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 Thor Wilhelm Gullickson final oral examination for the degree of

Master of Science.

We recommend that the degree of

Master of Science.

be conferred upon the candidate.

D A Coker
Chairman

L L Palmer

H K Hayes

Date August 7 1922

10-20 5M

THE UNIVERSITY OF MINNESOTA

GRADUATE SCHOOL

Report

of

Committee on Thesis

The undersigned, acting as a Committee of the Graduate School, have read the accompanying thesis submitted by Thor Wilhelm Gullickson 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 Master of Science.

C. A. Coakley
Chairman

L. D. Palmer

H. K. Hayes

Date August 7 1922

10-20 5M

THE INFLUENCE OF SEASON AND WEATHER UPON THE BUTTERFAT PERCENTAGE IN MILK

By

Thor Wilhelm Gullickson, B.S.

Submitted in partial fulfillment of the
requirements for the degree of
Master of Science
in the
Graduate School
of the
University of Minnesota
1922

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

INTRODUCTION

Wide variations in the fat content of milk are often observed that cannot be attributed to any known cause. The dairy control laboratories of our large cities, whose duty it is to protect the milk supply of their respective communities, also find that on certain days and especially during the summer season the number of samples of milk that fail to comply with the fat requirements is much greater than at other times. It is evident that the milk from a large number of cows will not all vary in quality in the same way and at the same time without a definite cause. Neither is it probable that milk producers are any more dishonest in the summer than at other seasons. Rather, it appears that some factor not well understood is involved.

Observations made by the writer of the herd at Beltsville, Md. owned by the United States Department of Agriculture has led him to believe that the daily and seasonal variations observed are to a great extent caused by daily and seasonal variations in the weather. The records from this herd over a period of over one month indicated that high temperature had an especially depressing effect on the fat content of the milk.

Furthermore it is well-known that season of year exerts a strong influence on the behavior and life processes of animals. The tendency to hibernate, and the shedding of the hair at certain seasons are fair examples of this fact. The probability therefore that milk secretion might likewise be affected in a characteristic manner by seasonal and daily variations in the weather is evident.

The economic importance of definite information relating to the influence of season of year and daily weather conditions upon the per cent of fat in

milk has already been suggested. It is apparent that in market milk production such knowledge may prove of great value, inasmuch as the difficulty encountered by dairymen at times in supplying a product that complies with the legal standard might be largely obviated, in that city ordinances will take cognizance of this factor. The wide variations that often occur in cow testing associations and official testing might also be largely explained, since the character of the weather and the season of the year when the records are made might be considerable factors in determining the quality of the milk. Likewise, the question as to the most desirable time of year for cows to freshen, from the standpoint of maximum butterfat production, depends on a number of conditions, the seasonal factor may however be a very important one.

From a scientific standpoint, information relating to the question is of exceeding great interest, for it is evident that it would open new avenues for further study of the milk secreting process in all its various ramifications.

Several studies already made of this question have indicated that a positive relation exists between butterfat percentage and season and weather conditions. They have however, been limited to areas or regions in which the climatic conditions are different from those found in Minnesota. Neither have they shown the relation of meteorological phenomena to the variations in the butterfat percentage. For these reasons it seemed desirable to make a further investigation of the question for the purpose of studying the influence of seasonal and daily weather conditions and their various meteorological phenomena upon the butterfat percentage in the milk produced under Minnesota conditions.

GENERAL DISCUSSION AND REVIEW OF LITERATURE

Factors influencing the percentage of fat in milk

It is a well-known fact that wide variations often occur in the fat content of cow's milk. Among the causes of these variations are known to be the breed of the animal, the stage of lactation, the individuality, and to a less extent the feed, besides numerous other factors that are usually considered of more or less minor importance.

Breed and individuality. The influence of the breed and the individuality of the animal upon the fat content of milk has been shown by the investigations of Wing(1), Eckles and Shaw(2), White and Judkins,(3) and others. They found that the percentage of fat varies in a characteristic way with the breed of animal, and also that wide differences occur between individuals of the same breed. Anderson(4) concluded from a study of 200 seven-day records made under ordinary herd conditions where regular feeding and milking were practiced, and 2000 seven-day records of official Advanced Registry tests, that "one may expect that during seven consecutive days about 30 percent of a herd of cows will show a range in the percentage of fat in the milk at different milkings of one per cent or less; 50 per cent of 1.1 to 2.0 per cent; 14 per cent of 2.1 to 3.0 per cent; and the remaining 6 per cent of the herd even greater variation. In other words, 6 per cent of the cows might yield milk testing 3 per cent of fat at one milking during the week and at some other milking produce milk containing 6 per cent of fat or over".

Stage of Lactation. The change in the fat content of milk during the lactation period has been determined by a large number of investigations. The results in every case have invariably been the same. Wing and Anderson(5) found as the result of investigations with the station herd at Ithaca over a period of eight years that beginning with the third week after calving and dividing the

remainder of the lactation into periods of four weeks, and then considering the average per cent of fat for the first period as 100, there was a decrease to 96 the second period and then gradually increased to 106 during the eleventh period. According to Van Slyke[6] the percentage of fat decreases in the second month, as compared with the first and then begins to decrease from month to month during the entire period of lactation. The rate of increase being more rapid during the last two or three months than previously. Beach[7] observed a regular monthly increase of one-tenth of one per cent in the fat content of the milk during the entire lactation period. Woll[8] on the other hand found from a study of the records of 323 cows entered in the Wisconsin Dairy Cow Competition that the average percentage of fat did not vary over 0.06 per cent during the first six months of the lactation period. After this the fat content increased gradually up to the ninth month, and more rapidly thereafter. Later from a compilation of records from various sources[9] he found that immediately after freshening the cows gave richer milk than later. It then grew poorer for a month or two, and after that slowly increased in richness until they became dry. Similar results were obtained by Crowther,[10] and Crowther and Ruston[11] in Scotland.

From the results of these investigations it appears that in general the average per cent of fat in milk is higher during the first month of the lactation than for any other excepting the last one or two, and that the second, third and fourth are nearly alike after which there is a gradual increase reaching its maximum in the last one or two months of the lactation period.

Feed. Food as a factor in influencing the fat content of milk has been extensively investigated. Authorities are agreed that the food given a cow bears an intimate relation to the amount of milk she will produce. The quite general belief among practical dairymen that they can increase the fat content of the milk by feeding certain foods rich in protein and fat, however, has not been confirmed by scientific investigations.

Hills[12] found that there was little change in the composition of the milk on increasingly heavy grain feeding, and that no connection could be traced between the quality of the milk and the food given.

After concluding ten years of investigational work, Lindsey[13] states that "different amounts of protein in the daily ration derived from linseed, cottonseed, soybean, and gluten meals do not seem to have any pronounced effect in changing the relative proportions of the several milk ingredients."

Experiments in feeding fat to cows have been equally unsuccessful in causing greater fat secretion in the milk.

Jordan[14] experimented on five cows with three different kinds of rations during three periods, the rations being made up so as to contain varying amounts of vegetable fats, and found that the yield of milk is diminished somewhat in passing from the ration rich in fat to the one containing less fat and increased slightly after changing again to the fat rich ration. He says, "The composition of the milk varied but little and no more, or even less, during the three periods than is often observed when the ration is not changed." Wing[15] found "no increase in the per cent of fat in the milk as a result of feeding tallow in addition to a liberal grain ration." Wood[16] states that "the first effect of an increase in fat in a cow's ration is to increase the per cent of fat in the milk, but that with the continuance of such a ration the tendency is for the milk to return to its normal condition."

The influence of food upon the quantity and quality of the milk produced is more apparent when underfed cows are dealt with. Wing and Foord[17] cite an experience with an underfed herd which when given a good ration increased its production 50 per cent. The fat per cent was increased one-fourth of one per cent. Hawk and Hammond[18] on the other hand, found that under a condition of a reduced state of nutrition, the milk is very rich in fat. But they point out that if after such a period of low feeding an abundant supply of food is given

the yield is increased but the percentage of fat is below normal. Their conclusions are in accord with those of Eckles[19] that provided a cow is underfed after calving, the percentage of fat in the milk is influenced to a considerable extent by the fatness of the cow at calving.

It is well known that dry fodder does not further milk flow as well as a succulent food. It follows that a change from stable to pasture and to dry feeding again has a marked effect on the quantity of milk produced at such times. These changes, however, have not been found to exert any definite effect on the fat content of the milk produced.

Kjarsgaard[20] observed 19 herds in Denmark averaging 33 cows to the herd. The average fat content of the milk from all the herds while on winter feed was 3.33 per cent. Twenty days after going on pasture, the average fat content was 3.67 per cent; and after the cows had been on pasture 40 days, the average was 3.60 per cent.

Farrington[21] made observations on six cows changing from winter feed to pasture and stated that the pasture had little effect on the quality of the milk but increased the quantity. Friis,[22] however, observed a marked increase in fat content on passing from winter feed to pasture but this had all disappeared at the end of thirty days. Similar results were obtained by Fleischmann,[23] Vorhees and Lane[24] on the other hand, found that there was a temporary decrease in the fat content when cows were changed from a dry ration to one more succulent. Hills[25] after eight years study of the question, found that out of 118 cows observed, 41 showed an increase in the fat content of their milk in the first two weeks on pasture, which disappeared after six weeks on pasture. Thirty-two were not affected by the change and 45 cows, studied only one year, showed a change from 4.88 per cent before going on pasture to 5.18 per cent six weeks after going on pasture. Smith[26] after observing 25 cows for five years, stated that, "Milk while the cows are at pasture is neither richer nor poorer on the average than the milk yielded when the cows are on winter feed."

Arenander[27] analyzed 2000 samples of milk delivered at creameries in northern Sweden, and found a general decrease in the fat content of the milk as the cows passed from pasture to ample stable feeding and then to scanty stable feeding. Results resembling these were obtained by Cranefield and Taylor[28] when cows were removed from poor pasture to a well-balanced ration in the barn.

Richmond[29] states that, "If the food given to the cattle be sufficient both in quantity and ratio of constituents no appreciable variation in the composition of the milk is found on changing the food. If the food given makes the cow scour the milk is likely to be low in fat, and the percentage of fat is raised by the addition of a more binding food."

The results of experiments in this country and abroad indicate that normally the richness of a cow's milk is not the immediate sequence of her feed and care, provided she receives sufficient nutriment to maintain her body. Almost invariably when a sudden change in the food occurs, it is accompanied by a more than ordinary variation in the per cent of fat, either upward or downward. After becoming accustomed to the new food however, her milk just as invariably returns to its former average per cent of fat.

The influence of season and weather on the fat content of milk

Among the factors that are usually considered as of minor importance in influencing the fat content of cow's milk are those of season and weather. The stimulating effect of sunlight and cool fresh air on the general health of all animals, as well as the lethargic condition of man and other animals in hot humid climates is well-known. From a purely deductive consideration of the question, inasmuch as the modern dairy cow is a highly sensitive animal in which the milk secreting process has been developed to a high degree being therefore very susceptible to influences of various kinds, it is apparent that in regions where the range of climatic conditions are wide that seasonal and weather changes might be important factors in determining the production of the dairy cattle of the section.

The observations of dairy farmers are in accord with this deduction. They are almost uniform in the statement that during the spring and summer months the butterfat tests reported by the creameries that buy their milk is much lower than it is in the winter months. State legislatures[30] also have recognized this factor and have enacted laws requiring legal whole milk to contain a higher percentage of fat in the winter than in the summer. Scientific investigations have further corroborated the opinion.

One of the first scientific investigations of the question was made by Vieth in 1884.[31] He analyzed over 14,000 samples of milk in the laboratory of the Aylesbury Dairy Company in England, the samples representing the milk from a great many different farms in each month. His results indicate, as Table 1 shows, a very close agreement with the observations of practical dairymen. Lawes and Gilbert[39] state that a careful consideration of the newly calved cows brought into the herds each month showed that his (Vieth) results were perfectly distinct independently of any influence of the period of lactation, of the different individuals of the herds.

T A B L E 1

BUTTERFAT PERCENTAGE EACH MONTH OF THE YEAR
Records from Aylesbury Dairy Company, England

Month	Per cent Fat	Month	Per cent Fat
January	3.55	July	3.47
February	3.53	August	3.87
March	3.50	September	4.11
April	3.43	October	4.26
May	3.34	November	4.36
June	3.31	December	4.10

Richmond[32] considers that the influence of season has been underestimated, he states that "The year roughly speaking, can be divided into four periods: (1) November, December, and January, the milk is rich both in fat and solids not-fat; (2) February, March and April, the solids-not-fat do not show appreciable dimimution, but the fat becomes less in quantity; (3) May, June and July and August,

the fat is low, though there is a tendency to rise at the end of the period; (4) September and October, an improvement in quality both as regards fat and solids-not-fat is noticed."

Ingle[33] found that the milk at Garforth at Easter time tested higher than during the following August. He suggested the possibility that the differences observed may have been due more to differences in the food and condition of the animal than to the actual influence of the season. Crowther,[34] however, from a compilation of the records of eight herds over a period of two years in Scotland obtained similar results. Results somewhat contradictory to these were obtained by Bull and Dymond[35]. They found but little difference between the mean values obtained during the winter months and those of the summer. They conclude, however, that "during the flush of milk in the spring there is, corresponding to the increase in quantity of milk, a decrease in the proportion of fat" and subsequently a reversal of this condition.

In South Africa, Juritz[36] found during a seven year period in which the composition of 5567 samples of the whole milk "sold in the streets of Capetown and Kimberley" were analyzed, that in both places "milk is richest in fat just before the coldest and poorest in fat just before the warmest part of the year".

In this country investigations have given somewhat similar results. Van Slyke and Publow[37] stated that the greatest production of milk and fat commences about the middle of May and continues for several months. They cite in support of their opinion not only their own analyses in New York State, but claim that reports of the Vermont and Wisconsin Experiment Stations are in harmony with their own. Smith[38] using a herd of twenty-five cows at the Michigan Station and eight cows at the New York State Experiment Station over a period of five years does not agree with this in every respect, he concluded that there is little difference in season as to the quality of the milk produced. Sherman,[39] on the other hand, basing his conclusions on the analyses of sixty average samples from a herd of 600 Jerseys in the state of New York over a period of five years, found

the highest per cent of fat to occur during the month of January and the lowest in July. In this herd it was arranged to have the cows freshen at regular intervals so that the supply of milk would remain constant throughout the year.

Eckles[40] after tabulating and studying the herd records from the Missouri and Iowa Experiment Stations, a total of 240 lactation periods, from the standpoint of the percentage of fat in the milk, says, "It may be stated in general that regardless of where these lactations begin, they follow a general curve for the year, which is less in June or July and gradually rises to the highest in December or January, usually December, and then gradually declines again until mid-summer. These curves are modified by the evident tendency for the percentage of fat to rise materially during the last two or three months of the milking period. We have these two factors combined to be taken into account." He suggests temperature as the most probable factor.

In an inquiry conducted by Boardman[41] involving the average per cent of fat in the milk delivered at 191 creameries located in 55 counties in Iowa, and representing the production of about 180,000 cows, mostly grade Shorthorns, like results were obtained as is shown by Table 2.

TABLE 2

BUTTERFAT PERCENTAGE EACH MONTH OF THE YEAR
Records from 191 Creameries in Iowa

Month	Per cent Fat	Month	Per cent Fat
January	4.02	July	3.67
February	3.80	August	3.79
March	3.81	September	3.80
April	3.71	October	3.96
May	3.69	November	4.05
June	3.65	December	4.12

White and Judkins[42] at the Connecticut Experiment Station also found after an examination of a total of 126 lactation periods that "milk tests lower for both fat and solids-not-fat in the summer than in the winter months". They

state that the general direction of fat and solids-not-fat tests for the winter calving cows is up, down and up; for summer calving cows it is down and up, and for fall calving cows gradually up and down.

Hills[43] found after the examination of over 100 lactation periods, including records of cows in Vermont, New York and Minnesota, that the average spring cow betters her milk in fat starting in about five months after calving, the summer cow starts in about the seventh month, while the fall cow maintains a fairly even quality throughout, seldom increasing the fat more than 0.5 per cent. He gave the second month of the lactation period the value of 100 and upon this basis found that the extremes in the fat percentages in milk were greater for spring calving cows. With twenty-two spring calving cows from the three stations the monthly ratio of the per cent fat was found to be as follows, beginning with the first month: 101, 102, 103, 105, 111, 117, 120, 122, and 132, and with the fall calving cows the ratio was, 100, 100, 101, 102, 103, 103, 102, 103, 105, and 107.

In connection with the butterfat tests made by the American Guernsey Cattle Club, Thorndike[44] found that if the per cent of fat in the milk produced by a cow during the month of March is taken as 100 the other months would tend to vary from this average richness as follows: April, 99.4; May, 98.6; June, 95.5; July, 95.7; August, 97.4; September, 98.8; October, 101.2; November, 101.3; December, 104.5; January, 104.9; and February, 103.1

One of the more recent investigations bearing upon this question was conducted by Clothier.[45] He reports in a study of nearly 900 farms in southern Arizona by the survey method that the farmers were practically agreed that in the spring and summer the butterfat tests were lower than during the winter months. He also found after an extensive study of creamery and cow testing association records involving hundreds of cows in the state that invariably the fat content of the milk was highest during the winter months and lowest in the early summer. He however does not attribute this variation to environmental conditions excepting so far as this involves a change in food. He says, "The most probable cause of

the difference in fat content of milk between winter and summer months seems to be the difference in the nature of the food."

Weather. If the general climatic conditions due to seasonal changes exert an influence onthe fat content of milk this would be expected to become more apparent with the more abrupt and often violent changes in the weather that occur daily, since the animal body does not have an equal opportunity of adjusting itself to its environment. It seems conceivable that a sudden exposure to cold, for instance, might check the formation of milk because of diverting the current of productive activities from the formation of milk to other and undesired forms of production. There is some evidence of a practical nature indicating that daily changes in climatic conditions produce marked results in the composition of milk. Dairymen with cows on Advanced Registry test believe that tests are higher during clear,cool weather than during periods of storm, or when it is extremely hot or cold. Observing creamery operators and milk dealers have noted a similar relation between the state of the weather and the quality of the milk delivered.

Only meager experimental evidence is available regarding the influence of temperature and other weather conditions on the composition of milk. Cooke and Hills(46) at the Vermont Agricultural Experiment Station reported that when cows were on pasturage the quality of milk varied with the temperature, but in the opposite direction, the milk becoming richer in cold weather and poorer in warm weather. Rain storms unless very heavy did not affect the quality or quantity. They explain as the temperature falls, the cow actually consumes more food and thus there is present in the system a larger amount of material from which to produce the milk nutrients. Abraham,(47) and Gilchrist,(48) on the other hand found that exposure to cold winds had the effect of causing milk low in fat to be produced. Gilchrist also observed that cows of a nervous and excitable temperament showed greater variations than those of a more quiet disposition. Ingersoll and Duncanson(49) found during a period in which ten sudden storms and cold waves occurred seven of these caused a dimished yield of milk, and in three the yield was

constant. The percent of fat diminished in five observations, remained constant in four, and increased in one observation. True[50] as the result of a temperature drop of seventeen degrees Fahrenheit in two days found that there was no falling off in the butterfat content of the milk but rather it acted as a stimulant causing a temporary rise. This is in agreement with the observations of Farrington.[51] Brooks[52] exchanged two lots of cows between an artificially heated stable kept at 55 degrees F. and a cooler, unheated one. Rather more milk was produced in the warm stable but its percentage of fat was lower. Richards and Jordan[53] found that more milk was produced in three cases out of four and more butterfat in two cases out of four at the higher stable temperature. Spier[54] reporting on a total of 88 animals concluded that the results did not show any perceptible effect on the composition of the milk with temperature fluctuations.

The most recent contribution on this question is that of Ragsdale and Brody.[55] In a preliminary experiment with a group of ten cows during the month of March and April of this year, they attempted to record data showing the relation of temperature to the percentage of fat in milk uninfluenced as far as possible under the usual conditions, by other factors. They state that "as far as the preliminary experiment is concerned, there is a relation between temperature and the percentage of fat showing roughly an increase of about 0.2 per cent in the fat for a decrease of 10 degrees Fahrenheit in the temperature between the observed temperature limits.

The influence of meteorological conditions on the physiological processes in animals

Milk secretion is a highly complicated process and, although not well understood, it apparently bears a close relation to other physiological processes in the cow's body, for it is known that the stimulation or inhibition of any of them almost invariably is reflected in the product of the mammary gland.

The reaction of the physiological processes in animals to weather conditions have not been extensively investigated. The meaning of the term weather as here used being based upon the definition given in Webster's International Dictionary: "The state of the air or atmosphere with respect to heat or cold, wetness or dryness, calm or storm, clearness or cloudiness, or any other meteorological phenomena." While there is some experimental evidence showing the influence of the various meteorological phenomena on man and some of the smaller animals, such information relating to the dairy cow is almost entirely lacking. There is however, more or less similarity between the physiological processes of the various species of animals and the reactions taking place in one may therefore, to some extent, be expected to occur in that of another under the same conditions. Therefore a review of literature on the influence of various meteorological phenomena on animal organisms is presented.

Light. The beneficial action of light on the body and the mind has been long recognized. Numerous animal experiments have shown clearly that there is an increase in the gaseous interchange with a change from darkness to light. It is generally held however, that this increased metabolism is exclusively brought about by more active muscular movements due to the presence of light.

Weiske and Graffenberger(56) advise that animals be given an abundance of light when it is desired to have healthy normal animals, for instance for breeding purposes and when an active metabolism is desirable as in the case of milch cows. They believe that light increases and that darkness diminishes metabolism. Milroy and Robertson(57) and Rubner and Cramer(58) are agreed however, that the marked influence on the general metabolism ascribed to light by Weiske and Graffenberger and others, is merely the expression and result of the heat rays upon the body in the form of greater physical activity. They state,"A direct influence of light upon oxidation processes in the tissue has not been scientifically proven."

Temperature. Temperature is the degree of sensible heat or cold. Milroy and Robertson[59] state that "A fall in the external temperature increases the heat formation, the CO_2 excretion, and the oxygen consumption in warm-blooded animals. If the external temperature rises very gradually, a normal condition is reached with the lowest metabolism at moderate temperatures, while at higher temperatures the metabolism is somewhat greater."

Murschhauser[60] found from 46 to 131 per cent more CO_2 was produced and from 36 to 91 per cent more oxygen was consumed at five degrees Centigrade than at 35 degrees in experiments with dogs. Pembrey[61] found that a mouse responded very rapidly in the CO_2 output to a change of the external temperature. This increase in the CO_2 output, Senator[62] believes to be due to increased physical activity. He found that in the absence of the latter the former showed no alteration. Speck[63] held practically the same opinion, and the experiments of A. Loewy[64] and Johansson[65] seem to have settled decisively the question that the increased CO_2 excretion is due to active movements and not to cell stimulation.

Relative humidity. Relative humidity may be defined as the ratio of the amount of vapor actually present to that which might be present if the air was saturated at the existing temperature. It is commonly expressed as a percentage.

In a general way it is well-known that conditions of relative humidity and wind movement are important factors in ameliorating or aggravating the effects of temperature.

Rubner[66] has studied the effect of altering (1) the humidity of the air with constant temperature; (2) the temperature with constant hmmidity. He found that if 100 calories were lost by radiation and conduction when the air was dry, 107 would be lost in this way at 75 per cent relative dryness, 116 at 50 per cent and 125 at 25 per cent. In other words, one per cent increase of humidity raised the loss by radiation and conduction 0.32 per cent. A twenty-five per cent increase in humidity equalled in effect a change in external temperature of two degrees Centigrade. In the case of the warmed air (25-30 C) the evaporation of

sweat proved to be a factor of great moment, a 50 per cent increase of humidity having the same effect as an increase in the temperature of 5 degrees C. He found that in small animals such as the guinea pig the minimum output of water occurred at 15 degrees C., when the temperature was varied under conditions of constant humidity. At lower temperatures in spite of the greater relative saturation of the air with moisture, the loss of water increased — "a physiological reaction due to the increased respiration and rate of metabolism excited by the cold." In larger animals he does not believe there is any such marked reaction.

MacLeod and Hill[67] found that air saturated with moisture at 20 degrees C. increased the CO_2 output of mice. In one case after eighteen hours ventilation with wet air they found the mouse almost dead with a rectal temperature of 22.5 degrees. C. It recovered in a current of dry warm air. So long as the temperature of the wet chamber was maintained at 24-25 degrees C. the mouse maintained its temperature by increased combustion. At 20 degrees C. the compensatory mechanism failed, and the increased heat loss passed over the increased heat production. Hill states, "Mice are, of course extremely susceptible to cold, but prolonged exposure to wet cold air must have a similar though far less marked effect on larger animals."

The influence of dry and of damp air at different temperatures on the CO_2 output in man has been investigated by Thomson.[68] He conducted experiments with three men breathing alternately dry and damp air, first the damp and then the dry air at about 56 degrees Fahrenheit, and afterwards damp and dry air at blood heat, the damp air in each case being as nearly as possible saturated with moisture at the two temperatures. He found the total average increase for the three persons on the dry over the damp cold air amounted to four per cent, and on the dry over the damp warm air at 7.53 per cent.

Atmospheric Pressure. In the Alpine pastures Ulmansky[73] observed the influence of meteorological factors on the milk production of 27 cows.

He found that the milk records of the herd seemed to show that the cows on mountain pasture produced a smaller amount of milk than those in the valley. The period of pregnancy of the mountain cattle was somewhat longer, but there was no appreciable differences in the live weights of the cows or in the birth weights of the calves.

