NOVEMBER, 1951 RESEARCH BULLETIN 485

UNIVERSITY OF MISSOURI COLLEGE OF AGRICULTURE
AGRICULTURAL EXPERIMENT STATION
J. H. LONGWELL, *Director*

The Influence of Environmental Temperatures on the Composition of Milk of the Dairy Cow

J. W. COBBLE AND H. A. HERMAN

Publication authorized October 23, 1951

COLUMBIA, MISSOURI

TABLE OF CONTENTS

Page

Introduction 3

Review of the Literature 4

Methods and Equipment 13

Experimental Results 16

Discussion 41

Summary 44

Abstract 46

Bibliography 47

ACKNOWLEDGMENTS

Grateful acknowledgment is made to A. C. Ragsdale, Department of Dairy Husbandry, and to M. M. Jones, Department of Agricultural Engineering, University of Missouri, for counsel and assistance; to Harold J. Thompson of the Bureau of Plant Industry, Soils and Agricultural Engineering, U. S. Department of Agriculture, for his personal cooperation and the use of equipment of the Environmental Physiology investigations; to H. L. Dannen, Dannen Mills, St. Joseph, Missouri, for the Brown Swiss cattle; and to J. V. Gates, Poteet, Texas, for the Brahman cattle.

The Influence of Environmental Temperatures on the Composition of Milk of the Dairy Cow

J. W. COBBLE AND H. A. HERMAN

INTRODUCTION

The variations in climatic conditions throughout America and other parts of the world and their effects on the composition of milk often create a serious problem for the dairy farmer and the milk processor. Brooks (1895), who studied the effects of warming stables for dairy cattle, emphasizes the early attention given the problem of changing environmental temperatures and its effect on milk production. Later, Davis (1913-14), Clothier (1919), White and Judkins (1918), Hays (1926), and others studied the influence of season and temperature as factors related to the yield and composition of milk. In recent years numerous investigators have concerned themselves with the problem of changes in milk constituents, especially during the summer months, due to climatic variation. Mathieson (1934), Jacobson (1936), Herman (1938), and others have observed that during hot summer months milk often is of low solids-not-fat and fat content (often below federal standards) and is rejected as abnormal milk.

The present trend in evaluation of food value of milk gives more importance to the non-fat portions. Our increasing knowledge of nutrition focused attention on the normal changes in the composition of milk. The economic aspects of purchasing milk for manufacturing purposes have also caused greater attention to be paid milk composition.

Richardson (1949) states that butterfat no longer occupies the position of nutritional pre-eminence it once held, and special attention should be given the non-fat solids. Clark and Tenley (1948) indicate some change should be made in the basis for purchasing milk to include payment for the true nutritional value of milk. Jacobson (1936) found a greater variation in the percentage of butterfat, the constituent now being used as the basis for purchase of milk, than in solids-not-fat.

Factors affecting the milk yield and changes in milk composition, as influenced by environmental temperatures, are of importance to the entire dairy industry. The type of shelter needed for the best performance of the herd both economically and physiologically, with ever increasing cost of building material, is but one of the practical implications.

The physiological importance of breed and individual differences in ability to withstand increasingly low or high temperatures without materially influencing milk yield or composition has a direct bearing on the breeding program to be instituted in various areas subjected to extreme climatic variations.

In view of the obvious importance of milk and dairy products in the human diet, it is necessary to understand as fully as possible the direct or indirect effect of varying environmental temperature on milk composition and milk production. In this study, a temperature controlled laboratory housing the milking cows was used to study the influence of temperatures on performance of the cows and the composition of milk produced.

REVIEW OF THE LITERATURE

The Influence of Varying Environmental Temperatures on Physiological Reactions of the Dairy Cow

In a study of the yield and quality of milk produced by dairy cattle, the physiological reactions, health, comfort, etc., in relation to environmental temperature are of primary importance. Numerous investigators have reported that physiological abnormalities of various kinds greatly influence the amount and composition of milk.

Respiration and Pulse Rate: In experiments with dairy cattle where humidity was held constant, Seath and Miller (1946) found that a partial correlation coefficient of 0.748 and 0.353 existed between air temperature and respiration rate for 1945 and 1946. Gaalaas (1945) previously had reported a similar correlation of 0.77 between temperature and respiration rate. Riek and Lee (1948) found an increase in respiration rate of 25.4 per minute to 160 per minute by increasing environmental temperature from 85° to 110° F. and absolute humidity from 6 to 16 grams of moisture per cubic foot.

Regan and Richardson (1938), with animals under controlled temperatures, found that environmental temperatures from 40° to 100° F. would cause a uniform increase in respiration rate. The respiration rate almost doubled for each increment of 18° F. This study confirms previous work on the subject of Kleiber and Regan (1933).

Kibler *et al.* (1949), and Kibler and Brody (1949) in recent work at the Missouri Station obtained an increase of some 500 per cent in the respiration rate of dairy cattle subjected to increasing temperatures of 50° to 105° F. In a range of 75° to 90° F. Jersey cows had a much higher respiration rate than the Holsteins. In studies using low temperatures (of 50° to 5° F.) there was a decrease in respiration rate from approximately 30 to 15 per minute.

In contrast to man (Best and Taylor, 1945), increasing environmental temperatures from 40° to 100° F. caused a decrease in the pulse rate of dairy cattle (Regan and Richardson, 1938).

Kibler *et al.* (1949), and Kibler and Brody (1949) reported a slight increase in pulse rate when temperature is raised from 60° to 70° F. The increased pulse rate underwent a rapid fall with temperatures above 70° F. In the case of Holsteins the pulse rate declined until environmental temperatures went above 95° F., after which an increase was noted. Jerseys, however, continued to decline in pulse rate at 105° F. At temperatures below 40° F. there was an increase of approximately 8 per cent in pulse rate.

Heat Production and Body Temperature: The zone of minimal heat production or thermoneutrality for lactating dairy cows occurs at temperatures from 40° to 60° F. (Kibler *et al.* 1949). In this study, it was also observed that as the temperature decreased, heat production increased about 25 per cent and 35 per cent for Holsteins and Jerseys respectively. Heat production decreased with increased temperature beginning at 80° F. Regan and Richardson (1938) reported that at 80° to 85° F., depending on the breed, a pyrexial point is reached where animals can no longer maintain heat balance and above this point anorexia developed. Ragsdale *et al.* (1948), and Ragsdale *et al.* (1949) noted a decline in feed consumption at temperatures above 80° F. with a corresponding decline in heat increment which amounted to approximately 25 per cent of the total heat production. Bonsma (1940) stated that beef cattle, not adapted to warm climate, ceased rumination at about 90° F. Rhoads (1936) stated that European cattle apparently reach their maximum effort of physical regulation through the lungs at 36° C.

Seath and Miller (1946, 1947), using 77 Holsteins and 43 Jerseys, over a ten-year period, obtained a correlation coefficient of 0.74 and 0.71 between air temperature and body temperature. It was found that the average body temperature of the Holsteins was 0.8 per cent higher than Jerseys at an average temperature of 85° F. Gaalaas (1945) found a correlation coefficient of 0.57 between 3298 individual body temperature samples for Jerseys and atmospheric temperatures. Kibler and Brody (1949) report an increase in rectal temperature of dairy cattle at environmental temperature above 70° F. The increase was greater in Holsteins than in Jerseys. At environmental temperatures of 105° F., rectal temperatures of 108° F. for Holsteins and 106° F. for Jerseys were obtained. Rectal temperatures were constant for both breeds at environmental temperatures of 70° to 5° F.

Lee and Riek (1947) observed rectal temperature in milking cows from 104° to 105° F. when the animals were exposed to an environmental temperature of 99.5° F.

Body Weight, Insensible Weight and Moisture Evaporation: Ragsdale *et al.* (1950) observed that Jerseys and Holsteins lost weight, while Brahman cattle maintained their weight, with rising temperatures above 75° F. All animals used in experiments with lower temperatures from 50° to 8° F. gained weight.

Thompson *et al.* (1949) reported that cows vaporize about 2 pounds of moisture per hour at temperatures between 90° to 100° F.—about the same rate vaporized by man at this temperature. The ratio of heat dissipation by vaporization to heat production became 100 per cent at 94° F. in man and at about 102° F. in cows.

Feed and Water Consumption: Anorexia was observed in cattle subjected to environmental temperatures above 80° to 85° F. by Regan and Richardson (1938). Lee and Riek (1947), and Riek and Lee (1948) report anorexia at high environmental temperatures. Rumination was observed only occasionally at air temperatures above 100° F. and then for short periods of about one minute. Bonsma (1940) made similar observations on cattle not adapted to the tropics.

Ragsdale *et al.* (1949), and Ragsdale *et al.* (1950) report a decline in feed consumption beginning at 75° to 80° F. in the Jersey and Holstein cows and at 90° to 95° F. in the case of Brahmans. Generally in declining temperatures from 50° to 8° F. there was an increase of hay consumption of 40 to 80 per cent above the initial 50° F. level. The T.D.N. consumption, however, did not increase as much as the hay consumption because the grain allotments were in proportion to the milk yield. The authors further reported that the critical temperature for water consumption is 80° F. although the individual variation between cows is very striking. With the exception of one Jersey (212) and the Brahmans, the cows either maintained or reduced their water consumption above 80° F. The drinking frequency usually increased with temperatures above 50° F. even in the cows decreasing their water consumption. At temperatures below 80° F. the water consumption paralleled the feed consumption.

Blood Composition: Relatively few references are to be found in literature regarding the influence of varying environmental temperatures on blood composition in dairy cattle. The work of Riek and Lee (1948) indicates that lactating Jerseys, when exposed to 110° F. temperatures, showed a decrease in blood sugar ranging from a mean value of 55.2 to 44.5 mg. per 100 ml. of blood.

Brody *et al.* (1949) reported that the level of glucose in blood from dairy cows subjected to temperatures from 50° to 100° F. showed disorderly fluctuation. (Brown, Petersen and Gortner, 1936, report similar fluctuation in hourly samples from apparently normal animals.) However, a detectable decline appeared to begin with 90° F. temperature.

Further studies of the blood indicated a decline in the non-protein nitrogen beginning with 85° F., presumably caused by a drop in non-protein nitrogen-rich alfalfa consumption. Control cows showed a much smaller decline than the experimental animals. Creatinine levels, a part of the non-protein nitrogen, rose steadily with increasing environmental temperatures. Plasma protein showed no decisive trend although the level at 100° F. tended to be lower than at 90° F., and the levels in Jerseys were somewhat below those in the Holsteins.

The fatty acid values appeared to follow a declining course with rising temperature. The cholesterol, likewise, declined steadily with increasing temperature.

Hemoglobin values and blood cell volume seem to increase with higher environmental temperature, with the carbon dioxide capacity of the blood definitely declining at temperatures above 85° F.

The authors concluded that the change in blood composition with rising ambient temperature is least in the most important constituents found in milk including sugar, protein, non-protein nitrogen, and leucocytes and erythrocytes.

Endocrine System of the Body: As a general rule the thyroid gland of animals is most active in the winter and least active during the summer (Brody, 1948, Byars *et al.*, 1932, and Riddle *et al.*, 1936). It is a well established fact that the thyroid secretions (thyroxine) regulate body metabolism. Kibler *et al.* (1949) report that heat production decreases with increasing body temperature and that it can be assumed that the thyroid function was involved. Spielman *et al.* (1944) and Graham (1934) found that thyroidectomy in dairy cattle caused a lowering of metabolic activity and thereby a decrease from 30 to 75 per cent in milk production, again indicating the importance of thyroid activity. Numerous reports have indicated a rise in metabolic activity by inducing additional thyroid-active material in cows at various stages of lactation (Herman *et al.*, 1938, Graham, 1934, and others).

The literature reveals that most of the investigations on changes of thyroid activity due to environmental temperature changes have been on laboratory animals.

Dempsey and Astwood (1943) demonstrated that rats showed a profound depression of thyroxine secretion with increasing temperature.

Bernstein (1941), using albino rats, observed that high temperatures cause thyroid morphological changes such as flattened epithelium and concomitant accumulation of intra-alveolar colloid material indicating inactivity of the gland either due to cell inactivity or occlusion of the ducts. The adrenals were reported to be more sensitive to heat than thyroid. High and long time temperatures caused extension of the cortical sudansphilic substance toward the medulla in such a way as to mark the normal lipoid-free *zona reticularis.* In short time exposures, the primary effect is a marked dilation of the cortical and medulla blood vessels. Ogle and Mills (1933) found in rabbits that the adrenal weighs less in animals under hot room conditions. A few hours of cooling each day completely overcame the depressing influence of the hot environment. They believe the difference in metabolism is mainly dependent on changes in the adrenal function secondarily influencing glycogen utilization.

Starr and Roskelley (1940) observed that rats exposed to cold 3 to 14 days at 12° to 17° C. showed definite but limited hypertrophy of the acinar cells of the thyroid. Wolf and Greep (1937) found that rats placed in a cold room for 34 days showed signs of atrophy in the central part of the thyroid but absorption of colloid was indicated in the peripheral vesicles by the higher epithelium. Animals in a warm room had a lower epithelium and few absorption vacuoles.

The Influence of Environmental Temperature on the Composition and Yield of Milk in the Dairy Cow

High Environmental Temperature: High environmental temperatures have, for many years, been considered an important factor contributing to lower yields and changes in the composition of milk.

Eckles (1909) observed in a study of 240 lactation periods of cows that a relationship existed between the season of the year and the butterfat percentage of milk. It was found that regardless of when the lactation began, the fat percentage when plotted followed a curve for the year with the lowest levels in June and July. The fat percentage gradually increased to the highest point in December and January. White and Judkins (1918) found similar seasonal changes in the butterfat and the solids-not-fat content of milk but indicated that the seasonal changes commonly observed did not seem to affect the constituents in any definite manner.

Bartlett (1935) stated that the decrease in solids-not-fat content due to high temperature was relatively small. He indicated the possibility of other factors being responsible for the low solids-not-fat content of milk found during the summer months.

The Ministry of Agriculture and Fisheries (1935) and Huston and Hale (1942) observed that milk is richest in fat and solids-not-fat content during the winter months and that the solids-not-fat percentage was lowest during June, July and August. The average depression for the solids-not-fat was about 0.20 per cent below the winter level.

Jacobson (1936), who analyzed more than 100,000 samples of milk delivered to plants in New England, found a small seasonal variation in the fat and solids-not-fat content. The greatest decline in solids-not-fat occurred during July, August and the early part of September.

It was further noted that the solids-not-fat content for normal milk of 3.2 to 4.8 per cent butterfat was less variable than milk containing 4.9 to 5.7 per cent butterfat.

Herman (1938) reported that solids-not-fat content of milk from a herd of 60 cows (49 per cent Holstein, 39 per cent Jerseys and 12 per cent Guernsey) ranged from 8.0 to 9.7 per cent over a twelve-month period. In the three summer months of July, August and September of this period the average range of solids-not-fat was 8.1 to 8.7 per cent. During the same period it was observed that the lactose and total nitrogen levels were lowered and that the chloride content increased substantially.

Davies (1938) found an increase in the chloride content of milk during the summer.

Using controlled temperature conditions, Hays (1926) found that environmental temperatures above 70° F. caused an increase in the butterfat percentage of milk. In the same study an increase in butterfat of 0.095 per cent and 0.189 per cent was obtained at each 10° F. interval, when the environmental temperature was lowered from 92.7° to 27° F. and 72.5° to 27° F., respectively.

Heinemann (1947), analyzing milk at a creamery, observed an increase of 0.093 per cent butterfat in whole milk for each 10° F. drop in atmospheric temperature over a range of 34.8° to 78.8° F. During the same period an increase of 0.067 per cent in total solids of separated milk was noted.

Weaver and Matthews (1928) observed a tendency for butterfat percentage to decrease with rising atmospheric temperatures. They report a sudden rise in the butterfat test at 87.6° F. for Ayrshire cows.

Regan and Richardson (1938), by the use of a psychrometer room, studied the influence of high environmental temperatures on high producing dairy cattle over a temperature range of 40° to 100° F. At temperatures above 80° F. they observed a decrease in milk yield, casein content and solid-not-fat level, and an increase in butterfat percentage and pH values.

Low Environmental Temperature: Relatively few recorded experiments were found in the literature regarding the effects of low environmental temperature on milk yield and on milk composition.

Brooks (1895) compared three cows kept at a stable temperature of 50° F. with cows maintained at a cooler temperature. He reported from this study that the most certain effect throughout the experiment was the lowering of the butterfat percentage in the milk from the cows kept at the 50° F. temperature level.

Buckley (1913) reported no great variation in the flow of milk from cows exposed to a temperature of –14° F. in open stables when compared to cows maintained at a temperature of 11° F. No temporary or permanent change could be attributed to the low temperature or to sudden fluctuations of temperature unless the cows were exposed to rain at the same time. Contrary to this, Davis (1913-14), in a similar experiment, concluded that a drop in atmospheric temperature in an open or closed stable caused a decrease in milk yield. He further observed that the cows in the open shed consumed slightly more roughage when compared to the cows housed in the barn.

