on the fourth day. In fact, the fat percentages during this entire underfeeding period were, in general, higher than both the normal and those found in the first, less intense, underfeeding period. In addition it is interesting to note that there was not only a rapid rise in the fat percentage following the intense underfeeding, but that there was also an actual increase in the fat production, from an average of 0.495 pounds on the last two days of the preceding period to a maximum of 0.558 pounds on the day of the high fat test. The fat production did not fall much below normal until near the last of the fifteen day period, thus showing the remarkable persistency with which the animal maintained her normal production under the most unfavorable circumstances. Even more striking examples of this persistency to produce the normal amount of milk constituents under such conditions will be given in experiments which will be reported in a later bulletin.

[8]The authors fed a cow 0.75 kg. of linseed oil a day in addition to a ration of 12 kg. hay and 0.75 kg. of extracted linseed meal (fat percentage 0.3) and another cow 0.5 kg. of the oil in addition to a ration of 8 kg. of hay, 1.25 kg. ground barley and 0.75 kg. of the extracted linseed meal and obtained butter fat from the cows showing the following properties:

	Cow I	Cow II
Iodin Number	58.3	57.2
Reichert-Meissl Number	17.2	14.3
Melting Point, degrees C.	38.6	38.0

TABLE 2.—THE INFLUENCE OF UNDER-FEEDING ON COMPOSITION AND PROPERTIES OF MILK AND BUTTER FAT[1]

Date	Average Daily Ration				Milk per day	Energy Required			Total Energy Received	Plane of Nutrition	Fat in Milk	Fat Yield 1 day	Reichert-Meissl Number	Iodin Number	Melting Point
	Hay	Ground Barley	Extracted Linseed	Vaseline Oil		Main-te-nance	Milk	Total							
1898	Lbs.	Lbs.	Lbs.	Grams	Lbs.	Therms	Therms	Therms	Therms	Per cent	Per cent	Lbs.		Hübl.	°C.
1/14–18	17.7	1.65	1.65	...	19.1	6.00	5.25	11.25	9.60	−14.65	3.36	0.643	....	31.4	....
1/19–23	17.7	1.65	1.65	...	19.9	6.00	5.40	11.40	9.60	−15.80	3.29	.654	....	32.7	....
1/24–28	17.7	1.65	1.65	...	18.5	6.00	5.21	11.21	9.60	−14.40	3.56	.660	....	....	....
1/29–2/3[2]	17.7	1.65	1.65	125	16.7	6.00	4.55	10.55	9.60	− 9.00	3.32	.561	....	43.6	....
2/4–8[2]	17.7	1.65	1.65	...	14.0	6.00	3.86	9.89	9.60	− 2.60	3.39	.474	....	46.7	....
2/9–13	17.7	1.65	1.65	...	16.7	6.00	4.46	10.46	9.60	− 8.20	3.42	.572	23.6	37.7	....
2/14–18	17.7	0	0	...	16.0	5.98	4.50	10.48	7.05	−32.70	3.54	.567	24.3	39.3	34.0
2/19–24	17.7	0	0	...	15.2	5.96	4.20	10.16	7.05	−30.60	3.41	.517	25.0	40.5	33.2
2/25	8.8	0	0	...	15.4	5.91	4.19	10.10	3.52	−65.30	3.33	.513	....	....	....
2/26	8.8	0	0	...	15.3	5.91	4.28	10.19	3.52	−65.50	3.52	.539	....	....	....
2/28	8.8	0	0	...	13.4	5.91	4.10	10.01	3.52	−65.80	4.07	.545	24.1	44.6	32.2
2/29	8.8	0	0	...	12.8	5.91	4.01	9.92	3.52	−64.50	4.36[3]	.558	....	....	....
3/1	8.8	0	0	...	12.5	5.91	3.32	9.23	3.52	−61.90	3.15	.394	....	....	....
3/2–6	8.8	0	0	0	13.2	5.84	3.77	9.61	3.52	−63.40	3.64	.482	22.5	44.1	32.1
3/7–11	8.8	0	0	0	12.4	5.73	3.47	9.20	3.52	−61.80	3.47	.430	23.5	43.1	31.7
3/12–16	26.4	0	0	0	14.0	5.75	3.67	9.42	10.57	+12.20	3.07	.430	23.0	31.3	35.5
3/17–21	26.4	0	0	0	13.9	5.75	3.62	9.37	10.57	+12.80	3.24	434	....	....	....
3/22–26	26.4	0	0	0	13.5	....	....	.....	.....	....	.....	.....	22.0	31.1	35.4

[1]The data in this table were taken from Henriques and Hansen's experiments and arranged according to the plan followed in the present bulletin. The energy calculations given in the table from which the percentage of underfeeding is calculated have been added by us for the sake of comparison with the tables given in connection with our own investigations. In making these calculations the weight of the cow, which was not given by Henriques and Hansen, was assumed to be 1000 pounds normal; and it was also assumed that the animal lost one pound a day during the first ten days of underfeeding and two pounds a day during the following fifteen days of underfeeding. The quality of the hay used was not mentioned in the experiment. It was assumed to be a mixed hay with an energy value of 40 therms per 100 pounds. The extracted linseed meal was allowed an energy value of 73 therms per 100 pounds, and the barley 81 therms.

[2]Animal off feed.

[3]Note high fat percentage.

EXPERIMENTAL METHODS

The investigations to be reported in this and the subsequent bulletin included 32, separate, experimental periods concerning the influence of the plane of nutrition upon the composition and properties of milk and butter fat. Four of these were studies of the influence of a supernormal plane of nutrition and form the basis of the material presented in this bulletin. In these overfeeding experiments the plane of nutrition varied from normal to plus 104 per cent. The 28 remaining experiments, which will be reported in the bulletin that is to follow, were in regard to a subnormal plane. These experiments involve portions of 16 lactation period of 14 cows, two cows being used for study in two different lactation periods. The length of the underfeeding period varied from 7 to 75 days, and the extent of underfeeding from 15 to 70 per cent, that is, from a condition of only slight undernutrition to almost complete starvation. These experiments thus represent a wide range of conditions, making the data obtained from them definite and conclusive.

Character of data.—The data collected in the course of the various experiments included the percentage of the various milk constituents, such as, moisture, fat, total solids, ash, lactose, total protein, casein and albumin. The physical and chemical constants of the fat were also determined, including the saponification value, or Koettstorfer number, the Reichert-Meissl number, the iodin absorption value or Hübl number, and the melting point of the fat. The methods of analysis used were the official methods of the American Association of Official Agricultural Chemists. In some of the later experimental studies a few of the above mentioned analyses were omitted, since it was found that certain constituents were not influenced in the earlier experiments.

Plane of nutrition.—In connection with the original data given in the tables found in the appendix there will be found a figure indicating the percentage plane of nutrition of the experimental animal. These figures are based an energy requirements for maintenance as found by Armsby[9] and the energy requirements for the production of milk of varying richness as suggested by Eckles.[10] The calculations for the plane of nutrition were made by finding the difference between the energy required for maintenance plus milk production, and the energy supplied by the ration, the latter figures being based on the average energy values of the various feeds as given by Armsby. The difference thus found divided by the total energy requirements, thus

[9]Armsby, H. P. The computation of rations for farm animals by the use of energy values. U. S. Dept. of Agr. Farmers' Bull. 346, p. 16, 1909.

[10]Eckles, C. H. Nutrients required for milk production. Mo. Agr. Exp. Sta. Res. Bull. 7, p. 138, 1913.

represented the percentage of underfeeding or overfeeding, depending, of course, on whether the supply of energy in the feed was insufficient, or more than sufficient to meet the total requirements. To make this calculation, accurate records were kept of the feed consumption, milk and fat production, and body weight. Such a calculation, based partly upon average energy values of the feeds, and subject to the inaccuracies of true body weight and idiosyncrasies of individual animals, is admittedly only a close approximation, but it is believed to be sufficiently close for the purposes of this experiment. Variations of a few per cent either way from the calculated normal plane of nutrition have been ignored in interpreting the results of the various experiments.

Feeding and care of animals.—The grain and hay part of the ration received by the experimental animals was of the same character in all the experiments. Choice alfalfa hay was fed in all cases, and the grain consisted of a mixture composed of corn chop, 4 parts; wheat bran, 2 parts; linseed meal, 1 part. The proportion of grain to hay varied somewhat in the different experiments. In a few of the experiments the hay was supplemented by corn silage, and in a portion of two of the experiments by green alfalfa. The character of the ration in each experiment is indicated in connection with the experimental data.

The animals were given special care thruout all experimental periods. They were housed in the barn during the night, but when the weather permitted were given access to a dry lot during the day. Weighings were always made in the morning after the animals were fed, but before they were watered. The animals were fed twice each day, preceding milking, the food being weighed to them and a record kept of any portion refused. The milking of each experimental animal was done by the same person thruout the experiment, as far as such an arrangement was possible.

Sampling and preparation of samples for analysis.—The procedure for taking the samples of milk and the preparation of the samples of milk and butter fat for analysis did not differ materially from the general practice of this station in other experiments. The procedure is described in detail in Bulletin 155[11] of the Bureau of Animal Industry, United States Department of Agriculture.

The samples of milk were preserved with formalin. The amount of preservative added was usually 1 part of formaldehyde to 2,500 parts of milk. The samples of butter fat, after rendering and filtering, were preserved in tightly corked bottles which were protected from light in a refrigerator until analyzed.

[11]Loc. cit.

THE INFLUENCE OF OVERFEEDING

Our experiments concerning the influence exerted by overfeeding the cow during lactation fall roughly into two classes, (1) those cases where a normal plane of nutrition prevailed previous to overfeeding, and (2) those cases where the overfeeding was preceded by a subnormal plane of nutrition.

In all the experiments observations were made as to the effect on the weight of the animal, the milk flow, the percentage composition of the milk constituents, and the physical and chemical constants of the milk fat.

The outstanding features of our results were, (1) that in both classes of experiments, as stated above, the most pronounced result of overfeeding was to cause the cow to gain in weight, and (2) that in none of the experiments did overfeeding exert an influence toward abnormality in the composition of the milk, or the physical and chemical constants of the milk fat. On the other hand, the influence in every case was in the other direction. For example, in Experiment 1, where the cow was well along in lactation at the beginning of overfeeding, and the declining lactation was clearly noticeable in the constants of the milk fat, a high supernormal plane of nutrition prevented any further change in the constants of the fat; no further changes occurred until the plane of nutrition was reduced to normal, at the end of two months. Still more striking examples of the beneficial influence of overfeeding are seen in Experiments 2 and 4, where the composition of the milk, as well as the constants of the milk fat were abnormal at the beginning of overfeeding, as the result of a previous subnormal plane of nutrition. The result of overfeeding in each case was to restore the abnormal composition to a normal one.

Our data seem to warrant the general conclusion that normal milk and butter is to be expected when the cow is on a supernormal plane of nutrition as well as when the plane of nutrition is normal, provided there are no other influencing factors, such as specific feeds.