Loewy and Zuntz[69] observed that dwelling at lofty altitudes where atmospheric pressure is much reduced greatly stimulates the metabolism. Jaquet[70] found a distinct rise in the gaseous interchange to the extent of 14.8 per cent CO_2 and 8.8 per cent O_2 at an altitude of 1600 metres. He found that the respiratory quotient had risen notwithstanding the fact that the mechanical condition of the respiration remained unaltered. Thomson[72] also found greater percentages of CO_2 in the exhaled air at higher elevations than in the valley, and higher in the valley than at the bottom of a deep coal pit. He found in his experiments with men, guinea pigs, and mice, that on all occasions where the barometer, hygrometer or thermometer alters appreciably, there is a corresponding change in the percentage of CO_2 in the exhaled air of all or nearly all, the persons or animals tested. A rise in the barometer producing a fall in the CO_2, and a fall in the barometer producing a rise in the CO_2 exhaled, and a marked increase in the humidity producing a fall, and a decrease producing a rise in the CO_2 exhaled. A rise of the temperature of the air produced a lowering of the CO_2 in exhaled air, and a fall in the temperature produced a rise.

General Discussion of Literature

It is evident from a careful consideration of the foregoing literature that season and weather exert more or less influence on the per cent of fat in milk. While investigations have in general shown that such a relation exists, which is entirely independent of the usual influencing factors, the number of such observations has not been sufficiently large nor have they been widely enough distributed to conclude that such a relationship is universal. Neither has the real nature or cause of this relation, if any such exists, been established, indeed but

few attempts have been made to explain it.

Temperature was suggested by Eckles after he had found that the seasonal variation in the butterfat percentage was independent of the usual factors influencing the fat content of milk, namely breed, individuality, stage of lactation, and feed. But the fact, as Eckles and others found to be the case, that the per cent of fat is lowest just before the warmest part of the year, and highest just before the period of coldest weather indicates that temperature is not the only influencing factor.

While Cooke and Hills, True, and Farrington, and later Ragsdale and Brody have shown an apparent relation between fat per cent and temperature, they failed to consider the possible influence of other meteorological phenomena. Also in the investigation of Ragsdale and Brody, the cows under observation were kept "indoors during stormy days and cooler nights", and the percentage of fat was recorded against outside temperatures, all of which would tend to lessen the value of their results.

Feed was suggested by Clothier as the most probable factor causing the seasonal variation in the butterfat content of the milk observed by him in Arizona. His conclusion however appears to be erroneous, for according to his own statement it might be questioned whether the nature of the feed of the region varied sufficiently from season to season to cause any material change in the composition of the milk.

OBJECT OF INVESTIGATION

Investigations have shown that combinations of temperature, relative humidity, and atmospheric pressure may exert a profound effect upon the metabolism of some of the smaller animals and of man. The possible relation, however, of these factors to butterfat, production by the dairy cow has received but little attention.

The evidence at hand seems to indicate that in certain regions or sections of this country at least, a definite relation exists between butterfat per cent and both season of year and daily weather conditions. Such a relation has not, however, been shown to occur in the state of Minnesota and similarly located regions. Furthermore, in the sections where a relationship has been established, climatic conditions differ widely from those in Minnesota. Whether season of year and daily weather conditions influence the butterfat percentage in the milk produced by cows under Minnesota conditions remains to be determined.

The specific object of this investigation was to study the relation of the season of the year and the daily weather conditions to the variation in fat percentage of milk. Since other studies of this subject already indicated that such relation does exist under certain conditions, the special purpose in this investigation was to study the available material from the standpoint of climatic conditions such as exist in Minnesota. It was planned, in the event that such a relation was found, to study the influence of various meteorological phenomena on butterfat percentage.

4-22-8M

PLAN OF THE INVESTIGATION

Two methods of investigation might be followed in a study of this kind. One would consist in a study of the results obtained when cows are subjected to the desired combinations of the various meteorological phenomena produced artificially. This method would be desirable inasmuch as it could be regulated so that almost any climatic condition desired might be produced. It would however have the drawback that it would be expensive to carry on, require a long period of time, and only a few animals could be used.

The other method involves the consideration of a large number of daily and monthly records of butterfat percentage in their relation to the various meteorological conditions that existed when they were made. It is evident that where a large number of records are used, obtained from a number of sources, there is danger that some of them may not be entirely reliable, and therefore decrease the value of the data. On the other hand the use of a very large number of records decreases the influence of individuality or unreliable records to a large extent. This method is inexpensive inasmuch as the data can be gathered easily from the records already made. With a large number of such records available that had been made under practically identical conditions the latter method of investigation seemed the more desirable one to follow in this study.

The plan of this investigation was to study the effect of: (1) Season of year; (2) Changes in weather conditions, and (3) Temperature, humidity, and atmospheric pressure, and vapor pressure, taken singly or combined, upon the percentage of fat in milk.

Source of data. Records were obtained from the following sources:

(1) The University Farm Herd records, St. Paul, Minnesota.

(2) The Advanced Registry records of Holstein-Friesians in Minnesota.

(3) The Jersey Register of Merit records in Minnesota

(4) The Guernsey Advanced Register records in the United States.

The records of the University Farm herd cover the period from 1893 to 1921, a total of twenty-eight years. This herd has been kept under practically uniform conditions from year to year. The animals have received only ordinary good care. In winter the feed has consisted of good roughage and grain, in summer a large part of the ration has been pasture supplemented more or less by other feeds when necessary. The custom has been to have cows freshen once each year if possible. Until 1916 butterfat tests were made of each milking of each cow in the herd, for a time after this tests were made at weekly or less frequent intervals from composite samples, and during the last few years the plan has been only to test each cow's milk once a month. Some of the records also represent tests that were made by supervisors of official testing inasmuch as all of the cows made at least one official yearly record. The data cover 139 lactation periods of the Holstein-Friesians, 169 of the Jerseys, 86 of the Guernseys, and 159 of other breeds and grade animals, a total of 553 lactation periods in all. The daily fat per cent records of ten cows for the months of June, July and August and part of January, 1911, are also included.

The official records of the Holstein-Friesians do not cover any definite period of time excepting that they were made during the four or five years preceding 1922. They include the records of animals from 38 herds in different parts of the state and cover a total of 764 lactation periods. The Register of Merit records of the Jerseys represent about the same period of time as those of the Holsteins. They include the records from animals in ten herds and cover a total of 125 lactation periods. The official records of both the Holsteins and Jerseys were obtained from the files in the office of the Superintendent of Official Testing in Minnesota.

The Advanced Register records of the Guernseys in the United States were obtained from The Herd Register of the American Guernsey Cattle Club, Vol. XXXIV, Part I, Nos. II, III, and IV. 1920-21, and cover a total of 1318 lactation periods.

4-22-8M

They were included in this study for the purpose of determining whether the fat per cent records of cows in all parts of the country follow the same seasonal trend as those in Minnesota.

Character of records. All records of butterfat percentage were based upon the Babcock method of testing milk for fat. In compiling the monthly average per cent of fat, use was made only of the lactation periods that exceeded seven months in duration, or in which at least seven monthly records were available. Most of these periods cover from ten to twelve months, a few of them running considerably longer. In quite a number of instances the records for several lactations from the same animals were included.

Meteorological data. The meteorological data was obtained from the original records of the United States Weather Bureau Station, Merchants Bank Building, St. Paul, Minnesota.

INVESTIGATIONAL DATA

Seasonal influences. The influence of season on the per cent of fat in milk was studied by collecting a large number of records from the various sources and grouping them according to their source and month of freshening. The average monthly per cent of fat was then found for each lactation period group. In this way the influence of stage of lactation was made the same for all the groups.

The tables relating to seasonal variations show the average per cent of butterfat for eachmonth of the lactation periods, also the number of lactations represented in each group. All tables and charts are given in the Appendix.

Table 3 (Charts 1, 2, and 3) includes the records from 553 lactation periods of cows in the University Farm herd.

Table 4 (Charts 4, 5, and 6) gives the records from 139 lactation periods of Holstein-Friesians in the University Farm Herd.

Table 5 (Charts 7, 8, and 9) gives the records from 169 lactations of Jerseys in the University Farm Herd.

Table 6 (Charts 10, 11, and 12) gives the records from 86 lactations of Guernseys in the University Farm herd.

Table 7 (Charts 13, 14 and 15) gives the records from 764 lactations of Advanced Registry Holstein-Friesians in Minnesota.

Table 8 (Charts 16, 17 and 18) gives the records from 125 lactations of Register of Merit Jerseys in Minnesota.

Table 9 (Charts 19, 20, and 21) gives the records from 1318 lactations of Advanced Register Guernseys in the United States.

Table 10 (Chart 22) shows the influence of stage of lactation, regardless of time of freshening on the monthly average per cent fat. In this table the data is given separately for each of the groups included in tables 3 to 9 inclusive, also an average which represents the 3154 lactation periods included in the entire study.

Chart 23 shows graphically the relation between the average tests of the first month of the lactation periods in several of the groups. Since the grouping is based upon the month of freshening, the charts show the influence of season upon the first month's test.

Table 11 (Chart 24) shows the average monthly temperature, relative humidity, atmospheric pressure, and vapor pressure for a ten year period.

Daily weather influences. The influence of daily weather conditions on the per cent of fat was studied from the daily records of the various meteorological phenomena and the per cent of fat in milk.

The daily butterfat percentage used in the data relating to daily weather influences were the averages for ten cows during the months included in this study. January, June, July, and August were the months chosen, because they represent extremes in weather conditions, also in the three latter months cows are

usually exposed night and day to all weather conditions incident to that season of the year.

Table 12 (Chart 25) shows the average daily per cent of fat, temperature, relative humidity, atmospheric pressure, vapor pressure, and state of weather, for the first fifteen days in January 1911.

Tables 13, 14, and 15 show similar data for the months of June, July and August as is given in table 12.

Charts 26 and 27 show graphically the daily average per cent fat, relative humidity, atmospheric pressure, and vapor pressure, for the first sixteen days in June and July respectively. Similar data is given in Chart 28 for the period from August 6 to August 20 inclusive.

Table 16 gives two correlation tables. Number A shows the correlation between relative humidity and per cent fat in milk. Number B shows the correlation between the average daily temperature and the per cent of fat in milk. The records used in the two tables represent the daily average for the three months, June, July, and August, 1911. The butterfat percentage is the daily averages for ten cows.

Table 18 shows the results of grouping the daily average per cent fat records into four classes according to the temperature and relative humidity that existed at the time the records were made. It shows the combined effect of average daily temperature and relative humidity on the per cent of fat, the period covered being June, July and August, 1911.

DISCUSSION OF DATA

When all the data used in this investigation are taken into consideration it is evident that there is a definite seasonal variation in the percent of fat in milk of the dairy cows in Minnesota. This fact is especially apparent in the groups where sufficiently large numbers of records are considered and the influence of individuality is wholly eliminated.

University Farm herd records. The data from the University Farm herd records are very significant for they represent a large number and are reliable. Table 3 (Charts 1, 2, and 3) show without exception a seasonal effect in each of the twelve lactation groups. The average per cent of fat for the January, February, March, and April groups (Chart 1) almost without exception show a marked decrease during the summer months, June and July, being usually the more marked in the latter month. With the approach of autumn the curves in this group rise again rapidly reaching the highest point in December or January.

The records of the cows calving in May, June, July, and August also show characteristic seasonal tendencies for their monthly average per cent of fat. (Chart 2). In this group the fat per cent is low for the first one to three months after which it rises rapidly. For the May group this increase in the per cent continues almost unabated to the end of the period. With the others a slight drop occurs for a month or two beginning with March after which the curve again rises very gradually to the end of the lactation period.

The fat percentage for the lactations beginning in September, October, and November (Chart 3) show a trend similar to that of the last two in the preceding group except that it increases from the beginning of the period, and the range between the two extremes is not as great.

The December group curve (Chart 3) is very similar to the one for January, showing a tendency to dip slightly for a month or two at first, rising during April and May, with a downward dip again in June and July followed by a constant rise to

the end of the period.

Holstein-Friesians University Farm herd. The data (Table 4, Charts, 4,5, and 6) representing the records of the Holstein-Friesians at University Farm as a whole show a tendency to differ slightly from those of the entire herd. The number of animals for some of the months however is too small to be representative. Almost invariably the first month of the lactation is higher than the following one or two. This is due to a characteristic of cows of this breed to yield richer milk when, as at the beginning of the lactation period, they are in a high condition of flesh. In the lactations beginning in the fall and winter (Table 4, Charts 4 and 6) this tendency is especially evident. This no doubt results from the fact that many of the cows freshening during these months were fitted for making high seven-day records. In other respects the plots show a trend similar to those for the whole herd.

Guernseys and Jerseys University Farm herd. The data for both the Guernseys and Jerseys in the University Farm herd, Tables 5, and 6 (Charts 6 to 12 inclusive) indicate that they follow very closely the same trend in their monthly per cent of fat as does the entire herd. The Guernsey plots show more irregularity due to the smaller number of animals represented, they nevertheless show the general tendency of the group.

Advanced Registry Holstein-Friesians and Register of Merit Jerseys in Minnesota. In considering data from select groups, such as are represented by animals in Advanced Registry or Register of Merit, somewhat different results might be expected than those obtained from cows kept under ordinary herd conditions inasmuch as there usually is considerable difference in the feed and care they receive. The possible influence of summer pasture is also eliminated since cows on semi-official test are usually fed a practically uniform ration throughout the entire test period. A consideration of Tables 7 and 8 (Charts 13 to 18 inclusive) however reveals a very close similarity between the plotted curves of the Advanced

4-22-8M

Registry Holsteins and Register of Merit Jerseys and the plots for the same breeds in the University Farm herd. This fact would seem to indicate that feed is not a factor in causing the seasonal variations observed. There is possibly a slight tendency for the records of the Advanced Registry Holsteins to be higher during the first one or two months of their lactations than those of the Holsteins at University Farm. This no doubt is due to the fact that the former are usually in a higher condition of flesh at parturition than the latter, having been fitted for making a high seven-day record in many cases, and consequently the per cent of fat in the milk produced is abnormally high.

Advanced Register Guernseys in the United States. The records from 1318 lactations of the Advanced Register Guernseys in the United States (Table 9, Charts 19, 20, and 21) represents cows from all parts of this country. They show that seasonal variations are not confined to the milk produced in Minnesota, for without exception each lactation group shows a tendency to be influenced downward during the summer months of June and July and upward during the colder part of the year.

The influence of stage of lactation on seasonal variation. It is well-known that stage of lactation is an important factor in causing variations in the per cent of fat. That the seasonal variations observed in this study are entirely independent of thetime of freshening and stage of lactation is indicated by the data presented in Table 10, (Chart 22), which represents the average of all the lactation periods included in this study by groups. Each group has a characteristic curve for the lactation period. This curve should in general be the direction followed by all lactations in the breed which it represents were they uninfluenced by other factors. The plots representing the fat per cent however do not, as has already been shown, follow the characteristic lactation curve representing their breed. Instead they invariably have a downward tendency during the season of warm weather and cold weather appears to have the opposite effect regardless of the time the lactation begins. It seems evident from this that both season and stage of

lactation are influencing factors. It is also clear that under proper conditions the two may work together to increase the per cent of fat while under other conditions they may oppose one another. That such is the case is evident from a consideration of the records of the various groups.

In the lactations commencing in the fall, September, October, and November, the accelerating affect of season at the beginning appears to be counteracted by the inhibitory influence of the stage of lactation. During the following summer this condition is reversed season becoming the inhibitory factor with stage of lactation tending to increase the per cent of fat. The result is, as is apparent from all the plots, that the fall freshening cows show the least amount of variation of any of the groups.

With the lactations beginning in January, February, March, and April the difference between the extremes in the variations is very marked especially for those beginning in the latter two months. Here apparently stage of lactation and season are acting together during most of the period.

A similar condition is observable but to a less marked degree in the case of the lactations beginning in May. With the June, July, and August lactations the tendency for milk to test low in fat during the spring and summer months of the year is greater than the influence of prolonged lactation to raise the test.

Influence of season on the first month of the lactation. Further evidence of the influence of season on the per cent of fat is given in Chart 23. The plots represent the average test of the first month of each lactation in each of the groups. They show that there is invariably a strong tendency for the cows freshening in the fall and winter months to yield richer milk during the first month of their lactation period than those freshening during the summer months. This fact coupled with the one already pointed out that the fall freshening cows show the least amount of variation and also as has been found by other investigations that they yield a larger total quantity of milk during their lactation period than

those freshening in the spring or summer, is of great significance to those who desire to secure the maximum production from their cows.

Meteorological phenomena as factors causing variations in the butter-fat percentage. No attempt has been made thus far in the discussion to point out the cause or causes for the observed seasonal variations in the per cent of fat. That the phenomenon is not peculiar to any breed is evident since it has been found to occur in the three different breeds studied. Feed apparently is not a factor inasmuch as cows on uniform rations show the same tendencies in the quality of their milk with respect to season as do animals under ordinary herd conditions. Stage of lactation it has just been shown either aids or abets the seasonal variations but is not the causative factor. Eckles in his study of this question suggested exercise as a possible factor, inasmuch as the average herd cows undergo considerable more exertion in the summer while in the pasture than while kept in the barn in winter. That it is not the cause of the variations, however is evident since all the groups considered, those in which the cows were kept under practically uniform conditions throughout the year as well as the average herd cows, showed similar seasonal variations in the quality of the milk produced. The number of hours of daylight or sunlight is another possible cause. The extent to which sunlight or daylight might be a factor is however problematic. Many opinions have been expressed both in general literature and in purely scientific writings as to the influence of this characteristic of climate on the general health and metabolism of animals. Definite corroborative investigational results of a conclusive nature are however lacking, and this is therefore a subject for further investigation. It seems probable that the number of hours of daylight and sunshine are factors only insofar as they affect the various meteorological phenomena which may have an effect. The cause or causes therefore seems to lie with some meteorological phenomena accompanying seasonal changes.

Table 11 (Chart 24) is a compilation of a ten year average of the monthly temperature, relative humidity, atmospheric pressure, and vapor pressure.

The temperature and vapor pressure plots are very similar. This is to be expected since the latter is dependent upon the former to a large degree. They both reach their maximum height during the month of July after which they gradually decrease reaching the lowest point in January.

The relative humidity curve on the other hand shows a gradual depression reaching its lowest point in May or June and the highest in January. It is therefore almost the opposite of the one for temperature. Atmospheric pressure does not follow a very definite seasonal cycle, although the tendency for it seems to be to follow somewhat the same curve as that of relative humidity.

It seems apparent that one or more of these meteorological phenomena is responsible for the seasonal variations in the per cent of fat in milk. The fact that they follow similar or opposite curves from those of the fat per cent would indicate at least a possible relation between them.

It is at once evident that temperature is the outstanding factor since the range of its variation is very much greater than that of the others. Also the curve representing it is highest at the time when the fat per cent curve has a tendency to be lowest, and lowest at a time when the richest milk is usually produced. Relative humidity appears lowest at the time when the fat per cent curve has a tendency to dip downward, namely in the spring and summer. It is however doubtful whether the small drop in the relative humidity has any particular influence on the quality of the milk, temperature more probably being responsible. Vapor pressure as has been mentioned depends on the degree of temperature. The curve representing atmospheric pressure does not show any definite relation to the observed variations in the per cent of fat.

Meteorological phenomena and daily variations in the butterfat percentage in milk. The preceding discussion has indicated that winter is the time for high fat tests and summer time for low ones, changes in temperature probably being the chief influencing factor. Obviously the same meteorological factors that operate over a long period of time to cause the gradual seasonal variations should

also bring about changes in the fat content of the milk when they occur more abruptly as is the case in daily weather conditions.

Tables 12, 13, 14, and 15, show the daily average per cent of butterfat, temperature, relative humidity, atmospheric pressure and vapor pressure for the months of June, July, August and the first fifteen days in January, 1911. Charts 25,26,27 and 28 represent periods in each of the months. It will be observed that there is a tendency for the daily average per cent of butterfat to show an inverse relation to temperature changes. This is also apparent to a less marked degree in the case of relative humidity and vapor pressure. Atmospheric pressure does not appear to be a factor except insofar as it may be related to the others. These relations are especially discernible in the plots representing the summer months. They are not so apparent in those for January (Chart 25), this might however be due to the fact that cows at that season of the year are always kept within doors.

The state of the weather in general does not appear to exert any marked effect on the per cent of fat. Even heavy rainfall does not show any results except that in some instances the tests appear to rise for a day or two following. This condition might however be due to the fact that cool clear weather very often follows a storm. High winds are likewise ineffective. The unusually low tests that occur at different times during the period cannot be attributed to any particular state of weather. They are probably due to some unusual occurrence in the regular daily routine of the cows. The cow is a creature of regular habits and whenever any disruption of the regular order occurs it is reflected in her production. This fact is apparent from a consideration of the per cent of fat in the milk produced on Sundays when the regular routine is often not followed. Out of a total of thirteen Sundays included,nine of them show a per cent of fat that is lower than that of the day preceding and the day following it. The fat per cent for July 4th also shows a similar tendency. It is evident that this

factor is of great importance when daily variations in the per cent of fat are to be considered.

Where the daily range of temperature is wide (over 25 degrees) there is no noticeable affect on the per cent of fat except when the average is also high. High average temperature rather than wide range seems to be the stronger factor.

In Table 16 are shown correlation tables that give further indications of the degree of relationship between the several meteorological factors and fat per cent in milk. The correlation coefficient of $-.088 \pm .069$ (No. A) between relative humidity and the per cent of fat is too low to be at all significant. It indicates that the influence of humidity alone as a factor is nil. In correlation table No. B, however the correlation coefficient of $-.353 \pm .060$ is an index which shows with practical certainty that a mutual relation exists between daily average temperature and per cent fat. Since the correlation coefficient is negative an inverse relation between the two is indicated, high temperature causing low fat per cent and vice versa. This result is in agreement with the conclusion reached by Ragsdale and Brody and is further substantiated by observations made by the writer while connected with the Dairy Division, B.A.I., Washington, D.C. At the Dairy Division Experiment Farm located at Beltsville, Md., a number of Holstein cows on semi-official test that had been shipped there from Minnesota in April were observed to suffer severely from the heat in August, 1918. The maximum temperature in July was 96 degrees which was reached on the 21st and 22d. During the first few days of August it was quite cool. On August 4th the maximum temperature was 85 degrees F.; on August 5th 98 degrees F.; on August 6th 106 degrees F.; on August 107, 104 degrees F.; on the 8th and 9th, 96 and 94 degrees respectively. On August 12th, the temperature was again up to 96 degrees and it continued to be hot until the 15th. The temperature was moderate for the remainder of the month, a maximum temperature of 91 and 93 degrees being reached on August 24th and 26th, respectively.

All the cows brought from the North suffered fromthe heat, but four of the heifers that were milking heavily suffered very severely. These cows panted like dogs, their mouths open and their tongues lolling. They were taken out of their box stalls several times a day and the hose turned on them.

All these heifers dropped very rapidly from August 5th to 8th. Number 227 went from 52.9 to 6.0 pounds milk per day. Their milk flow gained quite rapidly as the temperature went down and it did not go down again to any great extent later in the month when the temperature reached a high point.

The percentage of butterfat in the milk was as severely affected by the heat as the milk flow and did not return to normal as rapidly. Unfortunately daily tests were not made during this period. The following table shows the tests that were made:

TABLE 17

OFFICIAL BUTTERFAT PERCENTAGES FOR THREE MONTHS
Records from four cows

Date	No. 227 Aver. % Fat.	No. 229 Aver. % Fat	No. 230 Aver. % Fat	No. 231 Aver. % Fat
July 10 & 11	3.21	3.02	3.27	2.88
Aug. 21 & 22	2.69	1.72	1.76	1.74
Aug. 30 & 31	3.20	2.11	1.97	2.06
Sept.26 & 27	3.52	3.23	3.47	3.12

While no record was kept of other meteorological phenomena during the period, nevertheless it seems probable that the high temperature was accompanied by high humidity since the atmosphere seemed very sultry at the time.

The effect of various combinations of temperature and humidity is shown in Table 18. With temperature below 70 degrees F., and relative humidity under 70 per cent, the average per cent of fat for the 250 milkings represented in 4.490; with the temperature the same and the relative humidity above 70 per cent the

average per cent of fat for 210 day milkings is 4.437. This shows that high humidity has a slight affect on the per cent of fat in the milk produced. With a temperature of over 70 degrees F., and the relative humidity below 70 per cent the influence of high temperature is evident. The average per cent of fat for 360 milkings being 4.404, which shows that high temperature is more effective than high humidity in influencing the per cent of fat in milk. Neither one alone, however seems to be any considerable factor, but when the two are combined in the proper manner a marked effect on the per cent of fat results. The average per cent of fat of 100 day milkings with the temperature above 70 degrees F., and the relative humidity over 70 per cent being 4.298, or a decrease of nearly two-tenths under that for conditions exactly opposite.

The results of the observations relating to the influence of meteorological phenomena on the daily per cent of fat indicate that temperature is the principal factor. Relative humidity showing only slight affect except when combined with temperature, while the others apparently have no effect whatever on the per cent of fat. These conclusions are almost analogous to the ones resulting from the study of seasonal variations. Low per cent fat invariably occurring during the warmest part of the year and high tests appearing in the winter months. Humidity however does not seems to be a factor at all as in the daily variations. Low humidity appearing to contribute to the occurrence of low fat content rather than the inverse.

Meteorological phenomena and physiological processes. No attempt was made in this study to determine the manner in which temperature (and humidity in daily variations) cause variations to occur in the per cent of fat in milk. This is a subject for further investigation. A few possible connections may, however, be presented.

