THE UNIVERSITY OF MINNESOTA

GRADUATE SCHOOL

Report

of

Committee on Examination.

This is to certify that we the undersigned, as a Committee of the Graduate School, have given Samuel H. Harvey final oral examination for the degree of Master of Science. We recommend that the degree of Master of Science be conferred upon the candidate.

C. H. Eckles
Chairman

Andrew Boss

A. M. Field

September 3, 1921.

THE UNIVERSITY OF MINNESOTA

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Report

of

Committee on Thesis

The undersigned, acting as a Committee of the Graduate School, have read the accompanying thesis submitted by Samuel H. Harvey for the degree of Master of Science They approve it as a thesis meeting the requirements of the Graduate School of the University of Minnesota, and recommend that it be accepted in partial fulfillment of the requirements for the degree of

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LIMITS OF PROFITABLE GRAIN FEEDING

FOR MILK PRODUCTION

by

Samuel H. Harvey

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TABLE OF CONTENTS

4-21 6M

4-21 6M

INTRODUCTION

The whole question of feeding is fundamentally economic for in the first place, dairy animals are raised and cared for in order that human food may be produced and secondly, the men engaged in the dairy business are there in an attempt at least to make money. As such they are interested in making the largest possible profit i.e. the greatest spread between selling price and cost of production. Feed is the largest factor of cost and may make up 70 per cent of the total. Roughages and concentrates constitute the feed, of which concentrates are of most importance since with most dairymen they are largely a cash transaction and may take a considerable share of the income from product.

The system of feeding dairy cows in this country calls for a liberal feeding of concentrates either in the form of cereal grains or by-products. On the other hand, European practices call for a minimum allowance of concentrates, usually by-products, with a maximum feeding of roughage in the form of hays or roots. While these two systems of feeding are not diametrically opposed, they suggest that under different conditions one systemmay be as economical as the other; in the one case too low a proportion of concentrates may be uneconomical in another too large a proportion may be uneconomical.

With any individual animal under consideration it becomes a question whether light or heavy grain feeding is more efficient and then what is meant by light and heavy grain feeding. A great deal of work has been done by our experiment stations in all parts of the country in an effort to find out the profitableness of grain feeding under different conditions. Further a voluminous amount of experimenting has been done in relation to such things as protein, energy, min-

4-21 6M

eral matter, etc. Much of this would seem to have been done strictly from the standpoint of pure science yet in the last analysis this work effects a better understanding of economical feeding since the physiological condition of the cow may determine her height of efficiency at any time.

Probably as good a criterion as we have of the significance of the problem of grain feeding is the display of interest upon the part of dairymen themselves. The question and answer columns of the agricultural press are invariably full of inquiries about feeding and that usually with special relation to the concentrate part of the ration. The profitableness of grain feeding under different conditions is of vital importance to all dairymen.

The purpose of this thesis is to find out through a review of the work done and an analysis of available records what factors enter into profitable grain feeding and to what extent under varying conditions grain feeding may be desirable and economical.

LIMITING FACTORS IN THE RATION

Roughages and Concentrates.

The feed is the raw material from which the cow obtains the energy for maintenance, growth, production of milk, and nourishment for the development of the foetus. The common dairy feeds may be classified as roughages or concentrates. Henry[21] defines concentrates as feeding stuffs of a condensed nature which are low in fibre and furnish a large amount of digestible matter. These include the grains and by-products of the milling industry as corn, wheat, oats, bran, linseed meal, etc. Roughages are the coarser feeding stuffs which are high in fibre and supply a lower percentage of digestible matter. These include hays, corn fodder, silage, etc.

The cow is a herbivoran and as such is dependent upon plant production for food. The chemist groups plants differently than the dairyman, recognizing a division of nutrients somewhat as follows: proteins, carbohydrates, fibre, fat, water, and mineral matter. The adaptability of roughages and concentrates depends upon the relative and absolute amounts of the different nutrients in the feeds and their physiological effects upon the animal. To formulate an effective milk producing ration we must know something of the requirements of the cow, and then know how the available feeds fulfill those requirements.

Protein Content.

A great deal of the work in creating standards has had to do with the protein content of the ration, particularly its relation to the carbohydrates. This was called the nutritive ratio and was closely correlated with the idea of a balanced ration. However, later developments have shown that there are considerations other than those of protein and carbohydrate content, and for this reason a ration that meets all requirements for most efficient production is better termed a complete ration, rather than balanced.

Woll and Humphrey[64] in some studies on the protein requirements of milking cows have shown that rations of medium protein content on the average proved more economical and more effective than rations of high protein content approaching the German standards. This is especially significant since protein is usually the most expensive nutrient in the ration. Except where alfalfa or other leguminous roughages are fed the matter of protein becomes a grain problem. This is particularly the case where mixed hays and silage are fed.

Nutrients from restricted sources.

Further work at Wisconsin[17] has shown that a balanced ration is not very significant in itself when balanced from restricted sources. Animals receiving all nutrients from the wheat plant were unable to perform normally the processes of reproduction and milk secretion. On the other hand, a ration balanced with nutrients from the corn plant produced normal conditions. An oat ration proved more efficient than the wheat but less so than the corn.

Mineral Matter.

In a later study[18] of the influence of restricted rations, thinking that possibly the deficiency was due to a lack of mineral matter, rather than to the quality of protein, calcium salts were added resulting in improved conditions.

The work of Hart and Steenbock[19] indicates that for continued and high milk production with its extra drain on calcium the supply may be dangerously low. The depletion of mineral matter may account for the fact that following a year of very high production, most cows are likely to be correspondingly low or may give only an average production. This is further corroborated by Forbes[11] who indicates that liberal milking cows may often receive insufficient calcium and phosphorus in their rations.

A report by Meigs[32] and Woodward from the Beltsville Station elaborates the significance of calcium and phosphorus in the feed upon the milk yield. They comment that it is likely that cows reach the end of their lactation periods with their calcium and phosphorus stores depleted, and that under ordinary systems of

10-20 5M

feeding these stores cannot be restored to their proper level, unless rations are fed containing sufficient quantities of these minerals. Grains are likely to be deficient in calcium but comparatively rich in phosphorus. Roughages vary widely in calcium, straws containing the least, while legumes are rich in this element. Results of alternated feeding of phosphate to cows previously fed normal herd rations brought about an increase of 37.9 per cent more milk than would have been expected from their previous performance.

It would appear then that the mineral constituents assist to a considerable extent in attaining maximum production. This factor becomes of greater importance with cows of high production since a large proportion of the nutrients will be derived from concentrates and is thus tied up intimately with the economy of grain feeding. Efficient dairy husbandry is concerned with maximum economical production over consecutive lactation periods so that the mineral problem would seem to be a limiting factor or at least should demand more attention than has been given it in the past. This further emphasizes the need for variety in the ration and the careful selection of grain feeds.

Vitamines.

The vitamine problem[2] [6] in connection with feeding dairy cows has received no special study and at present no significance is attached to vitamines as affecting quantitative production of milk.

General Considerations.

For more thorough utilization of the ration such things as bulk, succulence, and palatability should be taken into account. Bulk in the grain ration is desirable since it allows for a more free action of the digestive juices while succulence and palatability aid in digestion and stimulate a larger consumption of feed.

Manurial Value.

In most of the work done in connection with heavy versus light feeding of concentrates, reference has been made to the extra manurial value to be obtained

It has been estimated that from 70 to 80 per cent of nitrogen, phosphoric acid, and pdtash in the feed consumed by farm animals is returned in the urine and feces, and that the amounts are directly proportional to that originally contained in the feed. The animal has no means of creating new fertilizing constituents however. The analysis of feeds ordinarily used for dairy cows shows considerable variation in the percentage of fertilizing constituents. It would seem then that the manurial value from grain feeding would be a compensating factor in heavy grain feeding. When the cost of fertilizing constituents is as cheap in concentrates as in commercial fertilizers, the feeding of concentrates in place of the purchase of commercial fertilizer would appear to be better farm management.

UTILIZATION OF FEED BY COW

Cow Adapted for Bulky Feed.

The anatomy of the cow or any ruminant is such that it is peculiarly adapted to the consumption of large amounts of bulky feed and it is this feature that makes the cow such an economical producer, her ability to manufacture into human food, pasture grasses and hays otherwise not usable as human food.

Milk Production.

The function of milk giving is the development of a specific character which has to do with the nourishment of the calf and is closely identified with the maternal instinct. In the natural state milk production is limited by the demand of the calf and ceases when the calf is able to sustain itself. But by selection and breeding man has greatly increased the natural milk producing capacity to the extent that in one instance a production of over 37,000 lbs. of milk is recorded. At the other extreme we find the beef cow which has difficulty many times in furnishing enough milk for her calf.

Cause of Milk Secretion.

The cow belongs to the mammalian group which is characterized by the secretion of milk from mammary glands for the purpose of suckling its young. The immediate or exciting cause of milk secretion has been the subject for much conjecture and considerable experimentation. The hormone[52] theory has been established by the work of numerous investigators who attribute the secretion of milk to the action of chemical secretions fromductless glands probably originating in the ovary. These cause the development of the mammary gland and bring about the commencement of the actual secretion. Suckling and the mechanics of milking probably furnish a physical stimulus which maintains the flow after the hormone has inaugurated the original activity of the gland. The declining production in the course of a lactation is accounted for by an inhibitory hormone originating in the developing foetus.

10-20 5M

Intensity of Function.

The intensity of the milk producing function is demonstrated by cows that are underfed. The composition of milk tends to remain normal even under adverse conditions so that with insufficient nutrients the cow draws upon her reserve, sacrificing her body condition. It is a very well known fact[10] also that test cows carrying surplus body weight do not require a full allowance of feed immediately after freshening, but turn the surplus flesh into milk solids. Cows of extreme dairy temperament, though receiving a ration sufficient to maintain only a fair flow of milk draw upon their reserve and yield a quantity in excess of the available energy in the feed for short periods.

Utilization of Feed.

The extent of the milk producing function of any individual can be measured in terms of her ability to turn food material into milk. Eckles[8] points out that after maintenance is subtracted, with the richness of the milk the same, the nutrients required for production are in the same proportion as the production of the animals. When the production per unit of feed tends to decline the cow will begin to lay on flesh and a condition of diminishing returns has been reached. This does not mean that for a time enough milk will not be produced to pay for the extra grain but that the normal capacity of the cow has been reached and further forced feeding will be done at a loss or at least no profit for the additional units.

However, this does not accurately represent the case for we have other considerations of concurrent fattening and katabolism. If we can think of an extreme dairy temperament where all the feed above maintenance requirements would be applied to milk production up to the limit of a rated capacity and that capacity a definitely inherited character capable of mathematical determination before parturition,we would have a definite basis for economical feeding. However a method of rating has not been found and ideal conditions are rarely existent.

Armsby[1] states that "it appears to be well established both by common experience and by direct experiment that a diversion of energy from milk production to other forms may in fact take place before the maximum capacity of the milk glands is reached." It is for this reason that, with cows having dual purpose tendencies, it is difficult to judge the most economical grain feeding since increasing production beyond a certain point will be paralleled by fattening or by the oxidation of a larger proportion of the digested organic matter. With cows of extreme dairy temperament body increase or fattening will be a fair index of the limit of the economical addition of concentrates. However, as a general rule we cannot escape the fact that the daily weighing of milk is absolutely essential to economical grain feeding since for all grades of cows the point beyond which it will be uneconomical to addgrain will be determined by a profit above each additional unit.

Internal Stimulus

The stimulus[9] to produce milk then is an internal rather than external character and develops an appetite in the cow which can only be satisfied by the consumption of feed. The feed becomes a secondary factor for no matter how much or how excellent the feed, without the presence of the internal excitation, capacity for feed consumption and production of milk cannot be developed.

It is right in this connection that grain feeding becomes of importance. Although the cow can handle large quantities of roughage, there is a limit to her ability in obtaining sufficient nutrients for her maximum production without the addition of concentrated feeds. It is generally conceded that on roughage alone a 6,000 pound production is about the best possibility. Higher production means grain feeding and is especially significant in economical production since concentrates are usually relatively higher in price than roughages.

GRAIN FEEDING ON PASTURE

Pasture Means Cheap Production.

Pasture conditions make for the most natural environment of the dairy cow and in the early part of the season furnish a palatable succulent ration and one complete from the standpoint of balance of nutrients and mineral matter. It has become traditional in many sections and upon the part of many dairymen to turn cows upon pasture in the spring expecting them to obtain their whole sustenance there until fall. Where pastures are plentiful and of good quality a herd can probably be maintained satisfactorily under such conditions. The kind of grasses present, the fertility of the soil and climatic conditions are considerable factors in determining the quality and quantity of pastures in any season.

Pearson[44] in a study of the seasonal cost of milk production confirms the opinion held among dairy farmers of the great importance of pasture in milk production. The feed expense in summer months in which pastures are good may be only one-fourth of that of certain winter months when large amounts of stored and purchased feeds are used. This is accomplished by a reduction in the expense for labor since the cows gather their own feed and require very little barn management; also in feed, since most pasturage is obtained from cheaper lands. In other words we find a fluctuating seasonal cost as shown in chart I. This condition would tend to stimulate production during the pasture months so that a flat yearly price would be out of the question. A fluctuating price best protects producer, distributor and consumer alike and is the condition we find as shown in the accompanying graph. The monthly cow cost per hundred weight of milk varies from 122 per cent in February and December to 67 per cent in June. The price of milk varies from 120.3 per cent in December to 70.6 per cent in June.

Supplementary Feed on Pasture.

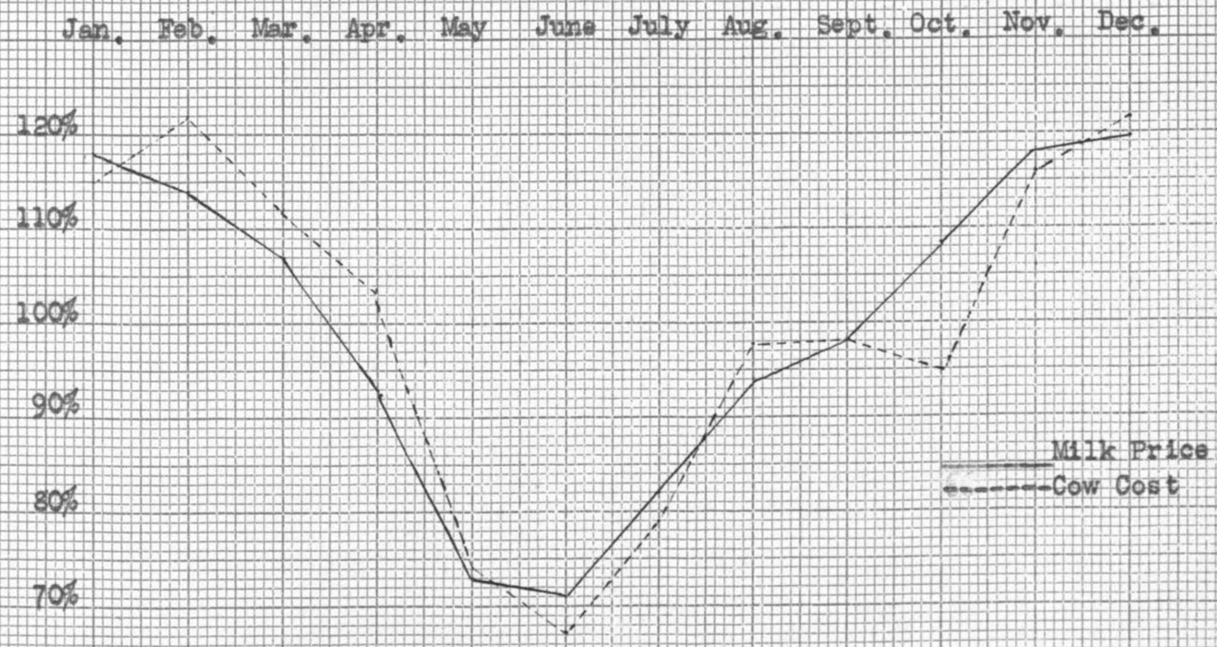
Is pasture in itself sufficient to bring about maximum yield and at the same time the most economical production? Helms[20] attempted to determine how much

CHART I

MONTHLY VARIATION IN PRICE OF MILK AND COST OF PRODUCTION - ON PER CENTAGE BASIS

I

From Ill. Sta. Bul. 224.



II.