Popoff (1927), using two varying environmental temperatures of 4° to –10° C. and 5° to 12° C., found that cows maintained a higher level of milk production in the warmer environmental temperatures.

Kelly and Rupel (1937) observed that cows kept in an open pen at an average temperature of 18° F. for five days underwent a drop in milk yield of 0.85 pounds per day below the average of the previous five days. A somewhat larger drop in milk yield than in fat-corrected milk indicated an increase in butterfat percentage. The authors concluded that generally cold weather affects cows little if they are well fed and are acclimated to open pens.

Ragsdale and Turner (1922), and Hays (1926) observed a rise in butterfat percentage as environmental temperature drops from 72.5° to 27° F.

Dice (1940), studying the influence of temperature on milk production and feed consumption, concluded that cattle protected from rain, wind and snow can stand exposure to cold and will produce practically the same as in a stable maintained at 50° F. He found that cows allowed to run loose in a cold shed will, if anything, require less protein and total digestible nutrients and show slightly more weight gain than animals kept in a standard dairy barn.

Factors Other Than Environmental Temperatures Influencing the Composition of Milk

Breed: A considerable difference in butterfat percentage of the milk of the various dairy breeds has been reported by Overman *et al.* (1929). They found less variation between breeds in lactose, protein, total solids and solids-not-fat content of milk than in fat content although these constituents showed a tendency to parallel the butterfat percentage of the breed.

Turner (1936) reported that variations in butterfat percentage generally followed milk yield, and were higher for those breeds producing a smaller amount of milk.

Age: A slight decline in butterfat percentage with increasing age of the cow has been observed by Putnam *et al.* (1944). Turner (1936) stated that the decline in fat percentage with age appears greatest in the breeds secreting the highest fat content. The percentage of all the major constituents of milk apparently decreases slightly with advancing age, as reported by Tocher (1925).

White and Judkins (1918) found that the milk of mature cows, on the average, had a lower butterfat and solids-not-fat content than that of younger cows.

Bartlett (1934), and Turner (1936) reported that the solids-not-fat and butterfat content was somewhat higher in heifers than in older cows.

Feed: The influence of feed and its relationship to milk yield and milk composition has been studied by numerous investigators.

Turner (1936) observed that an abundant, well-balanced ration for dairy cows has a tendency to maintain the constancy of milk composition. A reduction in feed below the normal level, resulting in underfeeding of the animal, caused the butterfat percentage to increase as the milk yield decreased.

White and Judkins (1918) observed that cows in moderately good flesh at calving time showed a higher solids-not-fat and butterfat content than thin cows. They report that cows secrete milk more abundantly when the ration contained a small amount of fat. Allen (1934) observed a slight increase in butterfat percentage of milk by feeding rations high in fat, particularly butterfat, over a six-day period.

Rowland (1944) and Van Rensburg (1946) reported instances where the solids-not-fat content of milk was usually lowest during the winter periods. They attributed this depression to a low plane of nutrition.

Nicholson and Lesser (1934) found in their studies that the low solids-not-fat content of the milk of Friesian cattle could not be changed by improving the ration previously fed, except by use of young grass in early spring. Often underfeeding and loss of bodyweight occurs on immature pasture and explains the above observed phenomena.

Eckles and Palmer (1916) observed an increase in butterfat percentage and a decline in milk yield during underfeeding (from a high to a low plane of nutrition). Underfeeding also affected the protein content of milk, resulting in a decline especially of the casein.

Gowen and Tobey (1931) and Smith *et al.* (1938) observed that cows dropped rapidly in milk yield during a period of inanition. Butterfat, solids-not-fat, protein and chloride content of the milk increased with the duration of the starvation period, while the lactose in the milk and the glucose in the blood showed a distinct decline.

Perkins *et al.* (1932), using several hundred samples of milk arranged according to the protein content of the ration fed the cows, found that the level of protein feeding had little or no effect on the character of milk produced.

Stage of Lactation: The stage of lactation has considerable influence on the composition of milk. Ragsdale and Turner (1922) found that the butterfat percentage of milk declines for the first two or three months of the lactation period and then gradually increases until the end of the period. Eckles and

Shaw (1913), and Drakeley and White (1928), and others reported that during the lactation period the percentage of fat in milk varies inversely with the amount of milk secreted, although not in direct proportion.

Davis *et al.* (1947) reported a steady increase in total solids, serum solids and protein values following the second month of lactation. The lactose content of milk tends to decline after the second month of lactation. Similar observations on milk were made during the progressing stages of lactation by Aschaffenburg and Temple (1941).

Azarme (1938) found that the protein percentage of milk decreased very significantly until the fourth week of lactation after which a gradual increase until the end of the lactation period was observed.

Bartlett (1934) observed that milk was richer in solids-not-fat immediately after calving, and during the last three months of the lactation period. Between these two periods the solids-not-fat percentage was lower and remained more constant.

The Government of North Ireland Ministry of Agriculture (1946) reported that barren cows tend to produce milk lower in solids-not-fat percentage than pregnant cows.

Disease: Most diseases of a systemic nature influence the rate of secretion and composition of milk.

Turner (1936), and Vanlandingham *et al.* (1941) observed an increase in chloride content and decrease in lactose content in milk from cows infected with chronic mastitis. The fat content may either increase, decrease slightly or remain about the same with mastitis infection. Anderson *et al.* (1936) found that diseases of the udder usually caused a decrease in the casein content of milk.

In a study of twenty-nine herds of cattle, Foot and Shallock (1938) found that 19.5 per cent of all animals in the early stage of lactation were yielding milk low in solids-not-fat. Among the cows producing milk low in solids-not-fat the evidence of mastitis was observed in approximately 70 per cent of the cases.

The associates of Rogers (1928), quoting several German workers, relate that milk is altered by digestive diseases, foot and mouth disease and other diseases which cause a reduction in yield. Some of the changes were increased chlorides and butterfat, and a decrease in lactose. Protein values were observed to fluctuate.

Managerial Factors: The general management of dairy cattle and the methods used in milking are important factors influencing milk yield and its composition.

With respect to the interval between milkings, Turner (1936) observed that the longer the interval between milkings the lower the percentage of fat. Davies

(1939) and Ludwin (1942) reported that a decrease in intervals between milkings increases the amount of milk and the percentage of fat in the milk.

Bartlett (1934) found that the solids-not-fat content showed little variation throughout the milking process.

Brown *et al.* (1936) found a close relationship between the lactose levels of morning and evening milk when samples were obtained at regular milking periods. Delaying the milking period two hours was found to cause variations amounting to 1 per cent in the lactose content of the milk when compared to the preceding milking.

Many other factors such as incomplete milking, rapid or slow milking, undue excitement of cows, insufficient supply of fresh water, etc., have been shown to influence the milk yield and especially butterfat percentage (Turner, 1936; Espe, 1946, and others).

METHODS AND EQUIPMENT

The Climatic or Psychroenergetic Laboratory for Dairy Cattle: Data on the composition of milk as influenced by changing environmental temperatures for this study were obtained through the use of the Climatic Laboratory, Department of Dairy Husbandry at the University of Missouri. The Climatic Laboratory has been described in detail elsewhere (McCalmont, 1946, and Ragsdale *et al.*, 1948).

Briefly, the laboratory (Figure 1) consists of two insulated chambers, 26x18x9 feet, each housing six cows. They may be operated independently of each other with respect to temperature, humidity, air movement and ventilation, thus facilitating the use of experimental and control groups of cattle.

Determination of Total Solids: The determinations for total solids of milk were made by the drying method described in Methods of Analysis of Milk and its Products (1933), and the procedures of Sharp and Hart (1936).

A thin layer of pure quartz sand was placed in flat aluminum pans and heated for 3 hours to get a constant weight. Two ml. of each milk sample, which had previously been heated to 112° F. and cooled to 86° F. to insure the proper physical state of the fat, were placed in the pans and heated in an oven at 101° C. for 2½ hours. The samples were then removed and placed into a desiccator for 15 minutes to cool, after which constant weights were taken on the analytical balance. All determinations were made in duplicate.

Determination of Butterfat Percentage: The standard Babcock procedure was used to determine butterfat percentages. The samples were heated and cooled prior to testing, as previously mentioned, for total solids determination. Duplicate butterfat tests were made.

Determination of Solids-Not-Fat: Solids-not-fat percentages were obtained by taking the difference between the average of the duplicate determinations for total solids and butterfat percentages of each sample of milk.

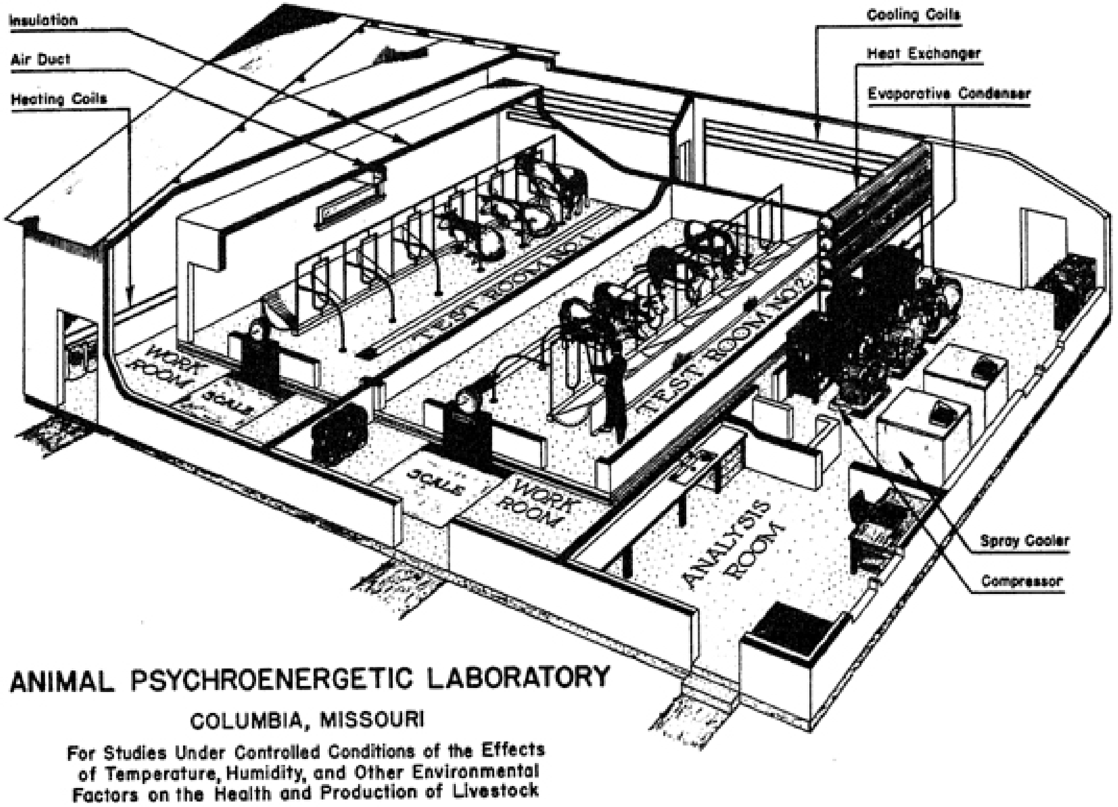

Fig. 1. Diagram of the climatic, or psychroenergetic laboratory.

Determination of Specific Gravity: The specific gravity for all milk samples was measured by a specially adapted Westphal balance. Samples were heated to 112° F. and cooled to 86° F. prior to making determination (Sharp and Hart, 1936).

Determination of Freezing Point Depression: The Hortvet cryoscope, with procedures as given by the Association of Official Agricultural Chemists (1945), was used in making freezing point depression determinations on milk.

Determination of Lactose: Lactose determinations, in duplicate, were made by Shaffer and Somogyi (1933) with minor modification in dilution rates.

The procedures consisted of adding 5 ml. of 0.5 N. sodium hydroxide and 5 ml. of 10 per cent zinc sulfate to 5 ml. milk in a 50 ml. volumetric flask. Distilled water was added to bring the volume to 50 ml. After mixing the contents and allowing the flask to stand for ten minutes the mixture was then filtered through No. 40 Whatman filter paper. Three ml. of the filtrate were diluted to 50 ml. and 5 ml. of the diluted filtrate was then placed in sugar test tubes. Five ml. of the copper iodometric reagent was added and the content of the covered tubes was strongly boiled for 35 minutes. The tubes were cooled to 40° F. without agitation, and after agitation 5 ml. of 1 N. sulfuric acid was added. After five minutes the solutions were titrated with 0.005 N. sodium thiosulphate until a straw color was obtained, then 1 ml. of starch solution was added and titration continued until the blue color was gone. A blank, composed of distilled water, was handled in a similar manner. The difference between the milk sample and distilled water sample represents the iodate value of the lactose. The dilution factor in this modified procedure was 3333.3.

Determination of Chloride: The method outlined by Davies (1932) was used in chloride determinations. Ten ml. milk was pipetted into a 250 ml. Erlenmeyer flask to which 10 ml. of 0.05 N. silver nitrate solution had been added. To this mixture was added 2 ml. of saturated potassium permanganate solution and 10 ml. of pure concentrated nitric acid. The contents were boiled until the liquid was clear, except for a small amount of white precipitate, and reddish-brown fumes were evolved. A small amount of urea (Ca. .25 gm.) was added to the hot solution and the contents were diluted to 50 ml. Six ml. of acetone and 1 ml. of a saturated solution of iron alum in 10 per cent nitric acid were then added. The excess of silver nitrate was titrated with 0.05 N. potassium thiocyanate. Ten ml. of 0.05 N. silver nitrate solution was found equivalent to 177.2 mg. of chloride per 100 ml. of milk.

Determination of Total Nitrogen: The standard Kjeldahl method for determining total nitrogen was used in all determinations (Association of Official Agricultural Chemists, 1945).

Obtaining and Handling Milk Samples: Milk samples were collected every second day throughout the experimental period and during the preliminary periods. Composite samples were made by taking aliquot parts of the morning and evening milkings. In some cases, at extremely high temperatures, daily samples were obtained. In one instance, during short interval high temperature trials, individual morning and evening samples were obtained and analyzed.

After collection of the milk samples, formaldehyde was added as a preservative (Palmer, 1919) and they were cooled to 40° F. The determinations of total solids, fat percentage and specific gravity were made within 24 hours after collection of the samples. Milk samples collected over a period of 4 to 6 days, varying with the anticipated critical heat periods, were mixed and analyzed for lactose, chloride and total nitrogen. At extremely high temperature, with relatively short time intervals, daily determinations for all constituents under study were made. Freezing point depressions were made on a one-day sample obtained every 4 to 7 days during the later trials. Daily milk production records were kept.

EXPERIMENTAL RESULTS

The Influence of High Ambient Temperature on Milk Composition

A review of the literature indicates that many milk constituents are subject to variations as a result of changes in temperature; perhaps humidity and other factors are associated with climatic conditions in the temperate zone. The purpose of this investigation was: (a) to determine, under controlled conditions, the effect of varying environmental temperatures on milk composition, (b) to determine the optimum temperature for maximum milk yield and for minimum changes in composition and (c) to determine breed differences in ability to withstand adverse climatic conditions.

Experimental Procedure

Trial 1

The first experiment was conducted during the period of March, 1948 to August, 1949. Facts pertaining to detail arrangement, temperature changing intervals and history of cows studied have been published by Ragsdale *et al.* (1948). A total of 790 milk samples were obtained from 6 Jersey and 4 Holstein cows, and analyzed for total solids, butterfat, solids-not-fat, lactose, chloride, total nitrogen levels and specific gravity.

The cows of each breed were "paired" with regard to age, body size, previous milk production, stage of lactation, daily milk yield, etc. One of each pair was placed in the experimental and control chamber respectively.

The experimental cows were subjected to a systematic increase in environmental temperature from 50° to 105° F. at intervals of 5° to 10° F. The control cows were maintained at 50° F. temperature throughout the trial. Near the end of the study, the temperature of the experimental room was lowered from 105° F. to 60° F. The cows, designated as controls, were subjected to increasing environmental temperature of 50° to 100° F. and then returned to 60° F. over a period of three weeks. The relative humidity was maintained between 60 to 70 per cent in both control and experimental chambers throughout the experiment.

Both groups of cows, experimental and control, were handled and managed in a similar manner. All animals were milked by machine twice daily.

The grain mix fed in this and the later studies was made up as follows:

800 parts	ground corn
460 parts	ground oats
400 parts	bran
300 parts	soybean oil meal
20 parts	steambone meal
20 parts	salt

Nopco XX Cod Liver Oil was added to the grain mix shortly after the trial began so that each cow received 10,000 units of vitamin D and 75,000 units vitamin A daily.