Due to the complexity of the milk secreting process it seems improbable that temperature is the immediate cause of the observed fat variations. Rather

it seems probable that this factor acts as the initial instigator of certain physiological processes which finally result in milk of a certain quality being produced.

Influence on metabolism. Comparatively little is known concerning the formation and secretion of the specific constituents of milk. Its intimate relation to the metabolic processes of the body is however admitted. Consequently any disturbance of the general metabolism might also be expected to affect the functioning of the mammary gland. It is a generally accepted fact that metabolism is affected by varying degrees of temperature. Cold weather being considered as conducive to an active metabolism, while hot weather retards it. It seems probable therefore that the high fat tests accompanying the cooler seasons and days, are due to the more active state of the cow's metabolic processes that maintain at such times.

The hormones and milk secretion. It is generally admitted that the mammary gland is, as regards its secretory activity, not under the direct influence of the nervous system. The agents or hormones which cause its activity and also the ones that are inhibitory in their action, it is believed, reach it by the blood stream. The hormone secreting organs are therefore the regulators of the milk secreting process. The investigations of Fenger and Seidel[72] have shown that the character and activity of certain of these glands of internal secretion are influenced by seasonal changes. In view of this fact it is at least probable that the seasonal and daily variations observed in the fat content of milk may be due to the character of the reactions of one or more of these organs to the seasonal temperature.

SUMMARY AND CONCLUSIONS

1. The data presented in this investigation show the influence of season of year upon the fat content of milk as evidenced by the results obtained from a study of a total of 3154 lactation periods. This includes 553 lactation periods from the University Farm herd representing several breeds; 139 Holstein-Friesian, 169 Jersey; and 86 Guernsey lactations in the University Farm herd; 764 Advanced Registry Holstein-Friesian, and 125 Register of Merit Jersey lactation periods in Minnesota; and 1318 Advanced Register Guernsey lactations in the United States. A ten year average of the monthly temperature, relative humidity, atmospheric pressure, and vapor pressure is presented. Compilations of records are given which show the influence of stage of lactation upon the butterfat percentage.

The relation of daily meteorological phenomena and butterfat percentage is shown by a compilation of the records from ten cows in the University Farm herd and the average daily temperature, relative humidity, atmospheric pressure, vapor pressure, and state of weather over periods covering a total of 107 days.

2. The results from the investigation show that there is a distinct seasonal variation in the butterfat percentage in the milk produced by cows in Minnesota.

3. The data from the Advanced Registry Guernseys in the United States also show a similar seasonal variation.

4. Invariably the milk produced during the summer months, June and July, has a tendency to test lower than that which is produced at other seasons. During the winter months, December and January, the seasonal tendency is for the richest milk to be produced. The milk at other seasons of the year varies between these two extremes.

5. These seasonal tendencies in the butterfat percentage are due to changes in the temperature accompanying change of season and are independent of breed,

4-22-8M

individuality, and food. Other meteorological phenomena do not appear to be influencing factors.

6. Stage of lactation either augments or retards the seasonal effect of temperature. The milk from the fall freshening cows showing the least variation in the butterfat percentage during the lactation period, while the ones beginning their lactations in late winter or early spring show the greatest range in quality of milk produced.

7. Daily changes in temperature influence the butterfat percentage in milk. A correlation of -0.353 ∓ .060 shows that high temperature depresses and low temperature tends to increase the per cent of fat in milk.

8. Relative humidity alone is not important as a factor in influencing the quality of milk produced. The influence of high temperature however, is greatly increased when combined with high relative humidity.

9. Vapor pressure, atmospheric pressure, storms and amount of sunshine do not have any apparent influence on the butterfat percentage in milk.

10. Changes in the regular daily routine of the cow has a material affect on the quality of the milk she produces. Nine Sundays out of thirteen and one holiday showing a marked decrease over the day preceding and the day following it.

11. Seasonal and daily variations in the butterfat percentage are probably caused either by the action of the meteorological factors concerned upon the metabolism of the cow, or upon the glands secreting the hormones which are believed to act as the regulators of the milk secreting process.

A C K N O W L E D G M E N T

The writer wishes to express his appreciation to C. H. Eckles, Chief of the Division of Dairy Husbandry, for his helpful suggestions in the preparation of this paper.

BIBLIOGRAPHY

1. Wing, H. H.

1920. Cited by Stocking, Wm. A. in Manual of Milk Products, pp. 44. The MacMillan Co., N.Y.

2. Eckles, C. H. and Shaw, Roscoe H.

1913. The influence of breed and individuality on the composition and properties of milk. U. S. Dept. of Agri. B.A.I Bul.156

3. White, G. C. and Judkins, H. F.

1918. Variations in the fat, solids-not-fat, and total solids in cow's milk. Conn. (Storrs) Agric. Exp. Sta. Bul. 94

4. Anderson, A. C.

Studies in the range of variation of the per cent of butter-fat in the milk of individual cows. Mich. Agr. Exp. Sta. Special Bul. 71

5. Wing, H. H. and Anderson, LeRoy

1899. Studies in milk secretion. Cornell Agr. Exp. Sta. (Ithaca) Bul. 169.

6. Van Slyke, L. L.

1920. Modern methods of testing milk and milk products. Orange Judd Co., p. 9

7. Beach, C. L.

Records of a Dairy herd for five years. Conn. (Storrs) Agr. Exp. Sta. Bul. 29.

8. Woll, F. W.

1903. Studies in milk production. Wis. Agr. Exp. Sta. Bul. 102

9. Woll, F. W.

1904. On the relation of food to the production of milk and butter-fat by dairy cows. Wis. Agr. Exp. Sta. Bul. 116.

10. Crowther, Chas.

1905. Variations in the composition of cow's milk. Jour. Agri. Sci. I No. 2, pp. 149-175

11. Crowther, Chas. and Rustom, Arthur G.

1911. Variations in the composition of cow's milk with advance of lactation. Trans. of the Highl. and Agr. Soc. of Scotland, 5th series, Vol. XXIII, pp. 93-102.

12. Hills, J. L.

1890. Vt. Agr. Exp. Sta. Rept. p. 75

13. Lindsey, Jos. B.

1907. Mass. (Hatch) Agr. Exp. Sta. Rept. p. 109.

14. Jordan, W. H.

1891. Maine Agr. Exp. Sta. Rept. p. 62

15. Wing, H. H.

1895. On the effect of feeding fat to cows. Cornell Agr. Exp. Sta. (Ithaca) Bul. 92.

16. Wood, A. H.

1894. Records of a dairy herd for five years. New Hamp. Agr. Exp. Sta. Bul. 20.

17. Wing, H. H. and Foord, J. A.

1909. Record of an attempt to increase the fat in milk by means of liberal feeding. Cornell Agr. Exp. Sta. (Ithaca) Bul. 222

18. Hawk, J. C. and Hammond, J.

1916-1917. Studies in milk secretion. I. The effect of nutrition on yield and composition. Jour. Agr. Sci. Vol. VIII, pt. 2 p. 139.

19. Eckles, C. H.

1912. Influence of fatness of cow at parturition, on per cent of fat in milk. Mo. Agr. Exp. Sta. Bul. 100.

20. Kjärsgaard, K. P.

1899. The influence of pasturage on the fat content of milk. Mälkeritid., 12, No. 18, pp. 319-21.

21. Farrington, E. H.

1893. Variations in milk. Ill. Agr. Exp. Sta. Bul. 24.

22. Friis, F.

1899. On the effect of pasture on the yield and quality of milk. 45th Rept. K. Vet. Landbohöjskoles Lab. Landökon Forsög (Copenhagen) pp 57-65; 88-93.

23. Fleischmann, W.

1891. Investigations of the milk of sixteen Thoro-bred Dutch cows during one period of lactation. Abstract in Exp. Sta. Record Vol. 3, pp. 424. Landw. Jahrb., 20, Supplement II, p. 368.

24. Vorhees, Edmund B. and Lane, Clarence B.

1897. Milk: Its value as a food and studies which suggest different methods of sale. New Jersey Agr. Exp. Sta. Bul. 123

25. Hills, J. L.

1893. Vt. Agr. Exp. Sta. Rept.

26. Smith, C. D.

1898. Some of the factors determining the richness of milk. Proc. Soc. Prom. Agri. Science, pp. 152-155.

27. Arenander, E. O.

1899. The effect of food on the quality of milk. Nord. Mejeri Tidn., 14, No. 6, pp. 76-77; No. 7, p. 91.

Exp. Sta. Record, Vol. 11, p. 184

28. Cranefield, H. T. and Taylor, G. D.

1915. The effect of feeding on the composition of milk and butter: Linseed cake and hempseed cake. Analyst, Vol. 40, p. 433.

29. Richmond, H. D.

1920. Dairy Chemistry, 3d edition, pp. 305-307. Charles Griffin and Co., Ltd., London.

30. Lythgoe, H. C.

1917. Sixth annual rept. of the International Assn. of Dairy and Milk Inspectors, Wash. D.C. p. 94.

31. Vieth,

1899. Food and milk production. Rothamsted Memoirs on Agr. Chem., and Physiology, Sir. John Bennett Lawes, and Sir J. Henry Gilbert. Vol. VII, (Supplementary) Spottiswoode and Co., London.

32. Richmond, H. D.

1920. Dairy Chemistry, 3d edition, pp. 305-307. Charles Griffin and Co., Ltd., London.

33. Ingle, Herbert

1903. Variations in the composition of cow's milk. Trans. Highl. and Agr. Soc. of Scotland, 5th series, Vol. XV, pp. 135-182.

34. Crowther, Chas.

1905. Variations in the composition of cow's milk. A resume of recent experimental work in Great Britain. Jour. Agr. Sci., Vol. I, No. 2, pp. 149-175.

35. Dymond, T. S. and Bull, B. W.

1903 and 1904. Variation in the milk of a dairy herd during the winter and summer months. Essex Education Comm., County Tech. Labs., March (1903) p. 19 and March (1904) p. 15.

36. Juritz, C. F.

1912. Seasonal variations in composition of Cape Peninsula and Kimberley milk. Agr. Jour. Union So. Africa, 4; No. 3, pp. 382-390.

37. Van Slyke, L. L. and Publow, C. A.

1910. The Science and practice of cheese making, Orange Judd Co., New York.

38. Smith, D.C.

1898. Some of the factors determining the richness of milk. Proc. Soc. Prom. Agr. Science, pp. 152-155.

39. Sherman, H. C.

1906. Seasonal variations in the composition of cows' milk. Jour. Amer. Chem. Soc., 28, No. 12. pp. 1719-1723

40. Eckles, C. H.

1909. Jahreszeitliche Schwankungen des Prozentischen Fettgehaltes in Kuhmilch. Milchwirtschaftliches Zentralblatt. Heft 11, Verlag von M. Heinsius. Nachfolger in Leipzig, pp. 488-502.

41. Boardman, W. K.

1896. Tenth Annual Report, State Dairy Commissioner of Iowa, pp.73-75.

42. White, G. C. and Judkins, H. F.

1918. Variations in the fat, solids-not-fat, and total solids in cow's milk. Conn. (Storrs) Agric. Exp. Sta. Bul. 94.

43. Hills, J. L.

1895. Variations in milk. Vermont Agr. Exp. Sta. Rept. pp.157-186.

44. Thorndike, E. L.

1913. The nature and causes of the variations in the richness in butterfat of milk from the same cow. Guern. Breeders' Jour. new series, 4, No. 5, pp. 35-39.

45. Clothier, R. W.

1919. Seasonal variation in butterfat content of milk in southern Arizona. Proc. 39th Annual Meeting of the Society for the Prom. of Agr. Sci., pp. 75-112.

46. Cooke, W. W. and Hills, J. L.

1891. Vt. Agr. Exp. Sta. Rept. pp. 59-74.

47. Richmond, H. D.

1920. Dairy Chemistry, 3d edition, pp. 305-307. Charles Griffin & Co., Ltd., London.

48. Gilchrist, D. A.

1903. Variations in the composition of milk and their probable causes. County Councils Cumberland, Durham and Northumberland, Agr. Dept. Durham Col. Sci. Rept. 12, pp. 54-75.

49. Ingersoll, C. L. and Duncanson, H. B.

1893. The influence of change of food and temperature on quantity and quality of the milk of dairy cows. Nebr. Agr. Exp. Sta. Bul. pp. 44-65.

50. True, G. H.

1902. Exp. Sta. Work, Vol. I, No. 20, pp. 28-31.

51. Farrington, E.H.

1891. Daily variations in the milk and butter production of cows. Ill. Agr. Exp. Sta. Bul. 17, pp. 9-16.

52. Brooks, Wm. P.

1895. Mass. (Hatch) Agr. Exp. Sta. Rept. 1895. p. 40

53. Richards, W. B. and Jordan, E. L.

1904. The effect of different stable temperatures upon the milk yield of dairy cows. Wis. Agr. Exp. Sta. Rept. pp. 143-148.

54. Spier, John

1909. Influence of temperature on milk yield. Experiments in the production of milk in winter under free versus restricted ventilation. Jour. Highland and Agr. Soc. pp. 255-306

55. Ragsdale, A. C. and Brody

1922. The effect of temperature on the percentage of fat in milk: A first report. Jour. of Dairy Science, Vol. V, No. 2

56, Weiske, and Graffenberger,

1895. The influence of light on animal metabolism. Milch Ztg., 24, No. 46, p. 747.

57. Milroy, A. J. and Robertson, Monica.

1907. In Metabolism and Practical Medicine, Physiology, Vol. I, edited by Carl von Norden, W. T. Keener Co., Chicago. pp. 244-245.

58. Rubner, M. and Cramer,

1900. Cited by Milroy and Robertson. Metabolism and Practical Medicine, Physiology, Vol. I, edited by Carl von Norden, W. T. Keener Co., Chicago, pp. 244-245.

59. Milroy, A. J. and Robertson, Monica

1907. Metabolism and Practical Medicine, Physiology, Vol. I, edited by Carl von Norden, W. T. Keener Co., Chicago, pp. 244-245.

60. Murschhauser, H.

1912. Gaseous exchange at extreme external temperatures in relation to body surface area. Hoppe-Seyler's Zeitschr. Physiol. Chem. 79, No. 5, pp. 301-326; Abstract in Jour. Chem. Soc. (London), 102, No. 598, II, p. 776.

61. Pembrey, M. S.

1908. In Recent Advances in Physiology and Bio-Chemistry. Edited by Leonard Hill, 2d Impression, Edward Arnold, London, pp 508-9

62. Senator,

1872. Die Wärmebildung und den Stoffwech, Dubois Archiv. Cited in Metabolism and Practical Medicine, Vol. I, The Physiology of Metabolism, Anglo-American issue under Editorship I. W. Hall, W. T. Keener & Co., Chicago, pp. 246-247.

63. Speck,

1893. Phys. d. mensch Atmens. (Kop. 12-14) und Deutsches Archiv für klin. Medicin. Cited by Senator, 1872. Die Wärmebildung und den Stoffwech. Dubois Archiv. Metabolism and Practical Medicine, Vol. I, The Physiology of Metabolism, Anglo-American issue under Editorship of I. W. Hall, W. T. Keener & Co., Chicago, pp. 246-247.

64. Loewy, A.

1889. U. den Einfluss der Abkühlung auf den Gaswechsel. Archiv für die gesammte Physiol. des Menschen. (Pflüger's) 46, p. 189.

65. Johansson,

1897. U. d. Einfluss der Temperatur, und Umgebung a. d. CO_2 Abgabe Skandinavisches Archiv für Physiologie 7, p. 123.

66. Rubner, M.

1900. Arch. Hyg. 38, No12, pp. 120-147. Cited by Hill, Leonard in Recent Advances in Physiology and Bio-chemistry, Edward Arnold Co., London, p. 268.

67. Mac Leod, J J. R. and Hill, Leonard

1908. Cited by Hill, Leonard in Recent Advances in Physiology and Biochemistry, Edward Arnold Co., London, p. 269.

68. Thomson, William

1912-1913. The influence of moisture in the air on metabolism in the body. Manchester Literary and Philosophical Society, Memoirs and Proceedings, Vol. 57, No. 14.

69. Loewy, A. and Zuntz, L.

1908. Cited by Hill, Leonard in Recent Advances in Physiology and Biochemistry, Edward Arnold Co., London, p. 229.

70. Jaquet,

1901. Cited in Physiol. of Metabolism (Physiology) Anglo-American issue under editorship of I. W. Hall, W. T. Keener & Co., Chicago, pp. 256-257.

71. Thomson, William

1912-1913. On the influence of atmospheric pressure, temperature, and humidity on animal metabolism. Manchester Literary and Philosophical Society. Memoirs and Proceedings, Vol. 57, No. 13.

72. Seidell, Atherton Seidell and Fenger, Frederic.

1912. Seasonal variation in the iodine content of the thyroid gland. Jour. Biol. Chem. Vol. 13, pp. 517-526.

73. Ulmansky, S.

1913. Influence of Alpine pastures and meteorological factors on milk production of 27 cows belonging to the herd of the Agricultural School at Rotholz. Mitt. Landw. Lehrkanz, K.K. Hochsch. Bodenkul. Wien, 1, No. 3, pp. 339-392.

TABLE 3

AVERAGE PERCENT OF BUTTERFAT BY MONTHS
GROUPING BASED UPON MONTH OF CALVING
From Records of University Farm Herd

Month of Calving	January	February	March	April	May	June	July	August	September	October	November	December
Number of Lactations	35	42	43	23	12	25	21	48	84	88	68	64
	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat
January	4.55	-	-	-	-	-	-	-	-	-	-	-
February	4.41	4.38	-	-	-	-	-	-	-	-	-	-
March	4.39	4.28	4.44	-	-	-	-	-	-	-	-	-
April	4.44	4.25	4.27	4.34	-	-	-	-	-	-	-	-
May	4.58	4.38	4.27	4.34	4.32	-	-	-	-	-	-	-
June	4.49	4.37	4.32	4.27	4.41	4.37	-	-	-	-	-	-
July	4.48	4.31	4.30	4.19	4.28	4.35	4.26	-	-	-	-	-
August	4.65	4.33	4.25	4.32	4.36	4.17	4.10	4.03	-	-	-	-
September	4.94	4.61	4.64	4.62	4.44	4.39	4.37	4.14	4.17	-	-	-
October	4.84	4.76	4.81	4.82	4.68	4.56	4.54	4.40	4.29	4.12	-	-
November	4.95	4.98	5.06	4.83	4.72	4.69	4.77	4.66	4.51	4.18	4.33	-
December	5.07	5.28	5.13	4.86	4.74	4.70	4.93	4.79	4.63	4.27	4.40	4.19
January	-	5.05	5.13	4.92	4.88	4.78	4.88	4.84	4.68	4.34	4.42	4.17
February	-	-	5.00	4.84	4.96	4.86	4.93	4.91	4.68	4.42	4.51	4.07
March	-	-	-	4.94	5.16	4.85	4.85	4.83	4.64	4.44	4.58	4.10
April	-	-	-	-	5.06	4.83	4.83	4.89	4.68	4.77	4.65	4.21
May	-	-	-	-	-	5.00	4.94	4.94	4.75	4.58	4.73	4.28
June	-	-	-	-	-	-	4.93	4.95	4.72	4.46	4.54	4.24
July	-	-	-	-	-	-	-	5.03	4.76	4.61	4.75	4.27
August	-	-	-	-	-	-	-	-	4.90	4.78	4.70	4.39
September	-	-	-	-	-	-	-	-	-	4.80	4.97	4.51
October	-	-	-	-	-	-	-	-	-	-	4.77	4.67
November	-	-	-	-	-	-	-	-	-	-	-	4.92

4-22-6M

TABLE 4

AVERAGE PERCENT OF BUTTERFAT BY MONTHS
GROUPING BASED UPON MONTH OF CALVING
From Records of Holstein-Friesians, University Farm Herd

Month of Calving	January	February	March	April	May	June	July	August	September	October	November	December
Number of Lactations	10	6	9	4	4	4	6	14	23	26	13	20
	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat
January	3.49	-	-	-	-	-	-	-	-	-	-	-
February	3.19	3.63	-	-	-	-	-	-	-	-	-	-
March	3.24	3.81	3.69	-	-	-	-	-	-	-	-	-
April	3.26	3.31	3.11	4.15	-	-	-	-	-	-	-	-
May	3.37	3.38	3.29	3.57	3.45	-	-	-	-	-	-	-
June	3.34	3.66	3.20	3.40	3.07	3.47	-	-	-	-	-	-
July	3.40	3.52	3.19	3.42	3.42	3.22	3.82	-	-	-	-	-
August	3.37	3.48	3.24	3.54	3.45	3.20	3.62	3.35	-	-	-	-
September	3.66	3.63	3.41	3.48	3.27	3.22	3.51	3.11	3.38	-	-	-
October	3.96	3.61	3.48	3.61	3.45	3.30	3.58	3.12	3.30	3.44	-	-
November	3.54	3.90	3.73	3.80	3.60	3.27	3.53	3.23	3.38	3.36	3.45	-
December	3.71	3.35	3.60	3.40	3.65	3.30	3.90	3.22	3.38	3.40	3.23	3.46
January	-	3.60	3.54	3.76	3.92	3.22	3.71	3.27	3.39	3.42	3.22	3.30
February	-	-	3.47	3.49	3.37	3.37	3.83	3.30	3.37	3.43	3.29	3.23
March	-	-	-	3.73	3.83	3.32	3.75	3.30	3.50	3.45	3.41	3.25
April	-	-	-	-	3.73	3.47	3.64	3.39	3.51	3.52	3.49	3.31
May	-	-	-	-	-	3.62	3.88	3.50	3.58	3.64	3.59	3.45
June	-	-	-	-	-	-	3.96	3.57	3.58	3.52	3.58	3.36
July	-	-	-	-	-	-	-	3.82	3.64	3.70	3.69	3.54
August	-	-	-	-	-	-	-	-	3.84	3.74	3.45	3.57
September	-	-	-	-	-	-	-	-	-	3.51	3.71	3.47
October	-	-	-	-	-	-	-	-	-	-	3.72	3.64
November	-	-	-	-	-	-	-	-	-	-	-	3.78

TABLE 5

AVERAGE PERCENT OF BUTTERFAT BY MONTHS
GROUPING BASED UPON MONTH OF CALVING
From Records of Jerseys, University Farm Herd

Month of Calving	January	February	March	April	May	June	July	August	September	October	November	December
Number of Lactations	13	12	10	3	3	6	5	16	40	23	24	14
	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat
January	4.94	-	-	-	-	-	-	-	-	-	-	-
February	4.94	5.08	-	-	-	-	-	-	-	-	-	-
March	5.11	5.03	5.16	-	-	-	-	-	-	-	-	-
April	5.23	5.01	5.40	5.34	-	-	-	-	-	-	-	-
May	5.43	5.13	5.55	5.58	4.52	-	-	-	-	-	-	-
June	5.19	5.17	5.37	5.36	5.01	4.39	-	-	-	-	-	-
July	5.15	5.08	5.21	5.37	4.94	4.55	4.88	-	-	-	-	-
August	5.36	5.15	5.29	5.39	5.01	4.44	4.49	4.53	-	-	-	-
September	5.66	5.43	5.63	5.70	5.19	4.68	5.24	4.54	4.62	-	-	-
October	5.70	5.53	5.86	5.92	5.49	5.03	5.29	5.01	4.94	4.57	-	-
November	5.96	5.77	6.23	6.13	5.32	5.28	6.02	5.31	5.22	4.80	4.58	-
December	5.44	5.99	6.49	6.67	5.36	5.36	6.21	5.53	5.40	4.97	4.98	4.90
January	-	5.99	6.34	6.43	5.61	5.87	6.23	5.55	5.50	5.18	5.03	4.76
February	-	-	6.64	6.45	5.39	5.44	6.04	5.69	5.48	5.23	5.09	5.05
March	-	-	-	6.09	5.56	5.30	5.93	5.58	5.35	5.39	5.16	4.47
April	-	-	-	-	5.36	5.44	5.93	5.66	5.38	5.30	5.31	5.37
May	-	-	-	-	-	5.66	5.94	5.63	5.48	5.41	5.30	5.40
June	-	-	-	-	-	-	5.87	5.61	5.29	5.33	5.27	5.34
July	-	-	-	-	-	-	-	5.79	5.19	5.39	5.18	5.22
August	-	-	-	-	-	-	-	-	5.30	5.43	5.19	5.18
September	-	-	-	-	-	-	-	-	-	5.57	5.46	5.45
October	-	-	-	-	-	-	-	-	-	-	5.64	5.54
November	-	-	-	-	-	-	-	-	-	-	-	5.67

4-22-8M

TABLE 6

AVERAGE PERCENT OF BUTTERFAT BY MONTHS
GROUPING BASED UPON MONTH OF CALVING
From Records of Guernseys, University Farm Herd