The results of the overfeeding experiments on the milk flow of the animals are particularly interesting and instructive. Only in certain cases, which are brought out in the data to be presented later, did an increase in the plane of nutrition above normal raise the flow of milk, and the influence in these cases was very limited. At present, it is generally accepted by physiologists that the phenomenon of milk secretion is due to a chemical stimulus, or "hormone" carried by the blood. It appears also to have been demonstrated that the secretion of milk is controlled by the central nervous system, either thru secretory nerves, or thru vasomotor fibers. According to Zeitzschmann,[12] the chemical and nervous stimuli are related in that a specific irritation of the nerves causes an increase in the flow of the milk precursors of the blood to the mammary gland.

The data resulting from our studies of the influence of the plane of nutrition on the milk flow also indicate that the secretion of milk is regulated by at least two factors. These factors can be designated as (1) chemical, and (2) nervous. Certain facts that have been brought out by the investigation here reported appear to admit of interpretation on the basis of such an hypothesis. The relations of these facts to this hypothesis, and the evidence upon which they are based may be briefly stated as follows:

1. The chemical stimulus for milk secretion is the predominating stimulus immediately following parturition, and continues to be so for a period of time, the limit of which is not brought out by the present investigations.

2. The chemical stimulus for milk secretion is the stimulus that fixes the maximum milk flow for each individual animal. It is more or less fixed for each individual. Just what controls the extent of the stimulus for individual animals is not as yet known. Our present knowledge indicates that it is a problem of heredity as well as one of physiology.

3. The chemical stimulus for milk secretion received at parturition is more or less independent of the plane of nutrition of the cow. Stated in another way, this stimulus neither requires a constant food supply from without the organism, nor is increased by an excess food supply from without the organism. Experimental evidence will be presented in a later bulletin showing that the chemical stimulus is so strong immediately following parturition that the milk flow will continue at a normal level for an astonishingly long period of time, at the expense of the body, with a food supply entirely inadequate for this purpose. In the present paper experimental evidence is presented showing that it is not possible to increase the chemical stimulus for milk production immediately following parturition by means of an excess food supply.

4. As the lactation period advances the chemical stimulus for milk secretion is gradually replaced by a stimulus with entirely different characteristics. We have designated this as the nervous stimulus.

5. The nervous stimulus for milk secretion is entirely dependent upon the plane of nutrition of the cow. Stated in other terms this means

[12]Zeitzschmann, in Grimmer: Chemie und physiologie der milch., p. 44. Paul Parey, Berlin, 1910.

that as soon as the nervous stimulus for the secretion of milk predominates, the milk flow is readily affected by a subnormal plane of nutrition, and can, moreover, be partially restored to its former figure by increasing the plane of nutrition. Experimental evidence of these facts is presented in a number of the experiments reported in this bulletin and particularly in the bulletin that is to follow. Experiments 1, 2 and 4 of this bulletin show these facts. Probably the best general example of these, however, is the ease with which it is possible to "dry a cow up" after she has been in milk long enough for the chemical stimulus to be replaced by the nervous stimulus. It is known to practical dairymen that after a cow has been in milk 9 or 10 months it is possible simply to stop milking a cow giving as much as 10 to 12 pounds of milk daily without any serious consequences, if the food supply is reduced at the same time. On the other hand, such a procedure would result in serious consequences to the cow if attempted while the chemical stimulus still predominated, namely, during the early part of the lactation period, no matter how small the normal milk flow.

SPECIFIC INFLUENCES OF A SUPERNORMAL PLANE OF NUTRITION

Influence on the weight of the cow.—Probably the most marked effect of supernormal feeding, especially when maintained on a high plane, is to cause a gain in body weight. The extent of the influence in this regard in the individual experiments is shown in Table 3.

TABLE 3.—INFLUENCE OF OVERFEEDING ON THE WEIGHT OF THE COW

Exp.	Cow	Weight at		Overfeeding	Plane of nutrition
		beginning	end		
		Lbs.	Lbs.	Days	Per cent
1	402	1130	1260	65	+75–110
2	301	945	950	30	+15
3	2	712	870	100	+50–60
4	2	840	915	15	+40–45

Influence on the milk flow.—One of the most important questions in connection with the influence of supernormal feeding is to what extent the animal can use the excess food for the production of milk. The data bearing on this question are shown in Table 4.

Considering the data in Table 4 in detail, it is seen that a plane of nutrition only slightly above normal, as in the case of Cow 301, had no effect whatever upon the milk production, in spite of the fact that the animal had been previously subjected to a plane of nutrition somewhat below normal. In the case of Cow 2, Experiment 4, however, a moderately high plane of nutrition quite rapidly re-

TABLE 4.—INFLUENCE OF OVERFEEDING ON THE MILK FLOW

Exp.	Cow	Milk Flow per day			Overfeeding	Plane of Nutrition
		at first	at end	average		
		Lbs.	Lbs.	Lbs.	Days	Per cent
1[1]	402	13.3	15.1	15.5	65	+75–110
2[2]	301	22.5	22.9	22.1	30	+15
3[3]	2	10.0	11.6	11.0	100	+50–60
4[4]	2	9.4	12.9	11.7	15	+40–45
5[5]	62	20.3	18.7	19.0	30	+50

[1]Cow well along in lactation when experiment was begun, but previously on normal plane of nutrition.
[2]Cow previously underfed about 20 per cent for 15 days.
[3]Experiment begun thirteen days after parturition, when cow was about 180 pounds under her normal weight, and in poor condition.
[4]Cow underfed 30 per cent for first 75 days of lactation period immediately preceding this experiment.
[5]Experiment begun fifty-first day of lactation period. Plane normal for 20 days preceding overfeeding.

stored to normal a flow that had been appreciably reduced by a previous subnormal plane of nutrition. Especially significant, however, is the failure of the high plane of nutrition to increase the milk flow in Experiment 3, Cow 2, and Experiment 5, Cow 62.

In the case of Cow 2, the lactation period was begun when the animal was nearly 200 pounds under her normal weight, and in very poor condition. A rapidly increasing higher plane of nutrition was imposed upon her almost immediately, in order to restore her condition and weight to normal as quickly as possible. This object was readily attained, but there was no accompanying influence on the milk flow. It might appear as tho the poor condition of this animal at parturition was the cause of her very low milk production of only ten pounds per day when fresh. As a matter of fact, however, this production must be considered normal for the animal, as shown (1) by the fact that her preceding lactation period, when the animal was normal (weight 825 pounds), began with a production of about seven pounds per day, and (2) by the fact that the succeeding lactation period began with a production of 13.5 pounds per day, the animal at this time being in unusually good condition, (weight 935 pounds). Since the lactation periods represented were the animal's first three, the increases in production appear to be normal ones; and the low average production must be attributed to another factor.

In the case of Experiment 5, Cow 62, we have another example of an increased plane failing to increase the milk flow, altho the animal was at the height of her milk flow when the experiment was begun. The data are taken from experiments already published[13] from this

[13]Eckles, C. H. A study of the cause of wide variation in milk production by dairy cows. Mo. Agr. Exp. Sta. Res. Bull 2, p. 145, Apr. 1910.

station. They are given again here on account of their bearing on the influence of overfeeding on the milk flow.

Experiment 1, Cow 402, appears to be the only one in which the supernormal feeding had a direct influence on the milk flow. The animal had been in lactation a little over five months when the overfeeding was induced. Previous to this the feeding conditions had been normal in every way, but owing to the advancing lactation the milk flow had dropped from 20 pounds a day, when fresh, to 13.3 pounds. The first effect of the increased feed was to raise the production almost five pounds a day. This eventually fell off, but was maintained for two months at an average of about 2 pounds per day above the flow with which the experimental period was begun, and in spite of the fact that the end of the lactation period was rapidly approaching, when the normal condition should have been a gradual decrease in the flow.

In short, the effect of the high plane of nutrition was to overcome the normal influence of advancing lactation. The best evidences of this influence are, (1) the immediate drop in the milk flow as soon as the plane of nutrition was reduced to normal, and (2) the comparison of the milk flow during the experimental period with that of the same days of the preceding lactation period. This comparison is shown graphically in Figure 1. An especially striking feature is the fact that the milk flow was lower at the start of the overfeeding experiment than at the corresponding time of the previous lactation period.

Altho the supernormal plane of nutrition undoubtedly had a beneficial influence in the case of Cow 402, the actual amount of solid matter produced in excess of the normal was in reality small compared with the solid matter stored in the body during the same period. The increased milk solids amounted to only about eleven pounds for the whole period, while the cow was at the same time storing about eighty pounds of solid matter in her body, estimating the increase in body weight as about sixty per cent[14] solid matter.

On considering the data as a whole in regard to the influence of overfeeding on the milk flow, one is impressed with the limited extent to which the animals used the excess food for the production of milk. Even under the most favorable circumstances, the animals seemed unable to increase their milk flow beyond the fixed stimulus for this function inherent in the individual. Overfeeding will sometimes cause a recovery of the milk flow lost because of poor nutrition,

[14]Unpublished data of the Department of Agricultural Chemistry show that the first 500 pounds gain in weight of a fattening steer consists of approximately sixty per cent solid matter.

as in Experiment 4, or because of advanced lactation, as in Experiment 1, but this recovery is only partial under the best conditions, e. g., Experiments 1 and 2. A very high plane of nutrition would appear, from these experiments, to be effective in holding off the decline in milk flow naturally resulting from advancing lactation. Such a result was obtained in Experiment 1. It probably would not be economical from the standpoint of milk production to stimulate secretion in this manner, but the results are interesting as an explanation, in part, of the remarkable success that has been attained in holding up the milk production when it is the purpose to obtain the highest possible yearly record. The results of these experiments also serve to give a clearer conception of the problem of feeding. As has already been pointed out by one[15] of us a high class dairy cow is one born with a strong stimulation to secrete milk; and the general problem in feeding is to supply the cow sufficient nutrients to support the milk production she has inherited.

Influence on the composition of the milk.—A brief summary of the influence of the supernormal plane of nutrition in the four experiments on the percentages of fat, total protein and lactose, is given in Table 5.

TABLE 5.—INFLUENCE OF OVERFEEDING ON COMPOSITION OF MILK

Experiment	Cow	Fat in Milk		Protein in milk		Lactose in milk	
		at first	average	at first	average	at first	average
		Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
1	402	3.91	3.70	3.31	3.68 to 3.78	5.50	5.25
2	301	4.27	4.07	2.90	3.12	4.60	4.92
3	2	4.30	4.41	3.64	3.44	4.81	5.25
4	2	5.85	4.66	3.10	3.45	5.23	5.20[1]

[1]A lactose percentage about 0.5 higher was attained as the result of the overfeeding, but the low figures at the beginning of the experiment kept the average down. Table 6 hows the lactose percentage on corresponding days of the two lactation periods of Cow 2—sepresented in the data.
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Per cent of fat.—An examination of Table 5 shows that the percentage of fat in the milk was influenced by overfeeding only in Experiments 1 and 4. In the former there was a definite average reduction of about 0.2 per cent, with some fluctuation as shown by Figure 1; but it is to be pointed out that this accompanied an increase in the milk flow such that the total fat production remained practically constant thruout the normal and supernormal feeding. In other words the decreased fat percentage was only an indirect ef-

[15]Eckles, C. H. Dairy cattle and milk production. pp. 130 and 269. The Macmillan Co., New York, 1912.

fect of the increased milk flow. In the case of Experiment 4, the conditions were similar. In this case, however, the high fat percentage at the beginning of the experiment was the result of a previous subnormal plane of nutrition, and the marked decrease that accompanied the change to the supernormal plane was merely a restoration to the normal percentage. The slightly lower fat percentage in the overfeeding period of Experiment 2, Cow 301, is an identical, but much less marked case of such a restoration, following an underfeeding period.