PERCENTAGE DECREASE IN BUTTERFAT YIELD OF COWS WHEN FED GRAIN ON PASTURE AND WHEN FED ON PASTURE ONLY

From Utah Sta. Bul. 101

grass could be consumed by cows on pasture. Two lots of six cows were tethered on grass within large measured circles and found to consume 155 pounds per head daily. He observed that cows consumed about the same whether giving smaller or larger quantities of milk. A very casual analysis shows that Helms' determination was hardly a practical experiment, since according to standards[21] 100 pounds of grass will furnish sufficient nutrients for maintenance of a 1000 pound cow with a production of 50 pounds of 4 per cent milk. There are no accurate figures to show how much grass a cow may be able to crop during a days grazing. It will no doubt vary with the quantity and quality of the pasture available and the capacity of the cow.

Recognizing that the demand for feed is largely governed by maintenance and production requirements, the latter determined by an internal stimulus, the question arises whether or not all cows will be able to crop enough grass to sustain their maximum capacity especially those of high production. Practical experience and every day observation demonstrates easily the fact that maximum production is not attainable on ordinary pastures. They must be supplemented by either soiling crops or grain feeds and that must be accomplished economically. The advisability of supplementing pastures by feeding concentrates resolves itself entirely into a question of economy.

At the New Mexico[12] station a ration of 6 pounds of grain was fed to a group of cows on pasture and compared with a group on the same pasture without grain. The grain fed cows produced about 7 per cent more milk and 9 per cent more butterfat but at more than double the feed cost. This experiment was repeated with approximately the same results, the pasture being regarded as very good in both cases and the cows in good flesh.

Stewart and Atwood[53] used twelve Jersey grades in conducting three feeding tests to determine the economy of grain feeding on pasture. In all cases the grain feeding brought about an increase in production but with an excessive cost for the increase. The grain fed groups all gained some in weight which

ENG. 4
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4-21-4M
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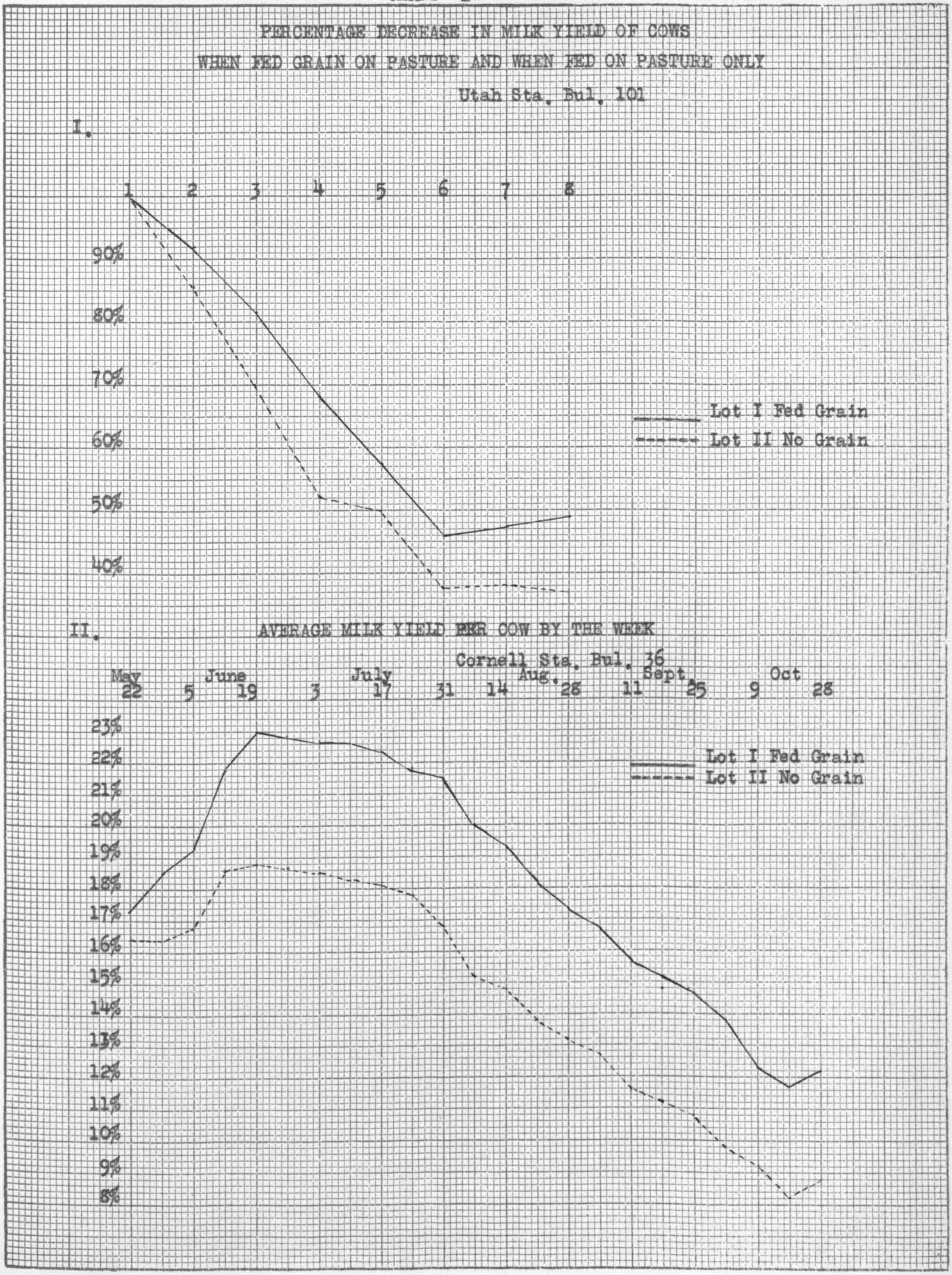
CHART 2



might indicate that the portion fed (6 pounds) was in excess of their capacity as dairy animals which averaged about 5000 pounds.

Hooper[24] at the Kentucky station fed five lots of five cows, one on poor pasture alone, while the other four groups were supplemented, one with 4 pounds grain mixture, another with 10 pounds corn silage, the third with 4 pounds grain and 10 pounds silage and the fourth with 8 pounds grain and 10 pounds silage. In every case the cows returned a profit for grain fed. The lot on pasture alone decreased rapidly in milk yield and some in weight while the group fed 4 pounds of grain and 10 pounds of silage showed the greatest profit.

Four years work by Linfield[31] at the Utah station on feeding grain to cows on pasture shows some interesting results. Each cow receiving grain on pasture produced in 108 days an average of 177 pounds milk and 6.38 pounds fat more than those receiving no grain on pasture. The average returns for the butterfat when grain was fed was $12.70 and on pasture alone $11.68; however deducting grain leaves $1.91 in favor of pasture alone. The grain fed group increased in weight and following the summer feeding period, though both groups were fed a grain ration similar in kind and amount, showed an ability to maintain a consistently higher level of production sufficient to more than pay for the grain fed. (See Chart 1(II) and Chart 2 (I).

Roberts and Wing[49] fed two groups of three cows each one on luxuriant pasture without grain and the other with a ration of 2 pounds bran and 2 pounds cottonseed meal. During a feeding period of fifteen weeks the grain fed group made no returns for grain fed. Plenty of pasture seemed to be sufficient for their capacity - 5000 pounds. The following season, which happened to be very dry, this experiment was repeated. The grain fed group showed an increase of only 4¾ pounds milk for 2822 pounds fed. However the cows on pasture alone shrunk an average of 37 pounds in weight, while the grain fed group gained an average of 77 pounds. In a further experiment,[50] barely enough was received to pay for the extra cost in the grain ration. However, in a continuation of this experiment the following year it was noted that those cows having made a gain of 53 pounds over those receiving no grain, during a period of six months, gave 480.2 pounds of milk per cow more than did the lot receiving no grain - a gain of 16 per cent. This factor of the residual effect showed particularly in two and three year old stock (See Chart 2 (II)).

The Cornell[51] work was continued the following year by a 22 weeks experiment on Jerseys, the grain fed group receiving four quarts per day of a mixture of two parts corn meal, one part wheat bran and one part cottonseed meal. The grain fed group showed a constant and well marked increase which was sustained throughout the period amounting to 5000 pounds for the 8 cows during twenty-two weeks. Three dollars were returned above cost of grain fed, while no account was taken of the increased value of the manure nor of the greater ability to produce in the succeeding lactation. Lot I receiving grain made an average gain for the period of 166 pounds while Lot II gained 113 pounds. All cows were small, ranging from 600 to 950 pounds with an average production capacity of about 5000 pounds.

Moore[33] reports a trial in which 3 pounds of cottonseed meal and 4 pounds wheat bran daily did not increase the milk flow enough to justify its use on pasture. In later tests Moore[34] concluded that it was not economical to feed grain to cows of average productive ability late in lactation when on fair pasture.

Work at the North Dakota[41] and New Mexico[38] stations as well as by Oedegaard[42] bears out the results of the previously cited experiments.

Pasture is a rather indeterminate quantity since it varies from one section of country to another as well as from year to year. Fertility of the soil and climatic conditions will determine the quantity at any particular time. To recommend any one procedure for grain feeding on pasture becomes rather an impossibility. Whether supplementary feeding of grain is necessary under any particular conditions will be a matter of judgment upon the part of the feeder. However general conditions point to the following conclusions, first, that supplementary feeding is absolutely essential on poor pastures even with cows of mediocre ability, is economical in its immediate returns, and its residual effect is very pronounced; secondly, on luxuriant pastures even light grain feeding seems to be desirable particularly because of the residual effect in maintaining a continued high level of production; third, cows with a capacity above 6,000 pounds milk should be fed a concentrated allowance in proportion to production and quality of milk.

The following recommendation for grain feeding on pasture is presented, using as a basis the results of the feeding trials reviewed in this paper and Professor Eckles'[7] suggested standard for cows yielding milk of varying richness. The allowances of supplementary grain might appear to be excessive but with a judicious feeding of leguminous soiling crops the figures could safely be reduced one-third.

Table I

Allowance of Grain for Cows on Pasture with Varying Production

Milk Pounds	Holstein and Ayrshire		Jersey and Guernsey	
Production	Poor Pasture	Good Pasture	Poor Pasture	Good Pasture
	lbs.	lbs.	lbs.	lbs.
20			4	2
25	4	2	6	4
30	6	4	8	6
35	8	7	11	8
40	10	8	13	9
45	12	9	15	11
50	14	11	18	13

GRAIN FEEDING WITH ALFALFA AS ROUGHAGE

Alfalfa Feeding Presents a Special Situation.

In sections of this country where the growing of alfalfa is accomplished very easily and cheaply the feeding problem presents a special situation. Alfalfa is recognized as the most efficient roughage for milk production as pasture, hay, or silage and the question arises as to the necessity for supplementing it with concentrates to obtain maximum production with cows of varying capacity, and that economically. Is alfalfa complete in itself from the nutritional standpoint so that grain feeding becomes only a matter of attaining maximum and economical production thru the addition of nutrients? If alfalfa as a sole feed may produce physiological disturbances then the factor of grain feeding to "balance" the ration is introduced. Any inefficiency brought on by faulty feeding becomes of chief interest because it will over long or short periods affect the net returns from the cow. Then grain feeding, whether for the purpose of "balancing" the ration or simply increasing the nutrients available for production resolves itself into a question of profitabliness. To obtain maximum returns from cows being fed alfalfa as roughage to what extent is grain feeding advisable or necessary? The problem of feeding grain in alfalfa sections becomes important and is quite general in parts of this country especially in California, and the Southwestern states and will, therefore, be considered in this thesis.

Physiology of Alfalfa Feeding.

Hart, Humphrey and Morrison[16] found the total nitrogen of alfalfa to show about the same percentage retention in both growth and milk production as did the total nitrogen of corn.

Woll[61] reports the results of an investigation of the value of an exclusive alfalfa diet for dairy cows and its physiological effects upon the body development and dairy production of the animals. A larger daily gain in weight and a slightly larger body development were made by animals on a mixed ration rather than on the alfalfa alone. It was further noted that the calves dropped by the mixed diet heifers were uniformly larger than those on alfalfa only. The mixed rations also proved superior to the alfalfa rations in milk production during one period averaging 92.86 pounds more butterfat, an increase of 45 per cent while during a second period an increase of 65.66 pounds or 23 per cent in favor of the mixed ration. The logical question is whether or not the extra milk produced, paid for the grain, and that will depend largely on market price. With grain feeds at from $25. to $30. per ton and alfalfa at $10. to $50. Woll concludes that the economy rests with alfalfa feeding unless physiological disturbances make grain feeding advisable. He points out for example that one herd of twenty-three cows in a California cow testing association averaged 410 pounds of butterfat on no other feed than alfalfa from the beginning of the year to the end, and further that tens of thousands of dairymen in the western states have followed the method of exclusive alfalfa feeding. However it is noteworthy that the alfalfa heifers did not, in their second lactation, show the increased production to the extent as did those fed on the mixed ration. The residual effect would seem quite as important as in connection with the feeding of grain on pasture.

Lindsey and Beals[29] at the Massachusetts station after carrying on numerous experiments involving the feeding of alfalfa in combination with other feeds arrive at the following conclusions:

1. The diuretic effect of the alfalfa appeared to be without influence in lessening the yield of milk and milk ingredients.

2. Too high an estimate should not be put upon the alfalfa, for while studies at this station and elsewhere have shown it to contain more protein than most other sources of roughages and equal to wheat bran in feeding value, it is quite inferior as a source of energy or fat production to most of the concentrates. In their experiments animals gained more in weight on a mixed hay ration than on alfalfa.

To determine the relative efficiency of alfalfa and timothy Fraser and Hayden [13] fed two lots of eight cows each for two periods of 9 weeks each. Alfalfa and timothy **were** alternated in a ration consisting of mixed grain (2½ pounds cornmeal to 1 pound of bran) and corn stover. The difference in milk yield between the alfalfa and timothy feeding periods was 2792 pounds of milk in favor of alfalfa. The condition of the cows was notably better during the alfalfa periods.

In a further experiment alfalfa was compared with bran in which results favored the feeding of alfalfa slightly. In a trial comparing alfalfa meal[30] and bran, in which each constituted 60 per cent of the grain fed, the bran showed a slight superiority.

Mairs used two lots of ten cows each to compare alfalfa meal and wheat bran as a result of which he did not recommend alfalfa meal as a substitute since it is less palatable and resulted in a decreased milk flow in every case. At the time of this experiment alfalfa meal was $23. per ton and bran $20.

Doane[5] found that cows produced more milk and gained more weight on an alfalfa and corn ration than one of corn silage and mixed grains.

Alfalfa Supplemented With Grain.

A further experiment reported by Doane[5] showed that animals when transferred from a grain and silage ration to an alfalfa and silage ration made a sudden drop in production indicating that the alfalfa and silage ration did not furnish all that was necessary for maximum production and that concentrates were necessary.

At the New York experiment station[39] it was found that when alfalfa forage was substituted for some other food or the amount of alfalfa in the ration was increased, in the majority of cases there was a decrease in the cost of milk. When the change was vice versa there was an increase in the cost of milk.

An experiment by Voorhees[58] and Love showed that the protein in alfalfa hay could be successfully and profitably substituted in a ration for dairy cows for that contained in wheat bran and brewer's grains. The use of alfalfa hay reduces the necessity for the purchase of protein feeds.

Foster and Latta[12] compared two groups of cows one on alfalfa hay alone the other fed alfalfa hay supplemented with equal parts of corn and bran, 6 pounds per head daily. When fed grain the cows ate about the same amount of hay but with 13.7 per cent increased production; 13.1 pounds daily average as compared with 11.5 pounds for those on hay only. There was no material difference in cost of production. The lots receiving grain made a gain in weight of 171 pounds as compared to a gain of 93 pounds by the lots fed no grain.

In order to determine the efficacy of barley feeding with alfalfa as roughage as opposed to feeding alfalfa alone two trials were conducted at the California[56] station. In the first, two lots of seven cows each were used. A loss was incurred during the barley feeding period when barley was figured at $24. per ton and alfalfa at $8. In the second experiment nine cows were fed in each group, the results in general being the same. Greater gains in weight were made during the barley feeding period.

While on alfalfa and barley the cows ate on the average 63 pounds green alfalfa, 13.6 pounds alfalfa hay and 5.8 pounds barley and when on alfalfa alone, 75 pounds green alfalfa and 14 pounds alfalfa hay. On barley the daily milk production averaged 19.3 pounds while on alfalfa alone, 17 pounds. However the increase in value of products was not sufficient to pay for the grain fed, basing returns upon whole milk at sixteen cents per gallon or butterfat at 33-1/3 cents per pound plus the beef rate on the increase in body.

Heavy and Light Grain Feeding.

Clark[3] reports an experiment in which light versus heavy grain feeding was compared in combination with alfalfa hay; also another in which light feeding is compared with a medium grain ration, with alfalfa hay for roughage in both cases. A daily consumption of 25 pounds of alfalfa hay and 4 pounds of grain (1/3 shorts and 2/3 bran) produced 17.7 pounds milk and a gain in live weight of 1/2 pound. The feed cost of 100 pounds of milk was 53 cents and 1 pound of butterfat 13 cents.