The amount of grain fed daily was based on the previous week's milk production. Jersey cows received 1 pound of grain for 3 pounds of milk and Holstein cows 1 pound of grain per 4 pounds of milk produced daily. The animals were fed 2 pounds of beet pulp daily, dry weight basis, and alfalfa hay *ad libitum*. Water was available at all times.

Trial 3

This study was conducted during the summer of 1949 on 418 milk samples obtained from 4 Jersey, 4 Holstein and 4 Brahman cows. One Brahman (189) was turned dry shortly after the study had begun. The cows were paired as in Trial 1.

The environmental temperature of the experimental cows was systematically increased from 50° to 105° F. and returned to the 50° F. level over a period of 70 days. The control group of cows was maintained at 50° F. temperature throughout the trial.

The feeding and management were the same as reported in Trial 1, except that the Brahman cows received 4 to 5 pounds of grain daily irrespective of their average low milk production.

Further data concerning the history of the cows, temperature changes, etc., are reported in a previous publication by Ragsdale *et al.* (1950).

Trial 5

This study was conducted on 3 high producing Brown Swiss cows and covered the period of February 6 to June 9, 1950. One hundred ninety-two milk samples were collected and analyzed. No control animals were used in this experiment. The environmental temperature was increased from 40° to 105° F. at intervals of 5° to 10° F. An extended period at 40° F. temperature during the beginning and at the end of the experimental period served as a basis for estimating the effects of environmental temperature.

In addition to the milk analyses made during the previous trials, the freezing point depressions were obtained on the milk throughout the experimental period involving the Brown Swiss cows.

Pertinent facts with respect to the feeding, management, temperature calendar and history of the cows used in the trial have been reported by Ragsdale *et al.* (1951).

Results

Milk Production: A decline in milk production was observed in all breeds except the Brahman cows, which were extremely low producers, throughout the trial as environmental temperatures were increased from 50° to 105° F.

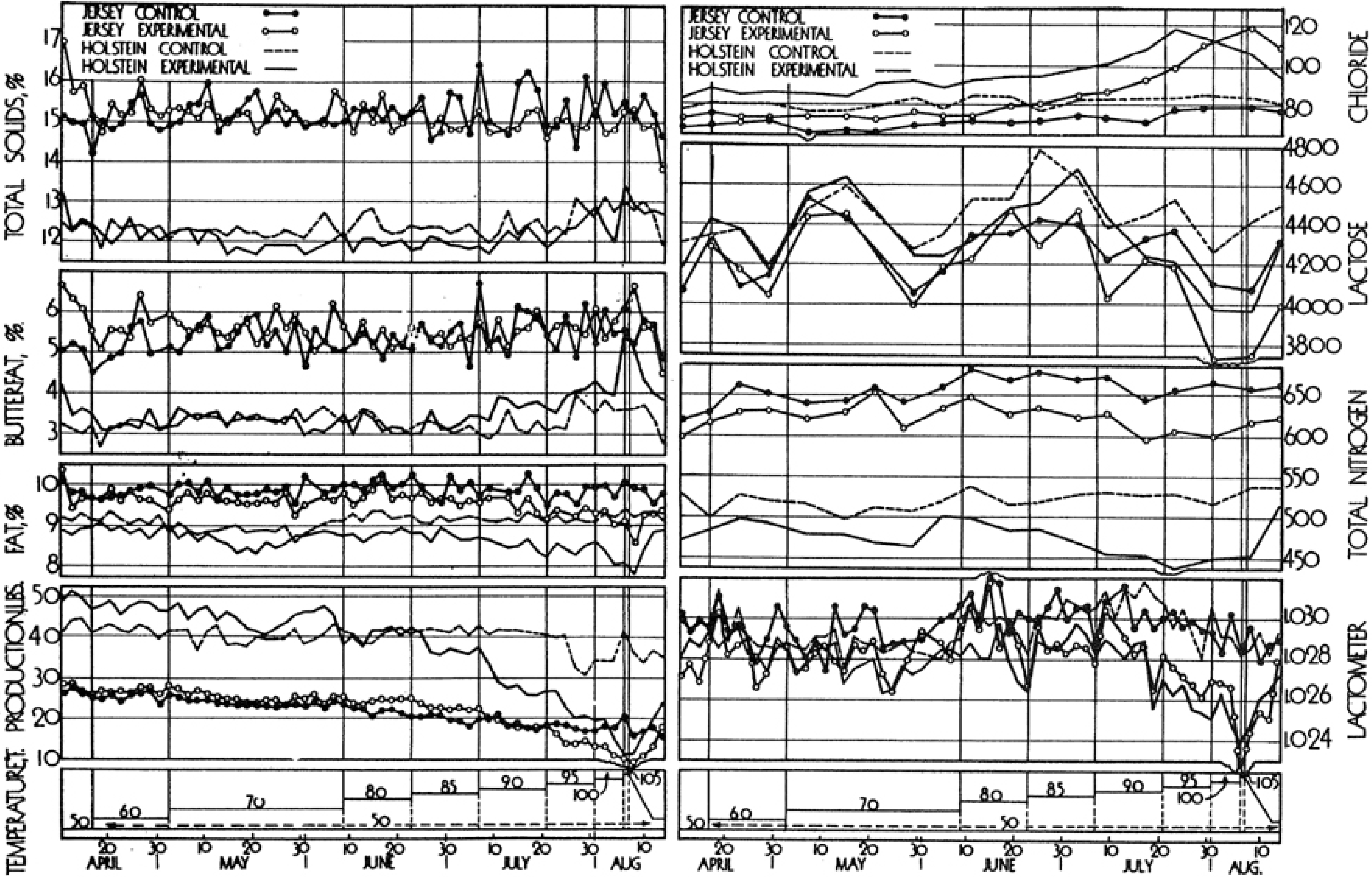

Fig. 2. The influence of environmental temperature (50° to 105° F.) on the averaged milk yield and milk composition of two Holstein and three Jersey cows and their controls.

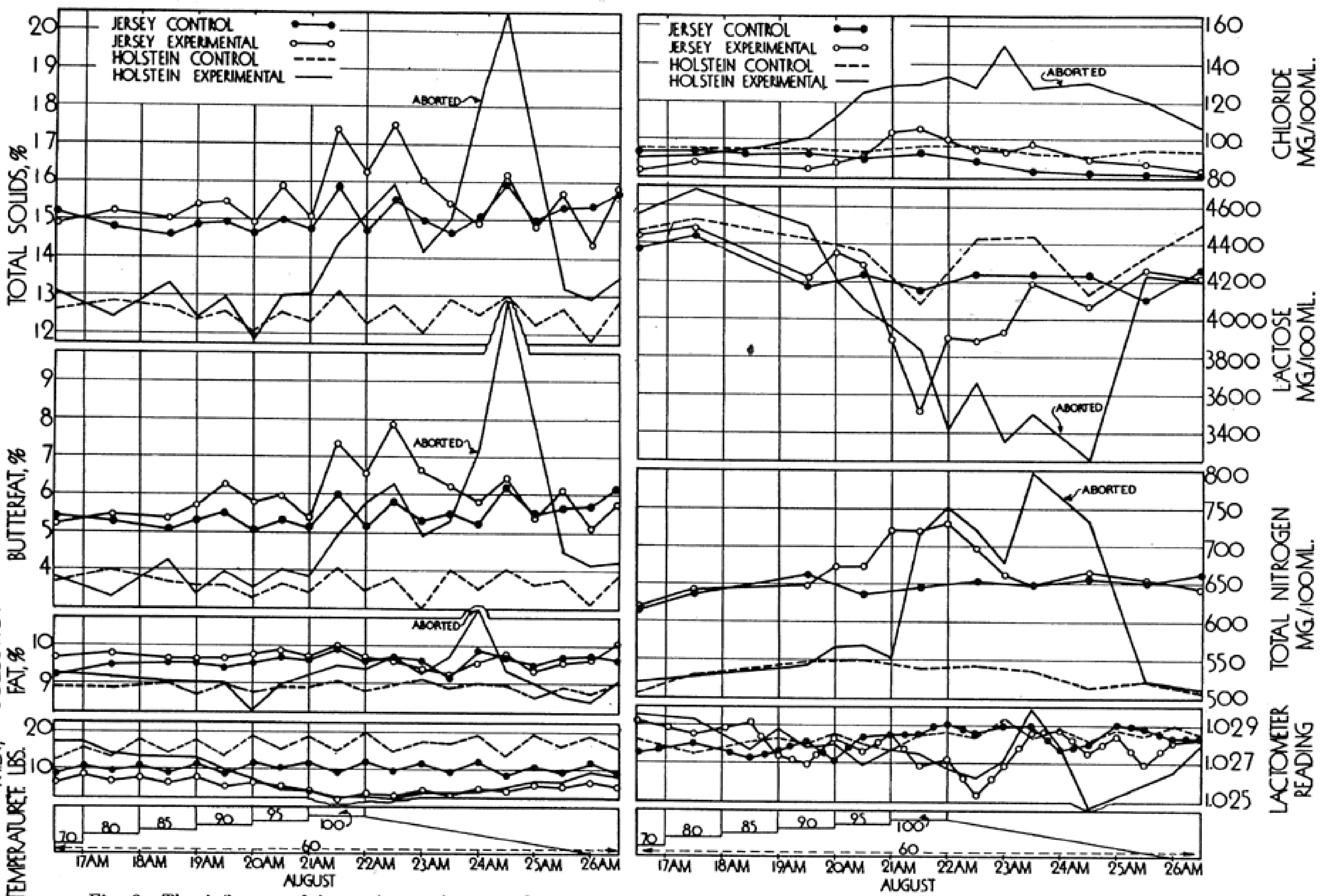

Fig. 3. The influence of increasing environmental temperature (70° to 100° F.) on the averaged milk yield and milk composition of three Jersey and two Holstein cows and their controls.

The average milk yield for the 4 experimental Holstein and 5 experimental Jersey cows and their controls are presented in Figures 2, 3 and 4. The decline in milk production of the experimental Holstein cows was first observed at a temperature of 80° to 85° F. as compared to their "pair mates."

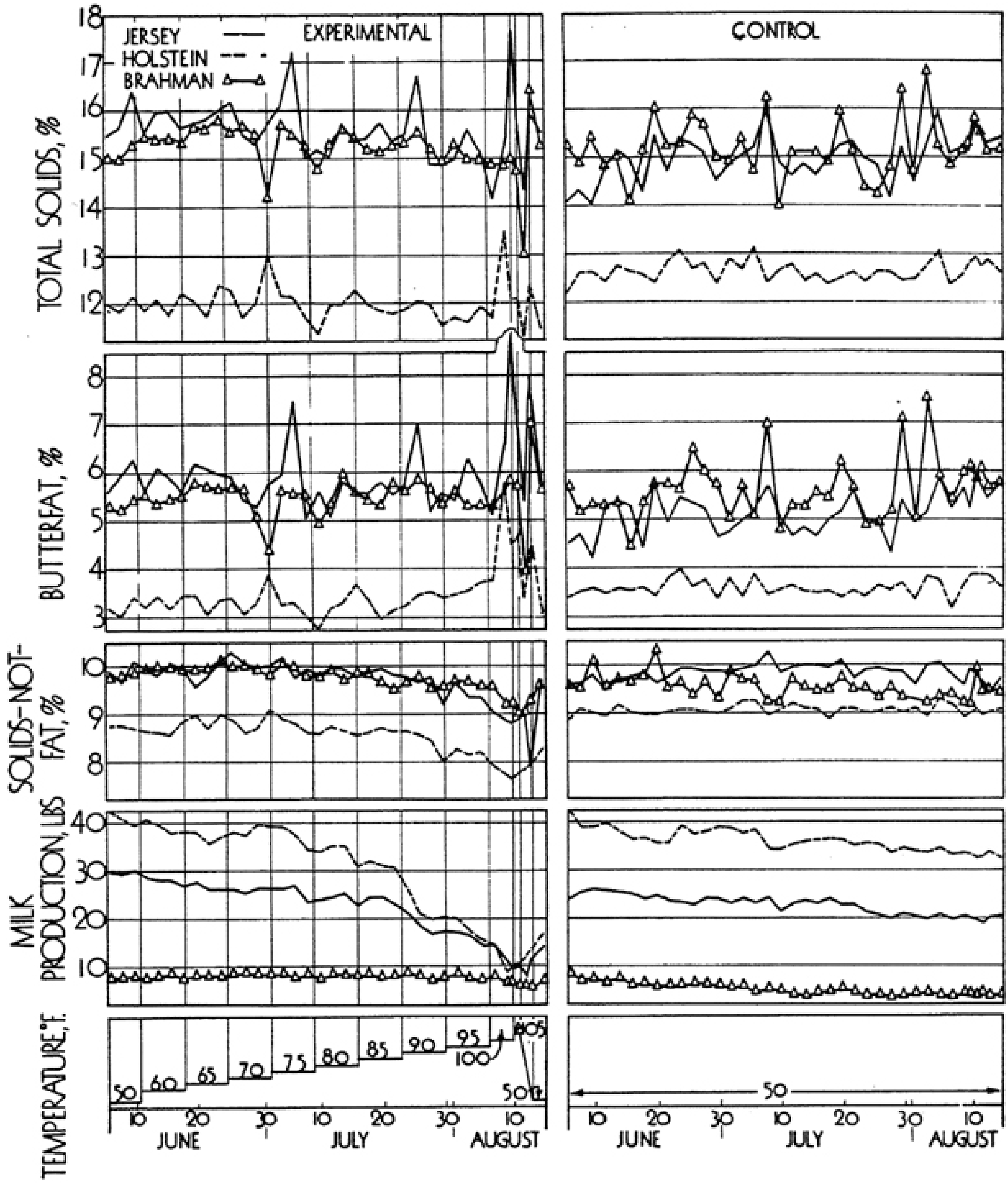

Fig. 4. The influence of environmental temperature (50° to 105° F.) on the averaged milk yield, total solids, butterfat, and solids-not-fat percentage of two Jersey, two Holstein and two Brahman cows and their controls.

The Brown Swiss cows (Figure 6) maintained milk production at a high level until the latter part of the 85° F. period, though their body size and average milk yield were comparable to that of the Holstein cows. In case of the Brahman cows, no apparent decrease in milk production was observed. It was noted, however, that on the average the Jersey, Holstein and Brown Swiss cows

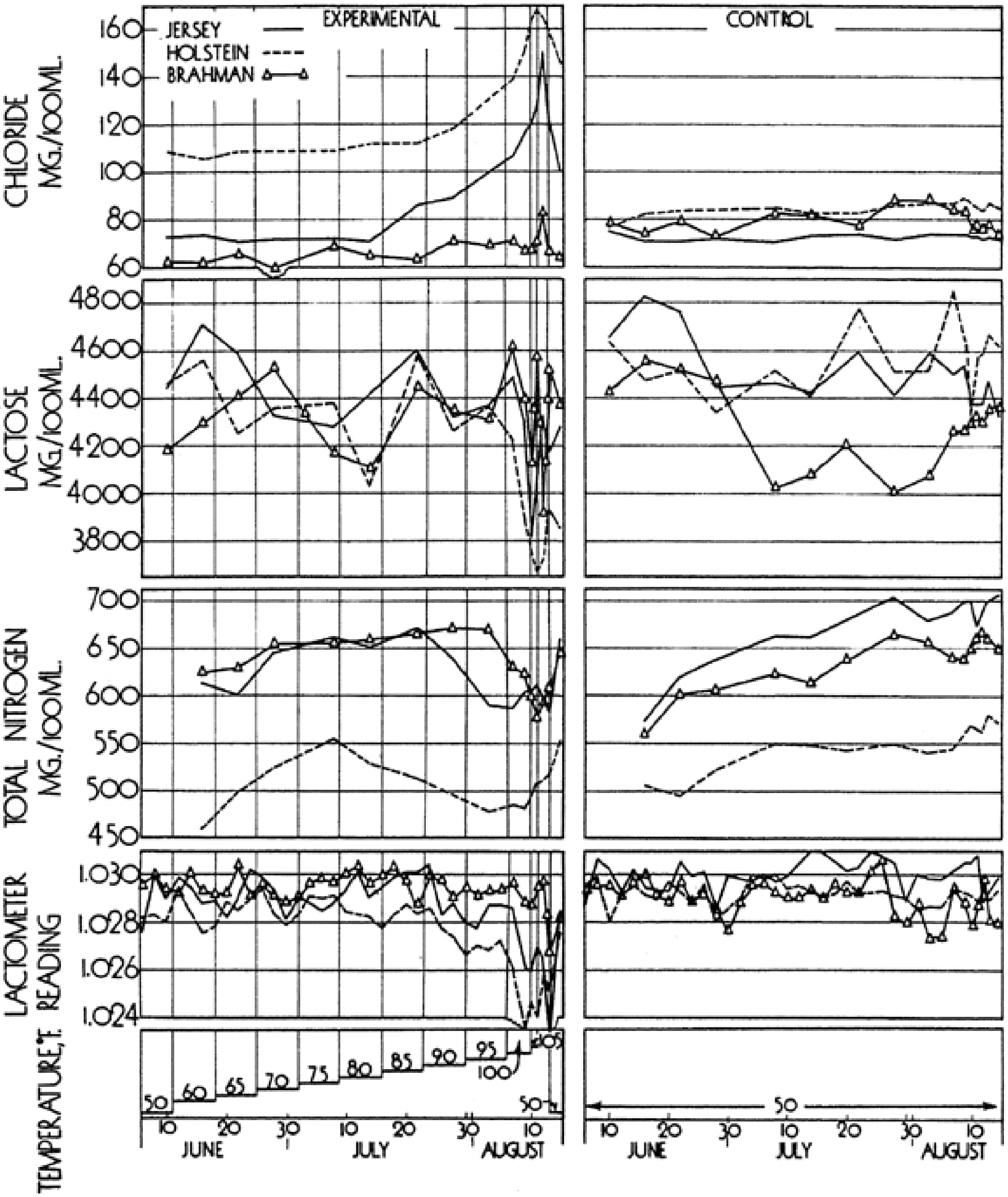

Fig. 5. The influence of environmental temperature (50° to 105° F.) on the averaged chloride, lactose, total nitrogen content and specific gravity of milk of two Jersey, two Holstein and two Brahman cows and their controls.