Total protein.—The influence of the supernormal plane of nutrition was more marked on the percentage of protein than on any of the milk constituents. In Experiments 2, 3, and 4 the high plane of nutrition had a beneficial effect upon the protein percentage, restoring it to normal in each case from a percentage appreciably depressed, in Experiment 3, probably by the condition of the animal at parturition, and in the other cases by a period of underfeeding, which in Experiment 4 was long continued. The detailed data given in Tables II, III, and IV, of the appendix show the interesting fact that this restoration of the protein percentage to normal was very gradual in the case of Experiment 3, but quite rapid in the case of Experiments 2 and 4. The influence of the supernormal plane of nutrition on the protein in the case of Experiment 3 is shown much better by the protein curve in Figure III than by the data in Table 5, which do not show the marked depression and gradual restoration of the percentage of this milk constituent.

The most interesting effect of overfeeding on the total protein percentage of the milk was obtained in Experiment 1, Cow. 402. The data in Table 5, and especially the protein curve in Figure I show that the intense overfeeding was accompanied by a constant higher protein level of 0.4 to 0.5 thruout the entire period. The curve shows that this fell back to normal when the plane of nutrition was reduced to normal, and then increased normally as the lactation period came to a close. This increased protein percentage during overfeeding is especially interesting inasmuch as the higher milk flow during the same period means that there was an actual increase in the protein output as well as in the percentage. The fat and lactose were affected in the normal way, both showing a decreased percentage accompanying the increased flow thereby maintaining the actual production at a uniform level. No explanation is apparent for the increased protein production in the case of Cow 402.

Lactose.—The percentage of lactose was the least uniformly affected by the supernormal feeding. In Experiment 1 there was a slight uniform depression during the overfeeding, undoubtedly an indirect effect of the increased milk flow. In Experiment 2 the lactose percentage was unquestionably somewhat higher during the supernormal plane of nutrition than in the preceding subnormal plane of nutrition. It would thus appear as tho the higher plane had the effect of restoring to normal a slightly depressed percentage due to underfeeding. It may, however, have been merely a normal fluctuation to which the lactose is subject, especially since the percentage was not depressed a corresponding amount in the subnormal plane of nutrition that immediately followed, as is shown, both by the lactose curve in Figure II and the data in Table II of the appendix.

The most definite effect of the overfeeding as far as the lactose is concerned was obtained in Experiment 3, Cow 2, in which the animal started her lactation period in a very low state of nutrition. Table 5 shows that the low state of nutrition at the beginning of the lactation period of this animal was accompanied by an abnormally low lactose percentage in the milk. The lactose curve, as well as the data in Table III of the appendix, shows that the high plane of nutrition imposed on the animal gradually raised this percentage to its normal value, but that it was not until approximately the fortieth day of the lactation period that this was attained. It is especially interesting to compare the lactose percentages on several corresponding days of the two lactation periods of Cow 2. Such a comparison is shown in Table 6.

TABLE 6.—INFLUENCE OF STATE OF NUTRITION AT PARTURITION ON LACTOSE

Day of lactation period	Lactose in milk	
	Low nutrition	High nutrition
	Per cent	Per cent
Thirteenth	4.60	5.24
Twenty-fifth	5.10	5.50
Fortieth	5.70	5.40

Influence on the physical and chemical constants of the fat.—It was stated in the introductory paragraphs of this paper that it will be pointed out in a later bulletin that a subnormal plane of nutrition may exert a very great influence on the composition of milk, particularly the milk fat. A consideration of the effects of a supernormal plane on the milk fat is therefore of special importance.

A summary of the data obtained in the four overfeeding experiments, as regards to the physical and chemical properties of the milk fat, is given in Table 7.

TABLE 7.—INFLUENCE OF OVERFEEDING ON THE PHYSICAL AND CHEMICAL CONSTANTS OF MILK FAT

Exp.	Cow	Saponification value		Reichert-Meissl number		Iodin value		Melting point of fat	
		at first	after over-feeding	at first	after over-feeding	at first	after over-feeding	at first	after over-feeding
								°C.	°C.
1	402	232.3	231.9[1]	20.50	20.55[2]	36.86	33.50[3]	33.80	33.20[4]
2	301	228.9	230.3[5]	27.60	29.50[6]	37.06	31.03[7]	31.60	33.00[8]
3	2	241.0	231.8	39.29	32.40	24.01	30.80	33.46	33.35
4	2	217.1	229.1	23.50	30.45	46.98	32.31	35.70	35.00

[1]With fluctuation between 229.5 and 235.0
[2] " " " 18.9 " 23.2
[3] " " " 31.07 " 39.80
[4] " " " 32.30 " 34.20
[5]With initial rise to 236.7
[6] " " " " 31.62
[7]With fluctuation between 28.33 and 33.34
[8]With slight fluctuation.

Saponification value.—The only effect of the supernormal feeding on the saponification value, or Koettstorfer number, of the butter fat was a strong tendency to produce a normal value. This was especially pronounced in Experiments 3 and 4 where very abnormal values prevailed previous to the overfeeding period, and furthermore where the conditions were as extreme as could well be found, as the values in column 1 of Table 7 show. The natural inference is that in the absence of other influencing factors, normal butter fat, as far as the mean molecular weight of the fatty acids is concerned, it to be expected during supernormal feeding as well as during a normal plane of nutrition.

Reichert-Meissl number.—Following the usual tendency in butter fat for the arbitrary measure of the proportion of volatile fatty acids to follow closely the saponification value, it is not surprising to find the influence of overfeeding upon the Reichert-Meissl numbers to be practically identical with that on the saponification value. Normal Reichert-Meissl numbers resulted in all the experiments following overfeeding, the changes in the case of Experiments 3 and 4 being from abnormal and extreme figures. This statement should possibly be qualified in the case of Experiment 1 where the average value resulting from the high plane of nutrition was between 20 and 21, an unquestionably low Reichert-Meissl figure. The data show, however, that the fat had a Reichert-Meissl number of 21.2 at the beginning of the overfeeding period, which must be regarded as normal for this animal at that stage of her lactation period, in view of the fact that she was on a normal plane of nutrition previous to the experimental overfeeding. That this value was maintained practically constant thruout the entire overfeeding, (as a matter of fact Figure I shows that the tendency was toward a slight rise) and then fell to the abnormally low figure of 14.5 as soon as the plane of nutrition was reduced to normal must be interpreted as a definite influence of the supernormal feeding in overcoming the effects of advancing lactation, which would otherwise have been dominant.

Hübl number.—As in the case of the saponification value and Reichert-Meissl number, the influence of overfeeding on the oleic acid content of the butter fat was largely to restore it to normal.[16] As with the Reichert-Meissl number in Experiment 1 the high plane of nutrition went so far as to overcome the effects of advancing lactation already manifested on the iodin absorption value, the influence being even more pronounced in this case than in the case of the Reichert-Meissl number.

Melting point.—The melting point of butter fat is so intimately connected with its oleic and volatile acid content that a direct influence of the plane of nutrition is not apparent. Since the data show, however, that the influence of the supernormal plane of nutrition was to produce butter with a normal proportion of its characteristic constituents it would be expected that the melting point of the fat would also be normal. The data show that this was the case.

One of the remarkable features of the data obtained in the long overfeeding experiment with Cow 2, (Experiment 3) was the apparent lack of effect upon the melting point of the butter fat of the very high Reichert-Meissl number which prevailed for a time after parturition. A glance at Table III of the appendix shows that the melting point remained constant at from 30° to 34° C. thruout the entire experiment in spite of the fact that the Reichert-Meissl numbers were never lower than 31.00 and during the first part of the experiment ranged between 36.00 and 41.50. It is now generally recognized that the amount of volatile fatty acids in butter fat, which is arbitrarily measured by the Reichert-Meissl number of the fat, has a greatly predominating influence upon the melting point of the fat, due to the extremely low melting point of butyric acid which is generally supposed to comprise by far the largest proportion of the total volatile fatty acids. Tri-butyrin is still liquid at from -60° to -70° C. There is much evidence at hand to show that a low percentage of volatile acids will nearly always mean a high melting point, even when the oleic acid content of the fat, as indicated by the iodin absorption value, is much higher than normal. Data of this character will be presented

[16]In explanation of the low iodin absorption value in the overfeeding period of Experiment 2, Cow 301, it should be stated that we have data to show that this is normal for this individual.

in a later bulletin in connection with the underfeeding studies. It is theoretically possible, and often happens. that the volatile acid content and oleic content offset one another with the result that altho both may change, there is no change in the melting point. Usually, however, a considerable increase in the oleic acid content is required to offset only a slight decrease in the volatile acids. We have unpublished data showing that a decrease in the Reichert-Meissl number of 5.00 from normal caused a sample of butter fat to have a melting point of 37.0° C., in spite of the fact that the fat at the same time had an iodin absorption value of 44.20.

With these figures as a basis it would be expected that the Reichert-Meissl numbers of the fat at the beginning of Experiment 3 should have resulted in fat with an abnormally low melting point, in spite of the fact that such a result would be partially offset by the low iodin absorption values that accompanied these conditions. The only explanation of the failure of the results in this case to conform to theory lies in the probability that the volatile acids were made up of unusually high proportions of the less common constituents, such as caprylic, capric, and lauric acids, whose melting points are 16.5°, 31.3°, and 43.6° C. respectively. It is certainly evident that an oleic acid content even as low as that indicated by an iodin-absorption value of 24.00, which was obtained in one case, could not possibly offset the effects on the melting point of the fat of a Reichert-Meissl number of 41.7, obtained at the same time, if the volatile acids thus represented contained their normal proportion of butyric acid. Even this, however, is admittedly mere conjecture. It is now generally believed that the bulk of the tri-glycerides in butter fat are "mixed" tri-glycerides. And there are so many different tri-glycerides possible in butter fat, and the effect of each on the melting point of the fat as a whole is so largely a matter of conjecture, that any attempt to explain the cause of the peculiar conditions obtained in the samples of butter under consideration, with the facts at hand, seems to be practically futile.

IS THE COMPOSITION OF BUTTER FAT IMMEDIATELY FOLLOWING PARTURITION INFLUENCED BY THE STATE OF NUTRITION?

In considering the data obtained in these experiments attention is strikingly drawn to the composition of the butter fat of Cow 2 at the beginning of Experiment 3, where the fat showed the abnormally high Reichert-Meissl number of 41.65, and the abnormally low iodin absorption value of 24.00 This cow began her lactation period in extremely poor condition. The sample of butter fat showing the most extreme chemical constants was taken on the thirteenth and fourteenth days following parturition. It is now well known that the milk fat secreted by the cow at the beginning of lactation normally shows the highest content of volatile fatty acids of the entire period, as indicated by the Reichert-Meissl number of the fat. This fact was definitely proved by experiments already published from this station.[17] These experiments indicated that Reichert-Meissl numbers as high as 31.0 and 32.0 may be expected during the first ten to fifteen days of lactation, and may be considered normal. Table 8, showing the comparison between the physical and chemical constants of the butter fat of Cow 2, on corresponding days of the second and third lactation periods, Experiments 3 and 4, shows that on the thirteenth and fourteenth days of the third lactation period represented by Experiment 4, when the animal was in normal condition, the composition of the butter fat corresponded to the average figures usually found. This would indicate that the extreme figures for the Reichert-Meissl and iodin values on the corresponding days of the second lactation period might be attributed to the poor condition of the animal which prevailed at the time.