Month of Calving	January	February	March	April	May	June	July	August	September	October	November	December
Number of Lactations	14	4	2	3	4	2	6	7	13	17	7	7
	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat
January	5.27	-	-	-	-	-	-	-	-	-	-	-
February	5.12	4.67	-	-	-	-	-	-	-	-	-	-
March	5.23	4.07	4.85	-	-	-	-	-	-	-	-	-
April	5.20	4.07	4.09	3.95	-	-	-	-	-	-	-	-
May	5.29	4.60	4.28	4.53	4.62	-	-	-	-	-	-	-
June	5.00	4.40	4.26	4.40	4.85	4.80	-	-	-	-	-	-
July	5.09	4.45	4.55	4.15	4.78	4.50	4.81	-	-	-	-	-
August	5.19	4.54	4.55	4.18	4.92	4.55	4.44	4.43	-	-	-	-
September	5.38	4.89	4.87	4.90	5.03	4.80	4.80	4.54	4.49	-	-	-
October	5.50	5.12	5.10	5.05	5.27	5.20	5.10	4.61	4.63	4.15	-	-
November	5.72	5.00	5.46	5.12	5.27	5.00	5.27	4.80	4.84	4.54	4.66	-
December	5.77	5.02	5.65	5.43	5.42	5.30	5.34	5.08	5.08	4.65	4.56	4.88
January	-	4.78	5.62	5.33	5.48	5.40	5.41	5.07	5.13	5.14	4.65	4.76
February	-	-	5.95	5.31	5.50	5.30	5.31	5.15	5.18	4.64	4.86	4.68
March	-	-	-	5.40	5.61	5.30	5.36	5.18	5.24	5.01	5.01	4.76
April	-	-	-	-	5.64	5.45	5.41	5.07	5.22	4.96	4.98	4.71
May	-	-	-	-	-	5.60	5.39	5.10	5.24	4.99	5.22	4.95
June	-	-	-	-	-	-	5.30	5.17	5.29	4.91	5.05	4.76
July	-	-	-	-	-	-	-	5.58	5.29	5.13	5.41	4.75
August	-	-	-	-	-	-	-	-	5.14	5.47	5.48	5.06
September	-	-	-	-	-	-	-	-	-	5.61	6.15	4.99
October	-	-	-	-	-	-	-	-	-	-	5.65	5.22
November	-	-	-	-	-	-	-	-	-	-	-	5.37

TABLE 7

AVERAGE PERCENT OF BUTTERFAT BY MONTHS
GROUPING BASED UPON MONTH OF CALVING
From Advanced Registry Holstein-Friesian Records in Minnesota

Month of Calving	January	February	March	April	May	June	July	August	September	October	November	December
Number of Lactations	96	89	82	52	64	40	26	25	40	74	81	95
	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat
January	3.65	-	-	-	-	-	-	-	-	-	-	-
February	3.36	3.65	-	-	-	-	-	-	-	-	-	-
March	3.29	3.37	3.68	-	-	-	-	-	-	-	-	-
April	3.27	3.24	3.37	3.67	-	-	-	-	-	-	-	-
May	3.24	3.22	3.20	3.42	3.66	-	-	-	-	-	-	-
June	3.21	3.20	3.20	3.16	3.32	3.55	-	-	-	-	-	-
July	3.30	3.17	3.28	3.27	3.25	3.28	3.50	-	-	-	-	-
August	3.32	3.27	3.26	3.22	3.26	3.14	3.73	3.38	-	-	-	-
September	3.48	3.35	3.38	3.21	3.12	3.19	3.21	3.21	3.36	-	-	-
October	3.52	3.40	3.36	3.37	3.33	3.29	3.18	3.39	3.27	3.47	-	-
November	3.51	3.51	3.50	3.38	3.40	3.37	3.34	3.40	3.30	3.36	3.46	-
December	3.54	3.58	3.63	3.54	3.48	3.38	3.35	3.38	3.28	3.25	3.33	3.53
January	-	3.59	3.71	3.56	3.46	3.44	3.40	3.31	3.32	3.26	3.29	3.37
February	-	-	3.60	3.57	3.47	3.47	3.43	3.36	3.29	3.23	3.23	3.28
March	-	-	-	3.62	3.54	3.50	3.42	3.49	3.32	3.36	3.29	3.25
April	-	-	-	-	3.65	3.39	3.49	3.61	3.38	3.38	3.35	3.32
May	-	-	-	-	-	3.41	3.44	3.51	3.38	3.36	3.30	3.24
June	-	-	-	-	-	-	3.62	3.62	3.38	3.43	3.26	3.26
July	-	-	-	-	-	-	-	3.74	3.67	3.48	3.54	3.30
August	-	-	-	-	-	-	-	-	3.80	3.50	3.68	3.43
September	-	-	-	-	-	-	-	-	-	3.52	3.67	3.50
October	-	-	-	-	-	-	-	-	-	-	3.61	3.46
November	-	-	-	-	-	-	-	-	-	-	-	3.64

4-22-8M

TABLE 8

AVERAGE PERCENT OF BUTTERFAT BY MONTHS
GROUPING BASED UPON MONTH OF CALVING
From Jersey Register of Merit Records in Minnesota

Month of Calving	January	February	March	April	May	June	July	August	September	October	November	December
Number of Lactations	8	18	19	18	13	10	5	4	5	7	8	10
	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat
January	4.89	-	-	-	-	-	-	-	-	-	-	-
February	4.89	5.25	-	-	-	-	-	-	-	-	-	-
March	5.18	5.18	4.72	-	-	-	-	-	-	-	-	-
April	5.18	5.05	4.55	4.72	-	-	-	-	-	-	-	-
May	5.60	5.18	4.74	4.81	4.79	-	-	-	-	-	-	-
June	5.46	5.37	4.87	5.11	4.97	4.92	-	-	-	-	-	-
July	5.78	5.25	4.78	5.06	4.75	4.67	4.61	-	-	-	-	-
August	5.62	5.51	5.05	5.29	4.88	4.99	4.84	4.43	-	-	-	-
September	6.08	5.77	5.46	5.70	5.38	5.50	5.15	4.82	4.61	-	-	-
October	5.32	5.79	5.78	5.65	5.29	5.60	5.56	4.61	5.26	4.72	-	-
November	5.24	6.37	6.12	6.15	5.73	5.97	5.89	5.32	5.56	5.33	4.82	-
December	4.97	6.72	5.87	6.19	5.74	6.00	6.03	5.11	5.49	5.52	5.02	5.43
January	-	6.57	6.36	6.29	6.00	6.30	6.12	5.47	5.43	5.28	5.40	5.27
February	-	-	6.24	6.33	5.63	5.83	6.06	5.35	5.40	5.14	5.22	5.38
March	-	-	-	6.82	6.54	5.66	5.90	5.35	5.37	5.26	5.35	5.02
April	-	-	-	-	6.58	5.50	6.21	5.20	5.44	5.25	5.52	5.62
May	-	-	-	-	-	5.51	5.74	5.16	5.66	5.08	5.29	5.38
June	-	-	-	-	-	-	5.28	5.28	5.53	5.14	5.31	5.19
July	-	-	-	-	-	-	-	5.19	5.19	5.25	5.47	5.40
August	-	-	-	-	-	-	-	-	5.90	5.12	5.30	5.65
September	-	-	-	-	-	-	-	-	-	5.96	5.74	6.02
October	-	-	-	-	-	-	-	-	-	-	5.51	5.76
November	-	-	-	-	-	-	-	-	-	-	-	6.25

TABLE 9

AVERAGE PERCENT OF BUTTERFAT BY MONTHS
GROUPING BASED UPON MONTHOF CALVING
From Advanced Register Guernsey Records in the United States

Month of Calving	January	February	March	April	May	June	July	August	September	October	November	December
Number of Lactations	74	85	142	141	118	111	74	72	101	131	161	108
	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat	Av. % Fat
January	4.54	-	-	-	-	-	-	-	-	-	-	-
February	4.69	4.52	-	-	-	-	-	-	-	-	-	-
March	4.92	4.58	4.64	-	-	-	-	-	-	-	-	-
April	4.93	4.68	4.56	4.60	-	-	-	-	-	-	-	-
May	5.03	4.81	4.70	4.57	4.53	-	-	-	-	-	-	-
June	5.06	4.83	4.66	4.59	4.48	4.43	-	-	-	-	-	-
July	5.07	4.86	4.84	4.71	4.60	4.45	4.21	-	-	-	-	-
August	5.21	4.98	4.94	4.84	4.72	4.54	4.28	4.37	-	-	-	-
September	5.46	5.37	5.21	5.17	4.94	4.82	4.62	4.46	4.46	-	-	-
October	5.65	5.53	5.42	5.35	5.17	5.14	4.79	4.77	4.54	4.55	-	-
November	5.98	5.62	5.62	5.50	5.39	5.43	5.13	5.06	4.96	4.75	4.69	-
December	5.88	5.78	5.73	5.80	5.57	5.49	5.17	5.26	5.13	5.00	4.77	4.65
January	-	5.95	5.86	5.77	5.62	5.57	5.29	5.31	5.24	5.13	4.96	4.64
February	-	-	5.84	5.81	5.66	5.61	5.26	5.32	5.25	5.16	5.08	4.74
March	-	-	-	5.86	5.65	5.60	5.36	5.34	5.27	5.15	5.16	4.92
April	-	-	-	-	5.35	5.64	5.37	5.32	5.28	5.20	5.17	4.99
May	-	-	-	-	-	5.73	5.40	5.34	5.23	5.15	5.20	5.10
June	-	-	-	-	-	-	5.53	5.35	5.29	5.15	5.11	5.04
July	-	-	-	-	-	-	-	5.43	5.30	5.28	5.20	5.07
August	-	-	-	-	-	-	-	-	5.47	5.39	5.29	5.17
September	-	-	-	-	-	-	-	-	-	5.58	5.50	5.41
October	-	-	-	-	-	-	-	-	-	-	5.62	5.57
November	-	-	-	-	-	-	-	-	-	-	-	5.43

TABLE 10

AVERAGE PERCENT OF BUTTERFAT BY MONTHS OF LACTATION PERIOD
GROUPING BASED UPON HERD OR BREED

Month of Lactation	BREED OR HERD							
	Univ. Farm	Holsteins Univ. Farm	Jerseys Univ. Farm	Guernseys Univ. Farm	Holsteins A.R. in Minn.	R.M. Jerseys in Minnesota	A.R. Guernseys in U. S.	Average
1st	4.291	3.565	4.792	4.631	3.546	4.825	4.516	4.309
2nd	4.278	3.324	4.918	4.552	3.365	4.967	4.564	4.281
3d	4.305	3.310	5.077	4.631	3.250	5.120	4.756	4.349
4th	4.405	3.340	5.127	4.806	3.292	5.213	4.896	4.439
5th	4.501	3.385	5.352	4.874	3.269	5.380	5.046	4.544
6th	4.571	3.435	5.439	4.975	3.287	5.481	5.148	4.619
7th	4.655	3.481	5.478	5.071	3.343	5.558	5.234	4.688
8th	4.687	3.545	5.575	5.135	3.379	5.666	5.320	4.758
9th	4.787	3.599	5.658	5.268	3.471	5.752	5.422	4.851
10th	4.832	3.604	5.664	5.306	3.519	5.717	5.500	4.877
11th	4.938	3.616	5.742	5.450	3.555	5.793	5.602	4.956
12th	4.955	3.657	5.751	5.482	3.628	5.898	5.639	5.001
Number of Lactations	553	139	169	86	764	125	1318	3154

T A B L E 11

VARIATIONS IN METEOROLOGICAL PHENOMENA
Monthly averages for ten year period

Month	Temperature	Relative Humidity	Atmospheric pressure	Vapor pressure
	degrees	Percent	inches	
January	7.8	78.5	29.168	.056
February	16.0	77.0	29.178	.076
March	35.0	66.6	29.118	.134
April	48.3	61.6	29.027	.198
May	59.0	58.3	29.031	.287
June	69.3	61.2	29.078	.423
July	71.7	62.3	29.049	.461
August	67.2	69.3	29.061	.437
September	66.3	71.0	29.097	.359
October	49.6	67.7	29.086	.231
November	29.3	73.0	29.089	.116
December	22.4	75.3	29.081	.093

TABLE 12

RELATION OF DAILY WEATHER CONDITIONS TO VARIATIONS IN FAT PERCENTAGE

January 1911	AVERAGE DAILY				State of Weather
	Percent Butterfat	Temperature	Relative Humidity	Vapor Pressure	Barometric Pressure	
		degrees	percent	inches	inches	
1	5.19	8	78	.041	28.928	Light snow
2	5.53	- 8	75	.024	29.293	Cloudy
3	5.44	-15	80	.013	29.377	Clear
4	5.57	2	79	.037	29.050	Cloudy
5	5.37	- 6	86	.025	29.143	Cloudy
6	5.32	4	85	.038	29.071	Cloudy
7	5.46	12	77	.054	28.793	Cloudy
8	5.27	15	70	.056	28.824	Cloudy
9	5.28	14	72	.060	29.088	Clear
10	5.23	18	64	.064	28.711	Clear
11	5.19	- 4	78	.025	29.250	Cloudy
12	5.21	10	84	.056	29.328	Cloudy
13	5.20	0	78	.032	29.382	Cloudy
14	5.43	- 4	73	.022	29.335	Clear
15	5.42	6	73	.035	29.507	Cloudy

TABLE 13

RELATION OF DAILY WEATHER CONDITIONS TO VARIATIONS IN FAT PERCENTAGE

1911	AVERAGE DAILY					STATE OF WEATHER		
June	Percent Butterfat	Temperature degrees	Relative Humidity %	Vapor Pressure inches	Barometric Pressure inches	% possible sunshine	Range of Temp.	Rainfall in.
1	4.38	68	62	.412	29.027	58	20	.02
2	4.28	66	81	.492	28.976	21	11	1.59
3	4.30	69	80	.566	29.010	47	20	.51
4	4.45	70	67	.476	28.985	71	22	.70
5	4.30	76	76	.598	28.945	80	29	T
6	4.44	67	53	.316	29.165	82	22	0
7	4.23	68	68	.448	29.194	92	22	0
8	4.34	75	67	.574	28.914	72	25	.45
9	4.21	82	64	.641	28.806	72	23	0
10	4.59	76	59	.499	28.833	76	15	0
11	4.28	62	75	.395	28.873	61	15	0
12	4.34	68	65	.424	28.932	71	17	.01
13	4.15	66	58	.373	29.028	74	20	.01
14	4.01	70	57	.383	29.028	89	22	0
15	4.33	68	66	.419	28.973	54	22	T
16	4.25	65	92	.536	28.936	5	8	.84
17	4.38	72	68	.499	29.002	87	23	0
18	3.94	74	53	.448	29.104	98	25	0
19	4.08	76	54	.486	29.144	100	26	0
20	4.41	80	46	.405	29.166	100	23	0
21	4.28	80	51	.501	29.099	99	26	0
22	4.22	81	69	.536	29.034	100	28	0
23	4.20	83	51	.536	28.916	100	22	0
24	4.26	80	70	.639	28.924	50	18	.06
25	4.15	78	81	.719	28.894	71	16	.02
26	4.32	68	78	.536	28.876	49	19	.67
27	4.24	56	70	.298	29.100	24	9	0
28	4.34	57	72	.362	29.153	69	22	0
29	4.10	71	77	.560	28.965	69	26	.28
30	4.15	84	56	.616	29.028	100	23	0

4-22-8M

TABLE 14

RELATION OF DAILY WEATHER CONDITIONS TO VARIATIONS IN FAT PERCENTAGE

1911 July	AVERAGE DAILY: Percent Butterfat	Temperature degrees	Relative Humidity %	Vapor Pressure inches	Barometric Pressure Inches	STATE OF WEATHER: Percent possible Sunshine	Range of Temperature degrees	Rainfall inches
1	4.69	88	51	.605	28.991	90	20	0
2	4.38	85	52	.538	28.974	73	28	.03
3	4.49	78	54	.484	29.101	88	21	0
4	4.06	79	70	.643	28.934	46	28	.61
5	4.24	76	75	.618	29.014	61	25	.16
6	4.61	70	61	.441	29.267	100	21	0
7	4.19	74	67	.563	29.079	58	21	.05
8	4.69	84	57	.616	28.874	100	21	0
9	4.22	75	65	.554	28.965	66	12	.11
10	4.70	73	50	.363	29.006	85	26	.01
11	4.48	68	50	.330	29.121	100	15	0
12	4.44	67	53	.335	29.245	99	26	0
13	4.53	70	51	.344	29.278	100	19	0
14	4.19	70	51	.362	29.227	99	27	0
15	4.58	72	59	.374	29.106	73	27	0
16	4.59	60	53	.266	29.195	97	18	0
17	4.54	64	50	.300	29.065	81	21	0
18	4.11	60	81	.396	28.949	7	9	1.23
19	4.62	63	65	.367	29.059	100	26	0
20	4.51	68	58	.354	29.013	68	27	.01
21	4.55	65	52	.322	29.061	100	24	0
22	4.56	70	55	.387	28.977	85	32	.01
23	4.52	63	74	.421	28.784	41	14	.86
24	4.24	55	76	.328	29.028	59	18	.10
25	4.37	62	60	.316	29.181	73	20	.01
26	3.95	66	58	.334	29.155	100	27	0
27	4.29	70	57	.369	28.961	56	18	1.14
28	4.53	72	59	.404	28.924	77	22	.33
29	4.49	73	72	.474	28.994	81	26	.07
30	4.38	78	59	.526	28.895	78	29	0
31	4.39	70	85	.576	28.849	11	11	.39

TABLE 15

RELATION OF DAILY WEATHER CONDITIONS TO VARIATIONS IN FAT PERCENTAGE

1911 August	AVERAGE DAILY					STATE OF WEATHER		
	Percent Butterfat	Temperature degrees	Relative Humidity %	Vapor Pressure inches	Barometric pressure inches	Percent possible sunshine	Range of Temperature degrees	Rainfall inches
1	4.82	64	73	.410	28.866	63	13	.02
2	4.17	66	57	.369	29.066	93	24	0
3	4.52	66	78	.469	29.005	36	12	.1
4	4.47	68	72	.473	28.947	90	17	.02
5	4.36	70	67	.465	29.021	100	22	0
6	4.40	68	87	.557	29.026	18	9	.34
7	4.39	66	86	.545	28.864	58	13	2.56
8	4.75	71	78	.547	29.013	68	26	0
9	4.47	70	67	.465	29.167	60	11	T
10	4.67	61	71	.395	29.193	15	8	.39
11	4.71	62	73	.397	29.328	81	18	0
12	4.63	65	76	.474	29.196	66	16	0
13	4.24	72	80	.606	29.099	39	14	0
14	4.39	76	69	.565	29.075	75	19	.68
15	4.66	77	67	.565	29.054	83	26	.34
16	4.61	75	69	.575	28.996	73	16	.02
17	4.15	69	63	.417	29.105	95	18	0
18	4.87	66	55	.361	29.226	100	18	0
19	4.70	66	61	.382	29.201	99	21	0
20	4.53	70	61	.450	29.068	100	26	0
21	4.53	70	53	.396	28.860	54	15	.46
22	4.79	58	63	.276	29.267	100	17	0
23	4.48	60	61	.282	29.364	87	25	0
24	4.46	64	73	.389	29.202	62	13	.02
25	4.80	65	69	.360	29.034	87	24	0
26	4.76	68	61	.394	28.958	72	24	.09
27	4.48	58	75	.310	29.061	56	15	0
28	4.66	54	60	.244	29.267	96	19	0
29	4.95	57	67	.289	29.325	87	26	0
30	4.76	58	81	.380	29.113	31	15	.44
31	4.71	70	63	.436	29.024	100	29	.02

TABLE 16

A - CORRELATION OF DAILY RELATIVE HUMIDITY TO BUTTERFAT PERCENTAGE

RELATIVE HUMIDITY PERCENT	Percent Fat					
	3.75-3.99	4.00-4.24	4.25-4.49	4.50-4.75	4.75-4.99	F_h
40-49	-	-	1	-	-	1
50-59	1	7	8	13	2	31
60-69	-	6	11	8	4	29
70-79	-	5	9	5	2	21
80-89	-	3	5	-	1	9
90-99	-	-	1	-	-	1
F_f	1	21	35	26	9	92

$\sigma h = 10.432$

$\sigma f = .2363$

$r_{fh} = -.0887 \mp .06975$

B - CORRELATION OF DAILY TEMPERATURE TO BUTTERFAT PERCENTAGE

TEMPERATURE DEGREES	Percent Fat					
	3.75-3.99	4.00-4.24	4.25-4.49	4.50-4.74	4.75-4.99	F_t
50-59	-	2	2	1	3	8
60-69	1	5	17	11	4	38
70-79	1	10	12	11	1	35
80-89	-	4	5	2	-	11
F_f	2	21	36	25	8	92

$\sigma t = 8.136$

$\sigma f = .237$

$r_{tf} = -.353 \mp .060$

TABLE 18

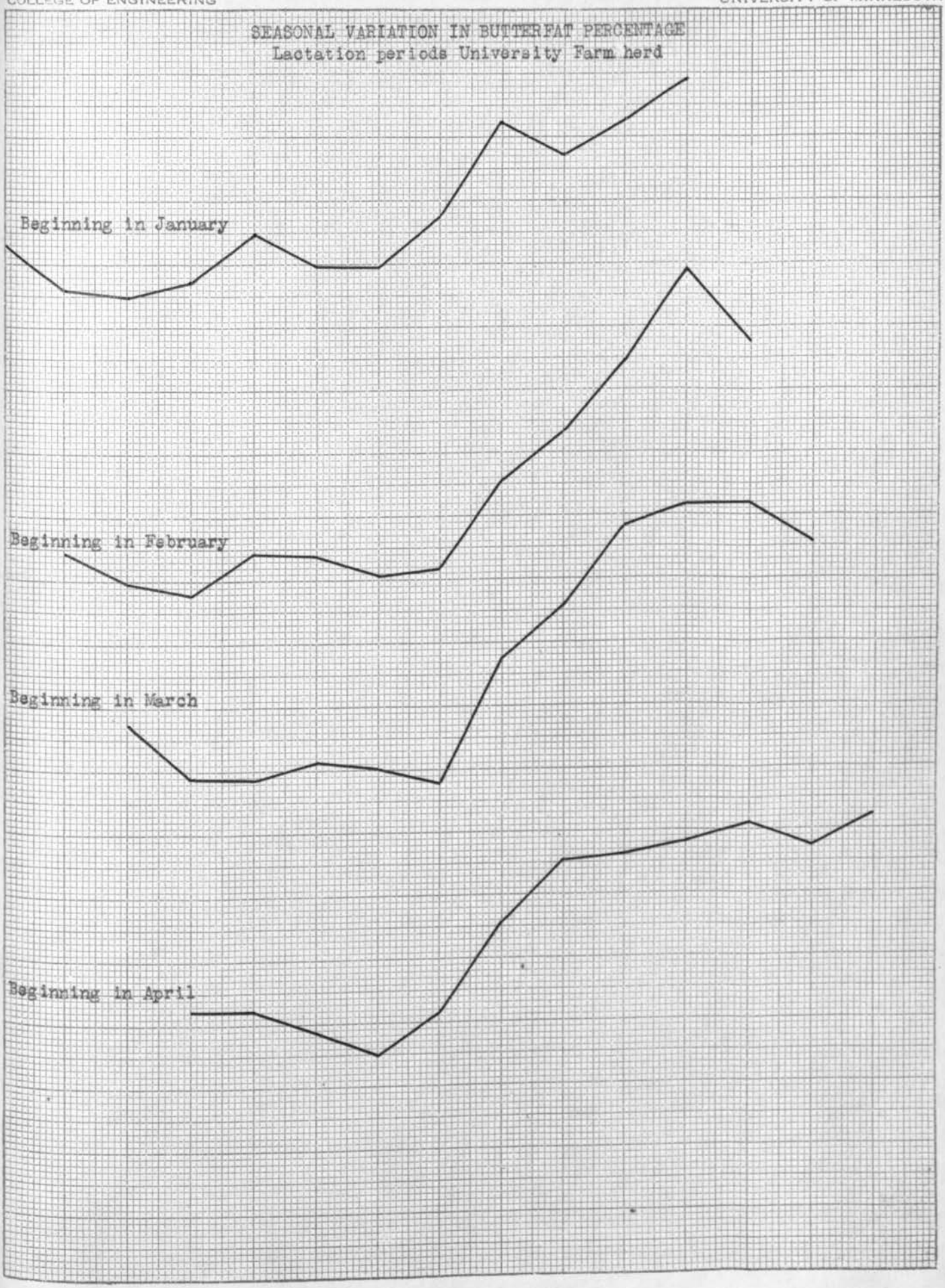
THE COMBINED EFFECT OF DAILY TEMPERATURE
AND RELATIVE HUMIDITY ON BUTTERFAT PERCENTAGE