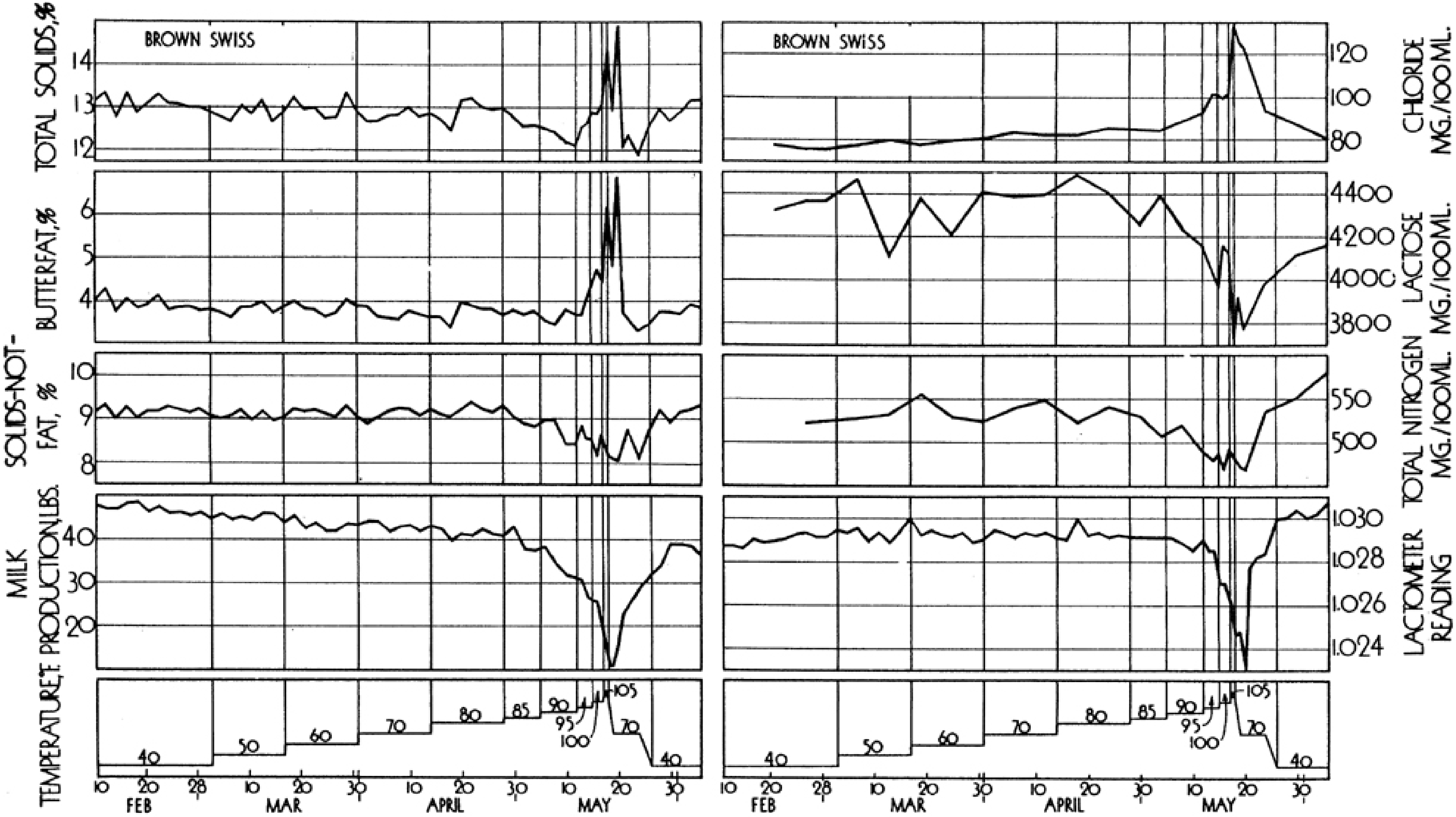

Fig. 6. The influence of environmental temperature (40° to 105° F.) on the averaged milk yield and composition of milk (three Brown Swiss cows).

failed to drop below the Brahman cow's milk level even at environmental temperatures of 100° to 105° F.

A substantial increase in milk yield was found in the case of the breeds affected by rising temperature shortly after the environmental temperatures were reduced below the 105° F. mark.

Butterfat: As shown in Figures 2, 3 and 6 the average butterfat percentage of milk from Holstein, Jersey and Brown Swiss cows declined slightly at environmental temperatures of 50° to 90° F. At temperatures above 90° F. a substantial increase in fat percentage was found for all three breeds.

The experimental Brahman cows, although showing considerable individual variability, failed to show any decided change in butterfat percentage of the milk produced, over the one control animal, as environmental temperatures increased from 50° to 105° F.

Figure 3 presents the data obtained during an increase in temperatures from 50° to 100° F. over a period of ten days. The butterfat percentage increased an average of 1 to 2 per cent for both the experimental Holstein and Jersey cows, as compared to their controls, at a temperature of 100° F. The two experimental Holstein cows aborted a few days after the high temperature of 100° F. This occurrence, no doubt, further emphasizes the physiological reaction resulting when cows have a limited time for proper acclimatization to adverse environmental temperature.

Table 1 pictures the average butterfat percentage obtained at different temperature levels in Trials 1 and 3. No statistically significant differences in

TABLE 1.--MILK BUTTERFAT PERCENTAGE -- JERSEY AND HOLSTEIN COWS

Ambient Temperature of Experimental Cows °F	Experimental				Control (50°F)			
	No. of Samples	Mean Butterfat %	Standard Error of Mean %	Standard Deviation %	No. of Samples	Mean Butterfat %	Standard Error of Mean %	Standard Deviation %
				JERSEY (10 Cows)				
**50	18	6.096	±0.1354	±0.569	18	4.818	±0.1516	±0.643
60	38	5.727	±0.1157	±0.711	38	5.095	±0.1076	±0.663
70	65	5.676	±0.0797	±0.641	65	5.292	±0.0868	±0.700
80	56	5.448	±0.0584	±0.437	56	5.293	±0.0979	±0.733
90	52	5.659	±0.0849	±0.612	52	5.389	±0.1106	±0.798
100	20	6.377	±0.2887	±1.291	20	5.651	±0.1207	±0.568
50	13	5.775	±0.3803	±1.371	13	5.482	±0.1774	±0.649
				HOLSTEIN (8 Cows)				
50	14	3.501	±0.1306	±0.488	14	3.304	±0.0674	±0.252
60	30	3.301	±0.0521	±0.285	30	3.379	±0.0725	±0.397
70	48	3.348	±0.0504	±0.349	48	3.430	±0.0428	±0.296
80	42	3.217	±0.0623	±0.404	42	3.469	±0.0486	±0.315
90	40	3.692	±0.0486	±0.307	40	3.406	±0.0618	±0.391
100	16	4.631	±0.2620	±1.048	16	3.740	±0.0796	±0.318
50	10	3.644	±0.1831	±0.579	10	3.568	±0.1089	±0.344

** Difference in means is significant $P < .05$.

the mean butterfat percentage for the two breeds involved were found at any temperature gradient. The mean butterfat percentage for the experimental cows at temperatures of 90° to 100° F. does indicate some tendency for increased butterfat test.

It is realized that statistical analyses of these data are of limited value in view of the number of cows involved and the variation in the time element of the trials.

The data obtained in this study on butterfat percentages have been previously reported for individual cows and by the percentage of the initial level at 50° F. temperature by Ragsdale *et al.* (1948), and Ragsdale *et al.* (1950). The authors found an increase, as a rule, in butterfat percentages where cows were maintained at temperatures of 90° and 100° F. Considerable individual variation in test was found for all cows studied.

A comparison of the butterfat percentage with other constituents of milk, as obtained at the various temperature levels, are presented in Table 2. Two Jersey cows (212 and 994) were used in both Trials 1 and 3. A difference was found between individual cows of the same breed handled under exactly the same conditions. It was further observed that the two cows, as individuals, did not react the same way in the two separate experimental periods. It appears that the shorter time intervals used at the various temperature gradients, in Trial 3, may be considered a factor in causing the more striking changes in milk composition.

Solids-Not-Fat: A reduction in the solids-not-fat percentage of milk was observed for all cattle studied during the period of increasing environmental temperature. The data are presented in Figures 2, 4 and 6.

TABLE 2.--MILK COMPOSITION OF TWO INDIVIDUAL JERSEY COWS AS INFLUENCED BY HIGH ENVIRONMENTAL TEMPERATURES

Ambient Temperature of Experimental Cows °F	Experiment 1				Experiment 3			
	Total Solids %	Butterfat %	Solids-Not-Fat %	Chloride mg./100ml.	Total Solids %	Butterfat %	Solids-Not-Fat %	Chloride mg./100ml.
				JERSEY COW No. 212				
50	16.44	6.26	10.18	67.22	15.53	5.61	9.92	67.83
60	15.40	5.47	9.93	65.77	15.68	5.61	10.07	63.51
70	15.79	5.75	10.04	62.14	15.82	5.74	10.08	64.34
80	15.68	5.50	10.18	71.03	15.23	5.27	9.96	72.86
90	15.50	5.58	9.92	77.03	15.02	5.45	9.57	83.04
100	15.15	5.31	9.84	88.00	15.74	6.44	9.10	109.04
50	15.36	5.45	9.91	80.57	14.80	5.40	9.40	89.83
				JERSEY COW No. 994				
50	15.95	6.47	9.48	78.92	16.19	6.31	9.88	79.75
60	15.94	6.18	9.76	76.48	16.01	6.30	9.71	82.22
70	15.50	5.98	9.52	77.65	15.97	5.97	10.00	81.40
80	15.09	5.58	9.51	83.82	15.66	5.88	9.78	85.47
90	15.38	5.99	9.39	104.42	15.48	6.10	9.38	124.30
100	15.91	6.64	9.27	127.74	16.21	7.90	8.31	151.36
50	14.92	5.68	9.24	113.95	16.09	6.30	9.79	112.02

The greatest decrease in solids-not-fat percentage was found in the Holstein cows. They showed a decline of 1 to 1½ per cent below that of the control animals at temperatures ranging from 90° to 105° F. Values considerably below the Federal Standards (8 per cent) were obtained in Trials 1 and 3. In Table 3, the Holstein experimental cows were significantly lower ($P<.01$) in solids-not-fat percentage when compared with their control mates at temperatures of 90° and 100° F.

TABLE 3.--MILK SOLIDS-NOT-FAT PERCENTAGE -- JERSEY AND HOLSTEIN COWS

Ambient Temperature of Experimental Cows °F	Experimental				Control (50°F)			
	No. of Samples	Mean Solids-Not-Fat %	Standard Error of Mean %	Standard Deviation %	No. of Samples	Mean Solids-Not-Fat %	Standard Error of Mean %	Standard Deviation %
				JERSEY (10 Cows)				
50	18	9.813	±0.1012	±0.429	18	9.801	±0.0614	±0.260
60	38	9.774	±0.0586	±0.361	38	9.871	±0.0429	±0.200
70	65	9.695	±0.0531	±0.428	65	9.903	±0.0453	±0.365
80	56	9.728	±0.0521	±0.390	56	9.942	±0.0404	±0.302
90	52	9.421	±0.0628	±0.452	52	9.840	±0.0399	±0.288
100	20	9.084	±0.1616	±0.722	20	9.844	±0.0819	±0.366
50	13	9.133	±0.2204	±0.794	13	9.683	±0.1210	±0.436
				HOLSTEIN (8 Cows)				
50	14	8.847	±0.0683	±0.255	14	9.125	±0.0709	±0.265
60	30	8.826	±0.0489	±0.267	30	9.089	±0.0578	±0.316
70	48	8.676	±0.0434	±0.300	48	8.962	±0.0416	±0.288
80	42	8.716	±0.0341	±0.221	42	9.162	±0.0489	±0.311
*90	40	8.398	±0.0398	±0.251	40	9.133	±0.0373	±0.218
*100	16	7.871	±0.0815	±0.326	16	9.136	±0.0761	±0.304
50	10	8.463	±0.1320	±0.417	10	9.176	±0.0846	±0.264

* Difference in means is significant $P<.01$.

The Jersey experimental cows also showed a decline in solids-not-fat content of the milk but not to the extent found in Holsteins (Figures 2, 4, and 6).

No significant difference between the experimental and control Jerseys in solids-not-fat of the milk was found at any temperature level studied. The depression in solids-not-fat percentage in the Brown Swiss cows was similar to that observed in the Jerseys. No change was observed in solids-not-fat at the short interval period as temperatures were increased to 100° F. (Figure 3).

Although the daily milk yield of the two Brahman cows (never very heavy producers) remained about the same irrespective of the temperature conditions, there was some tendency for the solids-not-fat percentage to decline at 100° to 105° F. temperature.

The control Jerseys and Holsteins showed a similar standard deviation and standard error of the mean per cent of solids-not-fat, indicating less variability between individual and breeds than found in the butterfat percentage.

Total Solids: The total solids percentages of milk obtained during the high temperature studies show relatively little change from environmental temperatures of 50° to 105° F. This finding is in keeping with the data previously presented for butterfat and solids-not-fat percentages at various temperatures.

At environmental temperatures of 100° and 105° F. some rise (Figures 2, 4 and 6) in total solids percentage, resulted in the Brown Swiss and to a lesser extent in the Jersey and Holstein cows, due to the marked increase in butterfat percentage which over-shadowed the decrease in solids-not-fat content. Data presented in Figures 2, 4 and 6 indicate that the total solids content of the milk generally paralleled the changes found in the butterfat percentage.

As may be observed in Table 4, no significant difference was found between the control and experimental cows of either the Jersey or Holstein breed. There was a slight tendency for the total solids percentage to decline at temperatures from 50° to 90° F., paralleling similar trends in the butterfat percentage (Table 1).

TABLE 4.--MILK TOTAL SOLIDS PERCENTAGE -- JERSEY AND HOLSTEIN COWS

Ambient Temperature of Experimental Cows °F	Experimental				Control (50°F)			
	No. of Samples	Mean Total Solids %	Standard Error of Mean %	Standard Deviation %	No. of Samples	Mean Total Solids %	Standard Error of Mean %	Standard Deviation %
				JERSEY (10 Cows)				
50	18	15.938	±0.1894	±0.803	18	14.619	±0.1743	±0.739
60	38	15.508	±0.1264	±0.779	38	15.037	±0.0970	±0.598
70	65	15.376	±0.1264	±0.815	65	15.216	±0.0992	±0.799
80	56	15.180	±0.0838	±0.627	56	15.226	±0.1142	±0.855
90	52	15.083	±0.1067	±0.769	52	15.236	±0.1316	±0.949
100	20	15.308	±0.2904	±1.298	20	15.442	±0.1324	±0.592
50	13	14.892	±0.3166	±1.141	13	15.238	±0.1973	±0.711
				HOLSTEIN (8 cows)				
50	14	12.349	±0.1675	±0.626	14	12.456	±0.0922	±0.363
60	30	12.115	±0.0613	±0.335	30	12.466	±0.1029	±0.563
70	48	12.022	±0.0795	±0.511	48	12.392	±0.0677	±0.469
80	42	11.942	±0.0798	±0.517	42	12.444	±0.0665	±0.431
90	40	12.094	±0.0640	±0.405	40	12.539	±0.0775	±0.490
100	16	12.465	±0.2690	±1.076	16	12.866	±0.1375	±0.550
50	10	12.397	±0.2932	±0.927	10	12.644	±0.1930	±0.610

Specific Gravity: Lactometer readings were obtained on all samples of milk analyzed during the trial periods. All readings were made at a milk temperature of 86° F. (Sharp and Hart, 1936). Since no corrections were made for the temperature used, all readings, as an average, were found to be somewhat below those generally reported in the literature where milk was not heated before determining the specific gravity.