TABLE 8.—CONSTANTS OF MILK FAT ON CORRESPONDING DAYS, EXPERIMENTS 3 AND 4, COW 2

	Experiment 3	Experiment 4
Days of lactation period	13th and 14th	13th and 14th
Weight of cow ... Lbs.	725	960
Saponification value	240.9	231.7
Reichert-Meissl number	41.65	31.31
Iodin number	23.99	31.87
Melting point of fat—Degrees C	32.76	33.20

It is probable, however, that another factor was responsible, in part at least, for the very high volatile acid content of the fat. As shown in Table III of the appendix, this cow was receiving practically two-thirds of her ration, by weight, in the form of corn silage at the time the first experimental sample was taken. On the energy basis the silage comprised about 40 per cent of the ration. Recent experiments conducted by Hunziker[18], as well as unpublished data from this Station, indicate that corn silage materially increases the Reichert-Meissl number of butter fat in comparison with other roughages. It

[17]Eckles, C. H. and Shaw, R. H. Influence of the stage of lactation on the composition and properties of milk U. S. Dept. of Agr., B. A. I., Bull. 155.

[18]Hunziker, O. F. Moisture control of butter. I. Factors not under control of the buttermaker. Purdue Univ. Agr. Exp. Sta., Bull. 159, Vol. XVI, p. 305, 1912.

is possible that the high proportion of silage in the ration, together with the normal tendency for high volatile acid production at this stage of the lactation period may have been entirely responsible for the results obtained. A low oleic acid content of the butter fat always appears to accompany a high volatile acid content produced by either of these factors. Such was the case in this experiment. That the condition of the animal was also partly responsible for the abnormal composition could be determined only by a check experiment, in which corn silage did not constitute a part of the ration. Data along this line are now being secured at this Station. Table III of the appendix shows that as the experimental period advanced the composition of the milk fat became more and more normal. The data also show that these changes accompanied a decline in the proportion of silage in the ration. This would indicate that the normal butter fat that gradually resulted from overfeeding was probably influenced to a greater extent by the character of the ration than by the overfeeding, which would at first be concluded.

GENERAL DESCRIPTION OF EXPERIMENTS

Experiment 1.—This experiment was conducted with Cow 402, a pure-bred milking Shorthorn. The animal was in her fourth lactation period and had been in milk about five months at the time the experiment began. The condition of the animal had been normal in every way during the five months preceding the experiment. Composite samples of milk and milk fat, covering seven days, were taken at the end of five months, and complete analyses made. The results secured were regarded as representing the normal composition of the milk and milk fat of the animal at that stage of her lactation period. The plane of nutrition of the cow, which had been normal up to this time, was then increased as rapidly as possible until an average percentage of plus 80-85, was reached, requiring about 15 days. In making this change, as in all others of this character in the experiment, no change was made in the kind of food given the animal or the proportion of grain to hay. The increase in the plane of nutrition was brought about by increasing the amount of grain and hay fed, the proportion between the two remaining constant, as indicated, at 1:1.5.

The first high plane secured in this experiment was maintained for 25 days, when another increase was made in the same manner to a maximum figure in the neighborhood of plus 100 per cent. This change was accomplished in 5 days, and was maintained for 15 days. A rather rapid reduction of the plane of nutrition then followed to a subnormal plane of minus 20-25 per cent, about 14 days being required for the change. The subnormal plane was maintained thruout the remaining 26 days of the experiment.

Complete analyses of the milk and milk fat were made every other day during the entire supernormal and subnormal periods. Fifty-one samples in all were analyzed. The results, together with other data connected with the experiment, are given in detail in Table I. The same data are shown graphically in Figure 1.

Experiment 2.—This experiment was conducted with Cow 301, a pure-bred Ayrshire. The animal was in her fourth lactation period at the time. The period of overfeeding, from which the experimental data are taken, lasted about 30 days, and began when the animal had been in milk a little over three months. Previous to the overfeeding the animal had been subjected to alternating periods of subnormal and normal planes of nutrition, one of the subnormal periods immediately preceding the experimental period under consideration. The period of overfeeding was followed by a short period of feeding on a normal plane of nutrition. Experimental data on the composition of the milk and milk fat were taken in all three periods, and are considered together in this experiment, altho the data secured in the underfeeding period preceding the overfeeding period properly belong to the data that will be considered in a later publication.

At the close of the underfeeding period the plane of nutrition of the cow was increased in three days from -15.2 per cent to +28.65 per cent. This was done almost entirely by increasing the grain in the ration. At the same time the amount of hay fed was increased slightly but the general effect was an increase in the proportion of grain to hay from 1:1.75 to 1:1.25. No change was made in the character of the food, but merely in the amount offered to the animal. The ration designed for the supernormal feeding period remained constant thruout the experiment. On account of an increase in the milk flow during the period, a general lowering of the plane of nutrition resulted, the average for the 30 days being about plus 18 per cent, instead of approximately plus 30 per cent, as planned.

The results of the analyses of the composite samples of milk and milk fat secured at intervals during the experimental period and the periods of underfeeding and normal feeding preceding and following the experimental period, together with other data connected with the experiment, are shown in detail in Table II. The same data are also shown graphically in Figure 2.

Experiment 3.—This experiment was conducted with Cow 2, a pure-bred Jersey. The animal was in her second lactation period, and had been in milk 19 days when the experiment was begun. The animal was dry for a period of four months previous to parturition, and during this time was fed a scant ration of hay alone. She was accordingly nearly two hundred pounds under her normal weight, immediately after parturition, the weights for the first three days after the birth of the calf averaging 707 pounds, against a normal weight of 890 pounds. The animal normally had a very low milk producing ability, her milk production, when fresh, averaging about ten pounds per day. These two conditions, subnormal weight and low milk production, were purposely secured in this animal since the purpose of the experiment was to study the composition and properties of the milk when the cow was gaining in weight as rapidly as could be brought about by pronounced overfeeding. It would be impossible to bring about this condition with a high milk production on acount of the well-known difficulty of causing a cow producing a large quantity of milk to gain in weight.

During the nineteen days following parturition the cow was on a normal plane of nutrition. Three composite samples of milk and butter fat, representing two days each, were taken at the close of the nineteen days. The analyses secured were regarded as representing the normal composition of the milk and milk fat under the experimental conditions obtaining at the time. The ration during this time consisted of grain, hay, and corn silage, but the silage comprised about 70 per cent of the ration, by weight, and 40 per cent on an energy basis.

Following the nineteen days on a normal plane of nutrition, the plane was gradually increased until at the end of 35 days it had reached plus 70-75 per cent. This was continued for 46 days, and was followed by a sudden drop in the plane to normal, the change being accomplished in three days. The changes in the plane of nutrition in this experiment were secured almost entirely by increasing and decreasing the amount of grain fed to the animal. No change was made in the amount of hay until the last 10 days of the overfeeding, when it was increased two pounds a day. The amount of silage fed remained constant thruout the entire experiment, including the preliminary and supplementary normal periods.

Frequent samples of milk and butter fat were taken thruout the the overfeeding period, and complete analyses made. All of the samples were composites representing two consecutive days. The results of the analyses, together with other data connected with the experiment are given in Table III. The same data are also shown graphically in Figure 3.

Experiment 4.—This experiment was conducted with Cow 2, the same cow used in Experiment 3. The animal was in her third lactation period, and had been in milk 77 days when the experiment was begun. The animal calved in good flesh, as shown by her average weight of 965 pounds for the first three days after parturition. Following parturition the animal was put on a subnormal plane of nutrition of minus 25 to minus 35 per cent for about 75 days. At the end of this time the animal had lost 125 pounds in weight and was about 50 pounds under her normal weight, (890 pounds.) In this condition the overfeeding experiment was begun. In five days the plane of nutrition was raised from minus 30 per cent to plus 34 per cent, and was then gradually increased up to plus 48 per cent during the 15 days of the overfeeding experiment, the average plane of nutrition for the period being plus 40.5 per cent. The plane of nutrition was increased in this experiment largely by increasing the grain, hay and silage in the same proportion, altho during the last half of the period the amount of grain was increased without increasing the hay and silage.

The results of the analyses of the samples of milk and butter fat secured during the overfeeding, together with other data connected with the experiment, are given in Table IV. Similar data taken at the end of the underfeeding experiment which preceded the supernormal feeding are also given in the table. Both sets of data are shown graphically in Figure 4.

Appendix

TABLE I.—INFLUENCE OF PLANE OF NUTRITION

Cow 402. February 25—June 11, 1909.