With the heavy grain ration a daily consumption of 12 pounds alfalfa and 15 pounds of grain produced 18.3 pounds milk and a gain in live weight per head of 1.1 pounds. The food cost of 100 pounds milk was 83 cents and 1 pound of butterfat 18.7 cents.

A so-called medium ration of 23 pounds of alfalfa and 8 pounds of grain produced 22.6 pounds of milk and a daily gain in live weight of .2 pounds. The feed cost of 100 pounds milk was 53 cents and 1 pound of butterfat 12.9 cents. A daily consumption of 26 pounds of alfalfa and 4 pounds of grain produced 22.5 pounds but with a decrease in live weight of .4 pounds. The feed cost of 100 pounds milk was 43 cents and 1 pound fat 11.3 cents.

This latter experiment was repeated with almost identical results.

Table II

Feed Required to Produce 100 pounds milk - also Cost per Hundred weight.
Utah Bulletin #101

Character of Ration	Alfalfa Pounds	Grain Pounds	Feed Cost of 1 Cwt of Milk
Heavy grain	68	83	83¢
Light grain	143	22	53¢
Medium grain	102	35.3	53¢
Light grain	114	17.7	43¢

At the California station[60] an experiment was conducted to determine results of heavy against light grain feeding for milk production in combination with roughage consisting of alfalfa and corn silage. ~~They~~ The authors draw the general conclusion that only a slight improvement in production can be expected by feeding a large amount of grain to ordinary good dairy cows receiving a liberal basal ration of alfalfa hay and silage. The cows on these experiments received on the average 4.2 pounds of grain on light feeding and 7.5 pounds per head daily on heavy grain feeding. The first experiments, which included a larger number of cows failed to show any improvement in production as a result of more intensive grain feeding while in other experiments an increase of 6 per cent and 9 per cent was secured.

Table III

Summary of Results of California Experiment (Bul. 323)

	Light Grain feeding Pounds	Heavy Grain feeding Pounds	Increase in per cent
Total Amount milk produced	46,664	48,805	5
Total solids	5,842	6,201	5
Butterfat	1,839	1,915.2	4
Average weight of cows	1,158	1,157	-
Total grain fed	7,076	15,992	79

A remarkable record[35] has been made at the Huntley, Montana experiment farm by a cow named Helen Uilkje Calamity 145857 on roughage alone, this consisting of alfalfa and corn silage. She produced in 365 days 14,212.1 pounds of milk containing 470.03 pounds of fat, on 113.5 days (24 hours) irrigated alfalfa pasture, 8489.0 pounds alfalfa hay, and 8935 pounds corn silage. This production shows what is possible with alfalfa when fed to a cow of extreme dairy capacity. The following year this cow produced 25,499.4 pounds milk containing 823.11 pounds fat when supplementary grain feeding was adapted.

While we must recognize the excellence of alfalfa as a dairy feed, yet it has its limitations, and from the feeding trials conducted to determine the economy of feeding this forage with and without grain, itseems reasonable to conclude that supplementary grain feeding is advisable under most conditions, at least to a limited extent. It may not be economical to add grain for cows of mediocre production but for cows from average to good ability at the pail, grain can probably be fed economically at the rate of 1 pound to 5 pounds of milk produced. This is borne out by the Utah[3] and California[60] investigations dealing with heavy and light feeding of concentrates in connection with alfalfa as roughage.

HEAVY VERSUS LIGHT GRAIN FEEDING

Probably maximum production is never obtained by feeding roughages alone at least over very long periods of time but it has been a vital question for some time just how far a cow of a given capacity may be pushed by grain feeding economically. Does it pay to feed a cow up to the point of overfeeding in an attempt to get maximum production?

Hills[22] says that "the amount of grain fed bears a closer relation to profit than does the nature of the grain ration," and asks the question whether he who feeds 4 pounds is losing money by under-feeding or is the one feeding 12 pounds losing by over-feeding. Forty-eight cows were used in feeding trials lasting twenty-eight weeks. Four, eight and twelve pounds of three different grain rations were fed with hay and silage during different periods. The extra grain fed seldom yielded enough more butterfat to pay for the increased cost. Figuring the skimmilk and extra manurial value the increased production more than offset the extra expense for grain. It was noted that following the fourth month there seemed to be a greater tendency to affect live weight than milk flow. The 4 pound ration of grain viewed from a financial standpoint proved better than the 8 pound ration when early cut hay containing considerable clover and well matured, well-eared silage were fed in fairly liberal quantities.

In later trials by Hills[23] he gave 12 cows a daily grain ration of 2 pounds each. He concludes that the restriction of the grain ration was made at the expense of the animals well being and of the owner's pocketbook. During this feeding experiment, hay and a rather poor quality of silage were fed. In order to check the results of this latter test, another experiment was conducted in which a comparison of feeding 2 pounds, 4 pounds and 8 pounds was made. In this trial no adequate return was obtained for a usage of grain in excess of 2 pounds daily, either in butterfat alone or from the butterfat, skimmilk, and manure combined. No consideration was given to labor and overhead. The light fed cows during two winters showed shrinkage in live weight, being in very gaunt condition. It was the experimenters judgment that a stinted grain ration would not inthe long run prove profitable, since live weight and the persistency of milking were affected.

Tests conducted by Jones[27] with twenty cows covering a period of forty eight weeks showed that a heavy grain ration of 12 pounds or more may cause an increase in the yield of milk but not always with profit. He noticed that cows on grain increased in weight more rapidly at the end of the lactation period and further, recommended feeding grain in proportion to production. Hills considered the cow the unit of measure rather than the quantity of milk produced.

Woll and Carlyle[62] experimented to determine whether feeding large quantities of grain gave enough better returns than those obtained with moderate amounts as to be economical. The reversal method was employed over three week periods, a normal ration being compared withone 50 per cent heavier. A normal ration was defined as one producing a good flow without increasing weight. The cost of feed required for producing 1 pound of fat was increased 23.2 per cent during the heavy feeding period. They conclude that a medium amount of grain, of about 8 pounds per head daily, which in this case was at the rate of 1 pound to 3½ of milk, is sufficient for most economical production, except with cows of high or mediocre production.

Ostermayer[43] found that liberal feeding of concentrates was moreeconomecal during the earlier part of the lactation than the latter, emphasizing the fact of a more intense stimulus for production in early lactation.

Murray[37] says that the chief factor contributing to the high cost of milk is the excessive use of concentrates.

Hopkins[25] found that the more concentrates are used, the less milk will be produced per unit of feed, though there may be and probably will be an increase in the total production. This was found true in connection with cows of average production.

The relative merits of heavy and light grain feeding are emphasized by Clark of the Utah station and Woll at California as discussed in the paper concerned with feeding grain in connection with alfalfa. The light feeding proved more economical. Most of the trials on heavy versus light grain feeding have been carried out with cows of only average production but they all tend to prove that a cow is endowed with a certain capacity for production and beyond a certain point returns a much smaller amount of milk in proportion to the addition of feed units. It is the expert feeders' business to know when her appetite for production has been satisfied and he can well afford to use the assistance of a set of scales.

4-21 6M

GENERAL DISCUSSION OF PROBLEM

Complications in Problem

The profitableness of grain feeding for milk production is complicated by numerous factors, economic as well as physiological. We are concerned with the capacity of the cow, the prices of feeds, particularly the relative prices of roughages and concentrates, and as well, with the relation of cost of labor and overhead to income from product. The quantity of concentrates to be fed will be governed by the kind and quality of roughage available, the kind and quality of the grain available, the size and capacity of the cow, and the relative prices of concentrates and roughages. Consideration must be given to such factors as quality and quantity of proteins, mineral matter, etc., all of these having been previously discussed. In the further handling of this problem the economic phases will be dealt with, recognizing that for maximum efficiency of the individual cow, all the afore mentioned factors are very closely tied up with the efficacy of grain feeding. For the purpose of analysis it will be assumed that a complete ration is being fed in so far as that is practically possible.

The economic side of the problem involves two sub-considerations; first that of maximum production thru forced feeding and secondly, the economy of production of varying capacities.

Significance of Problem.

The physiological necessity for the feeding of concentrates has been pointed out. The relative significance of grain feeding as a factor in the cost or production remains to be indicated. Table 4 contains the results of a number of cost of production studies showing the proportion of costs. Cost items are included under three heads[28] - total feed, labor, and indirect expense inclusive of all items excepting feed and labor. A cost of production study in Deleware County[55], N.Y. shows that the cost of feed represented 70.7 per cent of the total cost, labor 18.8 per cent and indirect expense 12.6 per cent. The cost of concentrates was 26.3 per cent of the total cost. In a Massachusetts[14] study, feed constituted 63.4 per cent, labor 22 per cent, and indirect expense 14.6 per cent. The cost of concentrates alone was 35.6 per cent. In other studies the cost of concentrates did not always represent such a high figure. However a truer index of the significance of the grain problem is the relation of grain cost to price received for product sold, since with a majority of dairy farmers the use of concentrates involves a cash transaction. The Rochester[40] survey shows that only 19 per cent of the total grain fed by farmers supplying that market was home grown. A Minnesota[46] report shows that in one district, farm grown grains constituted 62 per cent of the grain fed, in another place 91 per cent, and in a third 83 per cent. The average number of cows per farm was respectively 15, 10, and 15, in other words with smaller herds and newer country most grain can be home grown.

However the general practice is to purchase concentrates and raise the roughage. Returning to the table we notice that the cost of concentrates is 41.5 per cent of the price received for milk in Delaware County and in Massachusetts 52.7 per cent. These figures are particularly significant since they represent a condition of the average cow. With a production greater than 6,000 pounds a larger proportion of the nutrients will come from concentrates since production much beyond that point is not possible on roughages alone and as the figures demonstrate, even up to that scale of production, grain feeding is a considerable factor.

Roughages and Concentrates.

Van Norman and Goodling[57] compared the efficiency of two rations containing practically the same digestible nutrient and taken fromthe same feeds but so varied in proportions as to take a large amount of the nutrients from the grain in one case and from the roughage in the other. Two lots of twelve cows each were fed. Three years accumulation of data suggested that the proportion of nutrients in roughage to concentrates was a serious consideration in economical feeding. They concluded that "when 347 pounds of total digestible nutrients in roughage cost less than 100 pounds in a grain mixture so compounded to furnish needed protein etc. it is economy to feed a minimum grain allowance and a generous roughage supply. The advisability of using a large amount of roughage in the ration will depend largely upon the market prices of grain and roughages. For milk production one pound of total nutrients in grain was worth 3.47 pounds total nutrients in roughage. "The 'bulky' group was fed at the rate of 1 pound to 2½ - 3½ pounds of milk (fat 4.8), the 'concentrates' group 1 pound to 2 - 2½ pounds milk (fat 4.9). The average production of both groups of cows was a bit above 5000 pounds.

Müller[36] ran some tests comparing bulky with concentrated rations. He concludes that the ration of coarse fodder may be reduced or even eliminated for a short period without detriment to the health of the cow and without appreciably reducing the amount of milk although increasing its cost.

High Production a Grain Proposition.

The results of these two trials emphasize the fact that high production is largely a grain proposition and that whether a dairyman should try to keep 5000 pound cows or 8000 pound cows, 10,000 pound cows or 15,0000 pound cows will depend on whether the maintenance of such a herd is economically sound, i.e. is it cheaper to keep, for example one 20,000 pound cow or two 10,000 pound cows, one 16,000 pound cow or two 8,000 pound cows. In other words, is the most profitable herd determined by the profit per hundred pounds of milk, or by the greatest profit per cow. The solution involves the application of the law of diminishing returns which means that to or beyond some point in the ascending scale of production additional units of the factors of production give no profit.

Overhead considerations.

While there is no definite point at which three and four time milking should commence, probably for most cows producing over 10,000 pounds of milk it is necessary. The writer knows of one cow, which produced 11,430 pounds of milk containing 635 pounds of fat in ten months, that was milked but twice daily, and there are many other examples. Nevertheless it is probably sound dairy practice to milk a cow above 10,000 pounds or at least 12,000 pound capacity, three times daily. We are introducing an increased labor item. While it must be recognized that it takes longer to milk a cow giving 40 pounds daily than one giving 15 to 20 pounds the increase is not very significant until we begin milking three times daily. Again the higher producing cow will have a higher valuation so that the charges for insurance, interest, and depreciation will affect the factor of indirect expense. How far these two factors of cost are increased with increasingly higher production is difficult to ascertain. In attacking the situation, a review of some deductions from cost of production studies will be presented. A deplorable fact in connection with these studies is that the figures are not scientifically accurate, but largely estimates and generally are concerned with cows of average productive ability - 5000 to 6000 pounds. However, they will be illustrative of factors which influence the cost of production and its economic aspects.

Table 5[7] taken from a cost of production study by Rasmussen[47], shows that the average cost of milk production decreased from $1.86 per cwt. with cows with a production of 3,061 pounds to $.81 with cows averaging 10,875 pounds, a decrease of 56 per cent.

Hopper and Robertson[8] give a comparison of a herd of ten cows averaging 11,476 pounds with a group of cows averaging 6,621 pounds of milk. This group of ten cows produced milk at a cost of 14 per cent less and butterfat at 15 per cent less than that of the average of all herds. While the average production of this herd is 73.3 per cent above the average in this study the net cost of producing is increased only 49.3 per cent. The increased cost of production is off set by a profit 145.6 per cent greater than the average. Commenting on the production of this herd, which was accomplished in the same territory as the larger group the authors say: "labor and feed freely given have brought their reward bearing out what is obvious that under reasonable circumstances, good cows, rational feeding and intelligent management are the foundation of economic milk production."

Hopper and Robertson[26] have compiled a table (See Table 6) to show decreasing cost per cwt. of milk with higher production. From $1.37 for cows producing less than 5000 pounds the cost decreases to $.91 for cows producing an average of 12,377 pounds, or a 33 per cent decrease.

A table[40] from the Rochester survey (See Table 7) points out the same general condition though the general average of prices is considerably higher. The cost of producing one cwt. of milk is 45 per cent less in the case of cows averaging 9751 pounds of milk as compared with cows averaging 2841 pounds.

The relation of production per cow to labor shows interesting results, as brought out in another table from the Rochester survey[40] (See Table 8); that while the total hours per cow increase from170 to 266 as the production increases from under 4000 to over 9000 pounds, the hours per 100 pounds milk bears an inverse relationship decreasing from 6 hours to 2.7 hours as production increases. While the effect of number of cows on labor, building and equipment costs has no direct relation to the economy of high production, I wish to point out this factor (See Table 9) as one which will counteract the rising cost of labor and indirect expense per cow with high producers. The number of cows shows a definite relationship to decreasing and increasing cost of production as would develop out of Table 9 and as is illustrated in Table 10.

Cow Not a Standardized Machine.

As previously pointed out high production can be only attained through an increased feeding of grain and is therefore essentially a grain problem though being very closely correlated with the capacity of the cow. Probably very few would agree upon what might be defined as the normal capacity for any individual cow. As was shown in an earlier part of this thesis the ability of a cow is determined by the intensity of some internal factors, a stimulus that develops in the cow an appetite which is satisfied by a consumption of feed. The capacity for food consumption is directly proportional to the intensity of the stimulus. However, the only measure we have of that force at the present time, is the relation between feed consumed and milk produced, in other words, it might be a question a priori whether the stimulus is responsible for the consumption of feed or vice versa; since, instead of feeding according to capacity, we measure capacity in terms of efficient consumption of feed after the cow has been fed. If the cow was a standardized machine so that every heifer coming in milk had a rated capacity and we were able to obtain a definite measure of her ability it would be very easy to feed in the most economical way.

Table 11 shows the relation of production per cow to feeding. The total pounds of grain increases with increased production but per 100 pounds milk production shows considerable irregularity.

Pearson[45] in a study of 642 cows found that milk production is not a logarithmic function of grain costs but that the grain cost per cwt. of milk decreases until milk production reaches approximately 5000 pounds, is constant for productions ranging from 5000 to 8000 pounds of milk, and increases for milk yields above 8000 pounds. He comments that "after studying 19,000 cows it was found that approximately two per cent of the cows produced over 8000 pounds, which indicates that farmers evidently appreciate the fact that milk production for good cows above 8,000 does not yield increasing returns." It would seem that Pearson's conclusion is ill drawn since most cost of production studies show that an increasing production means greater economy. All he does bring out is that we have not enough of the 8000 pound cows. This study further shows that increasing production involves a larger proportion of concentrates.