The lactometer readings, although rather variable, showed a distinct decrease for the experimental Holstein, Jersey and Brown Swiss cows maintained at temperatures from 85° to 95° F. (Figures 2, 3 and 6). The depression observed was slightly below 1.023 as compared to approximately 1.029 for the control cows or the initial level obtained at the 50° F. temperature. In the case of the two experimental Brahman cows a slight decline in specific gravity of the milk was observed but since the one Brahman control showed an even greater fluctuation, the decrease in the case of the experimental animals may be of no significance in relationship to increased environmental temperature.

The depressed specific gravity readings of the milk returned to the expected normal quite rapidly as the environmental temperatures were lowered to 50° F.

Chlorides: High environmental temperatures caused a substantial increase in the chloride content of milk from the Holstein, Jersey and Brown Swiss cows as indicated in Figures 2, 3, 5 and 6. The milk of Brahman cows showed some tendency to increase in chlorides at the 105° F. temperature, but not to the extent exhibited by the other breeds.

The two Holstein cows, for which data on chlorides of milk are shown in Figure 2, showed an increase in chloride content of the milk as compared to their controls, but at a temperature of 95° F. the values began to decline. It is impossible to draw significant conclusions for this decline in chloride values as only limited samples were obtained during the period. In later experiments chloride determinations were made at more frequent intervals and are more indicative.

With high environmental temperatures, some experimental individual cows were observed to increase the chloride content of the milk as much as 100 per cent above that of their controls or their previous chloride level at temperatures of 50° F. The stage of lactation at the time the cows were placed in the laboratory, as well as individual cow variation, were probably influencing factors on the average chloride levels found between cows of different breeds and of the same breed. Table 2 illustrates variations found in the chloride content of milk from individual Jersey cows for the separate experimental periods carried on at high temperatures.

Generally, the chloride content of the milk of the experimental Holstein and Jersey cows was influenced first at environmental temperatures between 80° and 90° F. The Brown Swiss cows were affected at 90° F. temperature. Immediately after the 105° F. temperature, a slight increase in the chloride content was observed in the milk from the experimental Brahman cows.

A short time study of the chloride content of milk from individual quarters of all cows in Trial 3 was made at temperature levels of 50°, 85° and 100° F. (Table 5). The milk samples used were from a single day's milking obtained in all cases just prior to the regular milking period.

Although the data obtained are few in number they do indicate that certain quarters of the same cow may vary in chloride content.

TABLE 5.--MILK CHLORIDE VALUES FROM INDIVIDUAL QUARTERS OF COWS SUBJECTED TO ENVIRONMENTAL TEMPERATURES OF 50° TO 100°F.

	Experimental						Control				
Breed and Number	Ambient Temper-ature °F	Quarters				Breed and Number	Ambient Temper-ature °F	Quarters			
		R.F.	R.R.	L.F.	L.R.			R.F.	R.R.	L.F.	L.R.
		mg./100ml.						mg./100ml.			
Holstein 7	50	93.3	Blind	103.4	98.5	Holstein 146	50	88.2	84.7	86.5	81.4
	85	116.0	Blind	111.2	111.2		50	91.7	86.5	93.3	86.5
	100	186.2	Blind	181.7	173.3		50	93.3	84.7	98.3	84.7
Holstein 109	50	96.6	96.6	Blind	103.4	Holstein 147	50	66.0	69.5	66.0	67.8
	85	98.5	96.6	Blind	106.9		50	76.3	77.9	71.1	71.1
	100	161.4	186.2	Blind	200.4		50	77.9	77.6	74.6	77.9
Jersey 212	50	64.3	61.1	63.0	59.2	Jersey 205	50	71.1	----	72.8	64.3
	85	69.5	67.8	69.5	66.0		50	81.4	81.4	69.5	61.1
	100	108.5	98.5	96.6	106.9		50	81.4	84.7	71.1	67.8
Jersey 994	50	81.4	74.6	79.8	81.4	Jersey 504	50	89.8	67.8	71.1	67.8
	85	84.7	86.5	84.7	91.7		50	91.7	66.0	69.5	71.1
	100	137.9	134.1	147.7	154.7		50	103.9	69.4	79.7	71.1
Brahman 190	50	62.7	54.1	57.8	52.4	Brahman 196	50	72.8	69.5	72.8	74.6
	85	61.0	57.5	61.1	59.2		50	64.3	71.1	61.1	62.7
	100	77.9	71.1	88.2	71.1		50	74.6	71.1	57.5	71.1
Brahman 209	50	72.8	66.0	67.8	64.3	No Control					
	85	69.5	63.0	71.2	67.8						
	100	83.0	76.3	89.8	77.9						

With a decrease in environmental temperature from 105° to 50° F., the chloride content of the milk returned to the normal level within a relatively short period. The immediate return to normal milk chloride values with the lowering of high temperatures to 50° F. indicates that no extensive damage, if any, was done to the milk secreting tissue of the udder.

Lactose: The lactose content of milk was found to decrease at high environmental temperatures in Holstein, Jersey and Brown Swiss cows. The experimental Brahman cows exhibited considerable variation at high temperatures but no definite trend in order of the variations could be established. No plausible explanation can be given for the decline in the lactose content of the milk from the one control Brahman cow as shown in Figure 5. The only noticeable variation of any consequence in other constituents was observed in the irregular changes in butterfat percentage.

Figures 2 and 5 show that the average lactose content of milk from the experimental Holstein cows decreased at environmental temperature of 95° to 105° F.

During the rapid increase in environmental temperatures to 100° F. (Figure 3), a decline in lactose content of milk of approximately 1 per cent was found beginning at 90° F.

In the experimental Jersey cows, a decrease in the lactose content was found at environmental temperatures of 95° to 105° F. (Figures 2 and 5). Similar decreases were observed in the experimental Jersey cows with rapidly rising temperatures over a short period of time (Figure 3).

The three Brown Swiss cows, at temperature levels of 90° to 105° F., showed a substantial decrease in the lactose content of the milk produced.

Total Nitrogen: The total nitrogen content of milk samples secured, as the environmental temperature was increased from 50° to 105° F., was observed to decrease in all breeds of cattle studied (Figures 2, 5 and 6). The decrease was most apparent in Trial 3, especially in the Jersey cows. The nitrogen content of milk from the Brahman cows was affected to a relatively greater extent by high temperatures than the other constituents. Nitrogen decreased substantially from 95° to 105° F. as compared to the one control, or their previous levels.

The increasing of temperatures to 100° F. over a relatively short period of time as shown in Figure 3 caused an increase in the total nitrogen of the experimental groups as compared to the controls. A more drastic rise in nitrogen was found in the latter part of the short-time temperature increases of the Holstein cows, apparently due to the abortions which occurred. A decline was noted between the peak levels of milk nitrogen as a result of temperature and the peak levels attributed to abortion.

Freezing Point Depression: The effect of high environmental temperatures on the freezing point depression of milk from the three Brown Swiss cows was observed. Table 6 presents the average freezing point of the milk obtained as the environmental temperatures were systematically increased from 40° to 105° F. The freezing points obtained on the milk from these three animals were within the range of –0.5491° to –0.5732° C.

No important changes in freezing point depression were noticed as the environmental temperatures increased from 40° to 105° F., however, there appeared to be a very slight decline occurring as the trial progressed.

TABLE 6.--FREEZING POINT DEPRESSIONS AND KOESTLER NUMBER OF MILK FROM BROWN SWISS COWS

Ambient Temperature of Experimental Cows °F	No. of Samples	Relative Humidity %	Freezing Point °C	Koestler Number
40	9	61	-0.5732	1.751
50	6	58	-0.5683	1.837
60	9	70	-0.5655	1.827
70	6	70	-0.5583	1.879
80	6	67	-0.5658	1.884
85	6	68	-0.5516	1.970
90	3	66	-0.5583	2.100
95	6	59	-0.5491	2.377
100	6	56	-0.5500	2.418
105	3	55	-0.5600	3.552
81	6	63	-0.5549	3.227
40	6	63	-0.5540	2.037

The Koestler number of the milk indicated that there was a substantial change in lactose and chloride content. The changes observed apparently were made without greatly influencing the freezing point determinations.

It is well known that the osmotic pressure of milk is fairly constant and there is a compensatory reduction in chlorides as lactose increases and vice versa.

Summary: A summary of the data obtained from the three trial periods indicates that a decrease in milk yield and changes in milk composition occurred as environmental temperature rose above 80° F. The change varied with the breed of cattle but was little pronounced in the case of the Brahman.

Butterfat, total solids and chloride content showed increases at the higher environmental temperature levels in the case of the Jersey, Holstein and Brown Swiss cows. Decreases were observed in solids-not-fat percentage, total nitrogen and lactose levels. The specific gravity of milk was found to be lowered at the high temperatures. The freezing point depression values of milk from the Brown Swiss cows indicated that the high environmental temperatures apparently had little, if any, influence on the freezing point of milk even though changes had occurred in the chloride and lactose content of milk.

The Effects of Low Environmental Temperature on the Composition of Milk

Experimental Procedure

Trial 2

This study includes trials with six Jersey and four Holstein cows in the University of Missouri Psychroenergetic Laboratory during the period from October, 1948 to April, 1949. Analyses were made on 640 samples of milk collected during the course of the trial. The animals of each breed used were paired in accordance with age, body size, stage of lactation, and previous milk production. One animal of each pair served as a control.

The environmental temperature was lowered systematically from 50° to 5° F. at intervals of 3° to 10° F. on the experimental cows with the control cows remaining at 50° F. temperature. As the experimental animals were being returned to a 50° F. temperature, the control cows were rapidly subjected to a low temperature of 4° F. and maintained at that temperature for a period of two weeks.

The original experimental cows were then subjected to increasing environmental temperatures of 50° to 95° F. The data obtained on the milk collected during this part of the experiment have not been presented since both the experimental and control cows were near the end of their lactation period and the normal fluctuations in the composition of the milk in several of the animals at this time precluded drawing conclusions related to temperature changes.

No change in feeding or handling methods was made over preceding trial periods as reported for higher temperatures. Pertinent facts relative to the actual environmental temperature calendar, history of cows, etc., are available in the publication by Ragsdale *et al.* (1949).

Trial 4

Analyses were made on 448 milk samples obtained from four Jersey and four Holstein cows over a period from October, 1949 to February, 1950. The environmental temperature was lowered from 50° to 8° F. at 3° to 9° F. intervals (Figure 8) on the experimental group and then returned to 50° F.

The control cows were maintained at a temperature of 50° F. throughout the trial period.

Facts pertaining to the managerial practices, pairing methods and other information applicable to this study are available in the publication by Ragsdale *et al.* (1950).

Electrical power failures were experienced in both low temperature trials, causing some irregularities in the proposed low constant temperature levels, but the effects were of such short duration the plan of the experiment was not impaired.

Data

Milk Production: The milk yields of the experimental cows and the control cows used in the low ambient temperature studies are graphically presented in Figures 7 and 8.

The milk production of the experimental Holstein cows was not affected by the gradual lowering of the environmental temperature from 50° to 5° F. A rapid lowering of the temperature to 4° F. (Figure 7) over a two-week period in the Holstein cows (designated as control animals throughout the trial period) showed an average drop of about 10 pounds of milk per cow per day as compared to cows maintained at a temperature of 50° F.

Ambient temperatures of 32° F. or below caused a noticeable decline in the milk yields of the experimental Jersey cows as compared to their controls maintained at 50° F. An average decline in milk yield of 4 to 6 pounds per cow per day was observed at temperatures below freezing. When subjected to a rapid lowering of temperature from 50° to 4° F. over a two-week period, the Jersey cows showed a substantial decrease in milk yield amounting to 5 to 7 pounds per day.

Butterfat: The butterfat percentages of the milk from the experimental cows were found to increase with a systematic decrease in ambient temperature from 50° to 5° F.

As shown in Figures 7 and 8, the experimental Jersey cows increased their average butterfat percentage as compared to the control cows maintained at a

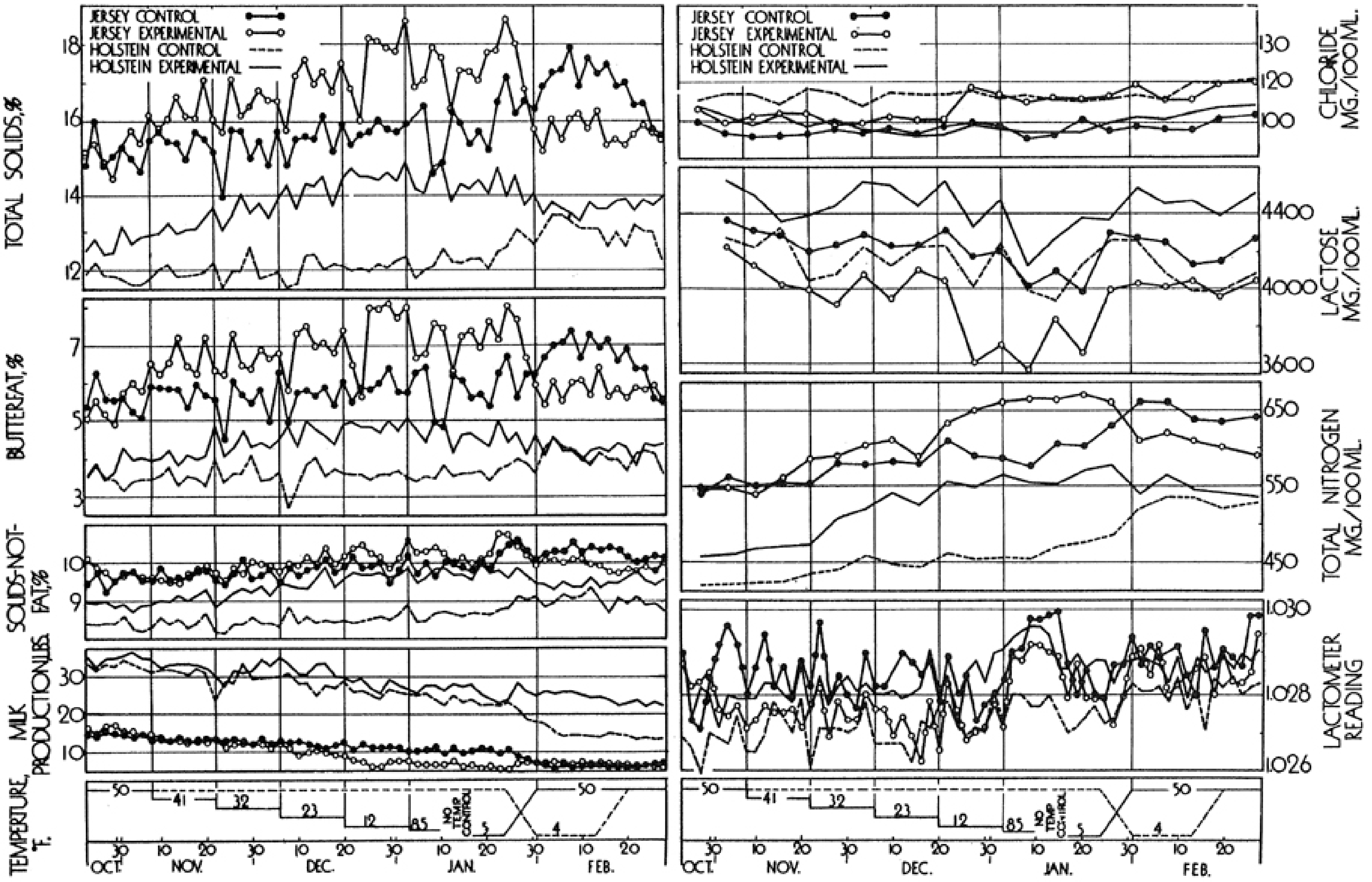

Fig. 7. The influence of environmental temperature (50° to 5° F.) on the averaged milk yield and milk composition of three Jersey and two Holstein cows and their controls.