Date of Feeding	Average Daily Ration		Weight of Cow Av,	Milk Yield Per Day Av,	Energy Required			Total Energy Received	Plane of Nutrition
	Grain	Alfalfa Hay			For Maintenance	For Milk Production	Total		
1909	Lbs.	Lbs.	Lbs.	Lbs.	Therms	Therms	Therms	Therm	Per cent
2/25–3/3	8.5	13.0	1133	13.3	6.54	3.937	10.48	10.92	+4.20
3/4–5	9.5	14.2	1125	14.0	6.50	4.368	10.87	12.09	+11.22
3/6–7	10.0	15.0	1130	13.3	6.52	4.309	10.83	12.74	+17.63
3/8–9	12.0	18.0	1146	14.1	6.60	4.230	10.83	15.28	+41.08
3/10–11	12.0	18.0	1150	14.7	6.60	4.351	10.95	15.28	+39.54
3/12–13	12.0	18.0	1141	14.2	6.56	3.806	10.37	15.28	+47.34
3/14–15	14.0	21.0	1130	15.6	6.52	4.306	10.83	17.82	+64.54
3/16–17	14.0	21.0	1160	18.3	6.64	4.831	11.47	17.82	+55.36
3/18–19	16.0	24.0	1155	16.8	6.62	4.569	11.19	20.36	+81.94
3/20–21	16.0	24.0	1170	15.3	6.68	4.345	11.03	20.36	+84.58
3/22–23	16.0	24.0	1191	14.7	6.76	4.263	11.02	20.36	+84.75
3/24–25	16.0	24.0	1157	14.1	6.64	4.174	10.81	20.36	+88.34
3/26–27	16.0	24.0	1192	15.6	6.76	4.618	11.38	20.36	+78.91
3/28–29	16.0	24.0	1193	15.4	6.76	4.435	11.19	20.36	+81.94
3/30–31	16.0	24.0	1200	15.1	6.80	4.288	11.09	20.36	+83.58
4/1–2	16.0	24.0	1204	14.5	6.80	4.205	11.00	20.36	+85.09
4/3–4	16.0	24.0	1202	14.5	6.80	4.611	11.41	20.36	+77.56
4/5–6	16.0	24.0	1213	16.9	6.84	4.732	11.57	20.36	+75.97
4/7–8	16.0	24.0	1201	15.9	6.80	4.579	11.38	20.36	+78.91
4/9–10	16.0	24.0	1212	16.2	6.84	4.536	11.37	20.36	+78.80
4/11–12	16.0	24.0	1216	16.0	6.88	4.416	11.29	20.36	+80.33
4/13–14	17.0	25.5	1212	15.4	6.84	4.558	11.40	21.66	+90.00
4/15–16	18.0	27.0	1227	15.9	6.92	4.706	11.63	22.94	+97.24
4/17–18	18.0	27.0	1217	14.7	6.88	4.116	10.99	22.94	+108.74
4/19–20	18.0	27.0	1227	14.5	6.92	4.234	11.15	22.94	+105.73
4/21–22	18.0	27.0	1222	15.0	6.88	4.380	11.26	22.94	+103.73
4/23–24	18.0	27.0	1250	15.9	7.00	4.388	11.39	22.94	+101.40
4/25–26	18.0	27.0	1251	16.5	7.00	4.752	11.75	22.94	+94.38
4/27–28	18.0	27.0	1244	16.0	6.96	4.736	11.69	22.94	+96.23
4/29–30	14.2	23.5	1251	15.9	7.00	4.706	11.70	18.88	+61.36
5/1–2	18.0	27.0	1257	16.4	7.04	4.723	11.76	22.94	+95.06
5/3–4	16.0	15.2	1262	14.4	7.04	3.974	11.01	17.32	+57.31
5/5–6	14.0	21.0	1265	15.1	7.06	4.228	11.29	17.82	+57.93
5/7–8	14.0	15.0	1247	14.3	7.00	4.633	11.63	15.76	+35.51
5/9–10	10.0	15.0	1232	11.3	6.92	3.525	10.45	12.74	+21.91
5/11–12	10.0	12.0	1222	13.3	6.88	3.830	10.71	11.71	+9.33
5/13–14	7.0	10.5	1208	13.2	6.84	3.696	10.54	8.91	−15.46
5/15–16	6.0	9.0	1215	12.5	6.86	3.550	10.41	7.64	−26.60
5/17–18	6.0	9.0	1022	12.1	6.80	3.666	10.47	7.64	−27.02
5/19–20	6.0	9.0	1162	10.7	6.64	3.124	19.76	7.64	−21.72
5/21–22	6.0	9.0	1193	10.5	6.76	.....	.....	7.64	....
5/23–24	6.0	9.0	1157	10.3	6.64	3.120	9.76	7.64	−21.72
5/25–26	6.0	9.0	1143	10.8	6.56	3.153	9.71	7.64	−21.32
5/27–28	6.0	9.0	1149	10.6	6.60	3.180	9.78	7.64	−21.88
5/29–30	6.0	9.0	1141	10.4	6.56	2.953	9.51	7.64	−19.66
5/31–6/1	6.0	9.0	1150	10.6	6.60	3.137	9.74	7.64	−21.56
6/2–3	6.0	9.0	1140	10.5	6.56	3.150	9.71	7.64	−21.32
6/4–5	6.0	9.0	1141	10.1	6.56	3.393	9.95	7.64	−23.21
6/6–7	6.0	9.0	1137	8.6	6.56	2.631	9.19	7.64	−16.86
6/8–9	6.0	9.0	1132	8.7	6.52	2.845	9.37	7.64	−18.46
6/10–11	6.0	9.0	1117	8.8	6.48	2.956	9.44	7.64	−19.06

ON COMPOSITION AND PROPERTIES OF MILK

Fresh September 25, 1908

Date of Sample	Total Protein	Casein	Albumin	Ash	Sugar	Fat	Saponification Number	Iodin Number	Reichert-Meissl Number	Melting Point
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent		(Hübl)		°C.
2/25–3/3	3.31	2.73	0.43	0.72	5.49	3.91	232.3	36.86	20.50	33.80
3/5	3.25	2.54	.38	.70	5.26	4.19	227.3	35.64	21.93	34.50
3/7	3.37	2.67	.38	.72	5.66	4.42	227.2	36.73	21.09	34.15
3/9	3.57	2.93	.35	.77	5.40	3.97	227.2	36.10	20.80	33.10
3/11	3.50	2.80	.41	.75	5.48	3.93	236.6	35.69	20.44	32.55
3/13	3.50	2.87	.35	.71	5.15	3.22	236.2	39.78	20.44	32.25
3/15	3.63	2.93	.41	.75	5.35	3.42	227.4	35.10	20.38	34.13
3/17	3.69	2.99	.23	.77	5.41	3.14	230.3	34.93	19.80	32.55
3/19	3.76	3.18	.39	.74	5.49	3.31	230.7	34.57	20.64	32.80
3/21	3.95	3.06	.34	...	5.28	3.57	237.9	34.50	19.87	32.70
3/23	3.69	2.93	.34	.74	5.25	3.75	234.8	32.90	21.07	33.48
3/25	3.57	2.73	.31	.74	5.21	3.92	231.0	31.07	20.10	33.35
3/27	3.57	2.87	.32	.75	5.56	3.89	229.1	32.74	20.88	32.95
3/29	3.76	2.93	.38	.74	5.04	3.68	227.9	32.97	21.54	32.80
3/31	3.83	3.12	.41	.78	5.26	3.61	230.5	34.44	21.65	32.35
4/2	3.63	2.99	.35	.75	5.14	3.75	231.0	33.26	19.84	33.75
4/4	4.14	3.12	.47	.70	5.11	4.29	229.2	32.52	21.15	33.65
4/6	3.69	2.87	.47	....	5.18	3.53	234.3	33.64	21.71	32.85
4/8	3.69	2.99	.40	.73	5.41	3.71	226.1	33.60	21.44	35.90
4/10	3.69	2.99	.38	....	5.29	3.46	225.3	34.50	18.85	33.05
4/12	3.76	2.99	.34	.76	5.25	3.37	227.8	33.84	20.36	34.30
4/14	3.69	2.87	.40	.77	5.09	3.87	229.0	34.81	21.92	32.30
4/16	3.57	2.73	.41	.79	5.08	3.87	231.8	33.94	23.20	32.60
4/18	3.50	2.73	.40	.74	5.03	3.48	229.9	34.29	22.69	33.60
4/20	3.69	2.93	.38	.77	5.01	3.80	229.6	34.52	20.79	33.55
4/22	3.50	2.87	.41	.75	5.03	3.77	229.2	34.19	19.59	34.45
4/24	3.57	2.87	.29	.74	4.99	3.42	224.2	34.65	20.24	33.10
4/26	3.69	2.93	.41	.70	5.36	3.66	229.7	32.55	21.57	34.70
4/28	3.69	2.80	.34	.72	5.15	3.86	231.9	35.54	21.90	34.60
4/30	3.95	3.06	.37	.79	5.34	3.92	229.6	35.92	21.51	34.90
5/2	3.69	2.87	.41	.72	5.16	3.71	......	39.82	21.42	32.00
5/4	3.63	2.80	.40	.69	5.03	3.40	229.8	34.86	21.88	33.40
5/6	3.50	2.74	.36	.68	5.14	3.51	229.6	35.04	21.43	34.20
5/8	3.31	2.61	.39	.66	4.80	4.42	227.4	37.71	22.07	33.73
5/10	3.38	2.68	.34	.65	4.66	4.19	......	36.88	20.55	34.65
5/12	3.38	2.48	.33	.67	5.04	3.66	229.0	41.34	20.34	35.25
5/14	3.38	2.54	.29	.68	5.23	3.52	231.9	41.64	19.20	34.10
5/16	3.31	2.61	.29	.68	5.25	3.56	224.1	44.77	18.10	35.00
5/18	3.18	2.54	.40	.72	5.10	4.05	224.8	42.73	16.79	35.25
5/20	3.18	2.61	.41	.70	5.03	3.79	231.5	38.88	17.01	33.90
5/22	.....	.....	.....	....	.....	.....	228.8	37.88	16.82	34.75
5/24	3.50	2.74	.42	.75	5.04	4.05	228.2	42.63	16.08	34.95
5/26	3.57	2.80	.41	.72	5.03	3.84	227.0	43.41	16.98	34.45
5/28	3.50	2.61	.43	.74	5.01	3.98	229.6	44.49	16.38	34.75
5/30	3.38	2.42	.43	....	5.09	3.63	.....	......	......	.....
6/1	3.50	2.54	.43	.73	4.86	3.93	231.9	45.29	15.77	34.50
6/3	3.50	2.54	.46	.75	5.03	3.98	233.0	42.71	15.87	34.45
6/5	3.50	2.86	.41	....	4.98	4.64	226.4	38.92	15.64	34.10
6/7	3.44	2.61	.50	.73	4.83	4.12	227.4	43.56	16.45	34.15
6/9	3.69	2.68	.47	....	4.96	4.45	220.2	42.56	14.43	34.65
6/11	3.69	2.74	.48	....	5.03	4.57	225.2	42.28	15.02	34.85

TABLE II.—INFLUENCE OF PLANE OF NUTRITION
Cow 301. September 15—November 18, 1910.

Date of Feeding	Average Daily Ration		Ave. Weight of Cow	Milk per Day	Energy Required			Total Energy Received	Plane of Nutrition
	Grain	Alfalfa Hay			For Maintenance	For Milk Production	Total		
1910	Lbs.	Lbs.	Lbs.	Lbs.	Therms	Therms	Therms	Therms	Per cent
9/15-16	10.5	15	976	29.8	5.92	8.41	14.33	13.11	− 8.50
9/17-18	8.5	14	945	28.0	5.77	8.65	14.42	11.27	−21.80
9/19-21	8.0	14	944	27.4	5.75	8.11	13.86	10.89	−21.42
9/22-27	8.0	14	948	22.2	5.79	7.06	12.85	10.89	−15.24
9/28-29	9.0	16	943	21.8	5.75	6.37	12.12	12.32	+ 1.54
10/1-2	12.4	16	973	18.4	5.87	5.71	11.58	14.90	+28.65
10/4-6	12.8	16	953	21.5	5.79	6.71	12.50	15.20	+21.61
10/7-9	12.8	16	961	23.7	5.83	7.06	12.89	15.20	+17.90
10/10-16	12.8	16	942	24.3	5.75	7.19	12.94	15.20	+17.44
10/18-24	12.8	16	932	23.5	5.71	7.40	13.11	15.20	+15.93
10/25-31	12.5	16	955	22.9	5.81	7.14	12.95	14.97	+15.56
11/2-3	9.0	16	955	21.5	5.81	6.71	12.52	12.33	− 1.50
11/5-11	9.0	16	955	21.1	5.81	6.58	12.39	12.33	− 0.48
11/12-18	8.9	16	945	18.8	5.77	6.20	11.97	11.74	− 1.95

ON COMPOSITION AND PROPERTIES OF MILK

Fresh June 17, 1910

Date of Sample	Total Protein	Casein	Ash	Sugar	Fat	Saponification Number	Iodin Number	Reichert-Meissl Number	Melting Point
	Per cent	Per cent	Per cent	Per cent	Per cent		(Hübl)		°C
9/16	3.06	2.23	0.58	4.68	3.56	232.4	32.08	29.12	33.33
9/18	2.97	2.22	.54	4.52	4.16	227.2	37.26	27.07	32.83
9/19–21	3.12	2.35	.56	4.39	3.90	228.7	37.78	27.40	32.30
9/22–27	2.90	2.35	.65	4.60	4.27	227.2	37.06	27.61	31.60
9/29	3.18	2.16	.65	5.00	3.84	229.9	33.00	29.10	32.83
10/2	3.12	2.35	.69	4.62	4.20	236.7	28.33	31.62	33.20
10/4–6	3.06	2.23	.68	4.90	4.22	232.1	30.32	30.69	33.30
10/7–9	3.12	2.35	.69	5.03	3.95	234.5	30.85	31.42	32.90
10/10–16	3.12	2.42	.67	4.80	3.91	229.5	33.34	30.17	32.33
10/18–24	3.12	2.35	.69	5.03	4.24	230.3	30.89	29.44	33.00
10/25–31	3.18	2.23	.68	5.00	4.17	231.1	29.57	29.71	32.96
11/3	3.37	2.48	.70	5.28	4.20	225.7	31.47	25.51	31.90
11/5–11	3.18	2.42	.67	4.92	4.21	229.7	33.90	27.06	31.60
11/12–18	3.24	2.42	.68	4.83	4.46	231.6	30.67	28.69	32.16

TABLE III.—INFLUENCE OF PLANE OF NUTRITION
Cow 2. January 25—May 20, 1911.