TABLE 4

Proportion of Costs in Terms of Total Cost
Compiled from different surveys

Reference *	Total feed %	Concentrates %	Labor %	Indirect %	Price of: Milk per CWT	#% Cost concentrates to returns	Average production of cows lbs.
55	68.6	26.3	18.8	12.6	$1.65	41.5	4575
55	70.7	29.9	16.8	12.5	1.76	39.8	4600
47	49.4	26.8	21.8	28.8	1.80	33.9	6463
14	63.4	35.6	22.0	14.6	2.76	52.7	5005
15	54.0	20.6	28.0	18.0	1.69	20.4	5884
46	46.8	15.8	25.6	27.6			5540
46	47.7	18.5	25.4	26.9			4944
46	51.0	15.1	23.0	26.0			4849
54	48.9	18.7	26.1	25.0			5328
48	48.9		24.1	27.0	2.30		7211
48	46.4		25.2	28.4	2.05		6047
40	48.2	21.8	27.7	24.1	2.91	41.5	4334
40	50.8	20.9	24.9	24.3	3.39	26.1	6053
40	50.4	23.9	25.8	23.8	3.41	33.4	7133
4					2.38	35.0	7672

* See Bibliography

Percentage that cost of concentrates is of the price received for milk.

4-21 6M

TABLE 5

RELATION OF YIELD TO COST AND PROFIT. COMPARISON OF GROUPS OF DIFFERENT PRODUCTIVE CAPACITIES

From N.H. Ext. Cir. #2

Number of Cows	Pounds Milk produced	Average production Milk lbs.	Average production Fat lbs.	Average cost of feed	Average returns above cost of feed	Cost of concentrates	Average cost 1 Cwt of milk	Cost of roughage
8	10,000	10,875	380.37	$88.59	$106.82	$ 51.26	$.81	$37.33
14	9-10,000	9,396	343.43	88.25	79.18	50.02	.93	38.23
26	8- 9,000	8,434	301.30	83.46	63.86	45.17	.98	38.29
41	7- 8,000	7,381	277.16	81.18	52.11	42.72	1.10	38.47
40	6- 7,000	6,499	239.60	73.59	43.65	36.09	1.13	37.50
39	5- 6,000	5,540	209.37	65.91	34.56	32.14	1.19	33.76
25	4-5 ,000	4,605	176.00	56.61	27.20	27.02	1.23	29.58
10	less than 4,000	3,061	117.40	57.22	- 4.25	20.61	1.86	36.62

TABLE 6

Relation of Yield to Cost and Profit for 834 Cows.
Comparison of Groups of Different Productive Capacities
From Cornell Bul. 357

Group lbs.	Number of Cows	Average production	Net Cost of product	Value of Product	Profit per Cow	Net Cost per CWT of Milk	Profit per CWT of Milk
5,000 or less	159	4,161	$57.20	$63.24	$6.04	$1.37	$.15
5-7,000	360	5,993	74.40	91.09	16.69	1.24	.28
7-9,000	214	7,843	92.00	119.21	27.21	1.17	.35
9-11,000	84	9,763	109.00	148.39	39.39	1.12	.40
Over 11,000	17	12,377	112.60	188.13	75.53	.91	.61

TABLE 7

Effect of Production per Cow on Cost of Production
Rochester Survey.

Production per Cow		Number of farms	Number of cows per farm	Cost of Production	
Group	Average lbs.			per CWT	per quart
4000 or under	2841	9	17.8	$7.10	$.152
4001 - 5000	4674	16	18.4	4.88	.105
5001 - 6000	5446	27	17.9	4.36	.093
6001 - 7000	6472	39	16.3	4.02	.086
7001 - 8000	7487	23	14.6	4.01	.086
8001 - 9000	8326	15	17.3	3.71	.079
over 9000	9751	12	12.1	3.89	.083

TABLE 8

Relation of Production per Cow to Labor
Rochester Survey

Production per cow	Hours of Human Labor per cow	Hours of Human Labor per 100 lbs milk	Rate charged per hour	Rate Received per hour
4000 or under	170	6.0	$.363	$- .291
4001 - 5000	192	4.1	.361	- .035
5001 - 6000	196	3.6	.347	.085
6001 - 7000	213	3.3	.330	.137
7001 - 8000	233	3.1	.349	.152
8001 - 9000	221	2.6	.353	.253
over 9000	266	2.7	.387	.232

TABLE 9

Effect of Number of Cows on Labor, Building and
Equipment Costs - Rochester Survey

Number of cows	Human labor: Hours per cow	Human labor: Hours per CWT milk	Building cost per cow	Equipment cost per cow
under 10	276	4.16	$14.68	$5.10
10 - 14	246	3.60	10.15	6.19
15 - 19	217	3.33	9.70	4.60
20- 29	194	3.19	7.61	4.79
30 or over	155	2.72	4.09	3.23

4-21 6M

TABLE 10

Effect of Number of Cows on Cost of Production
Rochester Survey

Number of Cows: Group	Number of Cows: Average	Number of farms	Production per cow	Cost of Production: Per Cwt.	Cost of Production: Per Quart
Under 10	7.7	24	6,635	$5.22	$.112
10 - 14	11.9	44	6,846	4.41	.095
15-19	16.1	36	6,507	4.14	.089
20 - 29	22.6	27	6,080	4.20	.090
30 or over	41.6	10	5,682	3.47	.075

TABLE 11

Relation of Production per Cow to Feeding
Rochester Survey

Production per cow	Pounds of Grain: per cow	Pounds of Grain: Per Cwt milk	Succulent Feed: Per Cow	Succulent Feed: Per Cwt: milk	Dry Forage: Per Cow	Dry Forage: PerCwt. milk
4000 or under	1381	48.6	5194	182.8	4738	166.8
4001 - 5000	1661	35.5	7087	151.6	4752	101.7
5001 -6000	2023	37.1	11285	207.2	3199	58.7
6001 - 7000	2480	38.3	11263	174.0	3410	52.7
7001 - 8000	3250	43.6	10657	143.1	4074	54.7
8001 - 9000	4342	52.1	12880	154.7	3548	42.6
9001 - or over	4245	43.5	12578	129.0	3874	39.7

10-20 5M

EXPLANATION

Object

It is the object of this thesis to ascertain if possible the limits of profitable grain feeding for milk production i.e. under what conditions and to what extent is grain necessary for the most profitable production, and to point out factors which are necessary to a more thorough understanding of the problem.

Method

The study will be accomplished by a gross analysis of the experimental work done which relates directly or indirectly to the problem and, more minutely by an analysis of available figures which by their nature seem applicable to the analysis. There are two definite phases, that of heavy and light feeding as related to any particular productive capacity and secondly, that of the economy of increasing production as it reaches higher levels.

Source of Data

It seemed difficult at first to obtain figures that were accurate enough on the average to be dependable. A review of some cow test association figures indicated that they were largely estimates, particularly as to the amount of roughage consumed, and it was evident from the first that the amount and quality of roughage might have an important bearing upon grain feeding. A voluminous amount of work has been done in cost of milk production studies but as the results are mostly expressed in terms of dollars, they are not applicable to this problem except as relative conditions are brought out. Further they deal with very average cows in most cases.

Wisconsin research bulletin Number 26 was selected as a source of figures for the basis of this study since it was possible to secure feed records on groups of cows varying in capacity from under 5000 pounds to over 20000 pounds. Being on a competitive basis, all cows were fed liberally a fairly complete ration so that the milk records may be taken as a fair test of their ability.

Weights of cows are given in most cases and an allowance has been made for pasture consumed, both these points being essential to a better treatment of the problem. Production is expressed in terms of pounds of milk and fat produced. Feed consumed has been expressed in feed units (See Table 12) while a complete record of the kinds of roughages and concentrates fed is also included. Records of 135 Holsteins, 122 Guernseys, and 57 Jerseys will be used as well as others which may be found useful for the purpose. For costs of feed used see Table 13.

Table 12

Feed Unit Standards for Feeding stuffs for Dairy Cows
Wisconsin Research Bulletin 26

Character of Feed	Feed Required to equal one unit
Concentrates	lbs.
Corn, wheat, rye, barley, hominy feed, dried brewers grains, wheat middlings, oat shorts, peas, unicorn, molasses beet pulp	1.0
Cottonseed meal	.8
Oilmeal, ajax flakes, gluten feed, soy beans	.9
Hay and Straw	
Alfalfa hay, clover hay	2.0
Mixed hay, oat hay, oat and pea hay barley and pea hay, red top hay	2.5
Timothy, prairie hay, sorghum hay	3.0
Corn stover, stalks or fodder, marsh hay	4.0
Soiling Crops, Silage and Other Succulent Feeds	
Green alfalfa	7.0
Green corn, sorghum, clover, peas and oats	8.0
Alfalfa silage	5.0
Corn silage, pea vine silage	6.0
Sugar beets	7.0
Rutabagas	9.0
Field beets, green rape	10.0
Sugar beet leaves and tops, whey	12.0
Turnips, mangels, fresh beet pulp	12.5

Table 13

Values Assigned Feeding Stuffs

Roughage	Value per 100 lbs	Concentrates	Value per 100 lbs
Alfalfa hay	$ .90	Cornmeal	$ 1.00
Clover hay	.80	Cottonseed meal	1.80
Timothy hay	.70	Dried beet pulp	1.00
Green Alfalfa	.125	Hominy feed	1.20
Green corn	.125	Ground oats	1.10
Green peas and oats	.125	Oilmeal	1.80
Beet pulp (wet	.20	Wheat bran	1.05
Corn silage	.15	Wheat middlings	1.10
pasture (per season)	5.00		

10-20 5M

ECONOMY OF HIGH PRODUCTION

- In order to determine the economy of high production the three groups of cows taken from the Wisconsin[63] study have been arranged according to their production based on a difference of 1000 pounds beginning with the Holsteins at 10,000 pounds, the Guernseys at 5,000 pounds, and the Jerseys at 4,000 pounds. The average milk and fat production for each division is given in Tables 23, 24 and 25.

Is the dairyman more concerned with cost per cwt. of milk or the net returns per cow. The term net returns is used to designate the difference between feed cost and total value of milk produced. Probably for any given plane of production, economical production means the expenditure of the least amounts of the factors of production per unit of milk made. To show that net returns per cow is of more importance than cost per cwt. the following example is introduced.

Record of Huntley Cow.

Helen Uilkje Calamity 145857, a Holstein cow fed at the Huntley, Montana[35] Experiment farm produced 14,212.1 pounds of milk containing 470.03 pounds fat on roughage alone. Figuring the pasture charge at $20. (irrigated alfalfa, twenty-four hours daily), alfalfa hay at $18. per ton, and corn silage at $6. per ton, the feed cost amounted to 86.8 cents per cwt. of milk produced.

The following year this same cow produced 25,499.4 pounds of milk containing 823.11 pounds of fat, but with supplementary grain feeding. Figuring her pasture at $10. since she grazed only half days, alfalfa at $18. per ton, corn silage at $6. per ton, sugar beets at $10. per ton, and the grain mixture at $30. per ton, the feed cost per cwt. of milk was $1.028. There is a difference of 16 cents between the two methods of feeding in favor of roughage. However, with milk at $2.50 per cwt. the net returns when fed roughage alone were $231.70 as compared with $375.21 from supplementary grain feeding or a difference of $143.51

TABLE 14

Feed and Production Record of
Helen Uilkje Calamity 145857 - 365 days

	Item	Cost	Income
	Pasture 113.5 days	$ 20.00	
	Alfalfa hay, 8489 pounds	76.50	
*I.	Corn silage, 8935 pounds	26.80	
	Labor	40.50	
	Indirect expense	24.88	
		188.68	
	Milk 14,212.1 pounds (470.03 pounds fat)		355.00
	Net profit		166.32
	Pasture 130 days (½ days)	10.00	
	Alfalfa 10,093 pounds	90.00	
	Silage 8,525 pounds	25.58	
II.	Sugar beets 4,230 pounds	21.00	
	Concentrates 7,715 pounds	115.73	
	Labor	48.15	
	Indirect expense	24.88	
		335.34	
	Milk 25,499.4 pounds @ $2.50 (fat 823.11)		637.50
	Net profit		302.16

*I On roughage alone
II. Supplementary grain feeding

in favor of the latter. A summary of production, feed consumed, and feed costs with labor and indirect expense is found in Table 14. This particular case demonstrates that net returns are much more significant than cost per cwt. of milk produced. It should be noted that this cow enjoyed unusually favorable conditions.

Increasing production and net returns.

Tables 17, 18 and 19, and Charts 3, 4, and 5 (I) show very conclusively that increasing production is closely correlated with increasing net returns. In the Holstein group (Table 17), the net returns for cows producing between 10 and 11,000 pounds of milk were $47.49, while those of 21,000 pound capacity yielded net returns of $119.50. In the Guernsey group (Table 18), net returns increased from $25.18 to $100.19 as production increased from between 5,000 and 6,000 pounds to over 13,000 pounds. The Jersey group (Table 19) showed the same condition, net returns increasing from $32.23 to $79.80 as production increased from between 4,000 and 5,000 pounds to over 9,000 pounds. Up to this point it has been shown that high production can only be accomplished through feeding of concentrates and secondly that high production means increased net returns.

Application of Labor Costs and Indirect Expense.

It was previously stated that the factors of production may be included under three heads, feed, labor, and indirect expense. In submitting net returns analysis thus far labor and indirect expense have not been considered. It remains to be shown to what extent labor and indirect expense cut down the net returns, in other words, from the management standpoint does it pay to feed for high production.

The labor item includes time in milking, feeding, and general care and management prorata. Indirect expense takes up depreciation, insurance, taxes and interest charges on the cow. As we are concerned primarily with a relative condition, housing, sire charge, and so-called miscellaneous expenses are excluded. In any event credits from calf and manure would balance these items. It is very evident that it will require more labor to care for a 20,000 pound cow than one producing 5,000 pounds; also that there will be considerable difference in valuation. It is the purpose of this present analysis to show how increasing production affects labor and indirect expense, and to what extent these costs reduce net returns.

Labor

Cost of production studies show a considerable variation in the total hours of labor per cow depending upon section of country, production of cows, market for milk, etc. In order to get a basic labor charge, an average was taken from figures of several stations which gave 192 hours for cows producing between 5,000 and 6,000 pounds of milk. An allowance of 8 hours labor is made for each additional 1,000 pounds production of milk which is sufficient for the time required to milk out 1,000 pounds. It was recognized that the high producing cows would require three time milking for a length of time, three minutes being given for each extra milking. It was considered that cows milking from 12 to 16,000 pounds inclusive would require three time milking for four months, those milking from 17,000 to 21,000 pounds inclusive a three time milking for six months. Table 15 shows the relation of production per cow to labor on the basis of hours of labor per cow and per cwt. of milk produced. The number of hours per cow increases from 176 for cows producing under 4,000 pounds to 321 for cows producing over 21,000 pounds, in other words, it takes only twice as much labor to get 21,000 pounds of milk from one cow as it does 4,000 pounds from another.

Valuation of Cow

In order to figure the indirect expense for cows of varying production it was necessary to place a valuation upon the cow. Milk production from the standpoint of grade animals was used as a forappraisal, correlating with the period that the milk and feed prices were effective. Table 16 from Cornell Bulletin

TABLE 15

Relation of Production to Labor

Production lbs	Hours of Labor per cow	Hours of Labor Per cwt. of milk
4000 or under	176	4.4
4 - 5,000	184	4.1
5 - 6,000	192	3.5
6 - 7,000	200	3.07
7 - 8,000	208	2.77
8 - 9,000	216	2.54
9 -10,000	224	2.35
10 -11,000	232	2.20
11 -12,000	246	2.14
12 -13,000	254	2.03
13 -14,000	262	1.94
14 -15,000	270	1.86
15 -16,000	278	1.79
16 -17,000	289	1.75
17 -18,000	297	1.69
18 -19,000	305	1.64
19 -20,000	313	1.60
20 -21,000	321	1.56

TABLE 16

Relation of Milk Production to Value per Cow
From Cornell Bul. 364

Production per cow - lbs.	Number of herds	Number of cows	Value per Cow
3500 or less	16	541	$ 35
3501 - 4500	61	1925	39
4501 - 5500	67	2069	42
5501 - 6500	23	585	43
6501 or over	7	188	52

10-20 5M

Number 364 by Thompson[55] shows the relation of milk production to value per cow in Delaware County, N.Y. 1912.

As this study is primarily to demonstrate a relative condition it would be inadvisable to use either minimum or maximum figures. A valuation of $50 was placed on the Jerseys and Guernseys producing between 5,000 and 6,000 pounds while $125. is the top price for the highest producing Guernseys and $150 for the highest producing Holsteins. It would seem that $150 was a rather low price for high producers. Probably cows with records above 15,000 pounds could never be bought for that, but it is rather a question of whether dairymen should try to breed cows of high average production. It is generally conceded that the best system of dairy management calls for raising of cows on the farm, and then the actual cost involved under the head of indirect expense will be based on the cost of raising the heifers rather than market price, which at all events will probably never exceed $150. Increases in valuation for higher planes of production were set arbitrarily.