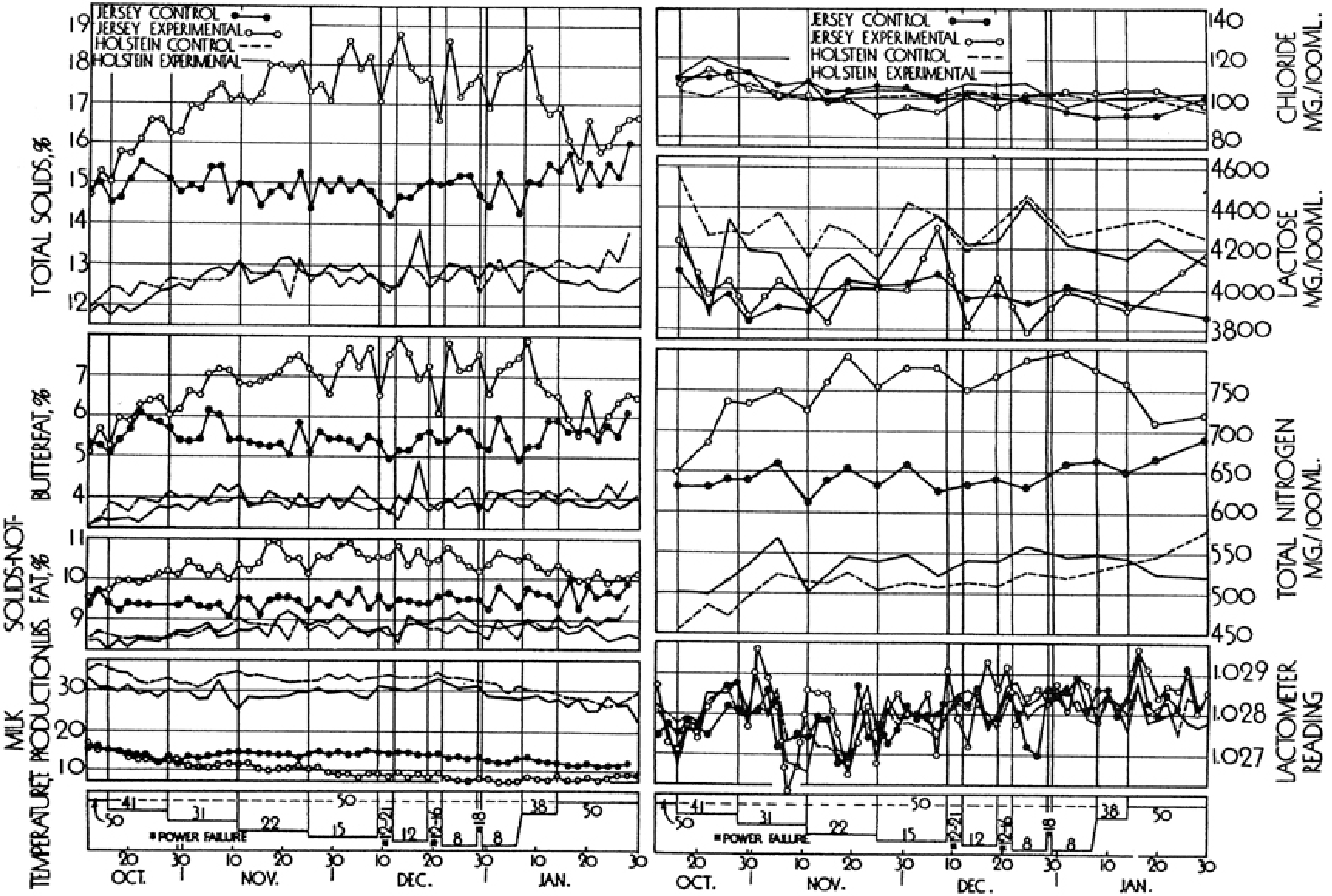

Fig. 8. The influence of environmental temperature (50° to 8° F.) on the averaged milk yield and milk composition of two Jersey and two Holstein cows and their controls.

temperature of approximately 40° F. or below. A decline in the butterfat percentages resulted when the temperature was increased from 5° to 50° F. Figure 7 indicates a rise in the butterfat percentage of the control Jersey cow subjected to rapidly decreasing temperatures (50° to 4° F. over a two-week period).

Table 7, prepared by combining the butterfat percentage data of Trials 2 and 4, shows the mean butterfat percentage was significantly higher (P<.02) in the experimental Jersey cows maintained at 31° F. temperature. Significantly higher butterfat percentages were also found at temperature levels of 22° F. (P<.01), 12-15° F. (P<.01) and 5-8° F. (P<.01).

TABLE 7.--MILK BUTTERFAT PERCENTAGE -- JERSEY AND HOLSTEIN COWS

Ambient Temperature of Experimental Cows °F	Experimental				Control (50°F)			
	No. of Samples	Mean Butterfat %	Standard Error of Mean %	Standard Deviation %	No. of Samples	Mean Butterfat %	Standard Error of Mean %	Standard Deviation %
				JERSEY (10 Cows)				
50	27	5.448	±0.0974	±0.512	27	5.470	±0.1855	±0.829
41	31	6.466	±0.1256	±0.699	31	5.773	±0.1173	±0.653
†31	35	6.677	±0.0907	±0.574	35	5.510	±0.1441	±0.852
*22	35	6.980	±0.1121	±0.653	35	5.538	±0.1215	±0.712
*12-15	49	7.266	±0.1308	±0.916	49	5.597	±0.1230	±0.861
* 5-8.5	53	7.280	±0.0995	±0.725	53	5.691	±0.1386	±1.009
					30#	6.847	±0.2137	±1.170
50	68	5.975	±0.0795	±0.655	38	5.952	±0.1517	±0.936
				HOLSTEIN (8 Cows)				
50	20	3.710	±0.0811	±0.362	20	3.486	±0.0761	±0.340
41	26	3.820	±0.0601	±0.361	26	3.671	±0.0718	±0.400
31	28	4.214	±0.0791	±0.418	28	3.807	±0.0668	±0.353
22	28	4.272	±0.0889	±0.470	28	3.701	±0.1130	±0.597
12-15	42	4.269	±0.0877	±0.569	42	3.745	±0.0548	±0.355
5-8.5	40	4.408	±0.0797	±0.504	40	3.746	±0.0652	±0.412
					20#	4.066	±0.1114	±0.410
50	52	4.118	±0.0518	±0.374	32	4.061	±0.0942	±0.533

\# Control cows at 4°F.
† Difference in means significant P<.02.
* Difference in means significant P<.01.

The butterfat test of Holstein cows was found to be influenced by lower environmental temperature but not to the extent observed in Jerseys. Considerable difference existed between the two Holstein trial groups with respect to their reactions to low environmental temperature. It is observed (Figure 8) that a considerable difference existed in butterfat percentage of experimental and control Holstein cows. In Figure 7, however, it is shown that a small difference existed in butterfat percentage of experimental and control Holstein cows. It should be noted, however, that the control group of Holsteins maintained an unusually high fat level throughout the trial period which is probably due to chance in selection of the group. As the environmental temperature was increased from 5° to 50° F. the experimental Holstein cows decreased in butter fat percentage.

The control Holstein cows which were subjected to rapid lowering of temperature to 4° F. showed an increase in butterfat percentage.

No significant difference was observed (Table 7) between the mean butterfat percentage of the experimental and control Holstein cows with decreasing environmental temperature, although a noticeable increase in test was noted in the experimental cows.

Throughout the two low temperature trial periods, the milk of the Jersey cows was more variable in butterfat percentage than that of the Holstein cows. This was especially true of the experimental groups.

Solids-Not-Fats: The lowering of ambient temperature from 50° to 5° F. caused a general increase in the solids-not-fat content of the milk produced during this investigation. The trend in the increased solids-not-fat levels tended to parallel the rise in butterfat percentage.

The milk from both the experimental Holstein and Jersey cows (Figures 7 and 8) showed increases in solids-not-fat as compared to the control animals maintained at approximately 50° F. Greater differences were observed as the temperatures were lowered systematically to 8° F. When ambient temperatures were increased from 5° to 50° F., a decrease was noted in the solids-not-fat content of the milk produced by the experimental cows.

It will be noted (Table 8) that the solids-not-fat percentage of the milk from the Jersey experimental cows was significantly higher than that of the control cows, at temperatures of 12° to 15° F. ($P < .02$). The milk from the experimental Holstein cows likewise showed a significantly higher solids-not-fat content at a temperature of 5° to 8° F. ($P < .05$) than the control animals.

TABLE 8.--MILK SOLIDS-NOT-FAT PERCENTAGE -- JERSEY AND HOLSTEIN COWS

Ambient Temperature of Experimental Cows °F	Experimental				Control (50°F)			
	No. of Samples	Mean Solids-not-fat %	Standard Error of Mean %	Standard Deviation %	No. of Samples	Mean Solids-not-fat %	Standard Error of Mean %	Standard Deviation %
				JERSEY (10 Cows)				
50	27	9.714	±0.0514	±0.267	27	9.556	±0.0682	±0.354
41	31	9.753	±0.0566	±0.311	31	9.597	±0.0545	±0.303
31	35	9.965	±0.0611	±0.361	35	9.569	±0.0592	±0.350
22	35	10.212	±0.0847	±0.509	35	9.647	±0.0523	±0.309
†12-15	49	10.395	±0.0543	±0.380	49	9.646	±0.0468	±0.328
5-8.5	53	10.308	±0.0524	±0.378	53	9.910	±0.0527	±0.383
					30#	10.309	±0.0495	±0.285
50	68	9.996	±0.0594	±0.490	38	9.866	±0.0624	±0.385
				HOLSTEIN (8 Cows)				
50	20	8.746	±0.0564	±0.252	20	8.453	±0.0441	±0.197
41	24	8.822	±0.0708	±0.347	24	8.490	±0.0276	±0.135
31	28	8.941	±0.0578	±0.305	28	8.549	±0.0529	±0.280
22	28	9.260	±0.0696	±0.368	21	8.669	±0.0652	±0.345
12-15	42	9.142	±0.0708	±0.431	42	8.663	±0.0325	±0.210
**5-8.5	40	9.443	±0.0722	±0.457	40	8.729	±0.0433	±0.274
					20#	9.030	±0.0927	±0.414
50	52	9.180	±0.0629	±0.453	32	8.973	±0.0633	±0.358

Control cows at 4°F.

† Difference in Means is significant $P \leq .02$.

** Difference in menas is significant $P \leq .05$.

Total Solids: The average solids content of the milk from the experimental Holstein and Jersey cows, with decreasing ambient temperatures (Figures 7 and 8), was higher than the percentage obtained for the control cows maintained at 50° F. temperature. As the ambient temperature was increased from 5° to 50° F., a decrease in total solids percentage was observed in the experimental animals. A similar increase in total solids percentage was observed as the environmental temperature was rapidly reduced to 4° F. over a two-week period in the milk produced by both the Holstein and Jersey groups.

The average of the data obtained in the two trial periods (Table 9) showed that the milk from the experimental Holstein cows was significantly higher in total solids as compared to controls at temperature levels of 22° F. ($P<.05$), 12-15° F. ($P<.05$), and 5-8° F. ($P<.01$) respectively. Likewise, significantly higher total solids levels were obtained for the milk from the experimental Jerseys at temperature levels of 31° F. ($P<.01$), 22° F. ($P<.01$), 12-15° F. ($P<.01$) and 5-8° F. ($P<.01$) respectively.

The power failures which occurred during both low temperature experiments appear to be responsible for some of the variation found in total solids and butterfat percentages at the lower temperatures.

Specific Gravity: The data for specific gravity of the milk as presented in Figures 7 and 8 show considerable variation in the lactometer readings and little, if any, change in values as a direct influence of decreasing environmental temperature. There appeared to be a slight tendency for the lactometer read-

TABLE 9.--MILK TOTAL SOLIDS PERCENTAGE -- JERSEY AND HOLSTEIN COWS

Ambient Temperature of Experimental Cows °F	Experimental				Control (50°F)			
	No. of Samples	Mean Total Solids %	Standard Error of Mean %	Standard Deviation %	No. of Samples	Mean Total Solids %	Standard Error of Mean %	Standard Deviation %
				JERSEY (10 Cows)				
50	27	15.165	±0.1193	±0.619	27	15.030	±0.1604	±0.833
41	31	16.220	±0.1316	±0.733	31	15.450	±0.1757	±0.979
*31	35	16.643	±0.1286	±0.761	35	15.081	±0.1707	±1.010
*22	35	17.175	±0.1600	±0.932	35	15.210	±0.1499	±0.897
*12-15	49	17.696	±0.1327	±0.929	45	15.253	±0.1457	±1.020
*5-8.5	53	17.633	±0.1145	±0.833	53	15.612	±0.1679	±1.222
					30#	17.156	±0.2137	±1.170
50	68	15.969	±0.0904	±0.746	38	15.844	±0.1820	±1.107
				HOLSTEIN (8 Cows)				
50	20	12.456	±0.1164	±0.520	20	11.939	±0.0798	±0.357
41	24	12.631	±0.1223	±0.599	24	12.133	±0.0873	±0.428
31	28	13.155	±0.1117	±0.591	28	12.356	±0.1077	±0.569
**22	28	13.532	±0.1366	±0.723	28	12.370	±0.1224	±0.647
**12-15	42	13.409	±0.1384	±0.899	42	12.455	±0.0795	±0.515
*5-8.5	40	13.878	±0.1396	±0.883	40	12.474	±0.0935	±0.585
					20#	13.096	±0.1807	±0.808
50	52	13.270	±0.0993	±0.716	32	13.034	±0.1456	±0.811

Control cows at 4°F.

* Difference in means is significant $P \leq .01$.

** Difference in means is significant $P \leq .05$.

ings to increase for both the control and experimental cows, as the experiments progressed. This factor is apparently a natural result of advanced lactation.

As previously stated, all lactometer readings were obtained on milk samples at temperatures of 86° F. (Sharp and Hart, 1936). The use of this technique accounts for the generally lower specific gravity values than usually reported in the literature where lower reading temperatures are used.

Chlorides: Relatively little change was found in the chloride content of milk from experimental cows subjected to environmental temperatures of 50° to 5° F. (Figures 7 and 8). Only in the case of the experimental Jersey cows, as observed in Figure 7, was there any appreciable change. At a temperature of 12° F., this group of Jerseys showed an average increase of about 20 mg. chloride per 100 ml. of milk. The increase in chloride content of the milk continued even after the temperature was increased to 50° F.

The data presented in Table 10 further indicate that the experimental Jersey cows produced milk significantly higher in chloride content, as compared to the control cows, when maintained at temperatures of 41° F. ($P<.05$), 5-8° F. ($P<.01$) and 50° F. ($P<.01$) respectively.

The milk from the experimental Holstein cows was found to be significantly lower in chloride content than that of the control cows at temperatures of 22° F. ($P<.05$) and 5-8° F. ($P<.01$). A substantial increase in milk chlorides was found for the Holstein cows subjected to a rapid decline in environmental temperature to 4° F.

TABLE 10.--MILK CHLORIDE LEVEL -- JERSEY AND HOLSTEIN COWS

Ambient Temperature of Experimental Cows °F	Experimental				Control			
	No. of Samples	Mean Chloride mg./100ml.	Standard Error of Mean mg./100ml.	Standard Deviation mg./100ml.	No. of Samples	Mean Chloride mg./100ml.	Standard Error of Mean mg./100ml.	Standard Deviation mg./100ml.
				JERSEY (10 Cows)				
50	8	103.6	±4.36	±12.30	8	100.3	±4.16	±11.78
**41	10	107.2	±4.40	±13.92	10	100.4	±3.95	±13.19
31	15	101.5	±2.25	± 8.76	15	100.2	±3.31	±12.85
22	12	99.2	±2.81	± 9.73	12	99.7	±3.62	±12.56
12-15	14	102.6	±3.84	±14.36	14	100.5	±2.83	±10.59
*5-8.5	23	108.8	±1.78	± 8.10	23	95.2	±1.79	± 8.58
					9#	96.4	±1.03	± 3.10
*50	19	113.5	±3.32	±14.51	10	100.2	±2.11	± 7.06
				HOLSTEIN (8 Cows)				
50	6	107.4	±4.39	±10.75	6	109.5	±7.71	±18.89
41	8	109.6	±6.55	±18.52	8	107.2	±5.82	±16.48
31	12	102.7	±3.30	±11.45	12	108.4	±4.55	±15.77
**22	10	98.5	±2.68	± 8.42	10	105.8	±4.72	±14.92
12-15	12	102.1	±2.87	± 9.96	12	107.2	±3.83	±13.29
*5-8.5	18	98.3	±2.12	± 9.02	18	106.9	±2.59	±10.98
					6#	115.6	±4.67	±11.44
50	14	104.4	±1.40	± 5.25	8	109.2	±6.27	±17.74

Control cows at 4°F.

* Difference in means is significant $P \leq .01$.

** Difference in means is significant $P \leq .05$.

Although significant differences in the chloride content of the milk occurred in both breeds of cattle, no systematic changes with lowered temperature were obtained.

Lactose: In the experimental Holstein cows, in both trial periods, little or no differences in the lactose content of the milk, which could be related directly to decreasing environmental temperature, were observed.

In Trial 2, Figure 7, the lactose content of the milk appeared to decline at temperatures of 8.5° and 5° F., whereas the lactose content of milk in Trial 4, Figure 8, showed a slight increase at the lower temperatures.

A significant difference ($P<.01$) (Table 11) was found between the mean lactose content of the milk from the experimental and control cows at a temperature of 31° F., and throughout the remaining experimental periods. This difference apparently was not due to the influence of low temperature but to individual group differences in normal lactose level as observed in Figures 7 and 8.