Date of Feeding	Average Daily Ration			Av. Weight of Cow	Av. Milk Yield Per Day	Energy Required			Total Energy Received	Plane of Nutrition
	Grain	Alfalfa Hay	Silage			For Maintenance	For Milk Production	Total		
1911	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Therm	Therms	Therms	Therms	Per cent
1/25–26	2.50	8	20	742	9.95	4.90	3.26	8.16	7.96	−2.45
1/27–28	2.50	8	20	725	9.75	4.86	3.30	8.16	7.96	−2.45
1/29–30	2.50	8	20	712	10.20	4.97	3.15	8.12	7.96	−1.97
1/31–2/1	4.50	8	20	732	10.80	4.86	3.43	8.29	9.48	+14.3
2/2–3	4.50	8	20	735	11.15	4.90	3.65	8.55	9.48	+10.9
2/4–5	4.50	8	20	735	11.15	4.90	3.54	8.44	9.48	+12.3
2/6–7	5.50	8	20	710	10.90	4.77	3.93	8.70	10.23	+17.6
2/8–9	6.50	8	20	750	11.70	4.95	3.56	8.51	11.00	+29.3
2/10–11	6.50	8	20	737	11.10	4.90	3.57	8.47	11.00	+30.0
2/12–13	6.50	8	20	732	10.90	4.46	3.47	7.93	11.00	+38.7
2/14–15	6.50	8	20	727	11.20	4.46	3.55	8.01	11.00	+37.4
2/16–17	6.50	8	20	712	10.90	4.77	3.54	8.31	11.00	+32.4
2/18–19	7.25	8	20	742	10.35	4.90	3.15	8.05	11.56	+43.6
2/21–22	8.00	8	20	750	9.30	4.95	3.35	8.30	12.13	+46.2
2/23–24	8.00	8	20	730	10.90	4.86	4.03	8.89	12.13	+36.5
2/25–26	9.50	8	20	745	10.65	4.95	3.47	8.42	13.27	+57.5
2/27–28	10.00	8	20	752	11.25	4.95	3.41	8.36	13.64	+63.2
3/1–2	10.00	8	20	772	11.05	5.03	3.22	8.25	13.64	+65.3
3/3–4	10.00	8	20	775	12.05	5.07	3.85	8.92	13.64	+53.0
3/5–6	10.00	8	20	766	11.55	4.99	4.14	9.13	13.69	+49.3
3/7–15	12.00	8	20	773	11.35	5.04	3.75	8.79	15.16	+72.4
3/16–21	12.00	8	20	795	11.70	5.14	3.50	8.64	15.16	+75.5
3/22–31	12.00	8	20	812	11.25	5.21	3.79	9.00	15.16	+68.3
4/1–11	12.00	8	20	825	11.25	5.27	3.90	9.17	15.16	+65.3
4/12–20	11.70	10	20	842	11.55	5.34	4.02	9.36	15.70	+68.8
4/21–23	12.00	10	20	865	11.43	5.43	3.95	9.35	15.85	+68.9
4/24	9.00	10	20	870	10.90	5.45	3.53	8.98	13.57	+51.2
4/25	6.00	8	20	865	11.10	5.43	4.77	10.20	10.51	+ 3.0
4/26	4.00	8	20	842	10.60	5.33	4.16	9.49	8.09	−14.7
4/27	3.00	8	20	840	10.70	5.33	4.28	9.61	8.34	−13.2
4/28	3.60	10	20	855	10.80	5.39	4.23	9.62	9.48	− 1.4
4/29	6.00	10	20	860	10.90	5.41	3.92	9.33	11.20	+ 19.9
4/30	8.00	10	20	852	10.70	5.37	3.66	9.03	12.82	+ 41.9
5/1–8	12.00	10	20	861	11.65	5.41	4.09	9.50	15.85	+ 66.7
5/9–10	3.60	10	20	866	11.80	5.44	4.11	9.55	9.48	− 0.6
5/11–12	3.60	10	20	860	11.85	5.42	4.10	9.52	9.48	− 0.2
5/13–14	3.60	10	20	848	11.40	5.36	4.44	9.80	9.48	− 2.8
5/15–16	3.60	10	20	843	11.75	5.34	4.16	9.50	9.48	− 0.2
5/17–18	3.60	10	20	865	12.25	5.40	4.27	9.67	9.48	− 1.6
5/19–20	3.60	10	20	870	12.65	5.45	4.15	9.60	9.48	− 1.2

ON COMPOSITION AND PROPERTIES OF MILK

Fresh January 12, 1911

Date of Sample	Total Protein	Casein	Ash	Sugar	Fat	Saponification Number	Iodin Number (Hübl)	Reichert-Meissl Number	Melting Point
	Per cent	Per cent	Per cent	Per cent	Per cent				°C.
1/25–26	3.70	2.49	0.84	4.60	4.46	240.9	23.99	41.65	32.76
1/27–28	3.64	2.87	.77	5.05	4.64	243.3	22.36	37.74	33.90
1/29–30	3.58	2.87	.80	....	4.15	238.7	25.70	38.48	33.73
1/31–2/1	3.40	2.74	.77	4.46	4.29	235.6	27.87	37.19	34.20
2/2–3	3.45	2.87	.70	5.02	4.45	235.6	27.88	36.43	33.73
2/4–5	3.58	2.49	.77	4.65	4.27	234.8	27.98	34.21	34.00
2/6–7	3.39	2.68	.77	5.10	5.11	234.6	28.02	33.73	34.13
2/8–9	3.45	2.68	.80	4.87	4.07	235.1	28.63	33.66	34.37
2/10–11	3.59	2.42	.76	4.61	4.37	234.5	28.69	32.70	33.40
2/12–13	3.26	2.74	.78	5.13	3.96	233.6	29.34	33.42	33.73
2/14–15	3.24	2.30	.77	4.39	4.28	234.0	29.72	33.52	33.37
2/16–17	3.32	2.81	.75	5.19	4.41	233.0	29.82	33.16	33.67
2/18–19	3.13	2.55	.79	5.06	4.07	234.3	30.70	32.21	32.90
2/21–22	3.39	2.74	.75	5.70	5.03	236.8	25.98	33.58	32.97
2/23–24	3.32	2.68	.74	5.06	5.13	236.9	25.06	33.90	33.29
2/25–26	3.39	2.81	.75	5.65	4.42	234.6	26.02	34.67	33.37
2/27–28	3.56	2.87	.75	5.65	4.03	233.9	26.81	35.00	32.93
3/1–2	3.39	2.74	.74	5.21	3.80	232.5	28.12	34.98	33.00
3/3–4	3.51	2.81	.80	5.45	4.32	232.0	28.45	34.76	33.10
3/5–6	3.51	2.81	.80	....	4.93	231.1	28.03	32.78	33.23
3/14–15	3.39	2.81	.76	5.41	4.55	231.8	27.83	32.58	33.50
3/20–21	3.58	3.19	.75	5.14	3.96	230.2	28.93	32.93	33.37
3/30–31	3.58	3.06	.80	5.25	4.61	229.2	31.75	33.72	33.56
4/10–11	3.58	3.13	.76	5.56	4.79	230.2	30.41	33.77	33.33
4/19–20	3.66	2.93	.79	....	4.82	233.4	31.00	31.03	33.37
4/21–23	....	.....	.....	.....	4.75	.....	......	......	....
4/24	....	.....	.....	.....	4.40	.....	......	......	....
4/25	....	.....	.....	.....	5.80	.....	......	......	....
4/26	....	.....	.....	.....	5.40	.....	......	......	....
4/27	....	.....	.....	.....	5.50	.....	......	......	....
4/28	....	.....	.....	.....	5.40	.....	......	......	....
4/29	....	.....	.....	.....	5.00	.....	......	......	....
4/30	....	.....	.....	.....	4.70	.....	......	......	....
5/1–8	....	.....	.....	.....	4.86	.....	......	......	....
5/9–10	....	.....	.....	.....	4.80	.....	......	......	....
5/11–12	....	.....	.....	.....	4.80	.....	......	......	....
5/13–14	....	.....	.....	.....	5.30	.....	......	......	....
5/15–16	....	.....	.....	.....	4.90	.....	......	......	....
5/17–18	....	.....	.....	.....	4.82	.....	......	......	....
5/19–20	3.46	2.77	.72	5.35	4.45	229.2	30.75	31.49	34.00

TABLE IV.—INFLUENCE OF PLANE OF NUTRITION

Cow 2. February 28—June 5, 1912.