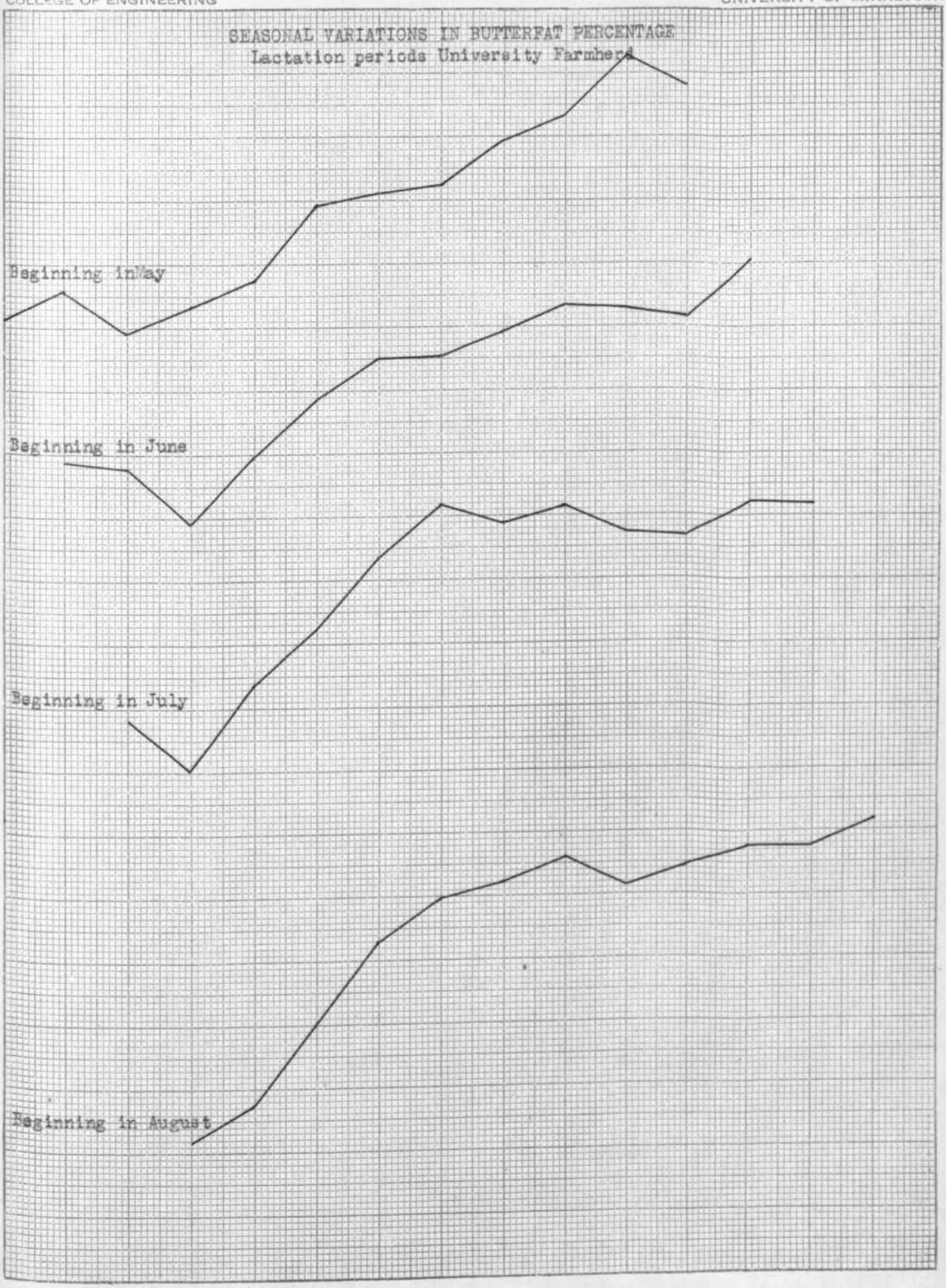
Average Relative Humidity	Temperature below 70°F		Temperature above 70°F	
	No. milkings	Av. % Fat	No. milkings	Av. % Fat
Below 70 percent	500	4.490	720	4.404
Above 70 percent	420	4.437	200	4.298

ENG. 4
COLLEGE OF ENGINEERING

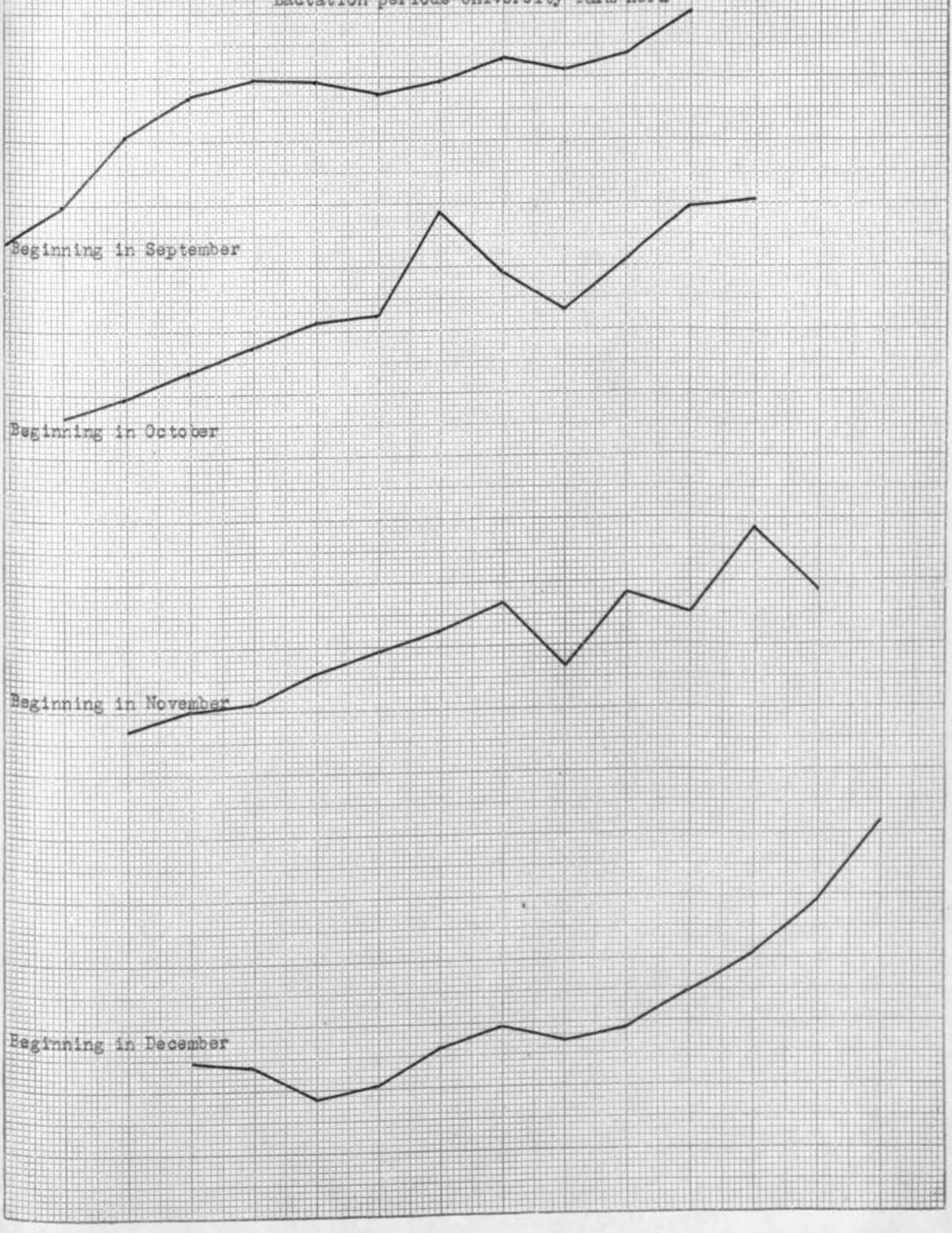
CHART 1

1-22-SM
UNIVERSITY OF MINNESOTA




SEASONAL VARIATIONS IN BUTTERFAT PERCENTAGE
Lactation periods University Farmherd
Beginning inMay
Beginning in June
Beginning in July
Beginning in August

SEASONAL VARIATIONS IN BUTTERFAT PERCENTAGE
Lactation periods University Farm herd

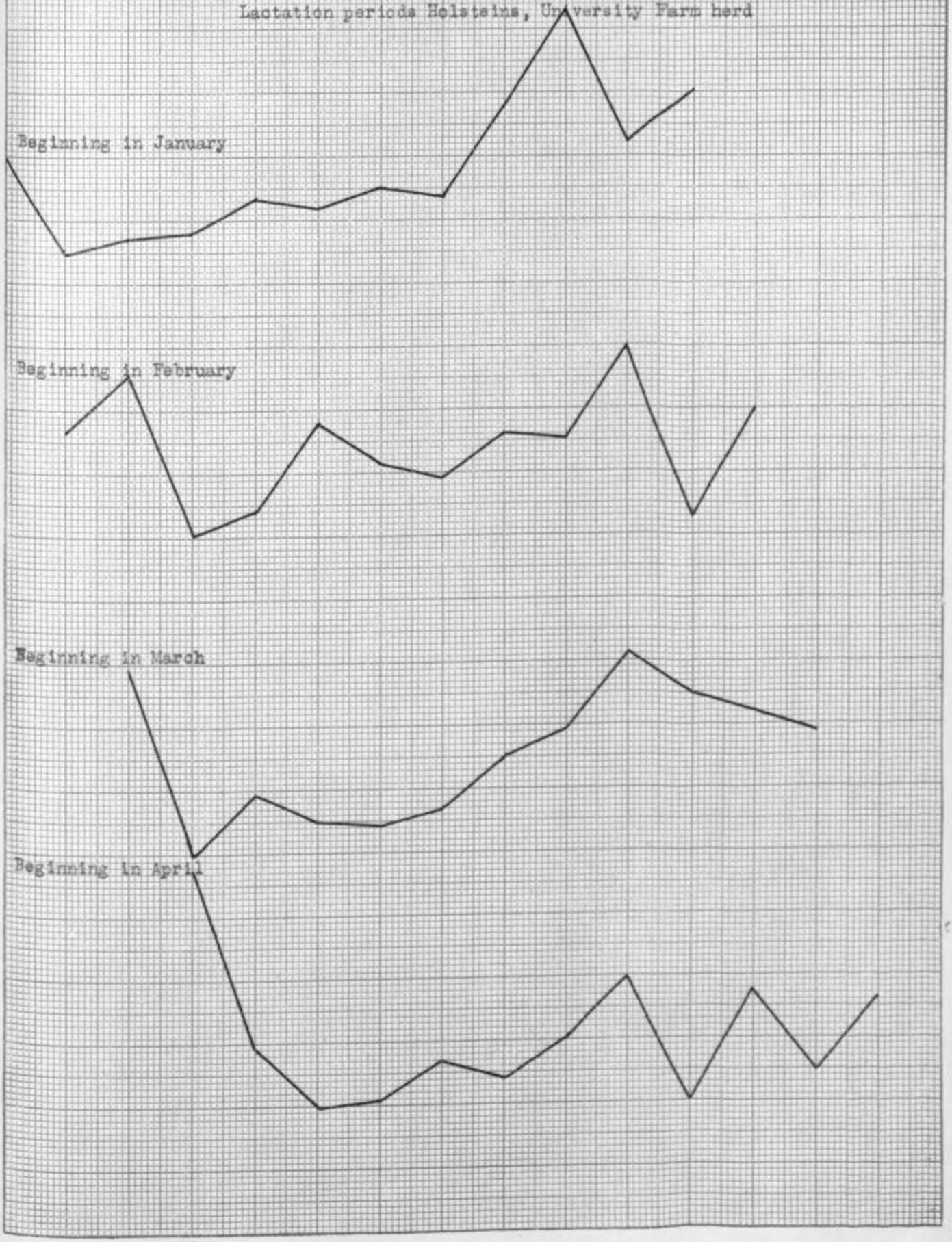


ENG. 4
COLLEGE OF ENGINEERING

CHART 4

1-22-8M
UNIVERSITY OF MINNESOTA

SEASONAL VARIATIONS IN BUTTERFAT PERCENTAGE
Lactation periods Holsteins, University Farm herd

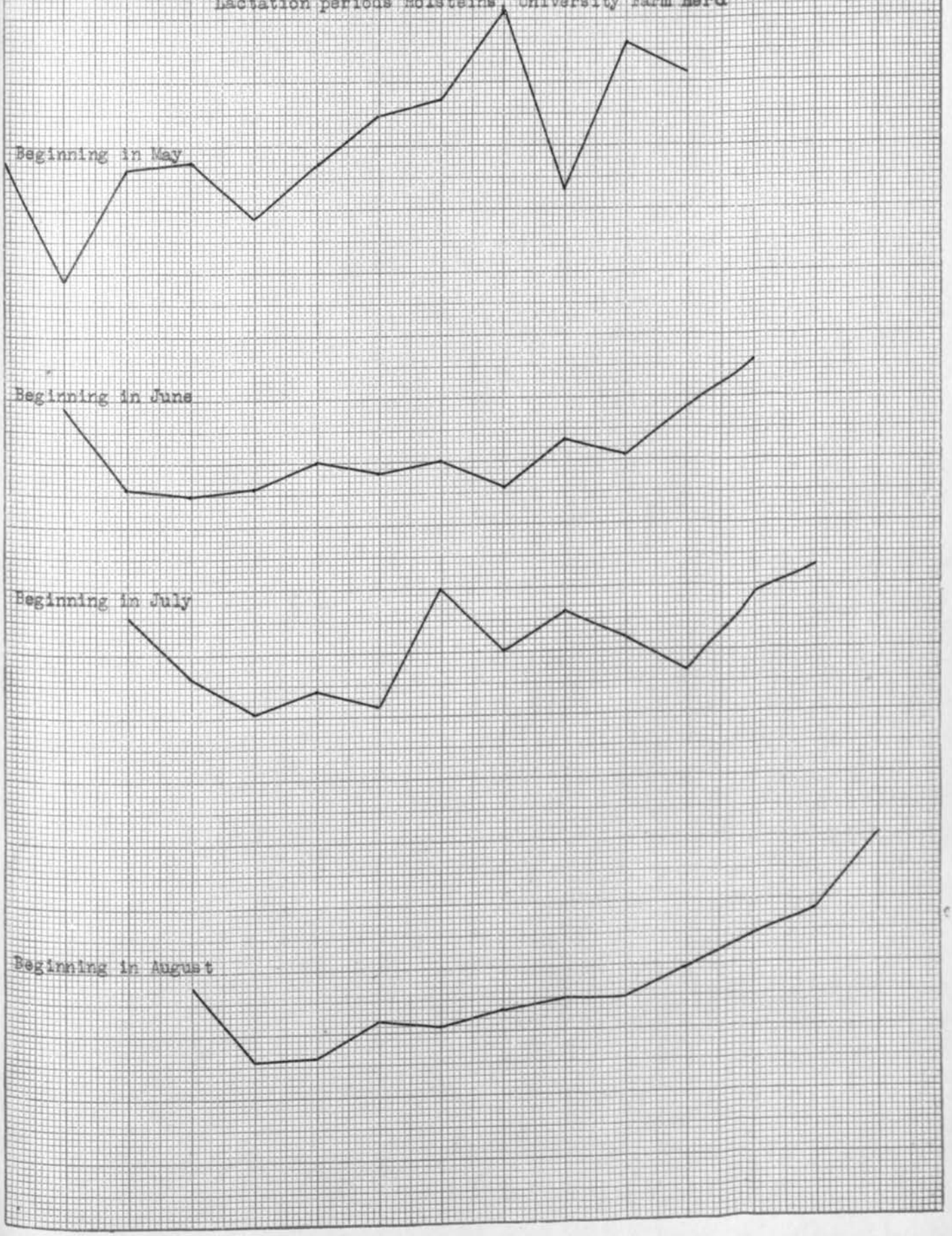


ENG. 4
COLLEGE OF ENGINEERING

CHART 5

1-22-8M
UNIVERSITY OF MINNESOTA

SEASONAL VARIATIONS IN BUTTERFAT PERCENTAGE
Lactation periods Holsteins, University Farm herd

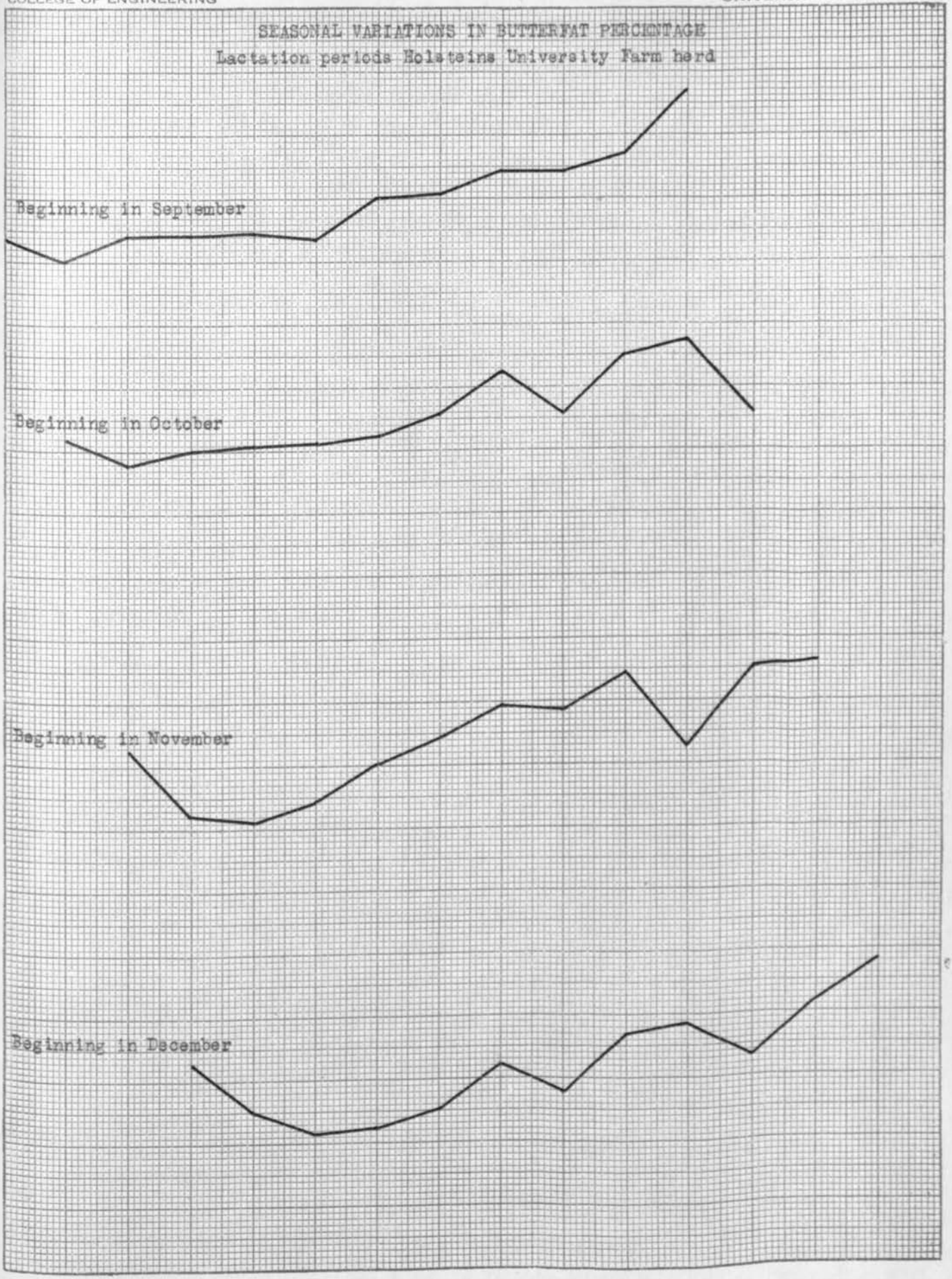


ENG. 4
COLLEGE OF ENGINEERING

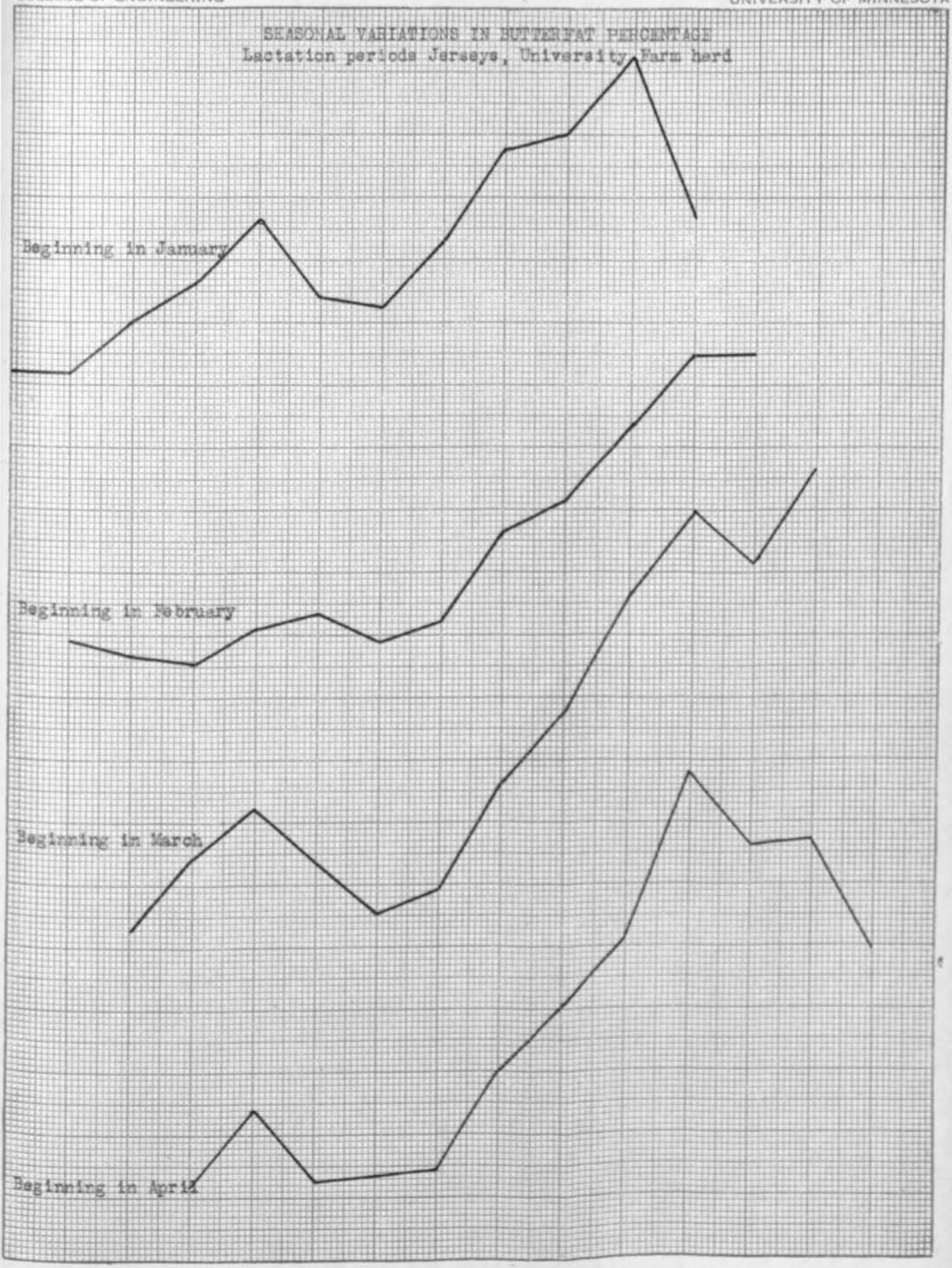
CHART 6

1-22-SM
UNIVERSITY OF MINNESOTA

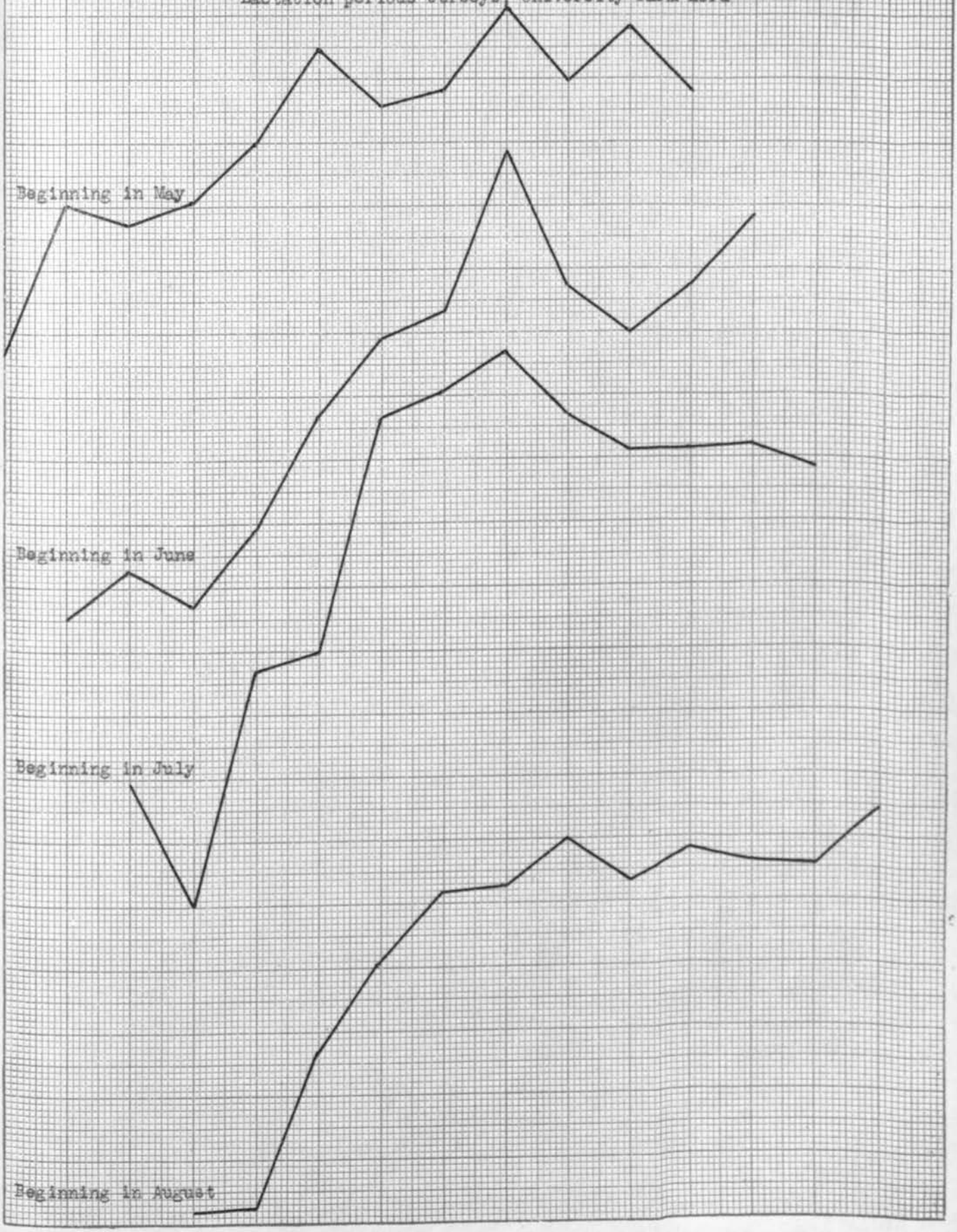
SEASONAL VARIATIONS IN BUTTERFAT PERCENTAGE
Lactation periods Holsteins University Farm herd