The experimental Jersey cows showed some indication that low environmental temperatures influenced the lactose content of the milk produced, particularly in Trial 2 (Figure 7). In this trial the lactose content of the milk of the experimental Jersey cows decreased noticeably at temperature levels of 12° and 8° F., as compared to the controls. As the temperature was increased from 8° to 50° F., an increase in the lactose content occurred.

A rapid lowering of the environmental temperature to 4° F., over a two-week period, produced no changes in lactose level of either the Jersey or Holstein cows.

TABLE 11.--MILK LACTOSE LEVEL -- JERSEY AND HOLSTEIN COWS

Ambient Temperature of Experimental Cows °F	Experimental				Control (50°F)			
	No. of Samples	Mean Lactose mg./100ml.	Standard Error of Mean mg./100ml.	Standard Deviation mg./100ml.	No. of Samples	Mean Lactose mg./100ml.	Standard Error of Mean mg./100ml.	Standard Deviation mg./100ml.
				JERSEY (10 Cows)				
50	5	4233.7	± 97.3	±217.7	5	4254.4	± 79.9	±178.7
*41	10	4049.8	± 41.1	±130.1	10	4151.8	± 68.1	±224.7
*31	15	3976.1	± 37.0	±112.2	15	4100.8	± 53.5	±207.3
*22	12	3986.3	± 56.4	±195.6	12	4099.2	± 50.1	±173.5
*12-15	13	3926.1	± 71.8	±259.1	14	4107.3	± 43.7	±163.5
*5-8.5	21	3792.3	± 51.8	±237.8	21	4072.0	± 38.4	±176.5
					9#	4220.8	± 41.4	±124.2
*50	19	4034.2	± 46.9	±204.5	10	4100.1	± 88.4	±245.8
				HOLSTEIN (8 Cows)				
50	4	4452.6	±120.6	±241.2	4	4417.0	±160.5	±321.1
41	8	4271.8	±109.0	±308.5	8	4278.3	± 93.2	±263.8
*31	12	4282.1	± 87.4	±302.8	12	4190.6	± 69.6	±241.2
*22	10	4265.4	± 79.5	±251.4	10	4220.2	± 88.6	±280.2
*12-15	12	4330.4	± 56.2	±194.7	12	4257.8	± 62.9	±218.0
*5-8.5	16	4312.0	± 41.1	±164.6	16	4208.1	± 53.1	±212.6
					6#	4118.0	± 96.6	±236.8
*50	14	4395.7	± 49.7	±186.1	8	4171.8	±103.4	±292.6

\# Control cows at 4°F.

* Difference in means is significant $P \leq .01$.

As observed in Table 11, the experimental Jersey cows showed significantly lower milk lactose values ($P<.01$) at all temperature levels below 50° F.

Total Nitrogen: A substantial increase in total nitrogen content of milk from both the experimental Jersey and the Holstein cows was found when the environmental temperature was decreased from 50° to 8° F. The influence of low environmental temperatures had a greater effect on the Jersey breed, which generally showed a higher total nitrogen content throughout the two experimental periods than the Holsteins.

The average total nitrogen content of the milk of the Jersey cows is presented in Figures 7 and 8. It will be noted that the values increased with decreasing temperature beginning at 41° F. As the ambient temperature was returned to 50° F., a sharp decline in the total nitrogen content of the milk was observed.

The total nitrogen content of milk from the experimental Holstein cows was observed to increase with decreasing environmental temperature (50° to 8° F.).

The milk from both Jersey and Holstein cows was influenced in a similar manner when the environmental temperature was reduced rapidly from 50° to 4°F. In both breeds, the total nitrogen content showed an increase over previous levels at 50° F. (Figure 7).

As shown in Table 12, a significant difference in the total nitrogen content was observed in the milk from the experimental Jersey and Holstein cows as compared to control animals. The experimental Jersey cows were significantly

TABLE 12.--MILK TOTAL NITROGEN LEVEL -- JERSEY AND HOLSTEIN COWS

Ambient Temperature of Experimental Cows °F	Experimental				Control (50°F)			
	No. of Samples	Mean Total Nitrogen mg./100ml.	Standard Error of Mean mg./100ml.	Standard Deviation mg./100ml.	No. of Samples	Mean Total Nitrogen mg./100ml.	Standard Error of Mean mg./100ml.	Standard Deviation mg./100ml.
				JERSEY (10 Cows)				
50	8	572.7	±17.04	±48.22	8	571.9	±15.46	±43.75
*41	10	615.0	±27.30	±86.33	10	586.7	±14.07	±44.59
*31	15	650.7	±20.06	±77.69	15	598.0	±11.07	±42.88
*22	12	684.6	±28.86	±99.97	12	612.9	±10.30	±35.70
*12-15	14	714.6	±18.12	±69.80	14	623.6	± 7.71	±28.87
*5-8.5	23	705.1	±12.92	±61.97	23	619.0	± 7.18	±34.43
					6#	660.2	± 9.20	±26.02
*50	19	630.1	±12.69	±55.31	10	655.0	± 8.21	±25.96
				HOLSTEIN (8 Cows)				
*50	6	473.5	±10.19	±24.96	6	431.5	±10.60	±25.97
*41	8	488.8	± 8.50	±24.06	8	451.6	±12.86	±36.38
*31	12	518.0	±11.53	±39.95	12	478.7	±12.70	±44.01
*22	10	536.1	± 9.30	±29.41	10	488.4	±13.60	±43.03
*12-15	12	543.4	± 5.69	±19.72	12	494.2	± 9.59	±33.21
*5-8.5	18	558.3	± 5.44	±23.09	18	495.9	±10.14	±43.04
					6#	531.1	±27.43	±67.19
50	14	539.9	± 6.02	±22.52	3	544.4	±23.91	±67.63

Control cows at 4°F.
* Difference in means is significant $P<.01$.

higher in total nitrogen (P<.01) at all temperature levels below 50° F. The experimental Holstein cows showed significantly higher (P<.01) total nitrogen content at 50° F. temperature over the control cows and maintained the increases at even a higher level as the environmental temperature was reduced.

Freezing Point Depression: The freezing point depression values of milk from the experimental Jersey cows were generally somewhat lower than those of the controls, however, at environmental temperatures of 8° F. the freezing point depression was increased in the experimental cows to a point above the average readings obtained for the controls (Table 13). Freezing point depression values of -0.545° C. and -0.535° C. obtained on the milk for the respective temperature of 12° and 8° F. in the experimental Jersey cows were above the determinations made during the other temperature levels studies for the same cows.

TABLE 13.--FREEZING POINT DEPRESSION AND KOESTLER NUMBER OF MILK FROM JERSEY AND HOLSTEIN COWS

Ambient Temperature of Experimental Cows °F	Experimental			Control	
	No. of Samples	Freezing Point °C	Koestler Number	Freezing Point °C	Koestler Number
			JERSEY		
41	4	-0.5525	2.803	-0.5487	2.838
31	6	-0.5566	2.634	-0.5483	2.810
22	6	-0.5558	2.443	-0.5441	2.639
15	4	-0.5575	2.269	-0.5475	2.630
12	2	-0.5450	2.671	-0.5400	2.628
8	6	-0.5350	2.376	-0.5400	2.438
50	6	-0.5583	2.544	-0.5441	2.484
			HOLSTEIN		
41	4	-0.5437	2.897	-0.5400	2.404
31	6	-0.5541	2.615	-0.5566	2.416
22	6	-0.5575	2.481	-0.5591	2.351
15	4	-0.5362	2.387	-0.5437	2.319
12	2	-0.5375	2.581	-0.5500	2.497
8	6	-0.5383	2.361	-0.5450	2.329
50	6	-0.5516	2.448	-0.5566	2.237

The milk from the experimental Holstein cows was found to show increased values in the freezing point depression as compared to controls at temperatures of 15°, 12°, and 8° F.

The Koestler number, which is based upon the relationship between lactose and chloride contents of milk, indicated that both experimental and control cows of each breed were within the range of 0 to 3.5 as usually found for normal milk.

Summary: These data indicate that environmental temperature below 40° F. influences the composition of milk of Jersey and Holstein cows. With the lowering of ambient temperature from 50° to 5° F., a substantial increase in the butterfat percentage and the total nitrogen content of milk was observed. The increases observed in these two constituents apparently were reflected in the values obtained for total solids and solids-not-fat, which, likewise, showed noticeable increases with lowered environmental temperature. The chloride content, lactose content, freezing point depression, and specific gravity values were influenced little, if any, by lowered temperatures.

The experimental Jersey cows were observed to decrease in milk yield as the environmental temperatures were lowered below 32° F., and they were more adversely affected at low ambient temperatures than Holstein cows.

DISCUSSION

This investigation brought to light some of the influences of environmental temperature on milk yield and milk composition in dairy cattle.

Daily milk yields were found to decrease in dairy cows of European origin at environmental temperatures above 80° F. Some variation in the ability of different breeds to withstand temperatures above 80° F. was observed. These observations agree with those of Regan and Richardson (1938), Rhoads (1936), Sinha and Minett (1947), and Lee and Riek (1947), who reported that high environmental temperatures reduce milk production. With increasing temperatures, the milk production of Holstein cows was influenced somewhat earlier than that of the Jersey and Brown Swiss cows. The Brown Swiss cows used in these studies, although larger in size and high in milk yield (comparable to the Holstein), apparently were influenced in milk at approximately the same temperature as the Jersey cows. It seems probable that there are some breed differences in ability to withstand high temperatures without lowering milk yields. In the observations made at low temperatures the Holstein cows showed little, if any, reduction in milk yield. However, with rapid lowering of temperature to 4° F. a decline in milk yield was observed. The Jersey cows showed a decrease in milk yield at temperatures below freezing. A breed difference possibly due to body size is indicated (Ragsdale *et al.*, 1948), however, further work is needed, especially with other breeds, to substantiate this point. Dice (1940), and Kelley and Rupel (1937) concluded that generally cows which are well fed and protected from wind, rain, and snow will produce practically the same at a low temperature as at an environmental temperature of 50° F.

The butterfat percentage was generally found to increase with decreased milk yield, with the possible exception of the Holstein cows which at low temperature showed fat increases but no noticeable change in milk yield. Drakeley and White (1928), Eckles and Shaw (1913), and Ragsdale and Turner (1922) have observed that an inverse ratio exists between milk production and butterfat percentage.

Butterfat percentages obtained in this study indicate a slight decline with increasing environmental temperatures from 5° to 80° or 90° F., after which increases were observed. These findings compare favorably with previous work reported by Hays (1926), Weaver and Matthews (1928), Regan and Richardson (1938), and others.

The experimental and control Jersey cows were found to test higher and show more variation in butterfat percentages than the other breeds studied. This confirms earlier work by White and Judkins (1918), Jacobson (1936), and Turner (1936) who reported that more variation is found in fat percentage where cows normally produce milk higher in butterfat percentage.

The total solids content and variations in milk seemed to parallel that of the fat percentage at temperatures of 5° to 80° or 90° F. At temperatures above 80° F., depending on the breed, the percentage of total solids tended to increase less rapidly than the butterfat percentage. This agrees with Regan and Richardson (1938), who found a decline in the solids-not-fat percentage with increasing environmental temperature.

With the exception of the high environmental temperatures, the solids-not-fat content of the milk followed the changes in butterfat percentages. The specific gravity determinations were lower at high temperatures, which gives added evidence that the ratio of butterfat to solids-not-fat content was lower.

With an increase in butterfat percentage, due either to high or low temperatures, the ratio of butterfat to solids-not-fat percentage is lower than the ratio found in a temperature range of 40° to 75° F. From a practical viewpoint this is of economical importance to the milk processing plants.

It is estimated from data obtained in this study that a plant may receive 10 to 40 per cent less solids-not-fat for each pound of butterfat purchased when butterfat percentages are high due to abnormally high or low environmental temperatures. Jacobson (1936) reported that the ratio of fat to solids-not-fat for milk testing 3 per cent was 1:2.76, whereas milk testing 6 per cent showed a ratio of 1:1.58.

The cost of meeting federal standards for milk by the addition of solids-not-fat content or removing the fat must necessarily be assumed by the processor and is reflected in the price to the producer or consumer.

Breed differences, especially in small milk plants where a larger part of the milk received is from breeds normally producing milk with a high percentage of butterfat, further emphasizes the problem of obtaining a desirable butterfat and solids-not-fat ratio.

Less variation was observed in solids-not-fat percentage than in butterfat percentage for all breeds observed. The standard deviations obtained for solids-not-fat percentages ranged from 0.135 to 0.345 per cent and 0.200 to 0.436 per cent in the control Holstein and Jersey cows respectively. In the case of butterfat percentages, the standard deviation was found to range from 0.252 to 0.597 per cent for Holsteins and 0.568 to 1.009 per cent for the Jersey cows. White and Judkins (1918) reported that the solids-not-fat content varied less than butterfat percentage and that more variation in butterfat and solids-not-fat percentage occurred in Jersey cows than in other breeds.

The chloride and lactose in milk accounts roughly for 75 per cent of the osmotic pressure in milk, irrespective of the composition of the sample (Espe, 1946, Davies, 1932). A lowering of the lactose content is necessarily accompanied by an increase in chloride content in order that the isotonic equilibrium between milk and blood plasma is maintained.

With these facts in mind it is of interest to note that the chloride content of milk increased sharply at temperatures above 80° F. As the environmental temperatures were returned to the 50° F. level, a drop in chloride content was noted. Considerable individual, as well as breed, differences in chloride content of milk were observed. Davies (1939), Turner (1936), Herman (1938), and Davis *et al.* (1947) reported an increase in the chloride content of milk during the hot summer weather. Sharp and Struble (1935) observed that chlorides increased in healthy cows when milk yields drop to 15 pounds per cow in the Jersey and 25 pounds per cow for the Holstein cows.

The chloride content of the milk from cows subjected to environmental temperatures ranging from 5° to 80° F. showed no change which could be attributed to temperature changes.

Throughout this study the lactose values were approximately 0.4 to 0.6 per cent below the averages reported by Overman *et al.* (1929). In addition to the lower values found for lactose, considerable variation between samples was noticed. This condition could be due to several factors such as length of milking period, the analytical methods used, excitement of the cows due to metabolism trials, collection of blood samples, etc. Brown *et al.* (1936) stated that considerable variation in the lactose content of milk was found. They observed that the lactose percentage may vary as much as 1 per cent over a two-hour delay in the milking period. Eckles and Shaw (1913) found that the lactose content of milk may vary as much as 0.5 per cent from the average in the case of individual cows.

Lactose content of milk was found to be depressed at temperatures above 85° F. in all breeds except Brahman cows, which showed considerable fluctuation but no definite pattern in fluctuation.

In the Jersey cows used in these studies there appeared to be a decline in lactose content of the milk at temperatures of 12° to 5° F., however, there was considerable difference between the two values for Trial Periods 2 and 4. Herman (1938), and Davis (1947) reported a depression in lactose content of milk from cows subjected to high temperatures.

Although there was considerable change in the lactose and chloride content of milk from Brown Swiss cows at high environmental temperature, relatively little change occurred in the freezing point depression values. The values found are practically all within the range of –0.552° C. and –0.572° C. reported by Jackson and Rothera (1914). At temperatures of 15° to 8° F. there was a slight tendency for higher freezing point depression values, especially in the Holstein cows.

Aschaffenburg and Veinglou (1938) reported that the highest freezing point depressions were found when the surrounding temperature was warmest. Regan and Richardson (1938) observed that the freezing point depression of milk was higher at temperatures above 85° F. which they attributed to a decrease in the soluble components of the milk.

The total nitrogen content of milk decreased at temperatures above 80° F. (Holstein), 85° F. (Jersey and Brown Swiss) and 100° F. (Brahman). With rapidly rising temperatures from 50° to 100° F., total nitrogen increased. In the Brahman cows the total nitrogen was the only constituent showing a definite trend in variation from the control. It is assumed the decrease in total nitrogen was a factor in causing the solids-not-fat values to show a decline at the same temperature. Regan and Richardson (1938) reported a decline in casein value with high environmental temperature. Herman (1938) observed a decrease in total nitrogen of milk produced during the summer months.

At low environmental temperatures the total nitrogen content increased substantially. Both breeds, Jersey and Holstein, showed increases beginning at temperatures of 41° F. and 32° F., respectively. Since other constituents change very slightly it seems quite probable that the increase observed in the solids-not-fat percentage was due to the increase in protein content at the lower temperature levels.

SUMMARY

The effect of environmental temperatures on the yield and composition of milk from dairy and Brahman cattle has been investigated by the use of the Psychroenergetic Laboratory maintained at the University of Missouri. Twenty Jersey, 16 Holstein, 3 Brown Swiss and 3 Brahman cows were used. Some breed differences in ability to withstand temperature changes were observed. Brahman cows were most resistant to changes in increasing temperature followed by Brown Swiss, Jersey and Holstein cows. The Holstein cows were affected less than Jerseys at lowered ambient temperatures.