Indirect expense.

In arriving at the indirect expense the following formula[28] for depreciation is used:

$$\frac{\text{Valuation minus block value}}{5}$$

It might be said that five years service in the herd is too short a period since cows of great capacity will be given better care and will probably be good for six or seven years. However it was thought best to avoid minimum estimates. The block value in every case was estimated at $40. Insurance is figured at 3 per cent, taxes at 2 per cent of one-half valuation, and interest at 5 per cent of valuation.

Application of factors.

Adjustments of labor and indirect expense were made with the three groups, Holstein, Guernsey, and Jersey in accorance with the pervious methods.

Table 17 and Chart 3 (II) (Holstein group) shows that the cost of labor increased from $34.80 with those producing from 10,000 - 11,000 pounds to $48.15 with those producing over 21,000 pounds, or 38 per cent. In the Guernsey group (Table 18, and Chart 4 (II)), the cost of labor increased from $28.80 to $38.10 or 32 per cent while with the Jerseys (Table 19, and Chart 5 (II) it went from $27.60 to $33.60 or 21.7 per cent increase. Indirect expense showed an increase of 168 per cent with the Holsteins, 383 per cent with the Guernseys, and 123 per cent with the Jersey group, from the low to high producers in each case. (Charts 3, 4, 5 (III)

Applying the factors of labor and indirect expense to the Huntley cow[35] we find the cost per cwt. to be $1.32 on roughage alone and $1.31 when fed with concentrates. The net profit was $166.32 in the former case and $302.16 in the latter, the application of the items of labor and indirect expense not materially affecting the relationship previously given.

It should be noted that the purchase price of any grade animal may be a very deciding factor in the economy of high production. Substituting a valuation of $300 in the Holstein group for those producing over 21,000 pounds of milk, the increase in indirect expense is enough to reduce net profits to 45 cents. Where cows are purchased for the purpose of milk production alone, a very high price will very materially reduce the profits. One cannot afford to pay too high a price for a grade cow on the basis of past performance since, as breeders, grade animals are very indefinite quantities and further, her diminishing period of productivity will increase the indirect expense.

Net Profits.

Net profits in all three groups showed an increase, though not always regular, with levels of higher production. See Tables 17,18, 19 and Charts 3, 4, 5 (IV). It was demonstrated that with an assignment of increased valuation for cows of high production, the indirect expense increased at a much more rapid rate than labor and tended very soon to dispose of all profits. Using as a basic valuation the cost of raising any given animal, the indirect expense will remain practically constant. It might be argued that a selling price should be used; however, with the cow sold the dairyman is in a position to make less money with his lower producing cows. While the figures presented may not present actual facts in themselves, the relative situation clearly shows that high levels of production make for the greatest net profits. On the basis of the figures used the Holsteins producing 11,000 - 12,000 pounds of milk showed a loss of $10.16 while those at 21,000 showed a net profit of $39.90. The Guernseys producing 5,000-6,000 pounds gave a loss of $8.77 but a net profit of $37.21 is returned by those producing between 13,000 and 14,000 pounds. The Jerseys producing between 4,000 and 5,000 pounds showed a loss of $.52 while a net profit of $34.47 was made by those producing 9,000 to 10,000 pounds.

Returns from product have been based on a price of 28 cents per pound for butterfat with skimmilk at 20 cents per cwt. This fact accounts partly for the comparatively low returns from the Holsteins from the standpoint of total production since there is a larger maintenance[9] requirement for the Holstein group.

TABLE 17 (Holstein group)

Relation of Production to Net Returns, Labor, Indirect Expense, and Net Profit.

Production Pounds	Net Returns	Labor Hours	Labor Cost	Value of cow	Indirect Expense	Net Profit
10 - 11,000	$ 47.49	232	$34.80	$75.00	$11.73	$ .96
11 - 12,000	45.04	246	36.90	100.00	18.30	- 10.16
12 - 13,000	58.92	254	38.10	100.00	18.30	2.52
13 - 14,000	59.34	262	39.30	100.00	18.30	1.74
14 - 15,000	74.83	270	40.50	125.00	24.88	9.45
15 - 16,000	75.24	278	41.70	125.00	24.88	8.66
16 - 17,000	83.36	289	43.35	125.00	24.88	15.13
17 - 18,000	98.31	297	44.55	150.00	31.45	22.31
18 - 19,000	115.70	305	45.75	150.00	31.45	38.50
20, 000	119.50	321	48.15	150.00	31.45	39.90

10-20 5M

TABLE 18 (Guernsey group)

Relation of Production to Net Returns, Labor, Indirect expense, and net profit

Production Pounds	Net Returns	Labor Hours	Labor Cost	Value of Cow	Indirect Expense	Net Profit
5 - 6,000	$ 25.18	192	$28.80	$50.	$ 5.15	$- 8.77
6 - 7,000	45.59	200	30.00	60.	7.78	7.81
7 - 8,000	50.49	208	31.20	65.	9.21	10.08
8 - 9,000	67.24	216	32.40	65	9.21	25.63
9 -10,000	73.19	224	33.60	75	11.73	27.86
10 - 11,000	74.49	232	34.80	75	11.73	27.96
11 - 12,000	93.44	246	36.90	100	18.30	38.24
13 - 14,000	100.19	254	38.10	125	24.88	37.21

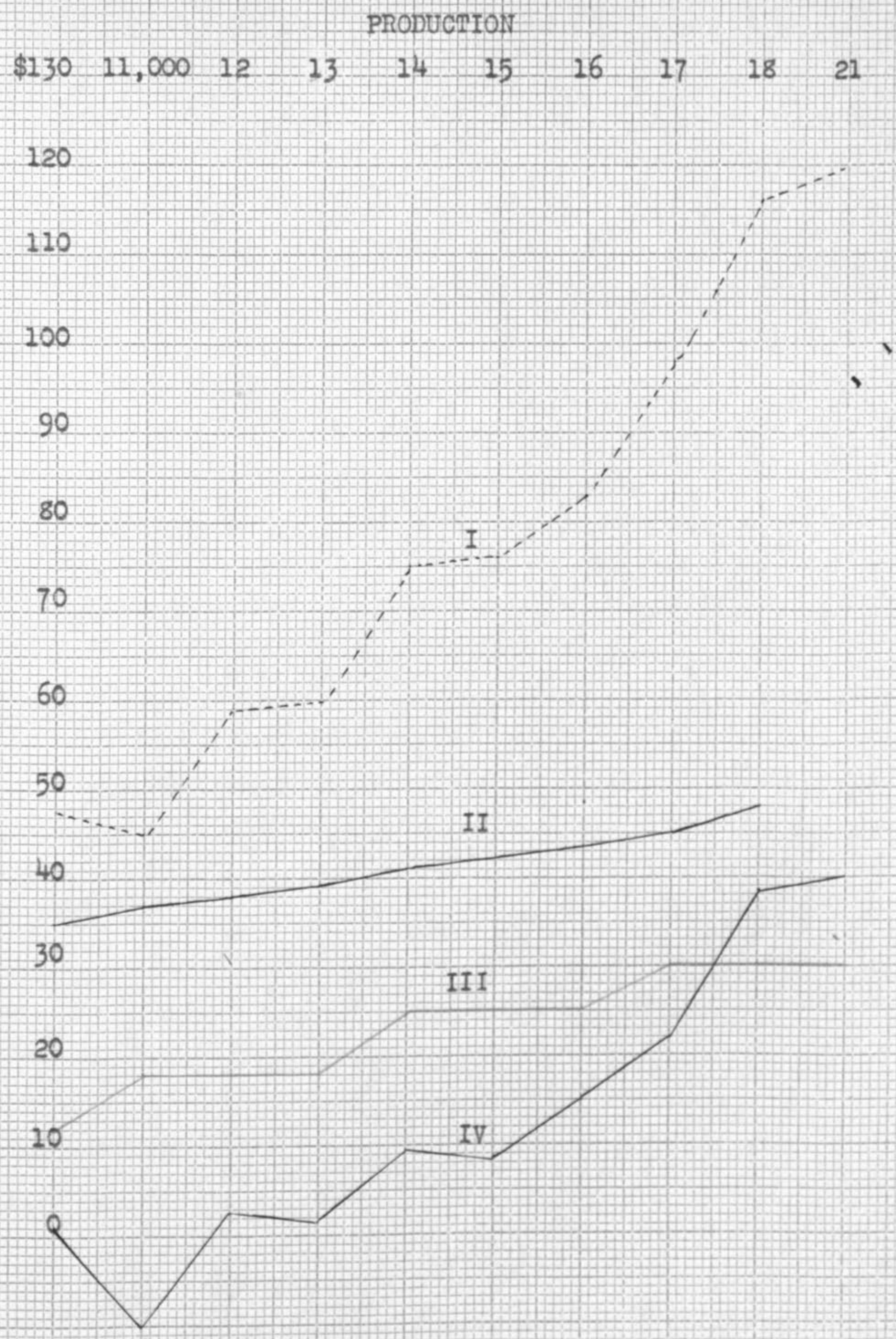
TABLE 19 (Jersey Group)

Relation of Production to Net Returns, Labor,
Indirect Expense, and Net Profit

Production lbs.	Net Returns	Labor		Value of dow	Indirect	Net
		Hours	Cost			
4 - 5,000	$ 32.23	184	$27.60	$50	$ 5.15	$ -.52
5 - 6,000	40.29	192	28.80	50	5.15	6.34
6 - 7,000	49.72	200	30.00	60	7.78	11.94
7 - 8,000	67.53	208	31.20	65	9.21	27.12
8 - 9,000	68.28	216	32.40	65	9.21	26.67
9 -10,000	79.80	224	33.60	75	11.73	34.47

4-21 6M

Chart 3 Holstein Group



I. Net returns and production

II. Labor cost and production

III. Indirect expense and production

IV. Net profit and Production

Chart 4 Guernsey Group

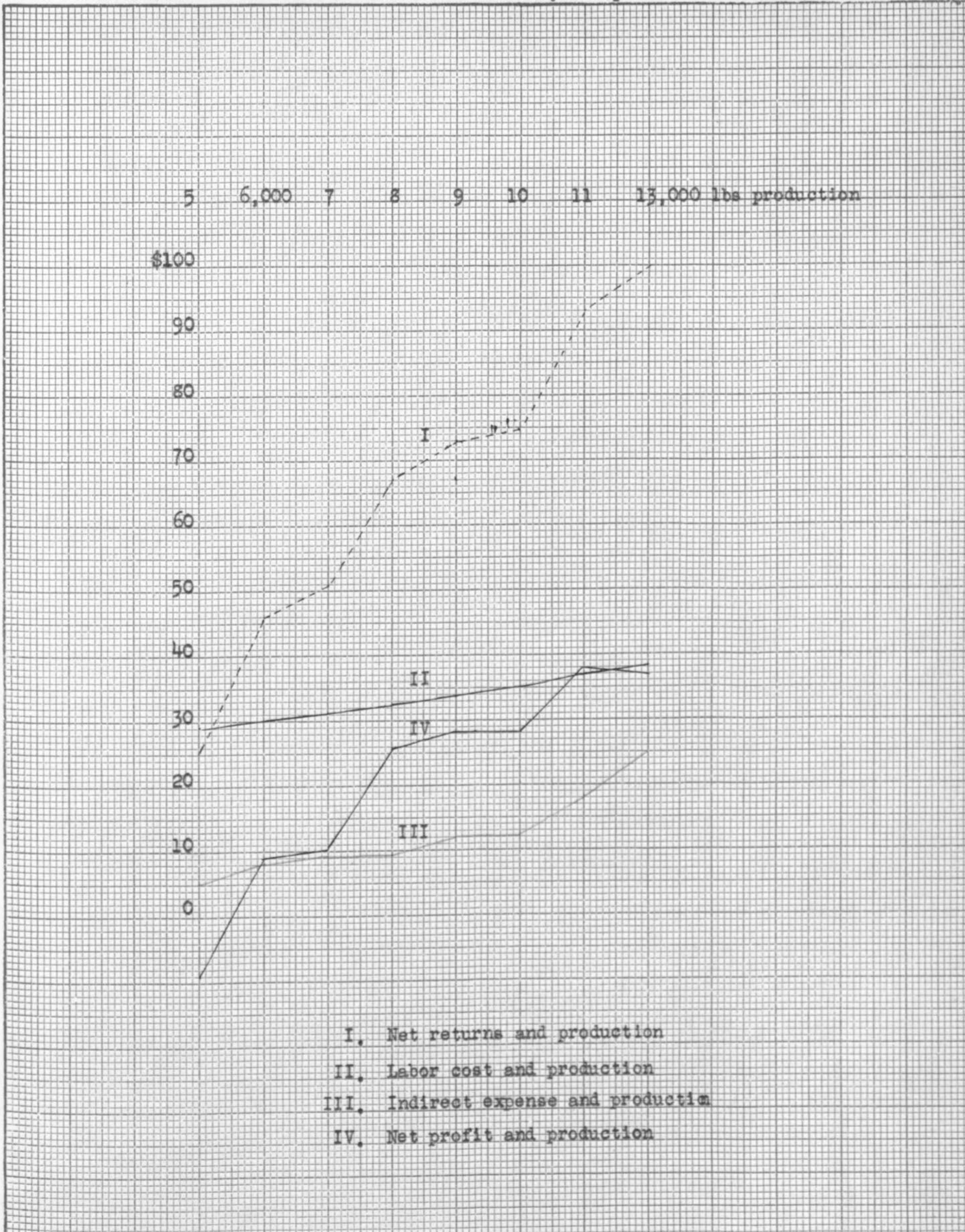
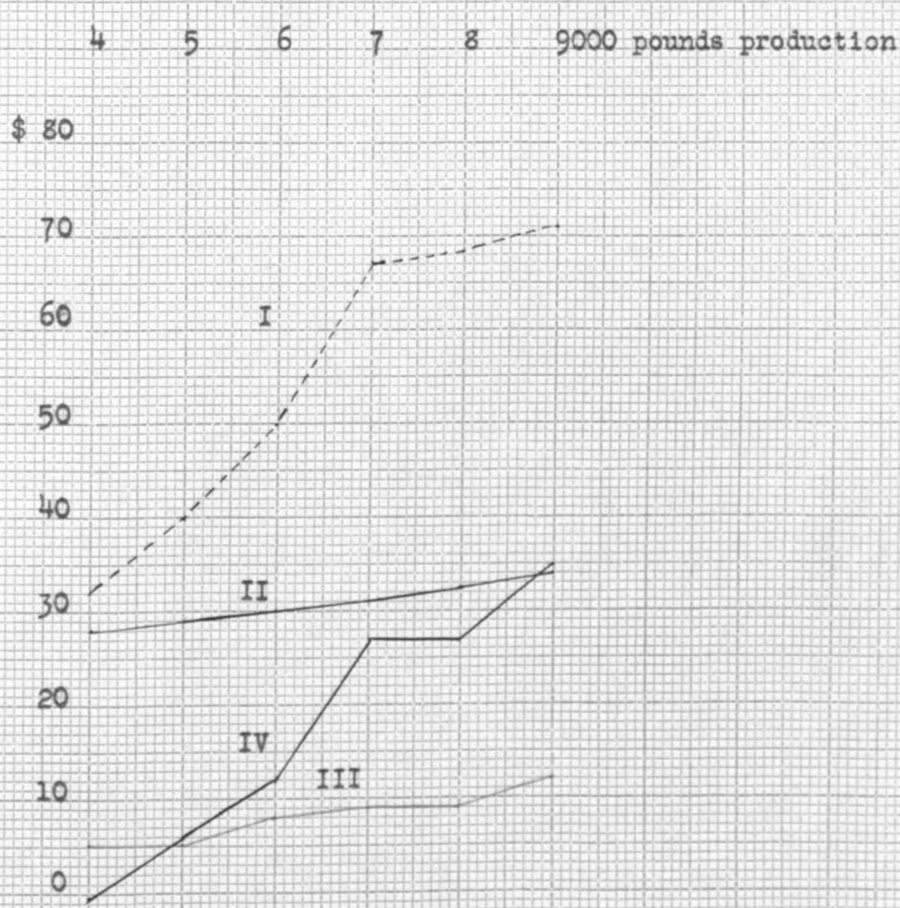


Chart 5 Jersey Group



I. Net returns and production

II. Labor Cost and production

III. Indirect expense and production.

IV. Net profit and production

Proportion of Concentrates to Roughage

It will be interesting to see what proportion of the feed is taken from concentrates and what fromroughages particularly by groups of cows with different productive capacities. In the Holstein group (Table 23, Chart 6) there is a range from 49.1 per cent to 59.3 per cent. There is a definite tendency for the proportion of concentrates to total feed units to increase as a higher level of production is reached although this is not regular.