SEASONAL VARIATIONS IN BUTTERFAT PERCENTAGE
Lactation periods Jerseys, University Farm herd



SEASONAL VARIATIONS IN BUTTERFAT PERCENTAGE
Lactation periods Jerseys, University Farm herd

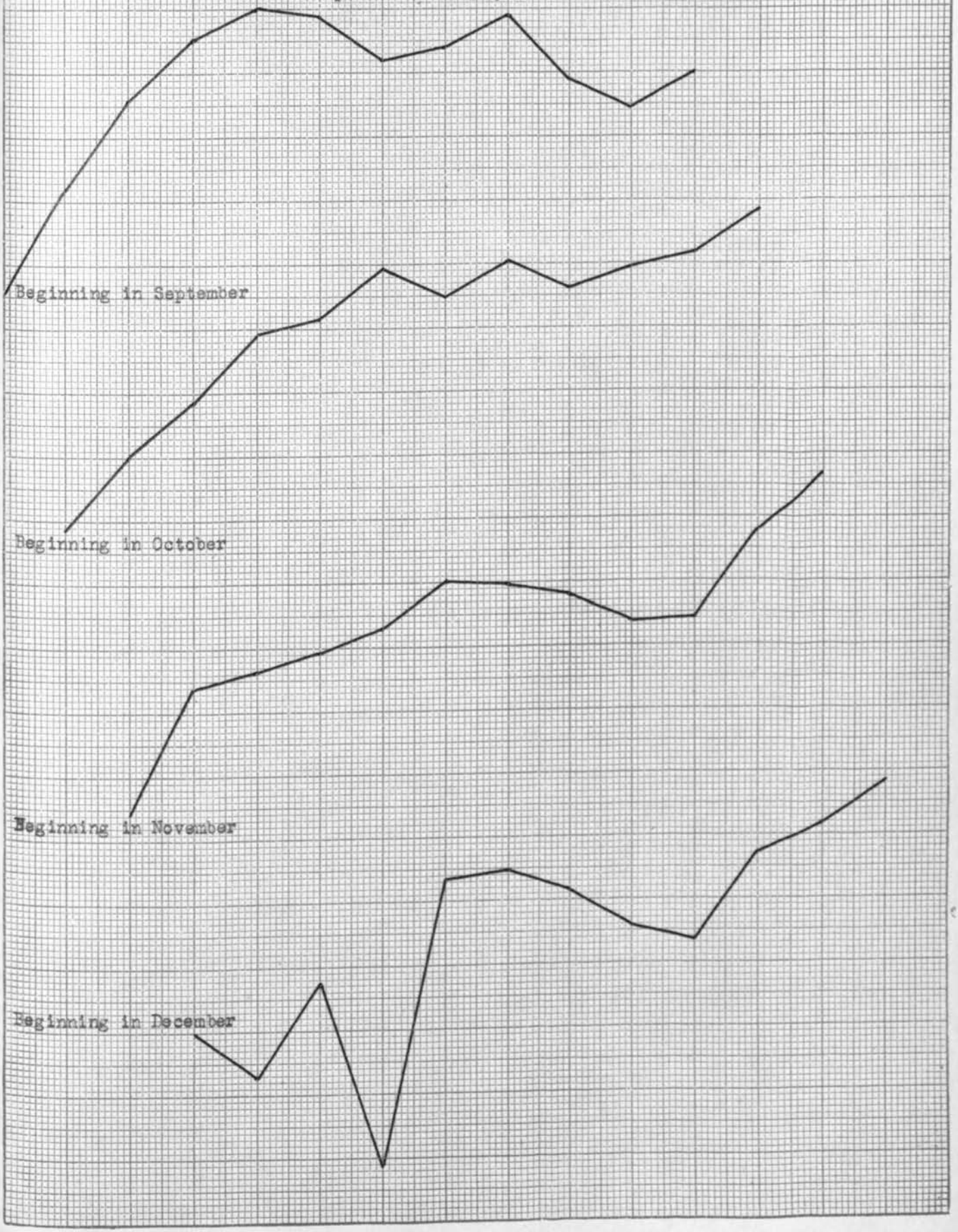


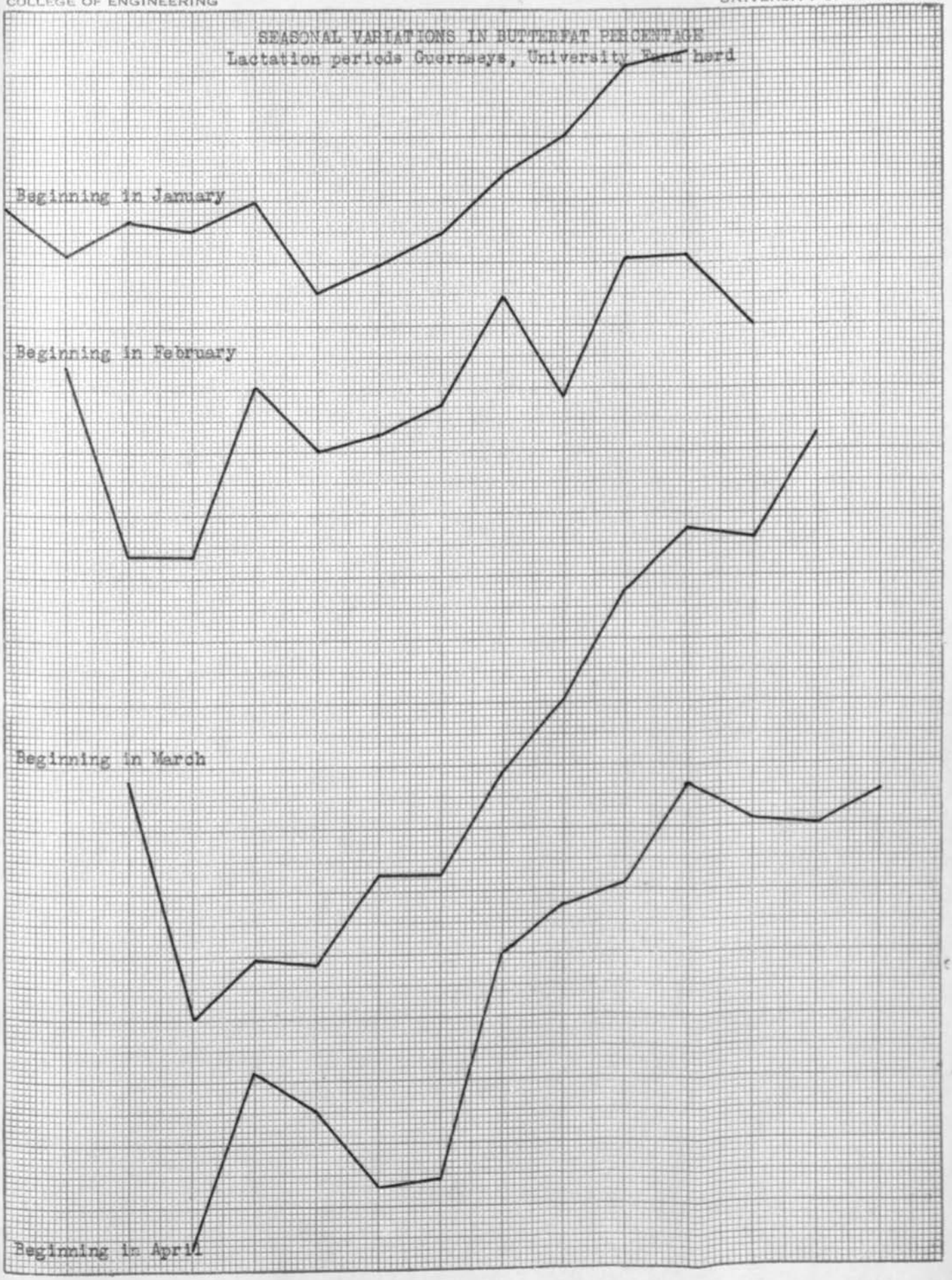
ENG. 4
COLLEGE OF ENGINEERING

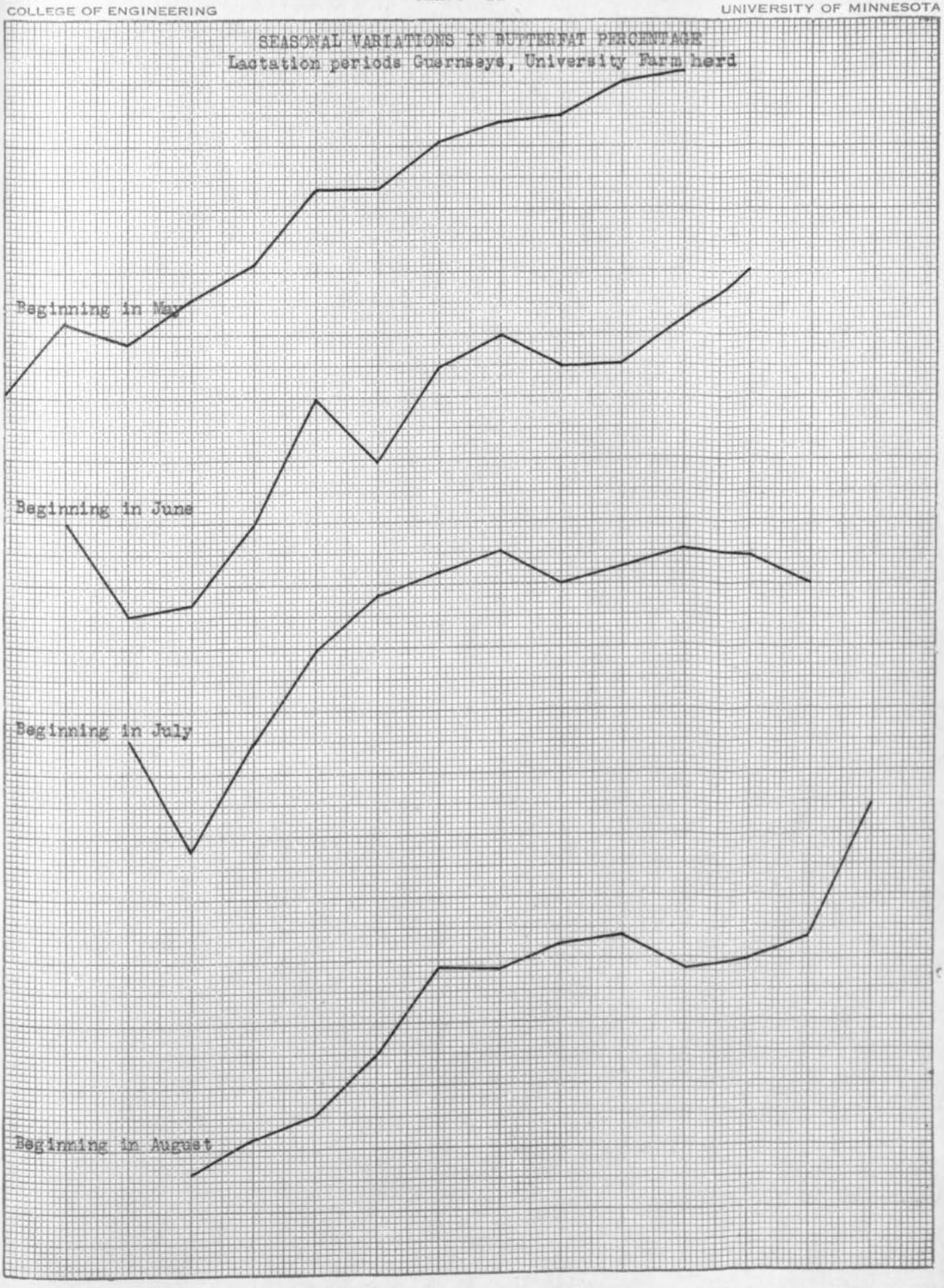
CHART 9

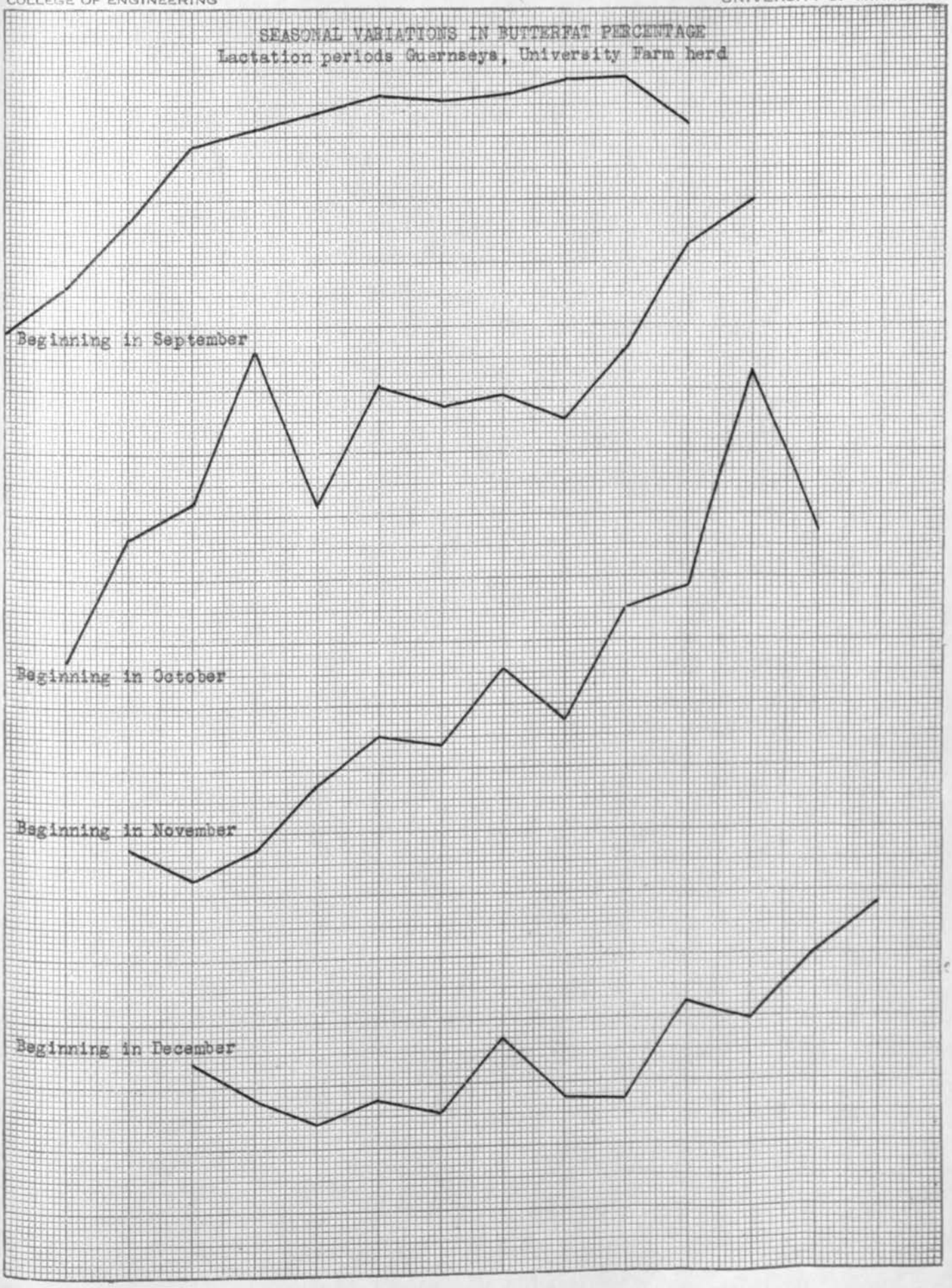
1-22-SM
UNIVERSITY OF MINNESOTA

SEASONAL VARIATIONS IN BUTTERFAT PERCENTAGE
Lactation periods Jerseys, University Farm herd

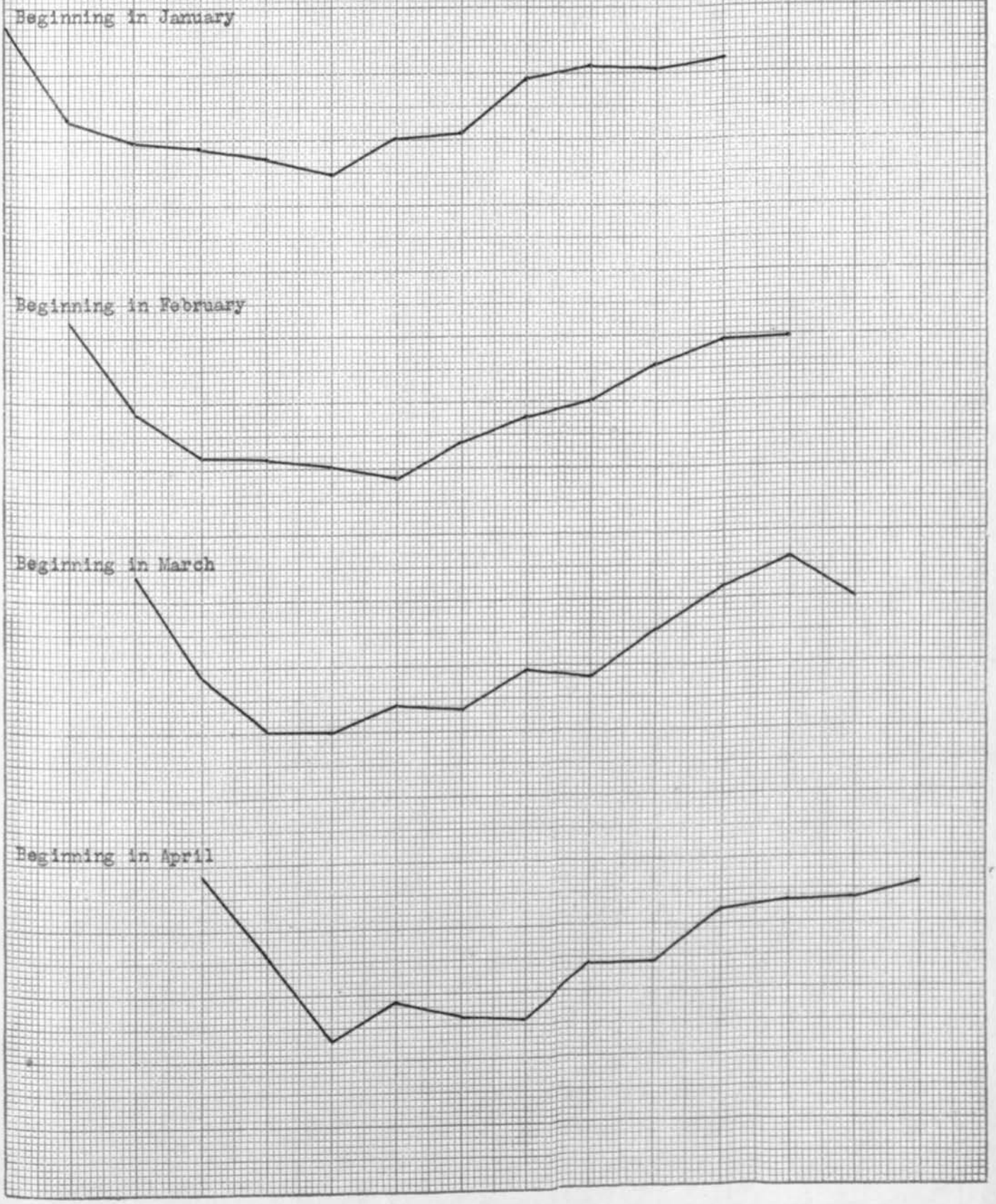



SEASONAL VARIATIONS IN BUTTERFAT PERCENTAGE
Lactation periods Guernseys, University Farm herd
Beginning in January
Beginning in February
Beginning in March
Beginning in April

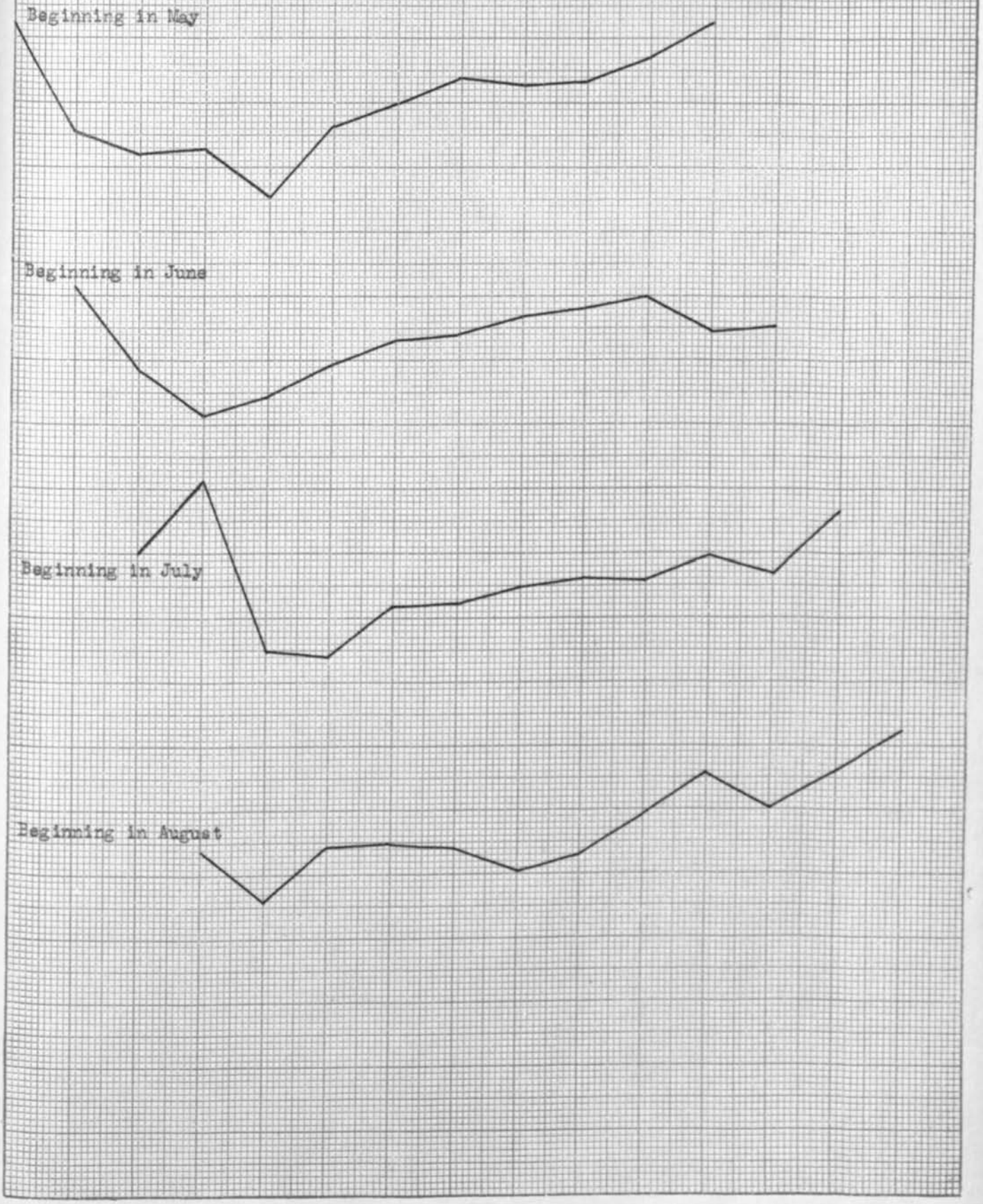

SEASONAL VARIATIONS IN BUTTERFAT PERCENTAGE
Lactation periods Guernseys, University Farm herd
Beginning in May
Beginning in June
Beginning in July
Beginning in August


SEASONAL VARIATIONS IN BUTTERFAT PERCENTAGE
Lactation periods Guernseys, University Farm herd
Beginning in September
Beginning in October
Beginning in November
Beginning in December