Date of Feeding	Average Daily Ration			Av. Weight of Cow	Av. Milk Yield per day	Energy Required			Total Energy Received	Plane of Nutrition
	Grain	Alfalfa Hay	Silage			For Maintenance	For Milk Production	Total		
1912	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Therms	Therms	Therms	Therms	Per cent
2/28–29	4.9	10.0	10.0	965	12.3	5.85	3.91	9.76	8.83	− 9.52
3/1–2	5.8	8.0	12.0	969	13.7	5.87	4.48	10.35	9.15	−11.59
3/3–4	5.8	8.0	12.0	968	14.4	5.87	4.67	10.54	9.15	−13.18
3/5–6	5.8	8.0	12.0	978	14.6	5.92	4.73	10.65	9.15	−14.08
3/7–8	5.0	8.0	12.0	968	14.6	5.87	4.82	10.69	8.55	−20.10
3/9–10	5.0	8.0	12.0	960	14.1	5.83	4.74	10.57	8.55	−19.11
3/11–12	5.0	8.0	12.0	959	14.0	5.83	5.21	11.04	8.55	−22.55
3/13–14	5.0	8.0	12.0	958	13.8	5.83	4.86	10.69	8.55	−21.10
3/15–16	5.0	8.0	12.0	964	14.1	5.83	4.82	10.65	8.55	−19.71
3/17–18	4.8	8.0	12.0	968	13.4	5.87	4.54	10.41	8.39	−19.40
3/19–20	4.5	8.0	12.0	964	14.1	5.83	5.13	10.96	8.16	−25.54
3/21–22	4.5	8.0	12.0	941	13.1	5.75	4.87	10.62	8.16	−23.16
3/23–24	4.3	8.0	12.0	950	13.2	5.79	4.65	10.44	8.01	−23.27
3/25–26	4.0	8.0	12.0	943	12.9	5.75	4.51	10.26	7.78	−24.17
3/27–28	4.0	8.0	12.0	940	13.3	5.75	4.68	10.43	7.78	−25.40
3/29-30	4.0	8.0	12.0	941	13.3	5.75	4.51	10.26	7.78	−24.17
3/31–4/1	4.0	8.0	12.0	940	13.1	5.75	4.40	10.15	7.78	−23.34
4/2–3	4.0	8.0	12.0	944	13.5	5.75	4.86	10.61	7.78	−26.67
4/4–5	3.8	8.0	12.0	948	13.7	5.87	4.60	10.47	7.63	−27.12
4/6–7	3.6	8.0	11.0	944	13.4	5.75	4.58	10.33	7.31	−29.23
4/8–9	3.6	8.0	10.0	936	13.7	5.75	4.77	10.52	7.15	−32.03
4/10–11	3.6	7.5	9.0	949	13.8	5.79	4.64	10.43	6.81	−34.70
4/12–13	3.6	7.0	8.0	938	13.8	5.75	4.55	10.30	6.47	−37.18
4/14–15	3.6	7.0	8.0	936	12.9	5.75	4.41	10.16	6.47	−36.31
4/16–17	3.6	7.0	8.0	939	12.7	5.75	4.11	9.86	6.47	−34.40
4/18–21	3.6	7.0	8.0	933	13.0	5.71	4.57	10.28	6.47	−37.06
4/22–25	3.6	7.0	8.0	918	12.1	5.66	4.07	9.73	6.47	−33.50
4/26–29	3.6	7.0	8.0	915	11.5	5.64	3.93	9.57	6.47	−32.49
4/30–5/3	3.6	7.0	8.0	890	11.0	5.54	3.76	9.30	6.47	−30.43
5/4–7	3.6	7.0	8.0	864	10.1	5.41	3.88	9.29	6.47	−30.35
5/10–11	4.0	7.9	8.5	841	9.0	5.33	3.91	9.24	7.23	−21.75
5/12–13	5.5	10.0	12.5	866	10.0	5.45	3.80	9.25	9.69	+ 4.95
5/14–16	7.0	10.0	20.0	893	10.5	5.54	3.49	9.03	12.09	+33.88
5/17–20	7.0	10.0	20.0	893	11.8	5.54	3.75	9.29	12.09	+30.13
5/21–25	10.0	10.0	16.0	901	12.0	5.58	3.82	9.40	13.96	+48.50
5/26–28	12.0	10.0	15.0	915	12.7	5.64	4.57	10.21	15.06	+47.50
5/30–31	3.5	8.0	10.0	935	12.9	5.73	4.49	10.22	7.07	−30.82
6/1	3.0	8.0	10.0	930	11.6	5.71	4.06	9.77	6.69	−31.52
6/3	3.0	8.0	10.0	915	12.6	5.64	4.12	9.76	6.69	−31.45
6/5	3.0	8.0	10.0	890	11.0	5.54	3.87	9.41	6.69	−28.85

ON COMPOSITION AND PROPERTIES OF MILK
Fresh February 25, 1912

Date of Sample	Total Protein	Sugar	Fat	Saponification Number	Iodin Number	Reichert-Meissl Number	Melting Point
	Per cent	Per cent	Per cent		(Hübl)		°C.
2/28–29	4.47	4.88	4.34	229.5	34.76	30.49	32.4
3/1–2	4.47	4.99	4.45	231.5	30.36	31.53	32.7
3/3–4	4.15	4.94	4.42	231.9	30.46	31.33	34.6
3/5–6	4.03	5.16	4.43	233.6	28.27	32.65	32.8
3/7–8	3.96	5.22	4.51	234.3	29.03	32.14	32.5
3/9–10	3.90	5.24	4.61	231.7	31.87	31.31	33.3
3/11–12	3.84	5.24	5.15	230.6	32.12	31.82	33.0
3/13–14	3.71	5.28	4.93	230.5	32.85	32.21	32.7
3/15–16	3.71	5.39	4.70	231.8	31.50	31.50	32.5
3/17–18	3.77	5.37	4.65	232.0	30.06	31.00	34.1
3/19–20	3.58	5.41	5.05	228.0	32.07	30.48	32.8
3/21–22	3.58	5.47	5.15	228.2	32.59	30.13	32.8
3/23–24	3.58	5.47	4.92	228.8	32.75	29.31	33.1
3/25–6	3.52	5.41	4.85	228.5	33.10	29.61	32.9
3/27–28	3.52	5.44	4.90	228.0	33.25	30.98	33.0
3/29–30	3.52	5.43	4.65	227.7	33.11	30.29	32.9
3/31–4/1	3.45	5.40	4.60	228.8	32.70	30.54	33.8
4/2–3	3.52	5.41	4.96	227.5	32.86	30.64	33.5
4/4–5	3.45	5.41	4.57	228.3	32.05	30.36	33.8
4/6–7	3.58	5.42	4.68	228.4	29.50	29.77	33.7
4/8–9	3.52	5.38	4.84	230.6	30.09	29.64	34.8
4/10–11	3.52	5.43	4.58	228.7	31.61	30.75	35.1
4/12–13	3.45	5.41	4.50	226.7	33.52	28.69	33.1
4/14–15	3.52	5.41	4.70	227.5	33.97	28.67	32.9
4/16–17	3.52	5.43	4.38	227.8	33.05	28.99	33.3
4/20–21	3.52	5.39	4.88	228.2	31.94	28.13	33.7
4/24–25	3.32	5.38	4.57	226.4	35.50	27.64	33.7
4/28–29	3.32	5.38	4.72	227.0	36.28	27.91	31.6
5/2–3	3.32	5.34	4.66	226.1	37.12	27.82	33.5
5/6–7	2.94	5.32	5.30	221.8	41.52	25.59	35.7
5/10–11	3.07	5.22	5.85	217.1	46.98	23.50	35.5
5/12–13	3.13	5.25	5.27	220.8	42.43	27.10	34.6
5/15–16	3.32	5.19	4.55	227.3	34.80	29.49	33.3
5/19–20	3.52	5.18	4.29	226.6	33.57	28.51	34.8
5/24–25	3.64	5.17	4.30	229.4	31.79	30.39	34.9
5/27–28	3.58	5.23	5.00	229.1	32.31	30.45	35.0
5/30–31	3.45	5.19	4.80	227.4	33.66	29.67	35.7
6/1	3.64	5.50	4.85	225.3	34.96	29.03	36.3
6/3	3.52	5.17	4.45	226.6	35.39	29.67	36.4
6/5	3.45	5.16	4.88	222.6	39.39	26.72	36.5

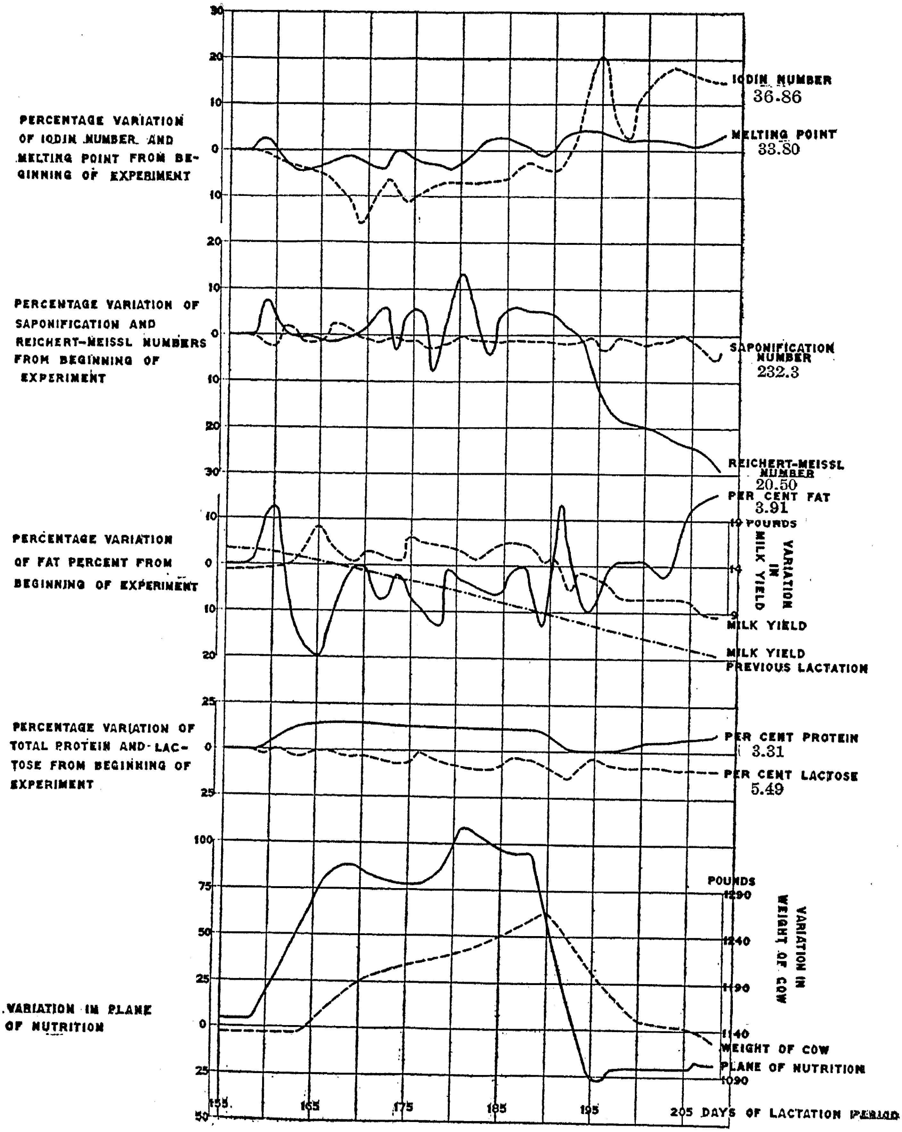

FIG. 1.—COW 402. FEBRUARY 24,—JUNE 11, 1909

The principal effects of overfeeding as indicated by these curves were, (1) a marked increase in the weight of the cow, (2) a slight increase in the milk flow, holding off the normal decline due to advancing lactation, (3) a definite rise in the percentage and yield of protein in the milk, (4) the maintenance of the saponification value, Reichert-Meissl number, iodin value and melting point of the milk fat at a constant level, holding off the normal changes which would be expected to accompany advancing lactation. The figures at the end of the curves are the values at the beginning of the experiment from which the percentage variations were calculated.