The Guernsey group (Table 24, Chart 7) exhibits a more marked tendency, the percentage of concentrates to total feed units increasing from 41.6 per cent with cows to producing between 7,000 and 8,000 pounds to 52 percent for cows producing between 13,000 and 14,000 pounds. It should be observed that the low producing cows, 5,000to 6,000 pounds, utilized a proportion of 47.2 per cent. This may be accounted for by the fact that these animals of lower capacity were being forced.

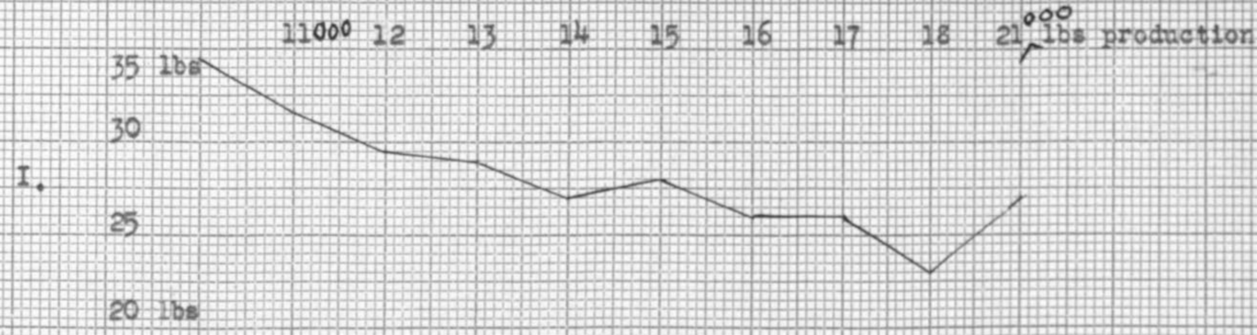
The Jersey group (Table 25, Chart 8) bears out the condition as found in the Holstein and Guernsey groups. Cows averaging between 4,000 and 5,000 pounds of milk received 34.6 per cent in the formof concentrates while those averaging between 9,000 and 10,000 pounds received 45.9 per cent. The 8,000 pound cows used a proportion of 51.9 per cent. This may be due to the fact that only a few cows appear in this division.

CONCENTRATES PER CWT MILK PRODUCED WITH VARYING PRODUCTION

The amount of concentrates per cwt. of milk is usuallyexpressed as one pound of grain to so many of milk. In the Holstein group (Table 23, Chart 6) we find that those producing between 10,000 and 11,000 pounds of milk used 34.7 pounds concentrates per cwt. of milk, while those producing between 18,000 and 19,000 pounds used 22.9 pounds. The nine cows averaging over 21,000 pounds used 27.3 pounds grain per cwt. of milk produced. There seems to be a general tendency, though not regular, for the amount of concentrates required, to de-

Chart 6 Holstein Group

RELATION OF POUNDS GRAIN FED PER Cwt. OF MILK PRODUCED TO INCREASING PRODUCTION



RELATION OF PER CENT GRAIN TO TOTAL FEED TO INCREASING PRODUCTION

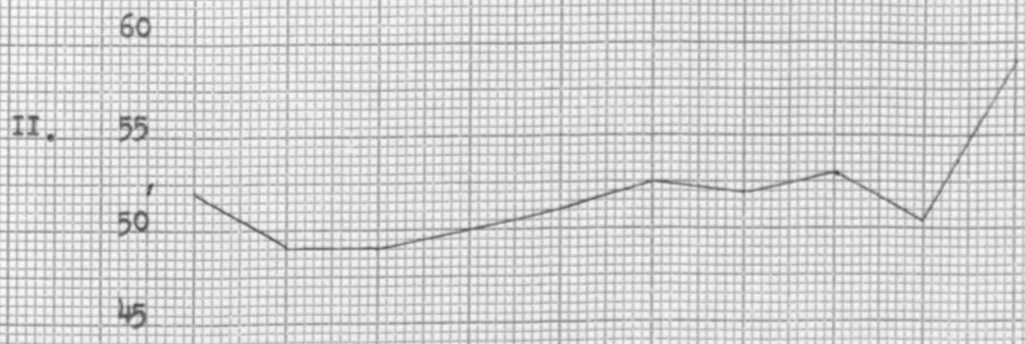


Chart 7 Guernsey Group

RELATION OF POUNDS GRAIN FED PER CWT OF
MILK PRODUCED TO INCREASING PRODUCTION

RELATION OF PER CENT GRAIN TO TOTAL FEED
TO INCREASING PRODUCTION

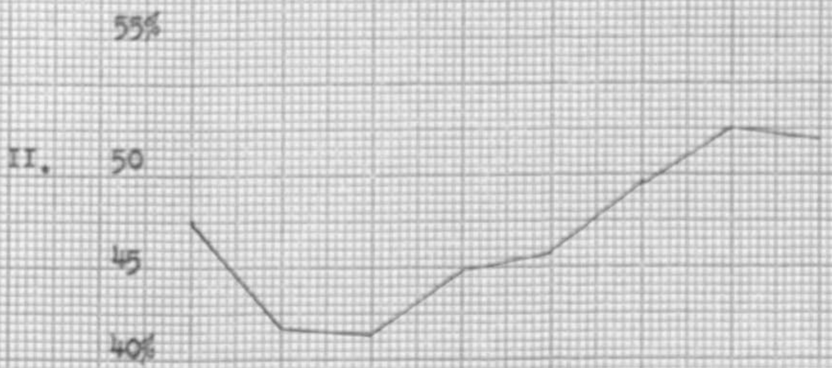
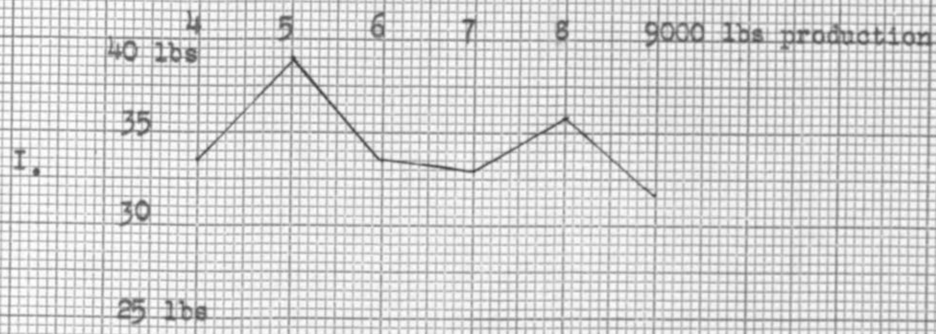


Chart 8 Jersey Group

RELATION OF POUNDS GRAIN FED PER CWT OF MILK PRODUCED TO INCREASING PRODUCTION



RELATION OF PER CENT GRAIN TO TOTAL FEED TO INCREASING PRODUCTION

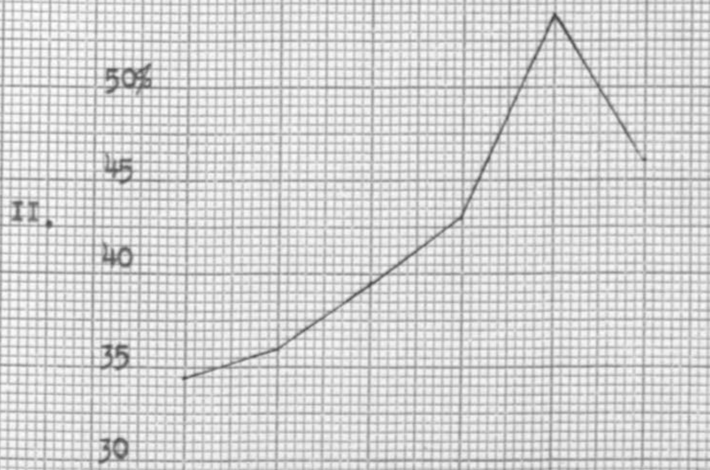


TABLE 20

Percentage Increase of Concentrates and Roughage
with High Production

Group	Production Pounds	Pounds concentrates	Per cent Increase	Pounds Roughage	Per Cent Increase	Average Weight
Holstein	10 - 11,000	3648	0.00	3,375	0.00	1170
Holstein	15 - 16,000	4334	18.8	3,899	15.4	1241
Holstein	21,000	5760	57.8	4,093	21.2	1400
Guernsey	5,- 6,000	2772	0.00	3,091	0.00	939
Guernsey	13 - 14,000	4079	47.1	3,751	21.3	1062
Jersey	5 - 6,000	1995		3,143		883
Jersey	9 - 10,000	2776	39.1	3,271	4.0	947

4-21 6M

crease with higher levels of production. Table 20 shows that the cows producing 15 - 16,000 pounds of milk required 18.8 per cent more concentrates and 15.4 per cent more roughage feed units and that those producing over 21,000 pounds required 57.8 per cent more concentrates and 21.2 per cent more roughage feed units than the lowest producing cows. It will be noticed that there is a difference in average weights which partly accounts for the increased consumption of roughage.

In the Guernsey group (Table 24, Chart 7) there is the same general tendency, though not regular. The cows producing between 5 and 6,000 pounds used 49.5 pounds concentrates and those producing over 13,000 pounds of milk used 30.1 pounds. The high producers required 47.1 per cent more grain and 21.3 per cent more roughage feed units than did the lowest producers. (Table 20)

The Jersey Group (Table 25, Chart 8) consisting of only 57 cows does not show the same regularity; however the lowest producers used 33.4 pounds concentrates and the highest producers 29.1 pounds per cwt. of milk produced. The highest producers utilized 39.1 per cent more grain and 4 per cent more roughage than the lowest producers.

It should be noted in connection with the low producers, that they were probably fed a higher proportion of grain in order to make maximum production. However, the figures show that high production is dependent upon a utilization of a larger proportion of concentrates by the cow.

In Table 21 the proportion of grain fed to milk produced has been reduced to a ratio between 1 pound of grain and the number of pounds milk returned such as would be employed by the feeder. An inspection of the table shows that the proportion of grain fed the higher testing groups, the Jerseys and Guernseys, was heavier than that of the Holstein. This would logically be expected and is in accordance with Eckles[7] findings. In the Jersey and Guernsey groups as summarized, we find a variation from 2.01 to 3.31. This is an average of 1 pound of grain to 2.95 pounds milk for the two groups of high testing cows num-

TABLE 21

PROPORTION OF GRAIN TO MILK PRODUCED

One Pound grain to Production Pounds	Pounds Milk		
	Holstein	Guernsey	Jersey
4 - 5,000			2.88
5 - 6,000		2.01	2.77
6 - 7,000		2.65	2.97
7 - 8,000		2.81	3.02
8 - 9,000		3.00	2.78
9 -10,000		3.29	3.42
10 -11,000	2.88	3.04	
11 -12,000	3.15	3.07	
12 -13,000	3.37		
13 -14,000	3.43	3.31	
14 -15,000	3.70		
15 -16,000	3.58		
16 -17,000	3.86		
17 -18,000	3.84		
18 -19,000	4.36		
21,000	3.66		

4-21 6M

TABLE 22

* Proportion of Grain and Grain Fed per Cwt. Milk with Varying Production

Production Pounds Milk	Production Pounds Fat	Grain per Cwt. Milk	Proportion of concentrates	1 Pound Grain to pounds milk
15,001.0	486	37.0	50.5	2.70
16,670.7	498	32.4	50.2	3.08
17,753.0	619	32.8	51.1	3.05
17,432.7	547	33.6	52.0	2.97
20,063.7	625	27.8	49.1	3.59
20,352.1	671	31.8	52.9	3.14
21,455.3	680	31.6	52.3	3.24

* 7 cows reported from Beltsville, Maryland Experiment Station.

4-21 6M

bering 179 animals. In the summary Holstein group there is a variation from 2.88 to 4.36 or an average of 1 pound of grain fed to 3.59 pounds milk produced, It must be recognized that these proportions include both winter and pasture seasons, also that most of the cows records reviewed are a good deal better than the average.

Beltsville Cows.

Table 22 gives the production of seven Holstein cows reported from the Beltsville[67] experiment station varying from 15,001 pounds to 21,455.3 pounds. The figures tend to corroborate those already presented, the grain per cwt. of milk produced decreasing with higher production and the proportion of concentrates in terms of feed units increasing. The average number pounds of milk returned for 1 pound of grain was 3.11 pounds. These cows were not pastured.

Grain per cwt. Milk and Net Returns.

In the paper concenned with the economy of high production it was pointed out that there was a rather definite tendency for the grain fed per cwt. of milk produced to decrease with higher levels of production; also that net returns increased with higher production. According to the axiom that things equal to the same thing or equal things are equal to each other, we would expect to find a decrease in the proportion of concentrates as net returns increased, which seems to be the case as brought out in Chart 9 (I).

Proportion of Grain and Net Returns.

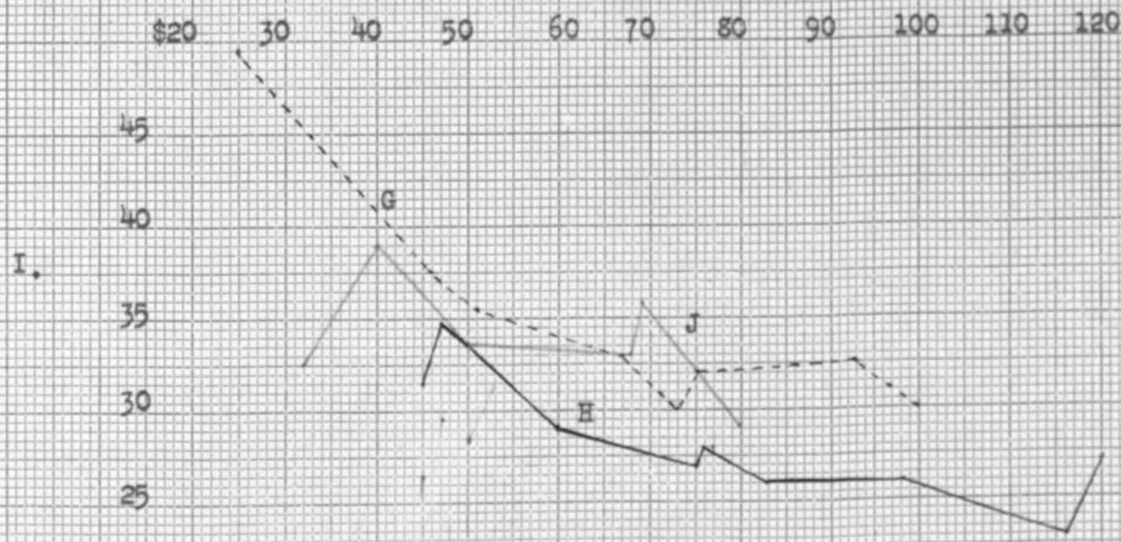
The relation of per cent grain to total feed to net returns shows a reverse condition in which the proportion increases with increased net returns as shown in Chart 9 (II).

Cow Test Association Figures.

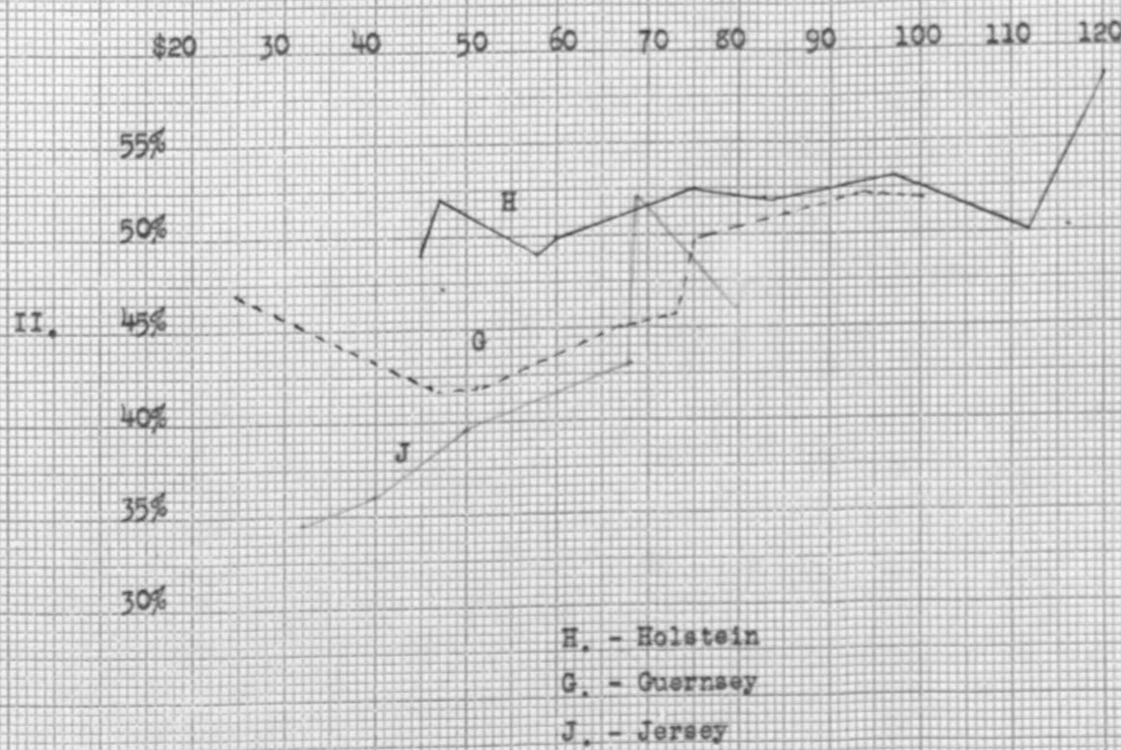
A review of some cost test association figures from Minnesota[66] and Wisconsin[68] shows very wide variations in the proportion of grain to milk, seemingly accounted for by differences in quality of roughage fed, length of pasture season, and natural capacity of the cow. Among high testing cows we find varia-

Chart 9

RELATION OF GRAIN FED PER CWT OF MILK TO NET RETURNS



RELATION OF PER CENT GRAIN TO TOTAL FEED TO NET RETURNS



tions from 2.04 to 6.4 and with the Holsteins from 2.07 to 6.80 which means that there is a good deal of difference of opinion as to the economy in grain feeding or else it may be accounted for by differences in natural capacity. It is probably a combination of the two.