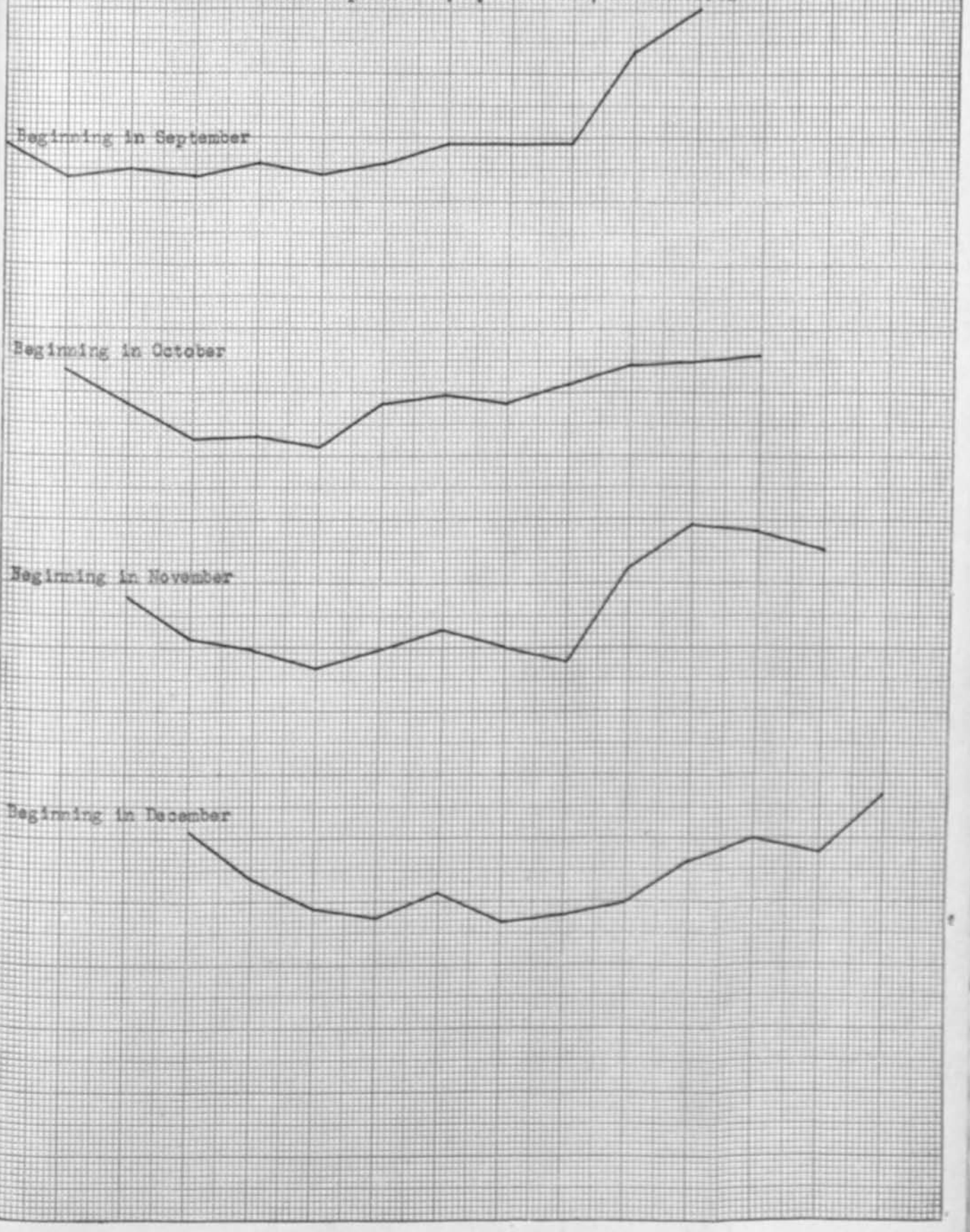
SEASONAL VARIATIONS IN BUTTERFAT PERCENTAGE
Lactation periods A. R. Holsteins in Minnesota

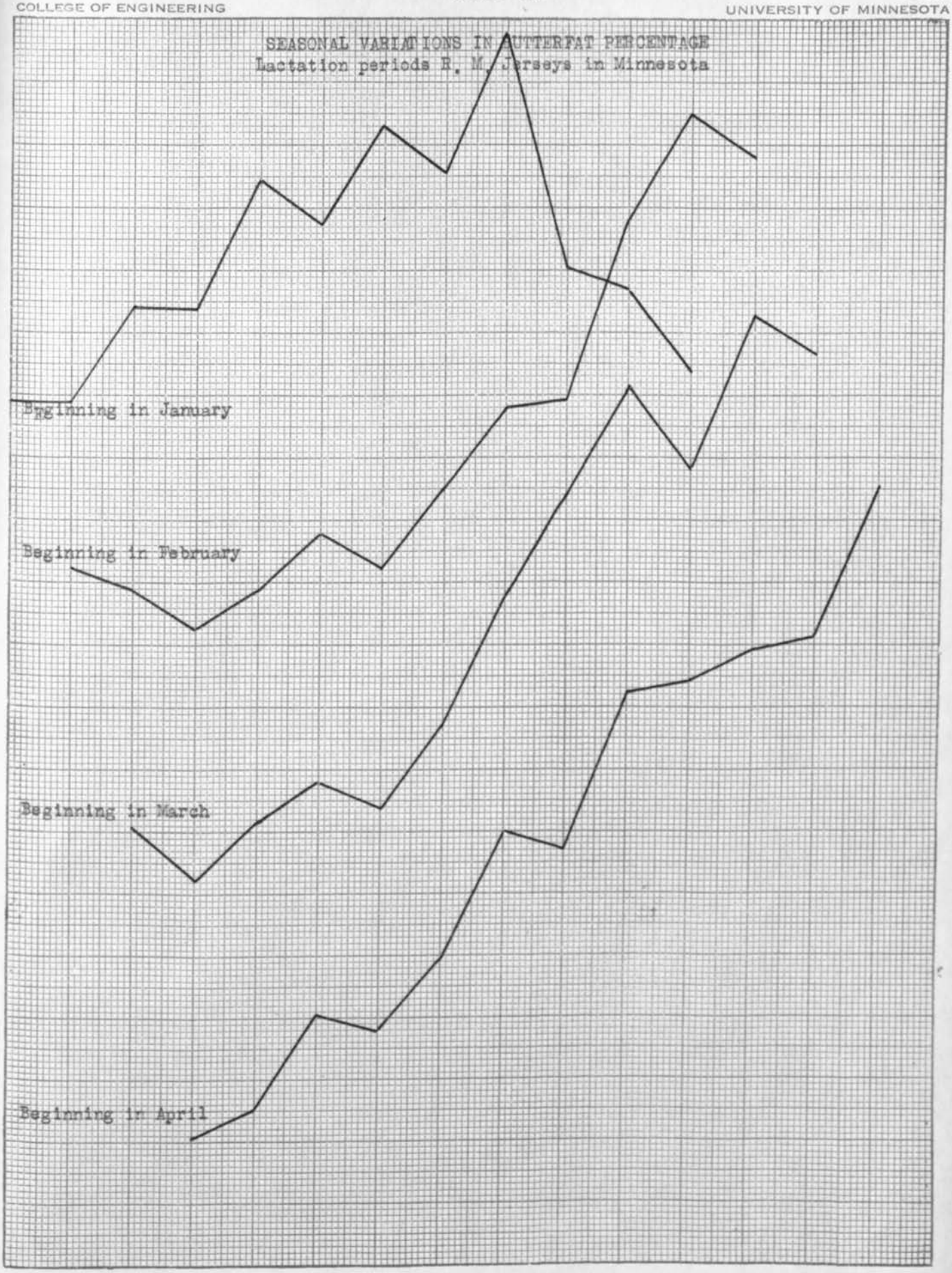


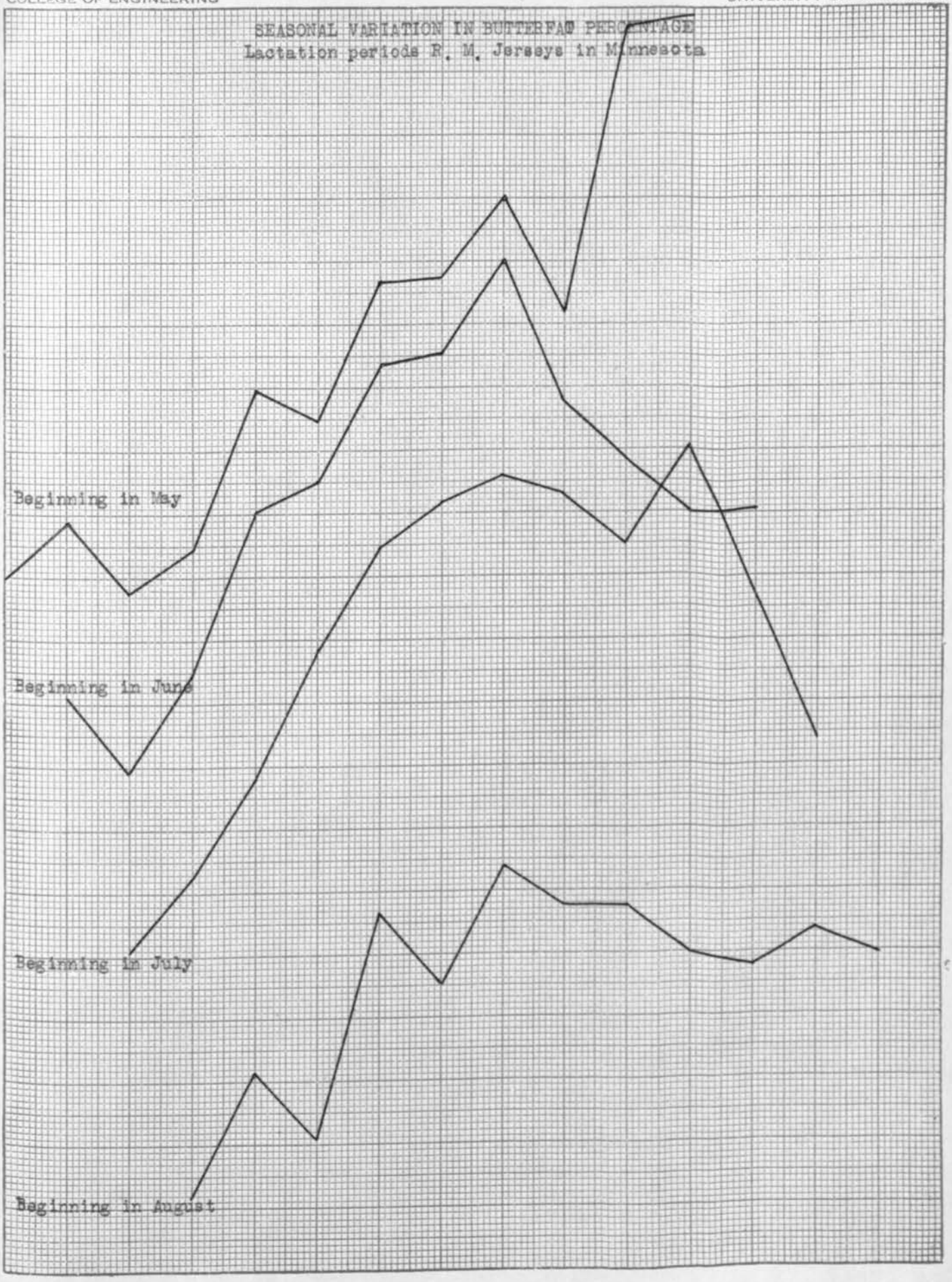
SEASONAL VARIATIONS IN BUTTERFAT PERCENTAGE
Lactation periods A.R. Holsteins, in Minnesota



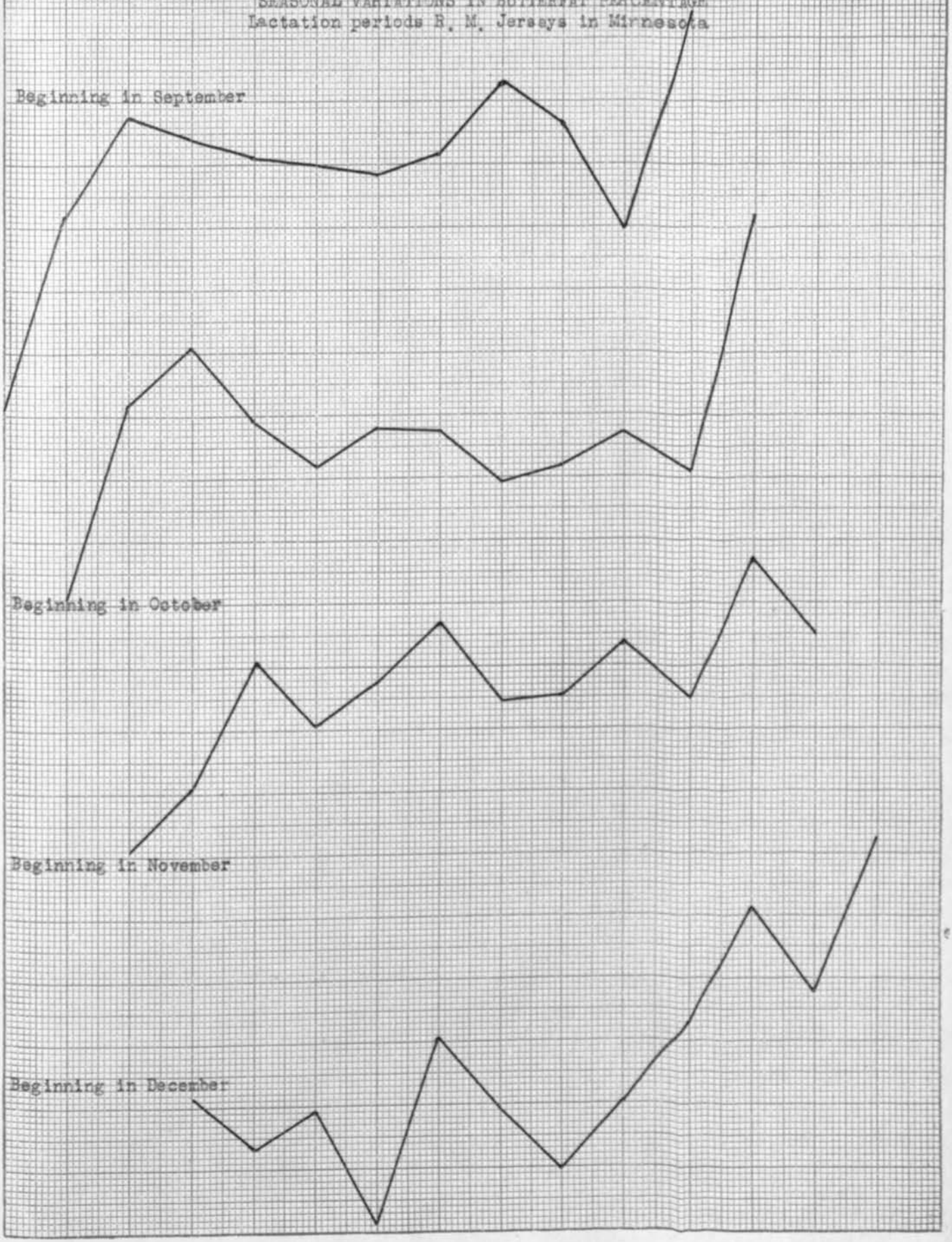
SEASONAL VARIATIONS IN BUTTERFAT PERCENTAGE
Lactation periods A. R. Holsteins, in Minnesota

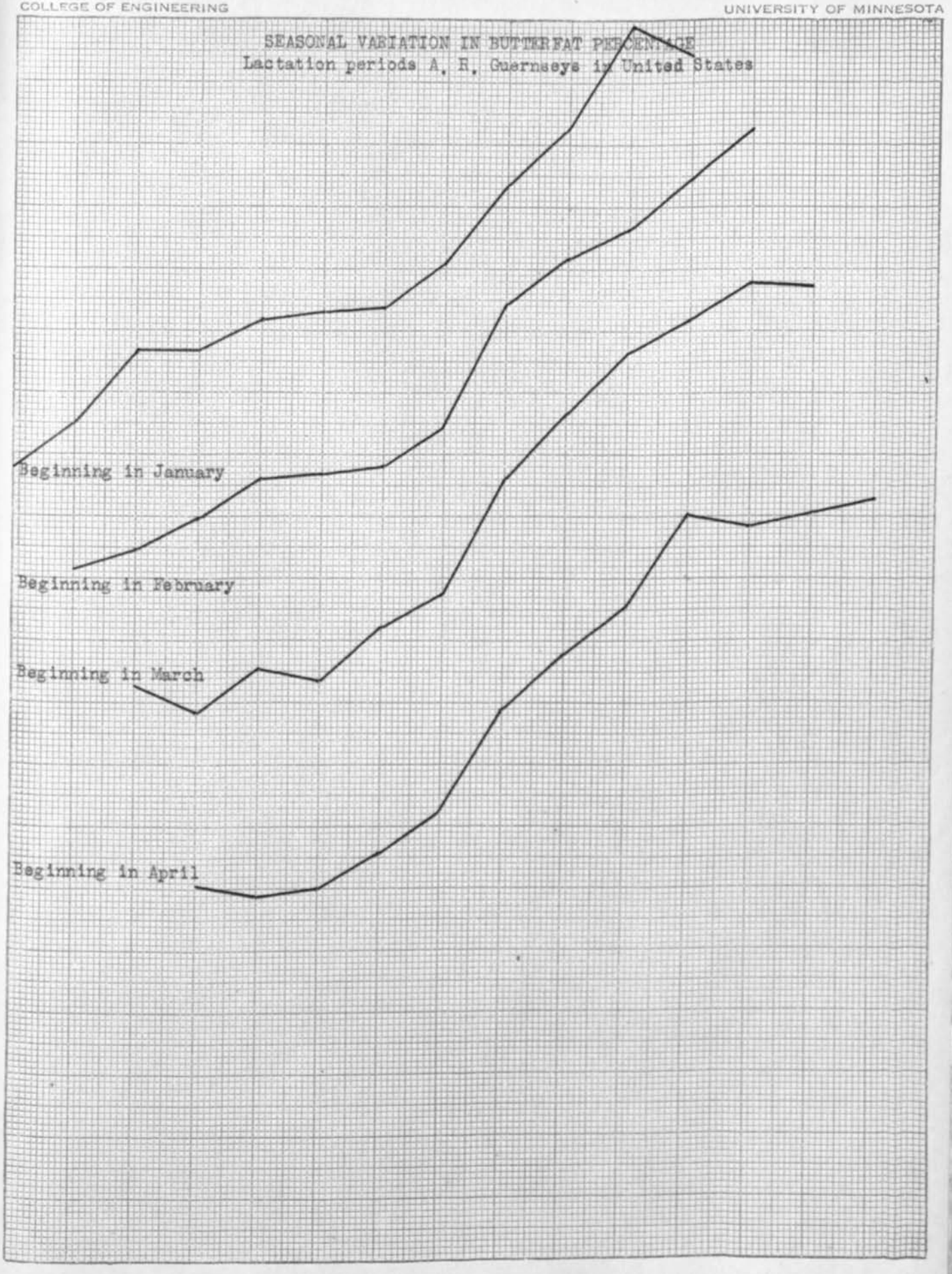


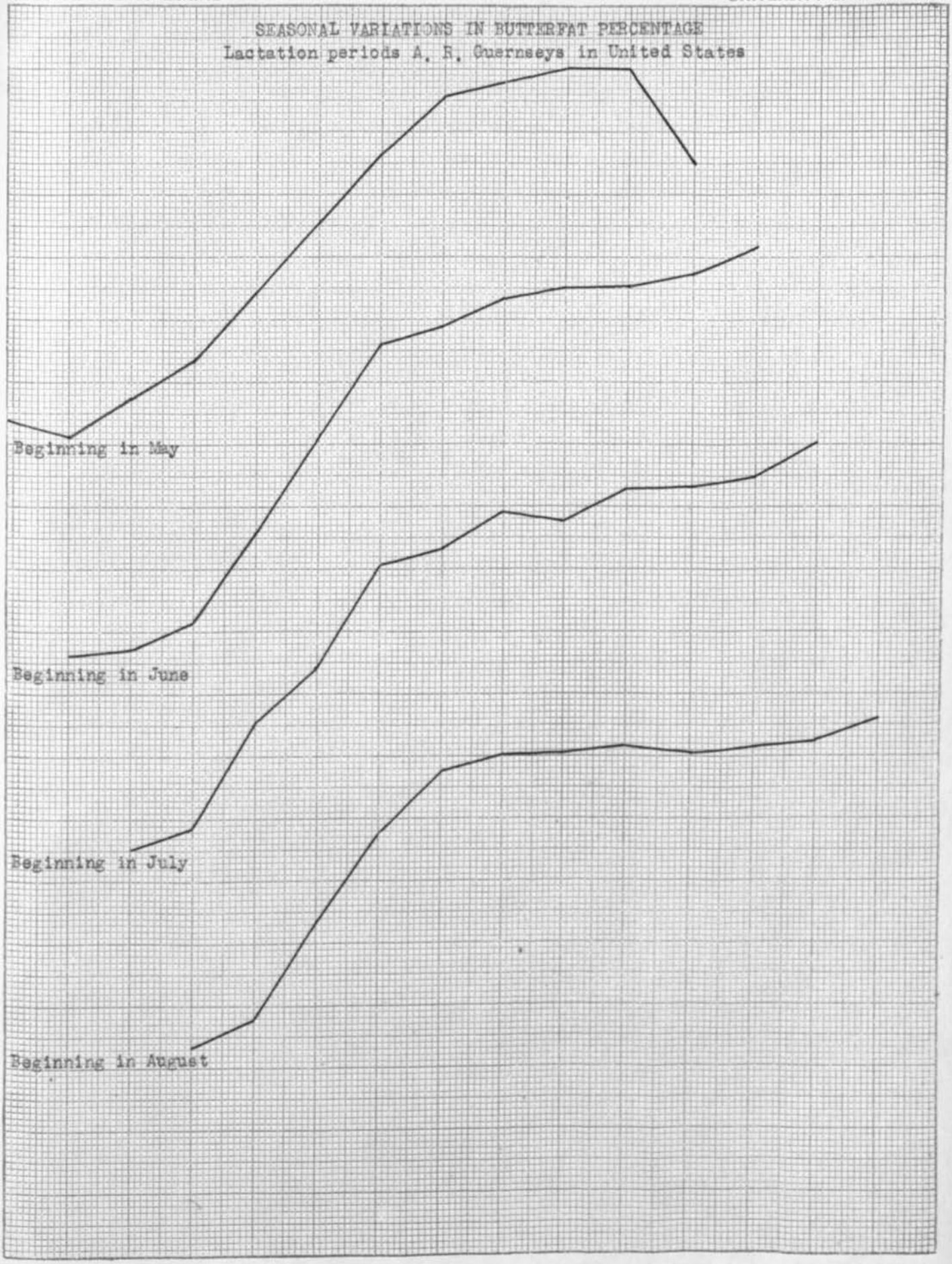

SEASONAL VARIATIONS IN BUTTERFAT PERCENTAGE
Lactation periods R. M. Jerseys in Minnesota
Beginning in January
Beginning in February
Beginning in March
Beginning in April


SEASONAL VARIATION IN BUTTERFAT PERCENTAGE
Lactation periods F. M. Jerseys in Minnesota
Beginning in May
Beginning in June
Beginning in July
Beginning in August

SEASONAL VARIATIONS IN BUTTERFAT PERCENTAGE
Lactation periods R. M. Jerseys in Minnesota




SEASONAL VARIATION IN BUTTERFAT PERCENTAGE
Lactation periods A. R. Guernseys in United States
Beginning in January
Beginning in February
Beginning in March
Beginning in April


SEASONAL VARIATIONS IN BUTTERFAT PERCENTAGE
Lactation periods A. R. Guernseys in United States
Beginning in May
Beginning in June
Beginning in July
Beginning in August

SEASONAL VARIATIONS IN BUTTERFAT PERCENTAGE
Lactation periods A. R. Guernseys in United States