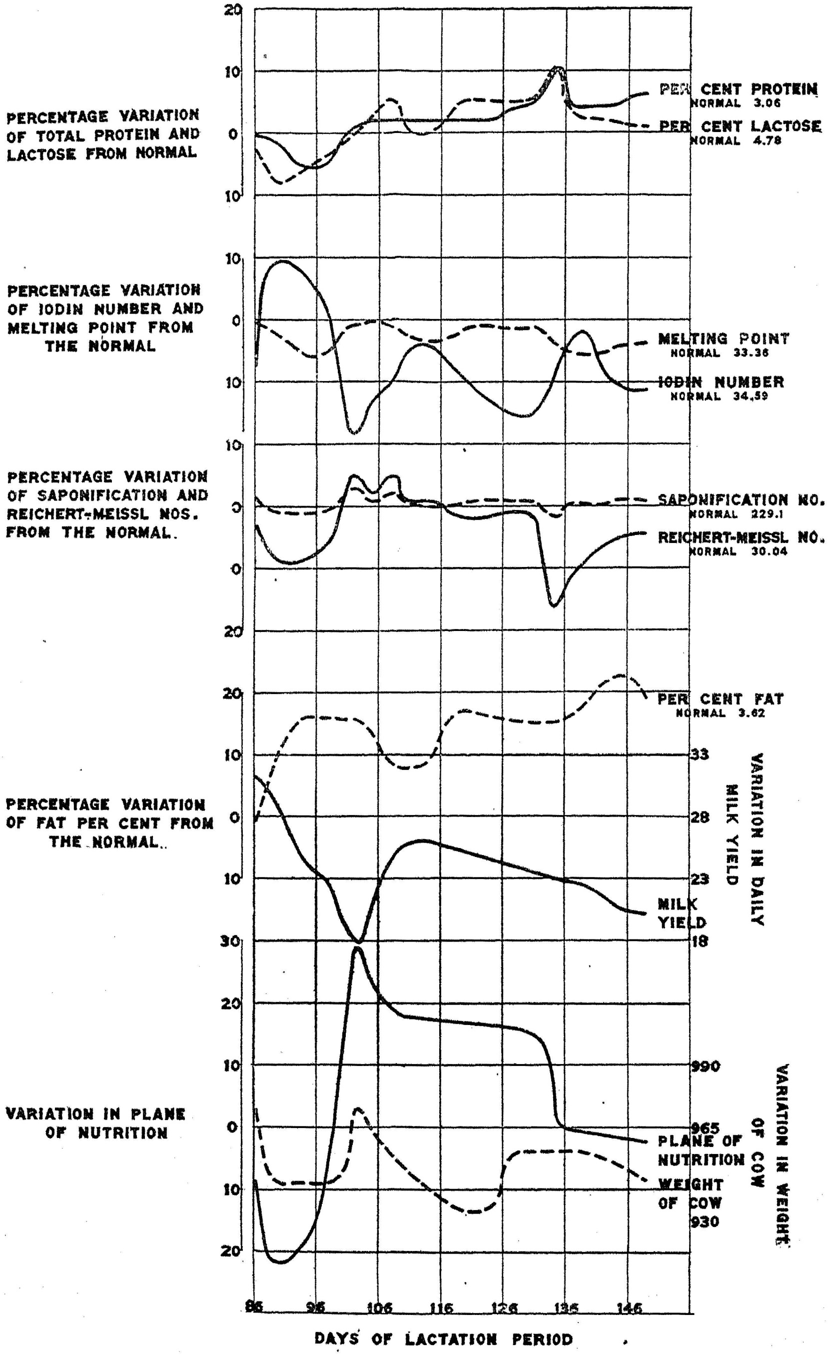

FIG. 2.—COW 301. SEPTEMBER 16—NOVEMBER 18, 1910

In this experiment the effects of overfeeding were (1) a partial restoration of a milk flow depressed by a previous underfeeding period, (2) a complete restoration to normal of the saponification value, Reichert-Meissl number, iodin value, and melting point of the milk fat, which were abnormal due to a previous underfeeding period.

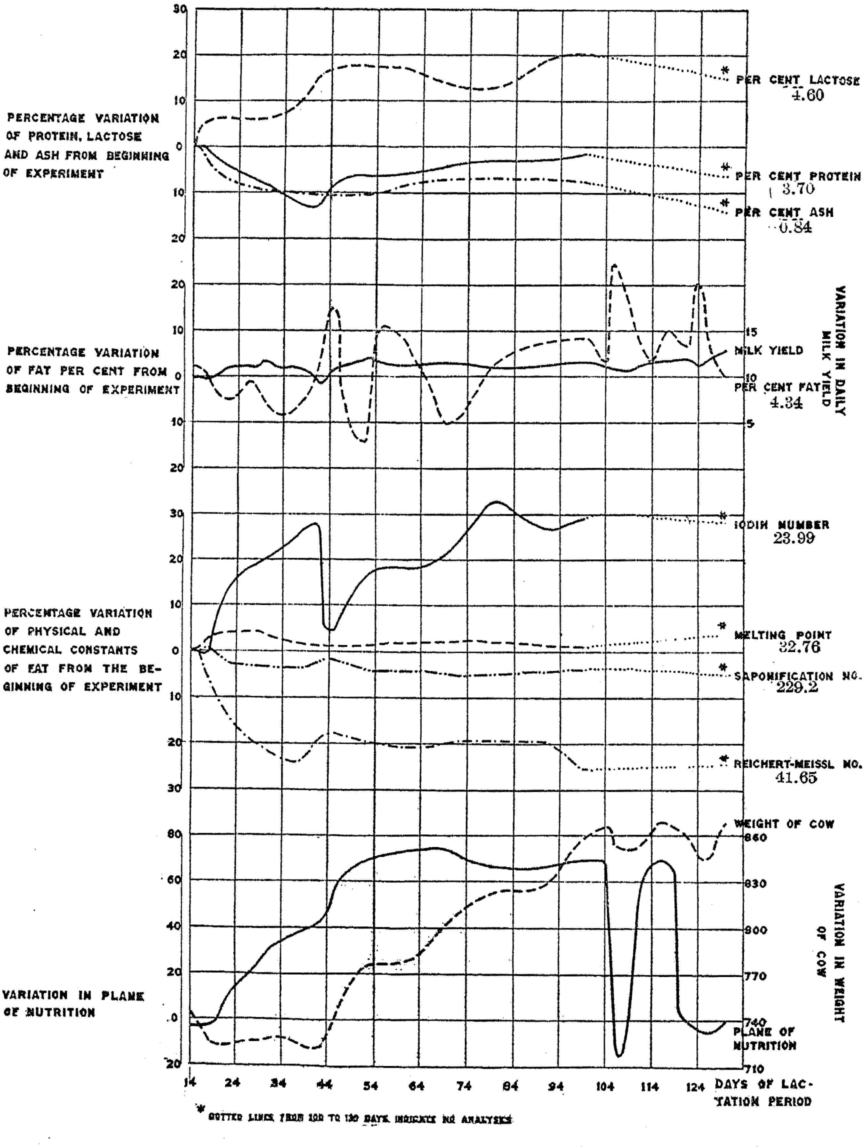

FIG. 3.—COW 2. JANUARY 25—MAY 20, 1911

The effect of overfeeding this cow which calved in a very thin condition, was to change the percentage of the milk constituents and the chemical and physical constants of the milk fat to normal. Notice the lack of effect of the high plane of nutrition on the milk flow. There was, however, a marked gain in body weight. The values at the end of the curves are the values obtained at the beginning of the experiment from which the percentage variations were calculated.

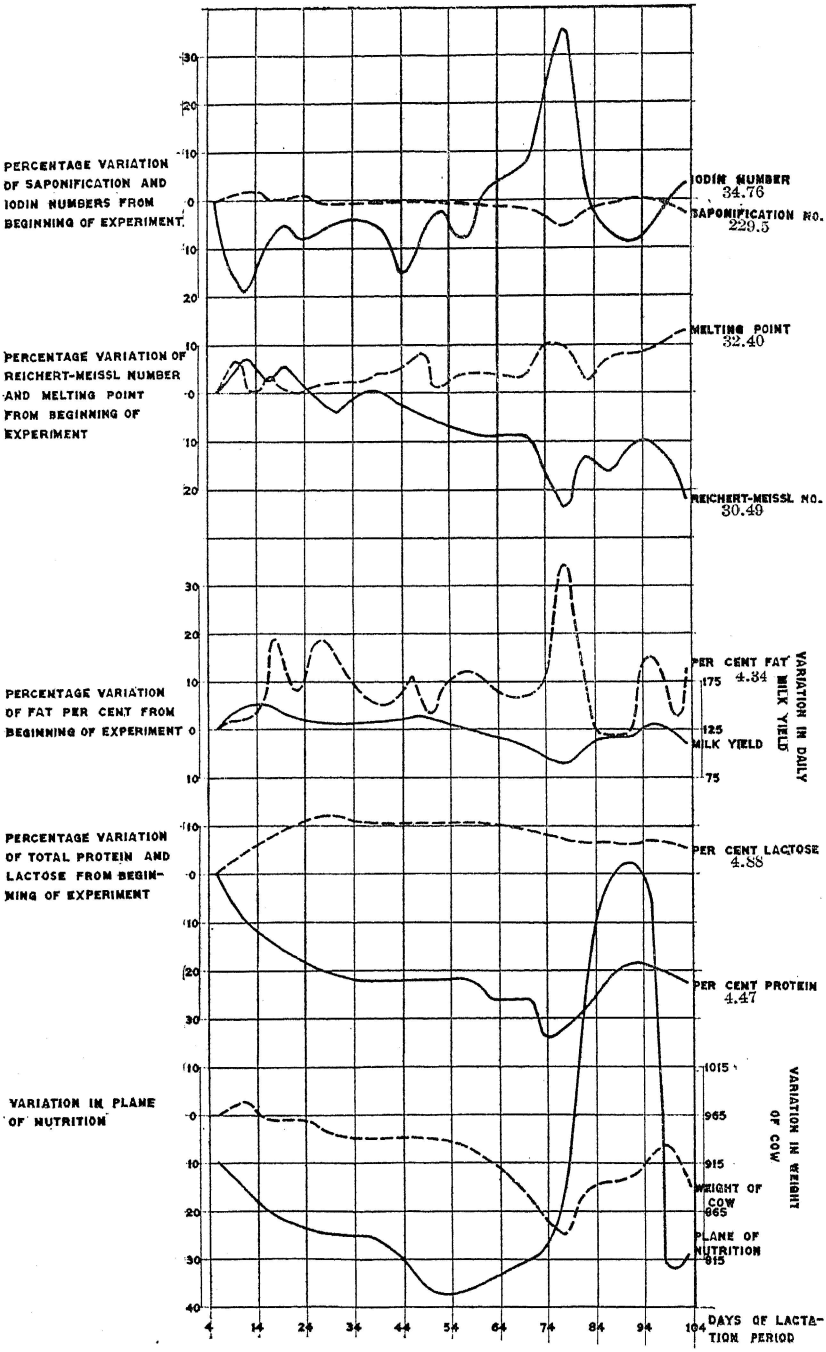

FIG. 4.—COW 2. FEBRUARY 23—JUNE 5, 1912

In this experiment overfeeding partially restored a milk flow depressed by a long period of underfeeding and brot about the production of normal milk and milk fat, which has been made abnormal by the same factor. Notice the changes in all the curves towards normality with the great increase in the plane of nutrition beginning about the seventy-eighth day of lactation. The figures at the end of the curves are the values at the beginning of the experiment from which the percentage variations were calculated.