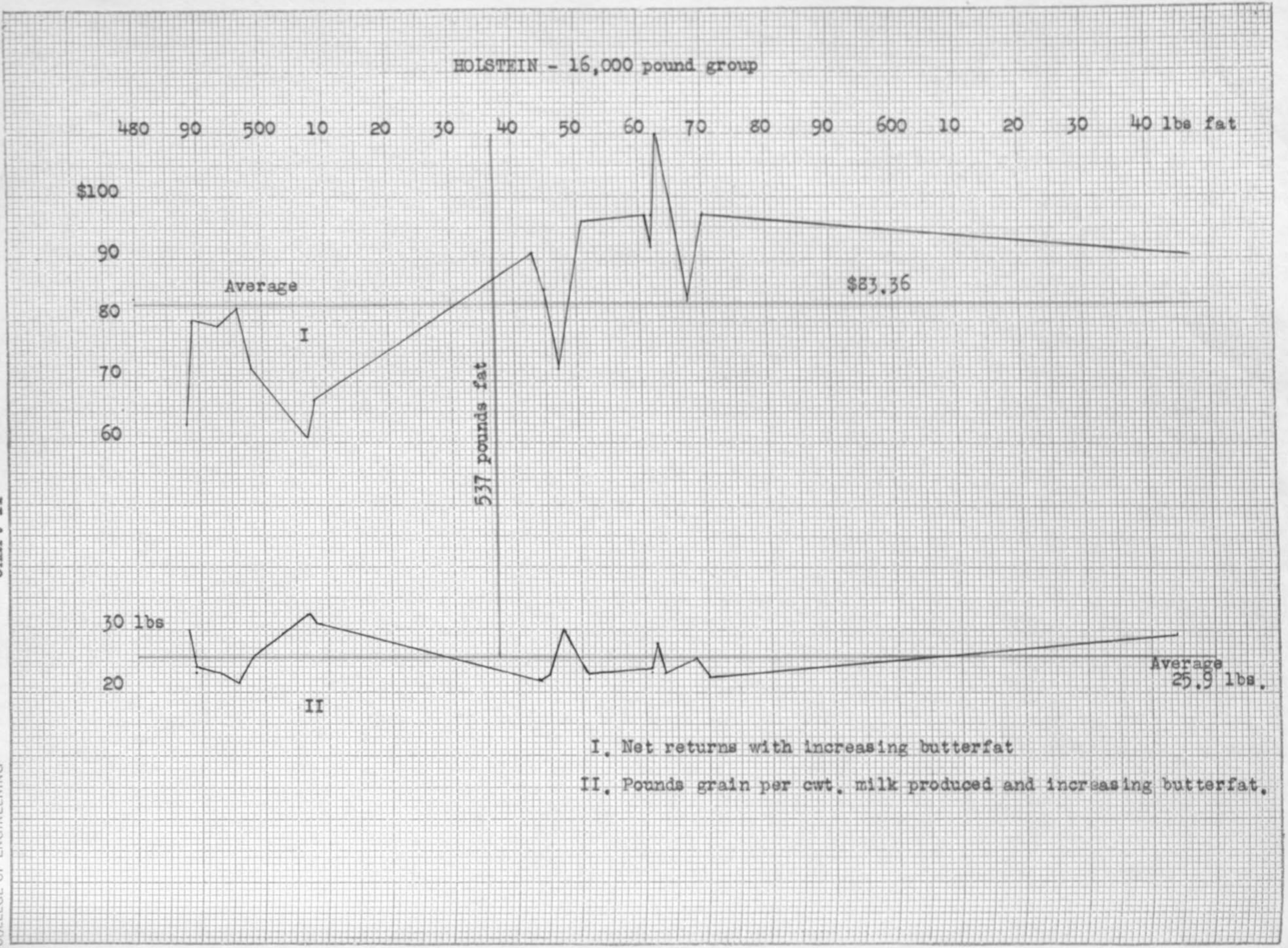
Heavy and Light Grain Feeding and Net Returns.

Under the head of economy of high production the three groups of cows were sub-divided according to production. However, within these smaller groups we find wide variations in the production of fat also in the proportion of grain fed. In order to discover any relationship that might exist between the amount of grain fed per cwt. of milk produced and the net returns from each cow, curves were plotted for each of the divisions within the three groups. This is really a study of light versus heavy grain feeding though the analysis can only be made to bring out tendencies since we have not all the necessary facts to deal with such as accurate weights, lactation, etc., besides making adjustments for the increased fat production, since net returns has been based upon butterfat at 28 cents per pound.

Charts 10 and 11 for the Holstein group, Chart 12 for the Guernsey, and Chart 13 for the Jersey group typify the results found in all divisions of the three groups. An extreme regularity is not always found but there is a definite correlation showing that grainfeeding greatly in excess of the average for any group, usually means decreased net returns. In the Holstein 16,000 pound class the figures have been reduced to a percentage basis. We find at 388, 507, 508 and 547 pounds of fat that we have the lowest net returns and the largest proportion of concentrates fed. On the other hand the highest net returns showed a use of concentrates below the average. Such an inspection of all these charts shows that grain feeding may have an important bearing upon net returns. Cost of maintenance and quality of roughage may effect apparent irregularities. A more detailed knowledge of production and feed records would be necessary to formulate any exact generalization.

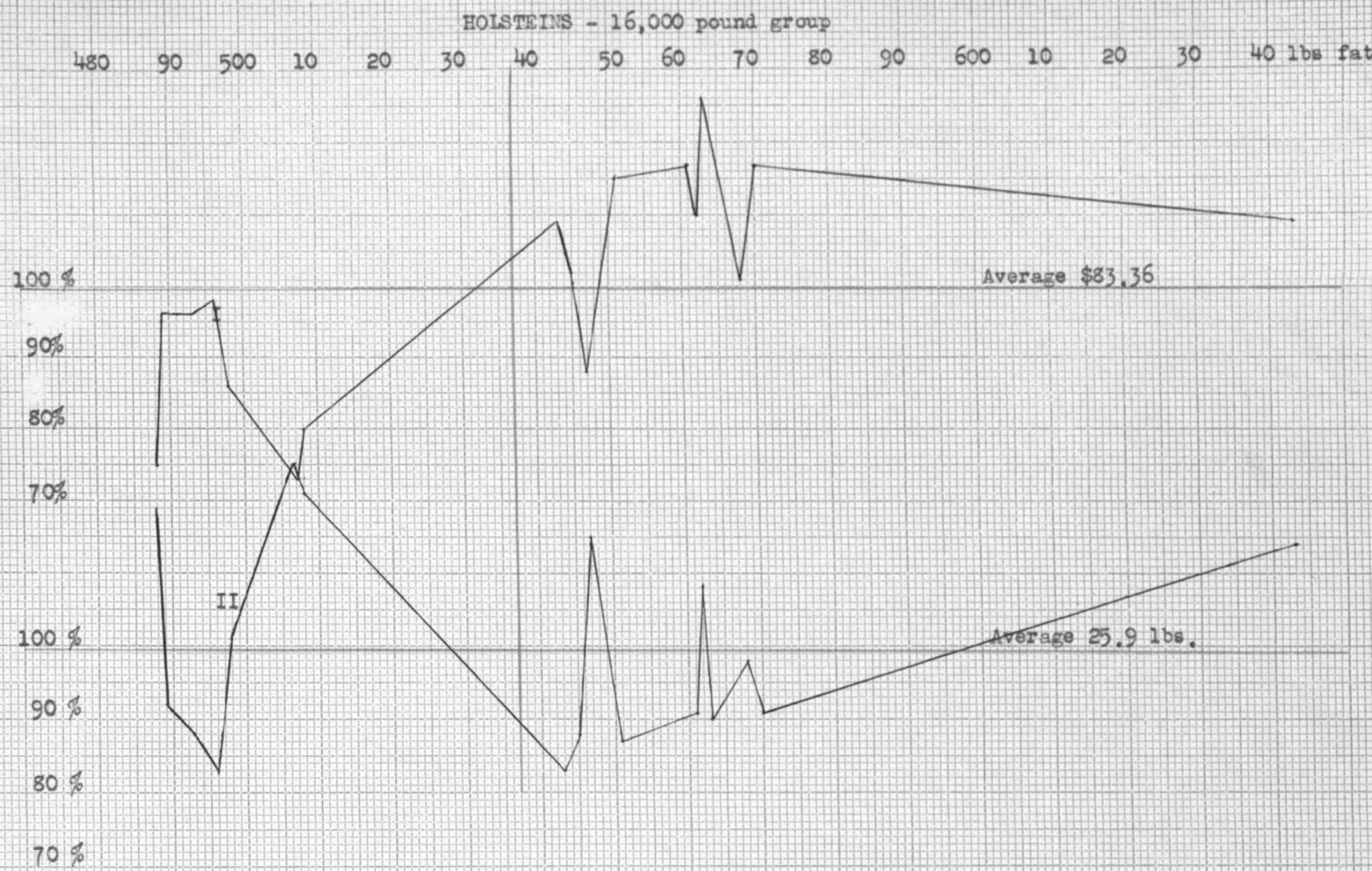
4-21 6M

Chart 11



HOLSTEIN - 16,000 pound group
480 90 500 10 20 30 40 50 60 70 80 90 600 10 20 30 40 lbs fat
$100
90
80
70
60
Average
$83.36
I
537 pounds fat
30 lbs
20
II
Average
25.9 lbs.
I. Net returns with increasing butterfat
II. Pounds grain per cwt. milk produced and increasing butterfat.

Chart 10



I. Net returns and butterfat - on percentage basis - average net returns $83.36, average fat 537.37 pounds.

II. Pounds grain per cwt. milk produced and increasing butterfat on percentage basis (See Chart 11)

Chart 12

4-21-4M
UNIVERSITY OF MINNESOTA

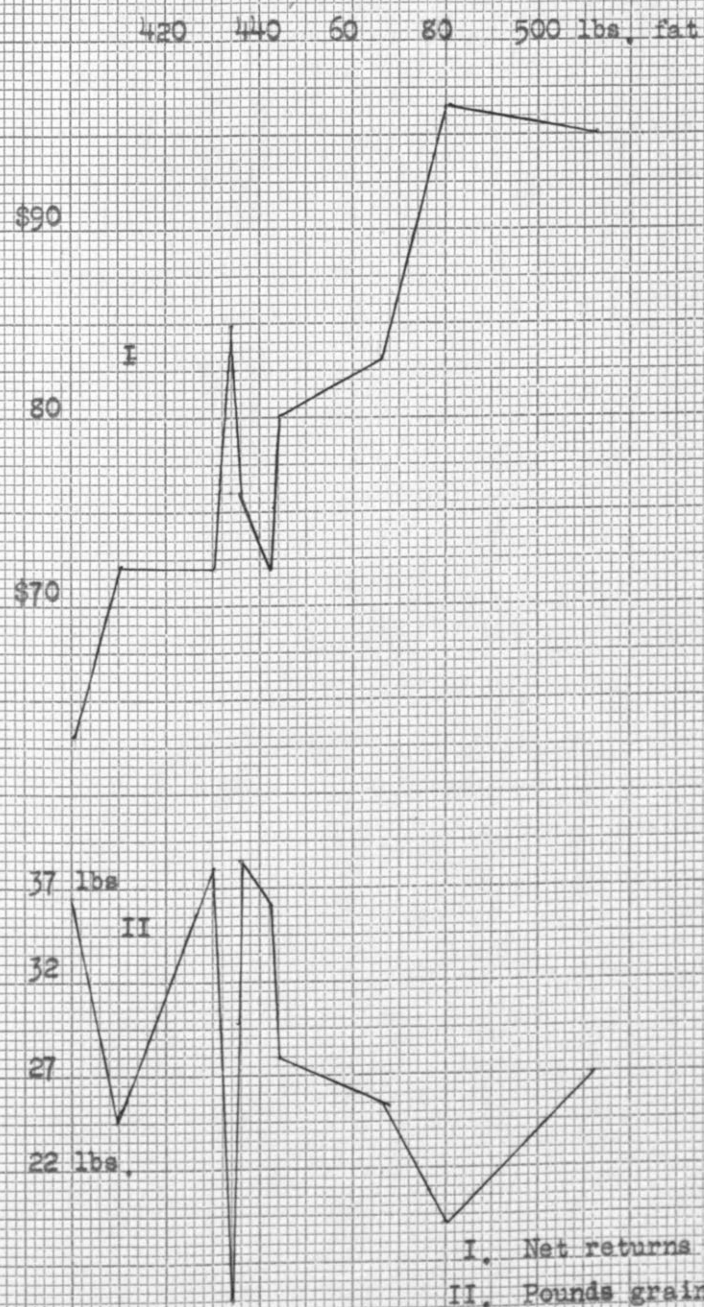
GUERNSEY - 8000 pound group

I. Net returns and increasing butterfat

II. Pounds grain per cwt. milk produced and increasing butterfat.

Chart 13

JERSEYS - 9000 pound group



I. Net returns and increasing butterfat.

II. Pounds grain per cwt. milk produced and increasing butterfat.

TABLE 23 (Holstein Group)

Proportion and Amount of Concentrates with Inereasing Production

Production Milk	Pounds Fat	Concentrates per 100 lbs MILK	Per Cent concentrates to total feed	Net Returns	Number of cows
10,487.65	390.33	34.7	51.9	$47.49	10
11,525.70	406.06	31.7	49.2	45.04	12
12,331.25	442.06	29.6	49.1	58.92	10
13,475.40	459.31	29.1	50.2	59.34	19
14,435.50	502.04	27.0	50.9	74.83	17
15,514.70	529.88	27.9	52.4	75.24	19
16,395.10	537.37	25.9	52.0	83.36	17
17,373.30	606.64	26.0	53.1	98.31	16
18,519.40	639.01	22.9	50.6	115.70	6
21,089.80	719.29	27.3	59.3	119.50	9

4-21 6M

TABLE 24 (Guernsey Group)

Proportion and Amount of Concentrates with Increasing Production

Production Pounds Milk	Fat	Concentrates per 100 lbs milk	Per Cent concentrates to total feed	Net Returns	Number of cows
5,599.53	286.13	49.5	47.2	$ 25.18	10.
6,580.70	353.27	37.6	41.8	45.59	20
7,480.50	386.61	35.5	41.6	50.49	20
8,595.03	443.86	33.2	45.0	67.24	20
9,459.00	450.34	30.3	45.7	73.19	20
10,515.28	492.22	32.3	49.7	74.49	16
11,491.70	559.63	32.5	52.4	93.44	7
13,527.80	604.38	30.1	52.0	100.19	9

10-20 5M

TABLE 25 (Jersey Group)

Proportion and Amount of Concentrates with Increasing Production.

Production Pounds		Concentrates per 100 lbs. Milk	Per cent Concentrates to total feed	Net Returns	Number of cows
Milk	Fat				
4588.40	253.16	33.4	34.6	$32.23	3
5526.80	290.99	38.8	36.0	40.29	7
6452.80	337.00	33.5	39.6	49.72	17
7554.20	396.80	33.1	42.9	67.53	15
8334.30	409.00	35.8	51.9	68.28	5
9531.90	445.40	29.1	45.9	79.80	10

MARKET SITUATION[65] - RELATIVE PRICES

It has been shown that the use of concentrates is essential for economical milk production, in some proportion, for cows of all capacities. Further it has been pointed out that this does not necessarily have to be accomplished by any standard mixture of grain and that the protein content may vary within reasonable limits without affecting production. This is especially important in connection with a study of market prices of feeds since certain feeds may be substituted for others at a considerable saving.