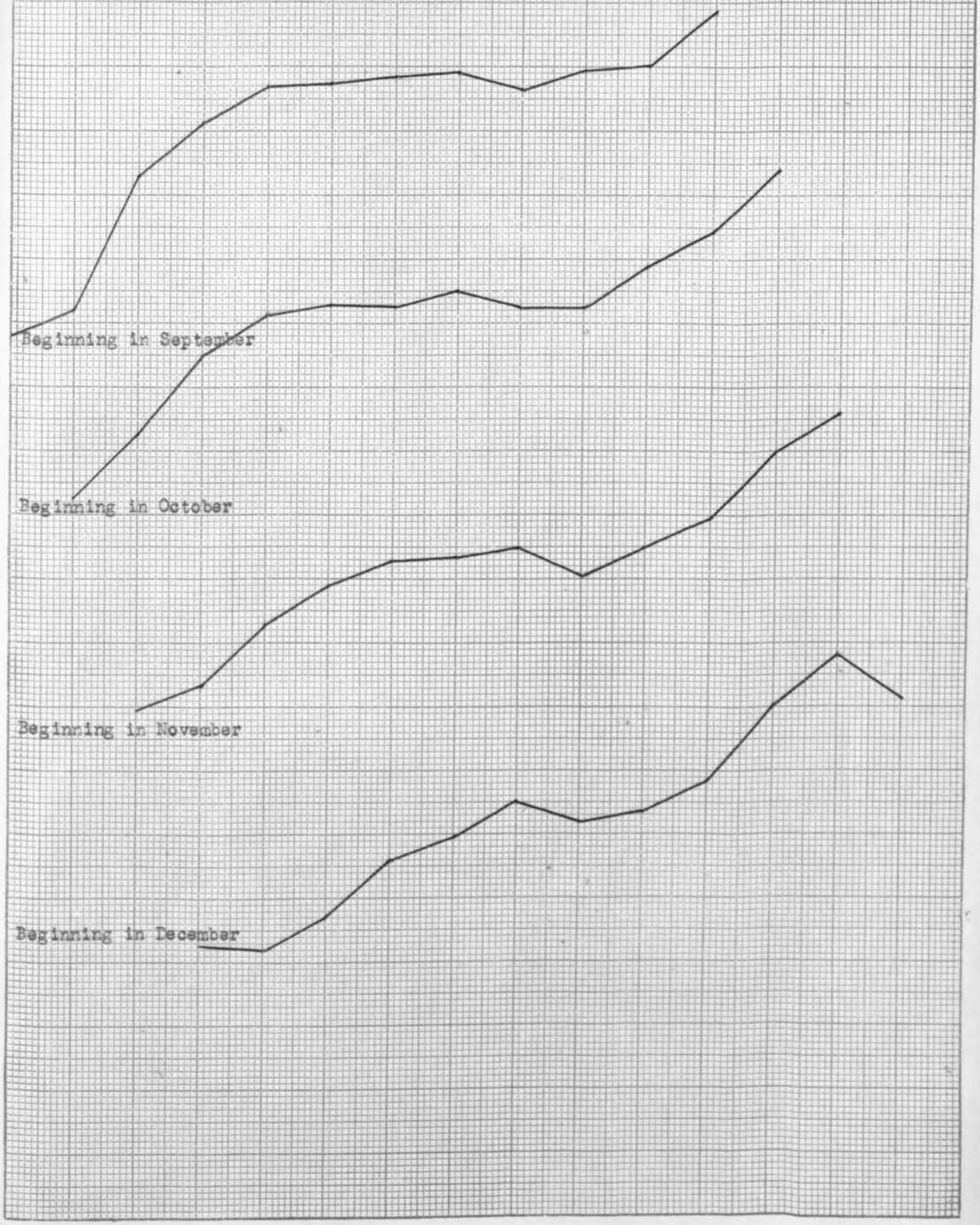
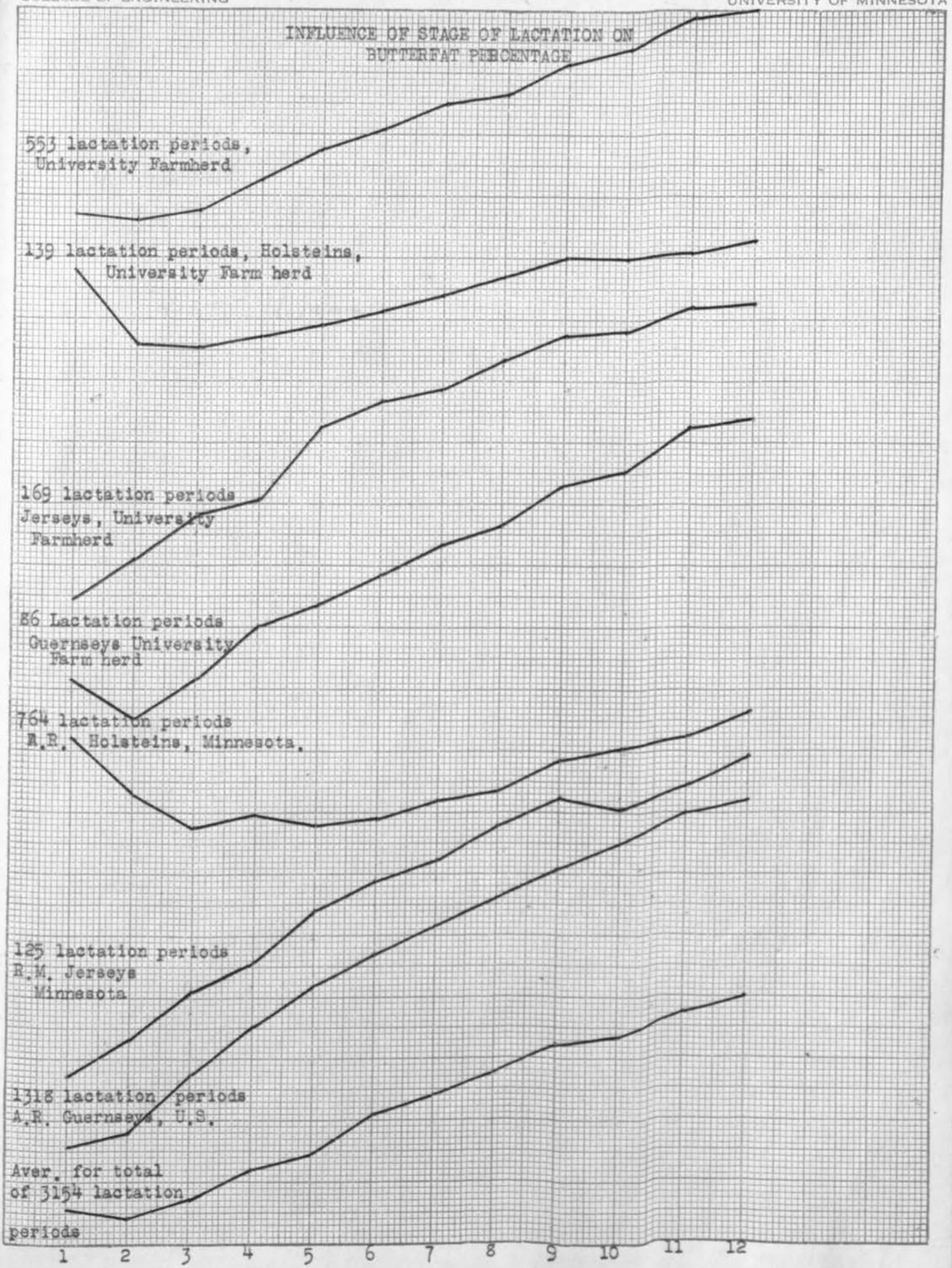
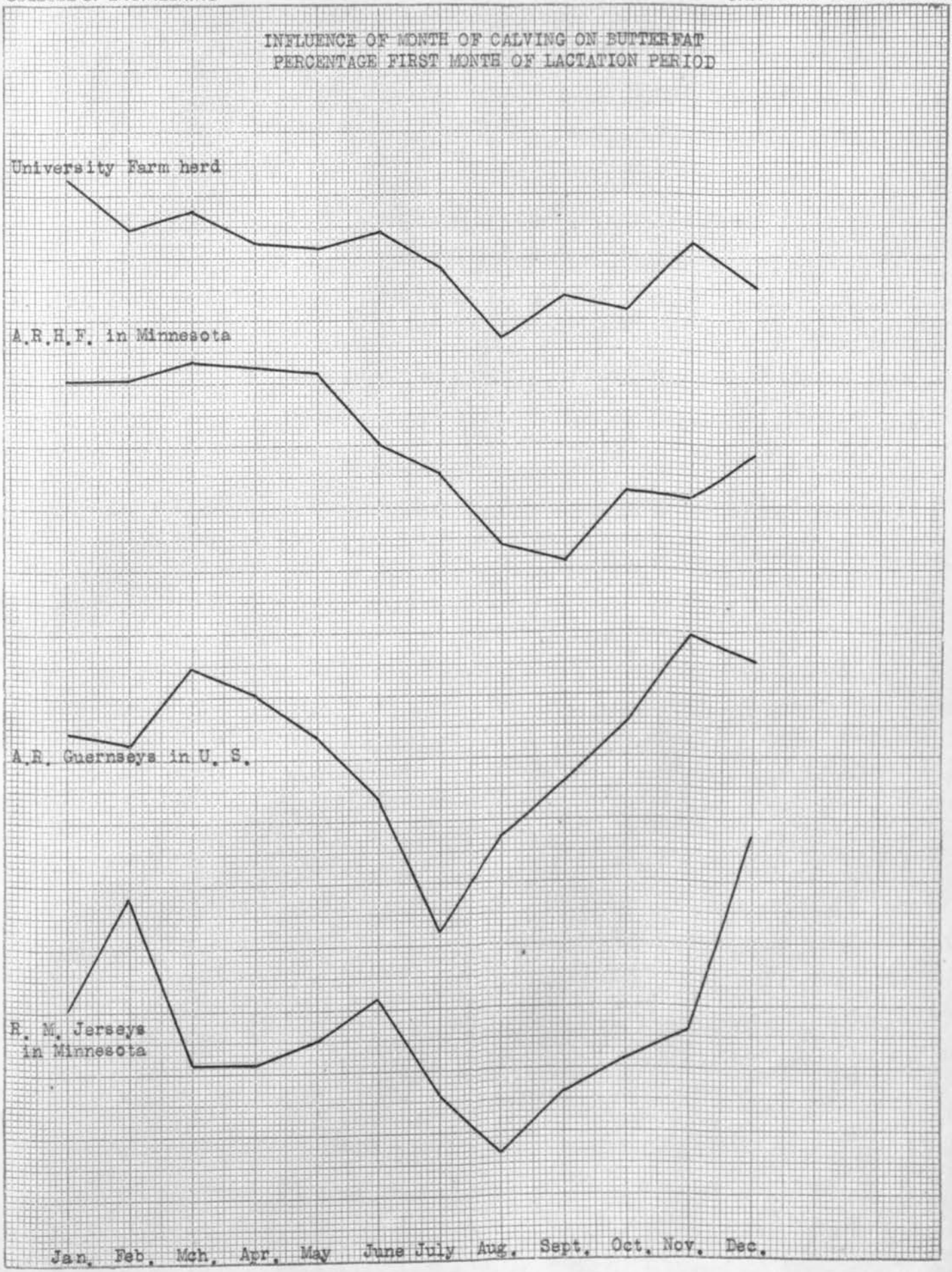
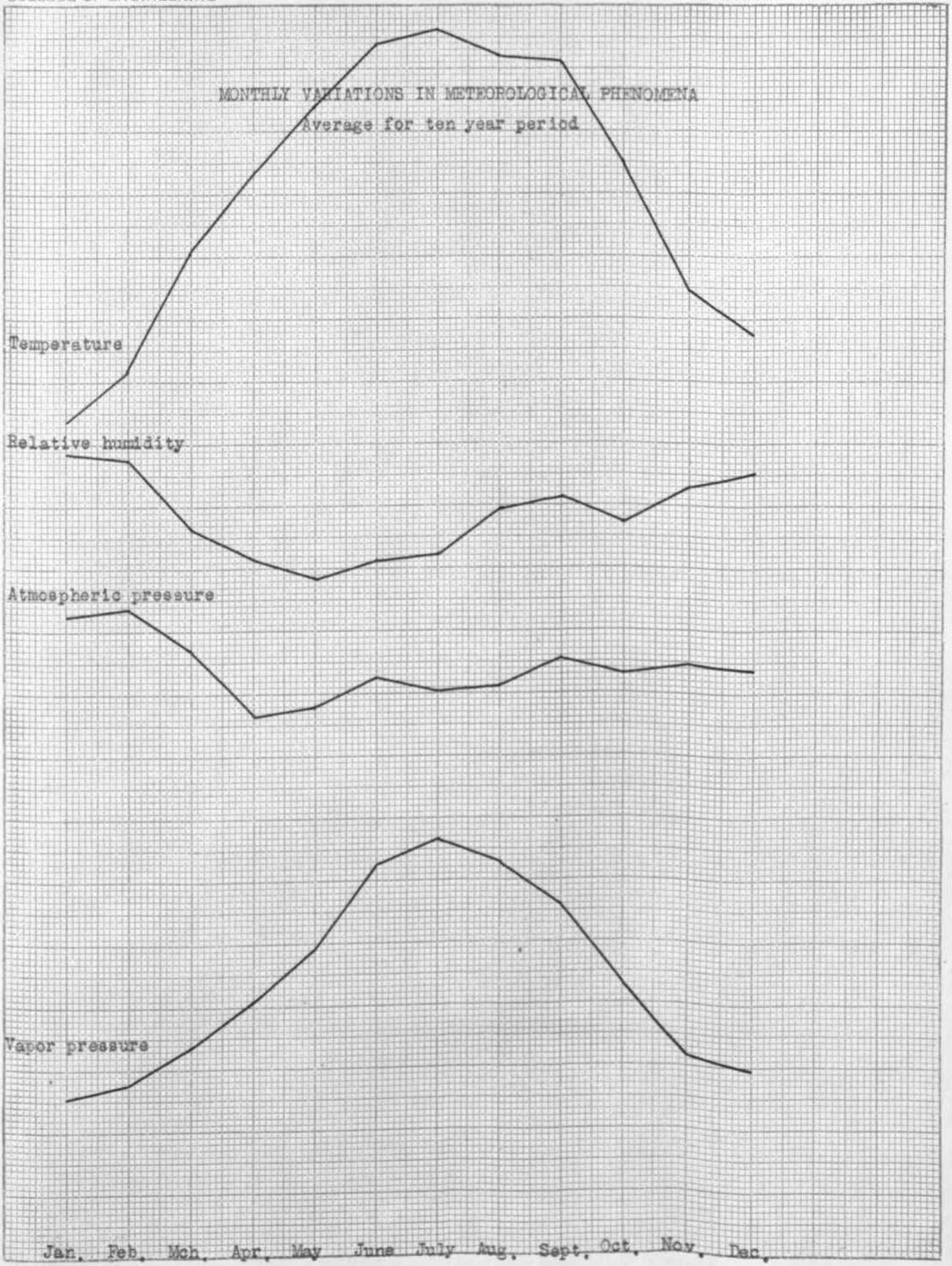


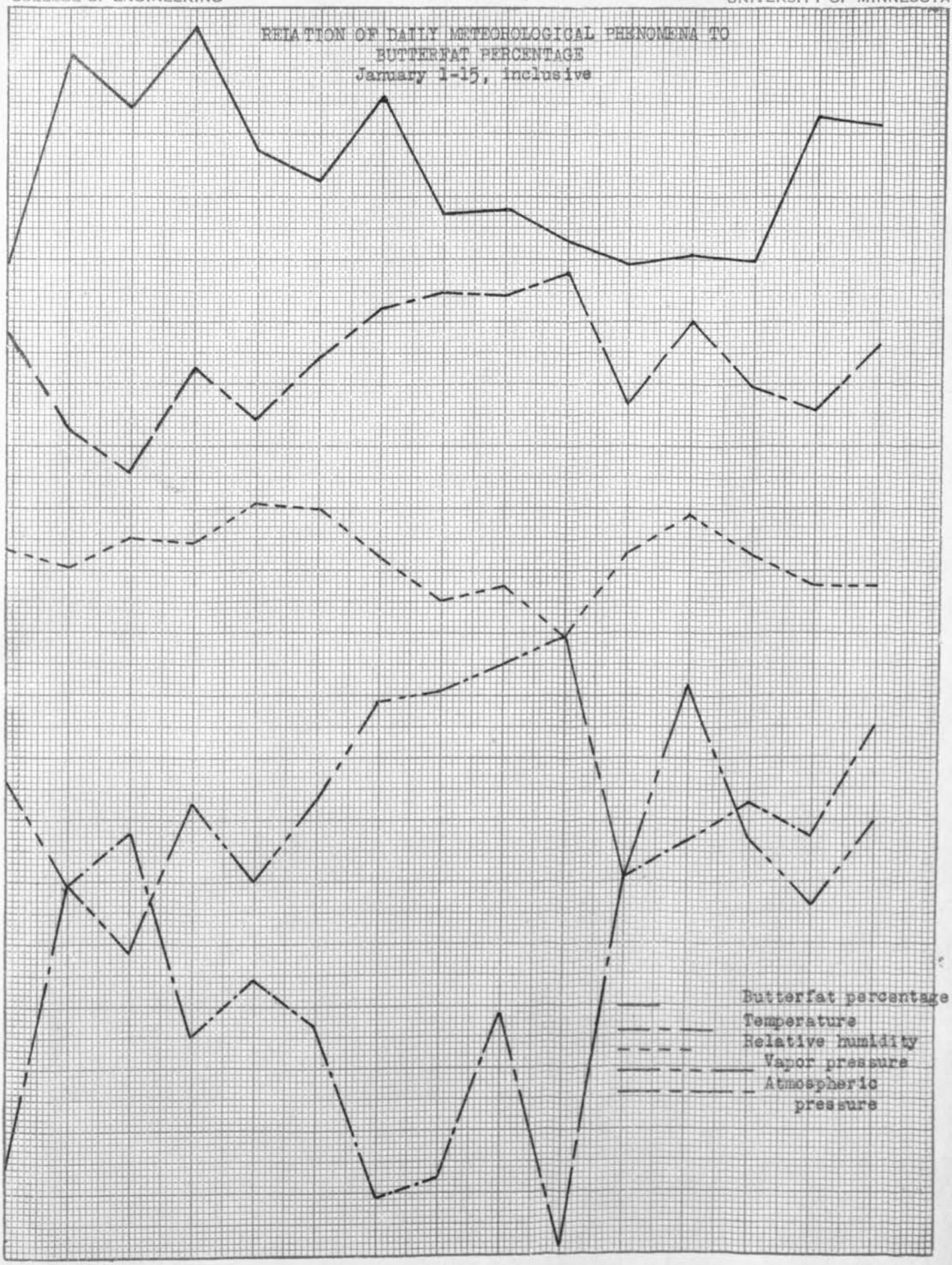
CHART 22

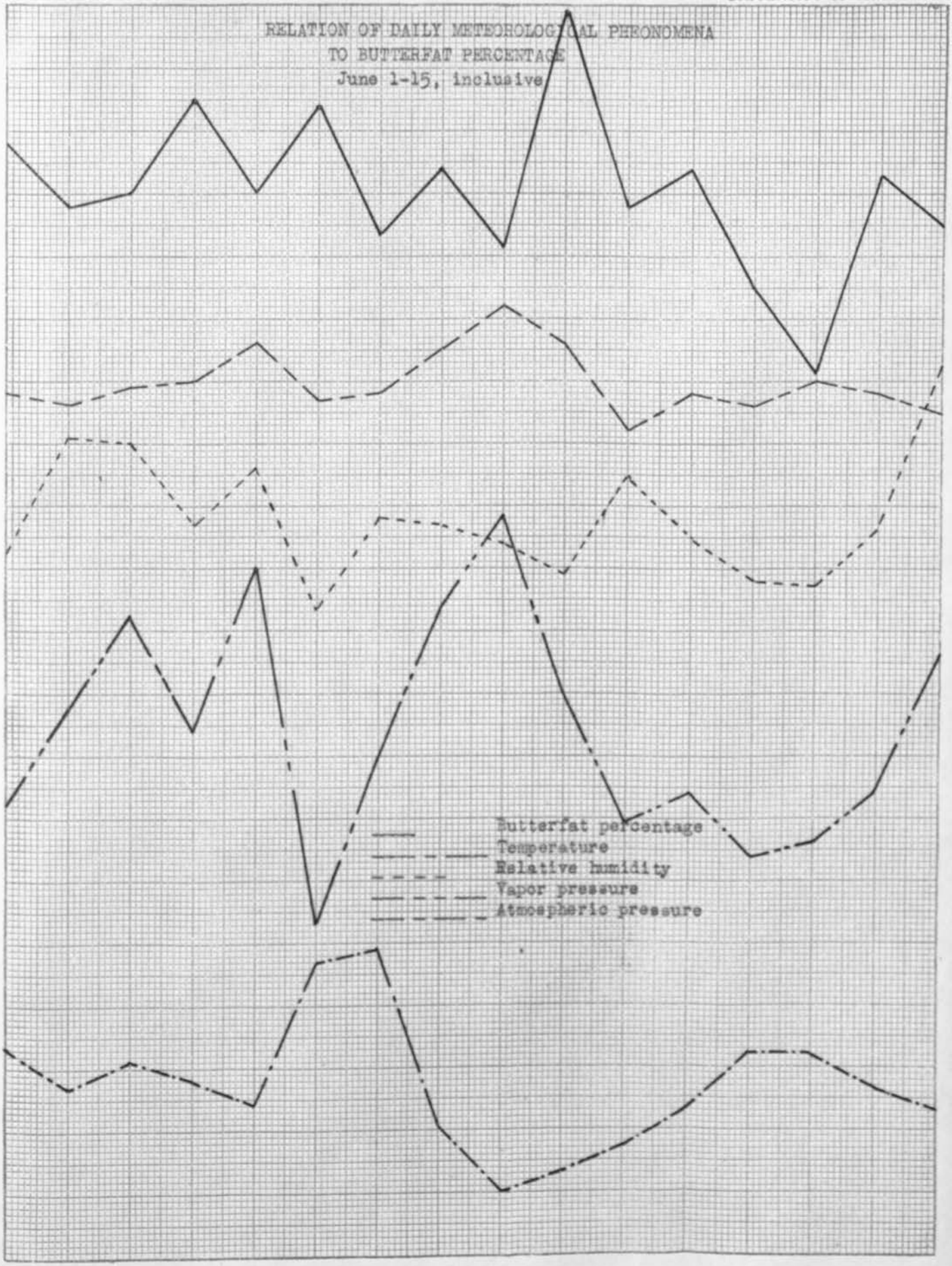

INFLUENCE OF STAGE OF LACTATION ON BUTTERFAT PERCENTAGE
553 lactation periods, University Farmherd
139 lactation periods, Holsteins, University Farm herd
169 lactation periods Jerseys, University Farmherd
86 Lactation periods Guernseys University Farm herd
764 lactation periods A.R., Holsteins, Minnesota.
125 lactation periods R.M. Jerseys Minnesota
1318 lactation periods A.R. Guernseys, U.S.
Aver. for total of 3154 lactation periods
1 2 3 4 5 6 7 8 9 10 11 12

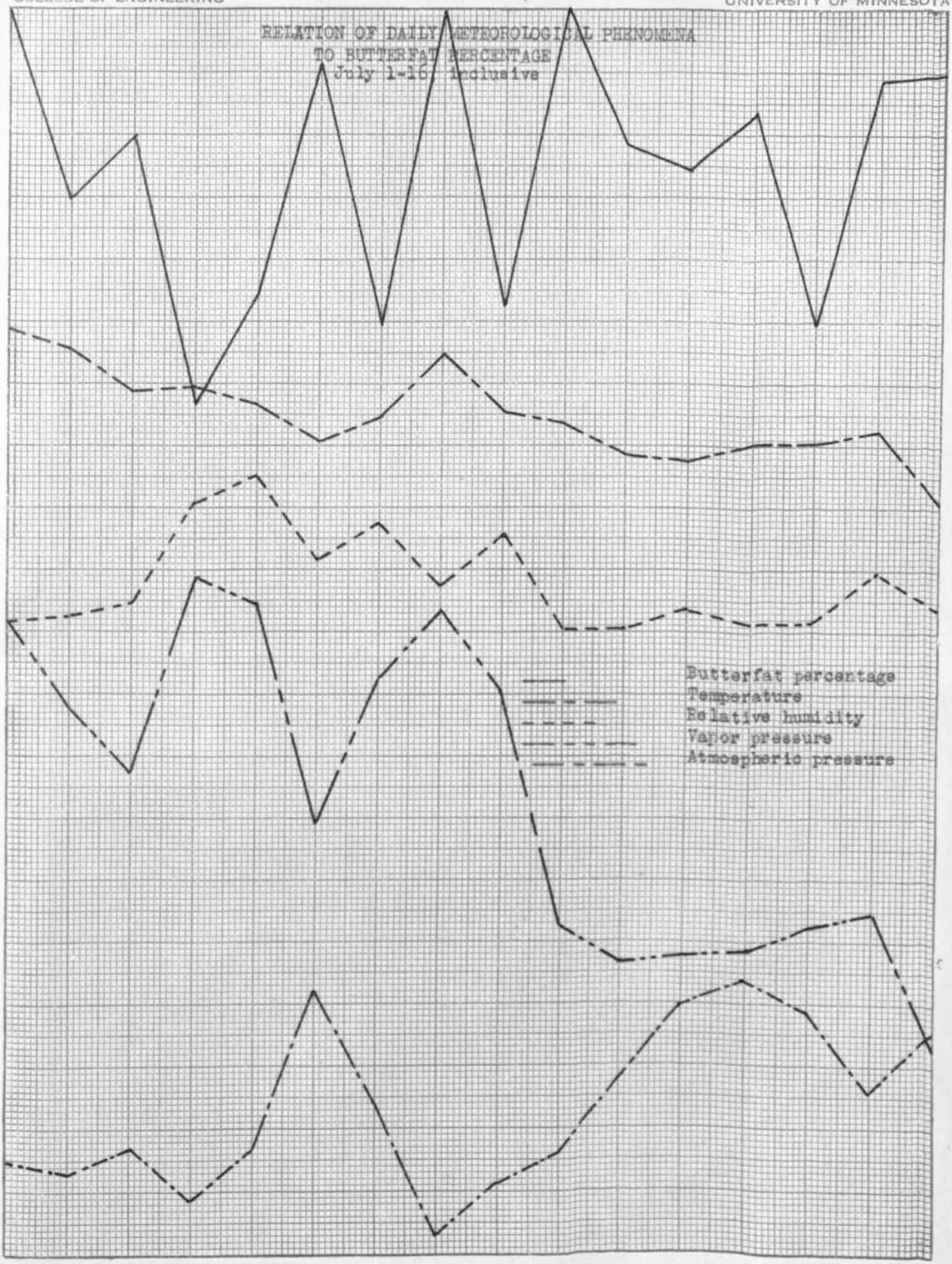

INFLUENCE OF MONTH OF CALVING ON BUTTERFAT
PERCENTAGE FIRST MONTH OF LACTATION PERIOD
University Farm herd
A.R.H.F. in Minnesota
A.R. Guernseys in U. S.
R. M. Jerseys
in Minnesota
Jan. Feb. Mch. Apr. May June July Aug. Sept. Oct. Nov. Dec.


MONTHLY VARIATIONS IN METEOROLOGICAL PHENOMENA
Average for ten year period
Temperature
Relative humidity
Atmospheric pressure
Vapor pressure
Jan. Feb. Mch. Apr. May June July Aug. Sept. Oct. Nov. Dec.

RELATION OF DAILY METEOROLOGICAL PHENOMENA TO
BUTTERFAT PERCENTAGE
January 1-15, inclusive




RELATION OF DAILY METEOROLOGICAL PHENOMENA
TO BUTTERFAT PERCENTAGE
June 1-15, inclusive
Butterfat percentage
Temperature
Relative humidity
Vapor pressure
Atmospheric pressure


RELATION OF DAILY METEOROLOGICAL PHENOMENA
TO BUTTERFAT PERCENTAGE
July 1-16, inclusive
Butterfat percentage
Temperature
Relative humidity
Vapor pressure
Atmospheric pressure

ENG. 4
COLLEGE OF ENGINEERING

CHART 28

1-22-8M
UNIVERSITY OF MINNESOTA

RELATION OF DAILY METEOROLOGICAL PHENOMENA TO BUTTERFAT PERCENTAGE

August 5-20, inclusive