Cost of Nutrients.

Table 26 gives the cost of nutrients in two roughages, alfalfa and timothy and in four concentrates corn, oats, bran and cottonseed meal under four different prices conditions; first, the average for the year 1913 which is t aken as the 100 price, second when corn reaches a maximum price, third with cottonseed meal at its maximum price, and lastly with timothy at its maximum price. An inspection of the table shows that cottonseed meal is the cheapest source of protein under all four conditions while from the standpoint of total digestible nutrients it is the most expensive.

The other feeds, compared on a basis of total digestible nutrients, show variations but the difference between the roughages and concentrates is not extremely pronounced. On the basis of farm price for roughage we would find nutrients cheapest in farm grown roughage, so that with dairymen raising all their roughage it is advisable that the cows consume as large a proportion as they will take. This procedure is born out by Chart 14 (I & II) which shows that over long periods of time the relative prices of feeds as well as milk and milk products follow the same general price curve. The individual farmer should plan to raise all his roughage and to utilize the maximum amount of pasture, supplementing with grain according to the capacity of the cow.

4-21 6M

TABLE 26

Cost of Nutrients in Different Feedstuffs

	Feedstuffs	Relative Price	Price per cwt.	Cost 1 lb. protein	Cost 1 lb. Total Digestible Nutrients
	Timothy	100	$ .80	$ .27	$ .016
	Alfalfa	100	.71	.067	.013
I.*	Corn	100	1.04	.15	.012
	Oats	100	1.17	.12	.016
	Bran	100	.918	.073	.015
	Cottonseed	100	1.58	.047	.021
	Timothy	133.4	1.06	.35	.0218
	Alfalfa	168.8	1.19	.11	.023
II.	Corn	331.3	3.45	.50	.041
	Oats	156.4	1.83	.188	.026
	Bran	164.2	1.50	.12	.024
	Cottonseed	151.9	2.40	.071	.031
	Timothy	183.3	1.47	.49	.030
	Alfalfa	235.1	1.67	.157	.032
III.	Corn	239.6	2.48	.36	.029
	Oats	193.8	2.27	.23	.032
	Bran	206.9	1.90	.152	.031
	Cottonseed	249.9	3.95	.118	.052
	Timothy	229.3	1.84	.61	.038
	Alfalfa	252.7	1.79	.168	.034
IV.	Corn	283.5	2.95	.427	.035
	Oats	185.	2.17	.223	.03
	Bran	202.5	1.86	.148	.03
	Cottonseed	197.7	3.12	.093	.041

I* 1913 Normal prices.
II. Corn high, September, 1917
III. Cottonseed high November, 1919
IV. Timothy high, May, 1919

All Feed Purchased.

In case a man is buying all his feed or finds that his roughage supply will not carry over we have another situation. It would seem most economical in such an event that a minimum of roughage be purchased to satisfy the need for bulk and that grain constitute the larger proportion. This is emphasized by the figures presented in Table 26 and the general price curves in Charts 14 and 15.

Seasonal Price Variations.

Chart 15 emphasizes the seasonal variations in relative prices of timothy and cottonseed of butter, cheese, and whole milk, and of four concentrates cottonseed, bran, oats, and corn. The latter shows that there are many seasonal variations in the prices of grain which the farmer should take advantage of in his selection of feeds, in other words a business farmer will follow the market. There will occur many periods when the price of feeds will fall below the average price to such an extent that a purchase means production at a less cost i.e. the interest on the money tied up and storage charges will be less than the saving made, than if the feed was purchased as needed. Chart 15 (III) brings this out in the case of bran. In 1917 which was a year of rising prices the low price for bran was in the month of June which it did not return to the rest of the year. Oats also dropped at the same time. It is also interesting to notice that during the latter part of this same year grain prices advanced more rapidly, relatively than those of milk, although whole milk held its own better than butter and cheese.

Price the equation of supply and demand.

If price is the equation between demand and supply, it represents a figure at which the consumer is willing to take the goods of the producer and at which the producer is able to produce and still stay in the business. While there are many fluctuations in the relative prices as shown in the accompanying

4-21 6M

charts, over long periods of time there is a rather consistent regularity between the prices of feeds and that of milk products. Chart 14 (I & II)

While this relationship exists, in which price of product is sufficient to take care of the items in the cost af production and which at the same time maintains a supply of milk and milk products sufficient to meet the needs of the consumer, the present method of grain feeding among our successful dairy men is most economical.

Will liberal grain feeding always be economical?

However the general trend of agriculture seems to point toward an evolutionary process in which dairying takes the place of beef and grain farming as population increases. It was stated earlier that the efficiency of the dairy cow lies in her ability to transform roughages into consumable human food; further we know that more nutrients in the form of roughage can be obtained from an acre of ground than from cereal grains. It would seem logical to ask the question whether the American method of liberal grain feeding will always be economical. European methods call for feeding a minimum of concentrates largely by-products with roughage in the form of hay and roots; and we know that grain farming, as found in this country, does not exist in the thickly settled European countries. Again this same trend is noticeable in our eastern states. This tendency is pointed out at the present as a possible situation to be dealt with in the future though no doubt for many years to come liberal grain feeding will continue to be sound American dairy husbandry.

Chart 14

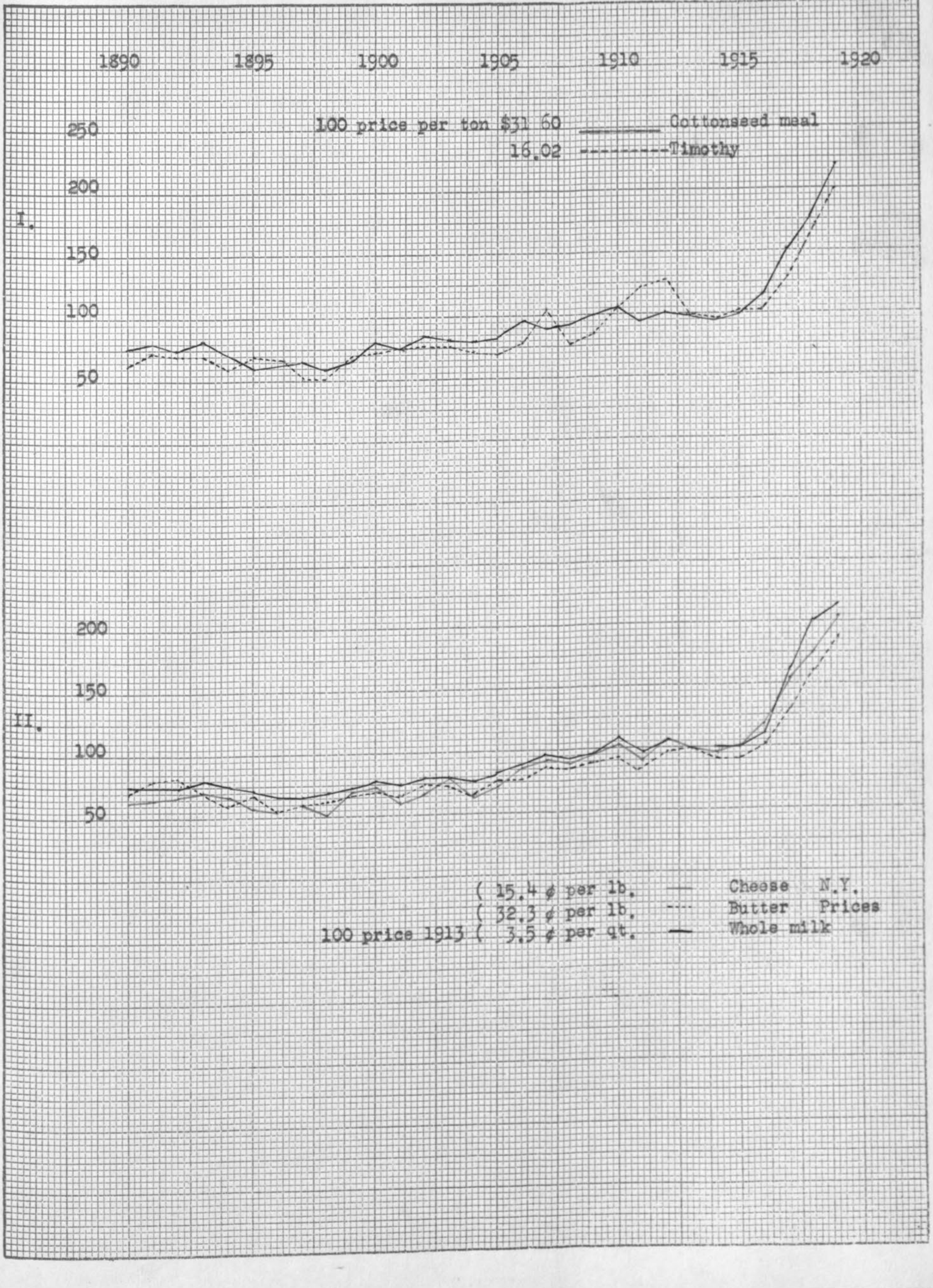
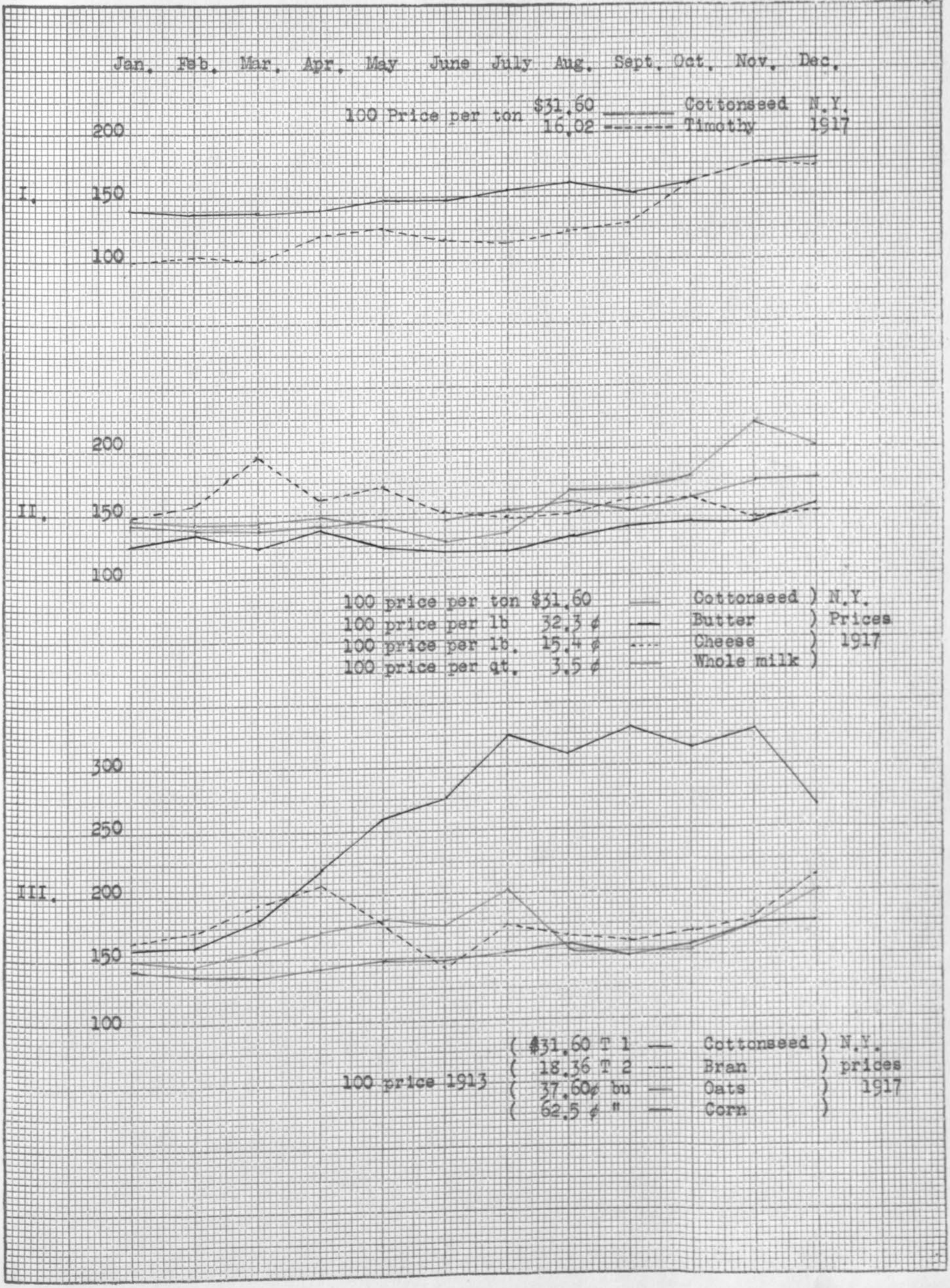

1890
1895
1900
1905
1910
1915
1920
250
200
150
100
50
I.
100 price per ton $31 60 ——— Cottonseed meal
16.02 --------- Timothy
II.
200
150
100
50
(15.4 ¢ per lb. — Cheese N.Y.
(32.3 ¢ per lb. ---- Butter Prices
100 price 1913 (3.5 ¢ per qt. — Whole milk

Chart 15


Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec.
100 Price per ton $31.60 Cottonseed N.Y.
16.02 Timothy 1917
I.
200
150
100
II.
200
150
100
100 price per ton $31.60 Cottonseed) N.Y.
100 price per lb 32.3 ¢ Butter) Prices
100 price per lb. 15.4 ¢ Cheese) 1917
100 price per qt. 3.5 ¢ Whole milk)
III.
300
250
200
150
100
100 price 1913
($31.60 T 1 Cottonseed) N.Y.
(18.36 T 2 Bran) prices
(37.60¢ bu Oats) 1917
(62.5 ¢ " Corn)

SUMMARY AND CONCLUSIONS

1. Grain feeding to some extent is essential to the most economical milk production of all levels of production except where good quality roughage is fed to cows of mediocre ability.

2. Limiting factors in the ration may hinder the fullest elaboration of the milk producing function. The complete ration should be physiologically perfect.

3. Supplementary feeding of concentrates is absolutely essential with poor pasture conditions even with cows of mediocre ability, is economical in its immediate returns and its residual effect is very pronounced.

Heavy milking cows cannot crop enough pasture grass to sustain a high production. A concentrate allowance should be fed in proportion to quantity and quality of milk.

4. To ordinary cows receiving a basal ration of alfalfa and silage or alfalfa pasture only a slight improvement in production can be expected from supplementary grain feeding. However a small quantity is desirable for its residual effect. Heavy producing cows will require a concentrate allowance in proportion to quantity and quality of milk produced. Alfalfa either as hay or pasture is a very efficient roughage and will materially reduce the grain bill.

5. Heavy grain feeding is relative - what may be overfeeding for a cow of one capacity may be underfeeding for a cow of greater capacity. The natural capacity of the cow will determine the limit for grain feeding with that particular cow.

6. The cow is endowed with a certain capacity for production and beyond a certain point returns a much smaller amount of milk in proportion to the

addition of feed units. Increase of body weight indicates that the limit of natural capacity is being approached. Weighing the milk will be found a much more satisfactory method of finding out the production for each unit of feed added.

7. In the three groups of cows studied the Jerseys and Guernseys returned an average of 2.95 pounds of milk per pound of grain fed, the Holsteins 3.59 pounds. Since the production records used represent probably the full productive capacity of the cows it would seem that a Jersey or Guernsey should return at least 2.95 pounds of milk for each pound of grain fed and a Holstein 3.59 pounds to be most profitable.

8. Higher producing cows require a larger proportion of concentrates. At the same time they show a more efficient use of the grain requiring less per cwt. of milk produced.

9. High production is dependent upon grain feeding and is the result of satisfying an appetite created by an internal stimulus to produce milk. With all three factors of feed, labor, and indirect expense applied, the higher the production, the larger is the profit returned. In this study, the highest average production was 21,000 pounds.

10. The absolute limit of profitable grain feeding for all levels of production has not been ascertained, most of the experimental work having dealt with cows of low production. These show, however, that the cows capacity for economical production is limited by the intensity of her milk producing function. Heavy grain feeding which brings about a considerable increase in body weight is probably a fair index of the limit of feeding capacity though it may not be the most economical point. To determine the absolute limit of profitable grain feeding will require an experiment in which all the factors may be kept as near as possible under control.

The conclusions drawn are largely generalizations though, within certain limits represent rather definite tendencies.

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