The following effects on milk yield and milk composition were observed where environmental temperatures were increased from 50° to 105° F., and when temperatures were lowered from 50° to 5° F.

1. Total milk yield was decreased 50 to 75 per cent at environmental temperatures above 80° F. in the Holstein; 85° F. for Jersey and Brown Swiss cows. The Brahman cows showed no apparent effect in milk yield at high temperatures. Milk yields decreased for the Jersey cows at approximately

freezing temperature. The Holstein cows showed no noticeable decrease in milk yield at low temperatures except during a period of two weeks when the temperature was suddenly decreased to 4° F.

2. Butterfat percentage decreased slightly from temperatures of 50° to 90° F., after which substantial increases of 10 to 40 per cent were found as compared to control animals. Increases of 10 to 35 per cent in butterfat percentage were observed at low environmental temperatures. The increases were evident in the Jersey and Holstein cows at temperatures of 41° F. and 32° F., respectively.

3. Solids-not-fat percentage decreased with increasing environmental temperatures above 85° to 90° F., in all breeds except the Brahman cows which showed a decrease at 100° F. temperature. With decreasing temperature (from 50° to 5° F.) the solids-not-fat content of the milk increased as did the butterfat percentage. With both high and low environmental temperatures a low butterfat solids-not-fat ratio was obtained.

4. The total solids content of milk increased gradually with declining environmental temperatures of 50° to 5° F. A slight decline in total solids was observed at temperatures from 50° to 85° or 90° F.

5. Specific gravity values of milk were decreased when cows were kept at environmental temperatures of 85° for Holstein and 90° F. or above for Jersey and Brown Swiss cows. The solids-not-fat percentage was likewise decreased. Little, if any, change occurred in the specific gravity values of milk with cows maintained at low environmental temperatures.

6. An increase of 30 to 100 per cent in the chloride content of milk occurred when cows were maintained at environmental temperatures above 85° to 90° F. The chloride content of the milk from Brahman cows increased slightly immediately following the 105° F. temperatures. No changes, which could be attributed to temperature effect, were observed in the chloride content of milk where cows were kept at low environmental temperature.

7. At temperatures above 85° to 90° F., varying with breeds and individual cows, the lactose content of the milk decreased with increasing temperatures. The average decrease in lactose values was less than 1 per cent. The Jersey cows showed decreases in milk lactose at environmental temperatures of 12° to 5° F. No definite trend was found in the fluctuation of the lactose content of the milk from Holstein cows at low temperatures.

8. The total nitrogen content of milk decreased where cows were kept at environmental temperatures above 80° to 90° F. Decrease in total nitrogen was observed in the milk of Brahman cows kept at a temperature of 100° F. Contrary to this, rapidly increased temperatures caused the total nitrogen content to increase. Increases in total nitrogen content were found in both Jersey and Holstein cows at low environmental temperatures beginning at 41° F. and 32° F.

9. The freezing point depression values obtained on milk from the Brown Swiss cows showed no significant change at high environmental temperatures. In Trial 4, some increases were observed in the freezing point depression value of the milk at temperature levels of 12° to 8° F. in the Jersey and at 15° to 8° F. in the Holstein cows.

10. It is concluded from these data that an environmental temperature ranging from 30° to 75° F. does not materially influence milk yield or milk composition in dairy cattle of European ancestry. Environmental temperatures below or above this range were found to cause substantial changes in the composition and yield of milk.

ABSTRACT

Changes in the composition of the milk of dairy cows as a result of varying environmental temperatures, 5° to 105° F., were studied on 43 cows in the Climatic Laboratory at the University of Missouri.

Some 2500 samples of milk from Jersey, Holstein, Brown Swiss and Brahman cows were collected and analyzed for total solids, butterfat, solids-not-fat percentages, lactose, chloride, total nitrogen, specific gravity and freezing point depression.

Data from these studies indicate an increase in butterfat percentage, total solids and chloride content and decreasing solids-not-fat percentage, lactose, total nitrogen content and specific gravity with rising temperatures above 80° to 90° F. Total milk yield was decreased 50 to 75 per cent on increasing ambient temperatures 80° to 105° F. in Holstein and 85° to 105° F. in Jersey and Brown Swiss cows. The Brahman cows showed no apparent effect on milk yield or milk composition at high environmental temperatures. The freezing point depression values on milk from Brown Swiss cows did not change significantly at high environmental temperatures.

Daily milk yields were found to decrease for Jersey cows at approximately freezing temperatures, whereas the Holstein cows evidenced no noticeable decrease in milk yield attributed to low temperatures except during a period of two weeks when the temperature was suddenly decreased to 4° F. At low ambient temperatures it was found that butterfat, total solids, solids-not-fat and total nitrogen content increased. Little, if any, change occurred in the specific gravity and freezing point depression values of milk with cows maintained at the low environmental temperatures. Although some variation was observed in the lactose and chloride content of the milk, no definite trend could be established indicating an influence of low temperatures. At both extremely high and extremely low environmental temperatures a low butterfat solids-not-fat ratio was obtained.

It is concluded from these data that environmental temperatures ranging from 30° to 75° F. do not materially influence milk yield or milk composition in dairy cattle of European ancestry. Temperatures below or above this range (30° to 75° F.) were found to cause substantial changes in the composition and yield of milk.

BIBLIOGRAPHY

Allen, N. N. 1934. The fat percentage of milk as affected by feeding fats to dairy cows. *J. Dairy Sci.* 17:379-395.

Anderson, E. O., C. L. Hankinson, W. N. Plastridge and F. J. Weirether. 1936. Infectious bovine mastitis. The curd tension of normal and mastitis milk. *Conn. Agr. Exp. Sta. Bul. 211.*

Aschaffenburg, R., and P. L. Temple. 1941. The freezing-point of milk. I. The freezing-point and solids-not-fat content of the milk of individual cows throughout a period of lactation. *J. Dairy Res.*, 12:315-321.

Aschaffenburg, R., and B. C. Veinoglou. 1938. The freezing point of milk. II. The influence of various factors and their bearing on the detection of added water. *J. Dairy Res.*, 9:267-280.

Association of Official Agricultural Chemists. 1945. *Official and tentative methods of analyses of the Association of Official Agricultural Chemists.* 6th ed. Assoc. Off. Agr. Chem., Washington, D. C.

Associates of Rogers. 1928. *Fundamentals of dairy science.* Monograph Ser. No. 41. The Chem. Catg. Co. New York, N. Y.

Azarme, E. 1938. Variations in the protein content of milk during lactation. *J. Dairy Res.*, 9:121-146.

Bartlett, S. 1934. Variation in the solids-not-fat content of milk. I. The influence of the act of milking on the composition of milk. II. The lactation curve and the influence of various factors upon it. *J. Dairy Res.*, 5:113-123.

Bartlett, S. 1935. The influence of high environmental temperatures on the secretion and composition of milk. *J. Dairy Res.*, 6:283-288.

Bernstein, J. G. 1941. The effect of thermal environment of the morphology of thyroid and adrenal cortical glands in the albino rat. *Endocrin.*, 28:985-998.

Best, C. H., and N. B. Taylor. 1945. *The physiological basis of medical practice.* 4th ed., The Williams and Wilkins Co., Baltimore, Md.

Bonsma, J. C. 1940. The influence of climatological factors on cattle. Observation on cattle in tropical regions. *Farming in S. Africa*, 15:373-385.

Brody, S. 1948. Environmental physiology with special reference to domestic animals. I. Physiological backgrounds. *Mo. Agr. Exp. Sta. Res. Bul. 423.*

Brody, S., G. Burge, C. Blincoe, J. Barton, R. Tary, and W. Platner. 1949. Environmental physiology with special reference to domestic animals. III. Influence of ambient temperatures, 50° to 100° F., on the blood composition of Jersey and Holstein cows. *Mo. Agr. Exp. Sta. Res. Bull. 433.*

Brooks, W. P. 1895. Experiment in warming a stable of cows. *Mass. Hatch Sta. Report. No. 39.*

Brown, W. R., W. E. Petersen, and R. A. Gortner. 1936. A study of variations in the lactose content of milk. *J. Dairy Sci.*, 19:81-90.

Buckley, S. S. 1913. Open stables versus closed stables for dairy animals. *Md. Agr. Exp. Sta. Bul. 177.*

Byars, L. T., H. Friedman, W. J. Seibert and L. Loeb. 1932. Are seasonal variations of thyroid gland dependent upon corresponding variations in anterior pituitary? *Soc. Exp. Biol. and Med. Proc.*, 29:797-799.

Clarke, D. A., Jr., and J. M. Tinley. 1948. *Bases for payment of milk.* (unpublished) Calif. Agr. Exp. Sta.

Clothier, R. W. 1919. Seasonal variations in the butterfat content of milk in Southern Arizona. *Proc. Soc. Prom. Agr. Sci.*, 39:75.

Davies, W. L. 1932. The determination of chlorides in dairy products and biological materials. *Analyst*, 57:79-85.

Davies, W. L. 1938. The chloride content of milk. *J. Dairy Res.*, 9:327-335.

Davies, W. L. 1939. *The chemistry of milk.* 2nd ed. D. Van Nostrand Co., New York, N. Y.

Davis, H. P. 1913-14. The effect of open-shed housing as compared with the closed stable for milk cows. *Ann. Rep., Pa. State College Agr. Exp. Sta. No. 19.*

Davis, R. N., F. G. Harland, A. B. Caster and R. H. Kellner. 1947. Variation in the constituents of milk under Arizona conditions. II. Influence of the month of the lactation in cows of different breeds. III. Variation in milk from Jersey, Guernsey and Holstein and mixed herds. *J. Dairy Sci.*, 30:425-442.

Dempsey, E. W., and E. B. Astwood. 1943. Determinations of the rate of thyroid hormone secretion at various environmental temperatures. *Endocrin.*, 32:809-818.

Dice, J. R. 1940. The influence of stable temperature on the production and feed requirements of dairy cattle. *J. Dairy Sci.*, 23:61-69.

Drakeley, T. J., and M. K. White. 1928. The joint influence of the period of lactation and the age of the cow on the yield and quality of the milk. *J. Agr. Sci.*, 18:496-506.

Eckles, C. H. 1909. Jahriszeitliche Schwankugen des Prozentischen Fettgehaltes in Kuhmilch. *Melchwirtschaftlickes Zentralblatt.* V. 448.

Eckles, C. H., and L. S. Palmer. 1916. Influence of plane of nutrition of the cow upon the composition and properties of milk and butterfat. Influence of underfeeding. *Mo. Agr. Exp. Sta. Res. Bul. 25.*

Eckles, C. H., and R. H. Shaw. 1913. The influence on the stage of lactation on the composition and properties of milk. *U. S. Bur. An. Ind. Bul. 155.*

Eckles, C. H., and R. H. Shaw. 1913. Variations in the composition and properties of the individual cows. *U.S. Bur. An. Ind. Bul. 157.*

Espe, Dwight. 1946. *Secretion of milk.* 3rd ed. The Collegiate Press, Inc., Ames, Ia.

Foot, A. S., and P. M. F. Shattock. 1938. The incidence of mastitis in cows yielding milk low in solids-not-fat. *J. Dairy Res.*, 9:166-173.

Gaalaas, R. F. 1945. The effect of atmospheric temperature on the body temperature and respiration rate of Jersey cattle. *J. Dairy Sci.*, 28:555-563.

Government of Northern Ireland Ministry of Agriculture. 1946. Variations in the composition of milk. *Monthly report, Gov. of N. Ireland Ministry of Agr.*, 21:134-137.

Gowen, J. W., and E. R. Tobey. 1931. Studies of milk secretion. The influence of inanition. *J. Gen. Physiol.*, 15:45-66.

Graham, W. R. 1934. The action of thyroxine on milk production of cows. *Biochem. J.*, 28:1368-1371.

Hays, W. P. 1926. The effect of environmental temperature on the percentage of fat in cow's milk. *J. Dairy Sci.*, 9:219-235.

Heimemann, Burdet. 1947. The relation of per cent total solids in separated milk and per cent fat in whole milk to atmospheric temperature. *J. Dairy Sci.*, 30:757-762.

Herman, H. A. 1938. Variations in composition of milk and the effects on solids-not-fat. (Abstract) *J. Dairy Sci.*, 21:146-147.

Herman, H. A., W. R. Graham and C. W. Turner. 1938. The effects of thyroid and thyroxine on milk secretion in dairy cattle. *Mo. Agr. Exp. Sta. Bul. 275.*

Huston, J., and R. W. Hale. 1942. The yield and composition of milk with special reference to the influence of climatic conditions and other factors. *J. Dairy Res.*, 3:294-309.

Jackson, L. C., and A. C. H. Rothera. 1914. Milk—its sugar, conductivity and depression of freezing point. *J. BioChem.*, 8:1-7.

Jacobson, M. S. 1936. Butterfat and total solids in New England Farmer's milk as delivered to processing plants. *J. Dairy Sci.*, 19:171-176.

Kelley, M. A. R., and I. W. Rupel. 1947. Relation of stable environment to milk production. *U.S.D.A. Tech. Bul. 591.*

Kibler, H. H., and Samuel Brody. 1949. Environmental physiology with special reference to domestic animals. VII. Influence of temperature, 50° to 5° F., and 50° to 95° F., on heat production and cardiorespiratory activities of dairy cattle. *Mo. Agr. Exp. Sta. Res. Bul. 450.*

Kibler, H. H., S. Brody, and D. M. Worstell. 1949. Environmental physiology with special reference to domestic animals. IV. Influence of temperature, 50° to 105° F., on heat production and cardiorespiratory activities in dairy cattle. *Mo. Agr. Exp. Sta. Res. Bul. 435.*

Kleiber, M., and W. M. Regan. 1933. Influence of temperature on respiration of cows. *Proc. Soc. Exp. Biol. and Med.*, 33:10.

Lee, D. H. K., and R. F. Riek. 1947. Reactions of dairy cattle over a range of controlled temperatures and humidities. *Fed. Proc.*, 6:150.

Ludwin, I. 1942. The effect of numbers of daily milkings upon persistency of milk production. *J. Animal Sci.*, 1:300-308.

McCalmont, J. R. 1946. The animal psychroenergetic laboratory. *Agr. Eng.*, 24:472.

Mathieson, H. A. 1934. Variations of solids-not-fat. Its relation to state and city minimum standards. Report to annual meeting of the Western Branch of the Am. Dairy Sci. Assoc., Portland, Oregon.

Milk Industry Foundation. 1933. *Methods of analysis of milk and its products.* Milk Ind. Foundation, Washington, D. C.

Ministry of Agriculture and Fisheries. 1935. *Variations in the composition of milk.* Bul. 16.

Nicholson, M. N., and C. W. Lesser. 1934. Investigations into the problems of milk with a low content of solids-not-fat. *University of Reading, Bul. 46.*

Ogle, C., and C. A. Mills. 1933. Animal adaptation to environmental temperature conditions. *Am. J. Physiol.* 103:606-612.

Overman, O. R., F. P. Sanmann, and K. E. Wright. 1929. Studies of the composition of milk. *Ill. Agr. Exp. Sta. Bul. 325.*

Palmer, L. S. 1919. The preservation of milk for chemical analysis. *Mo. Agr. Exp. Sta. Res. Bul. 34.*

Perkins, A. E., W. E. Krauss, and C. C. Hayden. 1932. The chemical composition and nutritive properties of milk as affected by the level of protein feeding. I. Chemical composition. II. Nutritional properties. *Ohio Agr. Exp. Sta. Bul. 515.*

Popoff, J. S. 1927. The influence of cold on the productivity of the dairy cow. *Zeit. F. Tier. u. Zuch.*, 10:285.

Putnam, D. N., G. A. Bowling and C. T. Conklin. 1944. The recognition of the influence of age on butterfat percentage when calculating mature equivalents. *J. Dairy Sci.*, 23:903-907.

Ragsdale, A. C., S. Brody, H. J. Thompson, and D. M. Worstell. 1948. Environmental physiology with special reference to domestic animals. II. Influence of temperature, 50° to 105° F., on milk production and feed consumption in dairy cattle. *Mo. Agr. Exp. Sta. Res. Bul. 425.*

Ragsdale, A. C., H. J. Thompson, D. M. Worstell and Samuel Brody. 1950. Environmental physiology with special reference to domestic animals. IX. Milk production and feed and water consumption responses of Brahman, Jersey and Holstein cows to changes in temperature, 50° to 105° F., and 50° to 8° F. *Mo. Agr. Exp. Sta. Res. Bul. 460.*

Ragsdale, A. C., H. J. Thompson, D. M. Worstell and Samuel Brody. 1951. Environmental physiology with special reference to domestic animals. XII. Influence of increasing temperature, 40° to 105° F., on milk production in Brown Swiss cows, and on feed and water consumption and body weight in Brown Swiss and Brahman cows and heifers. *Mo. Agr. Exp. Sta. Res. Bul. 471.*

Ragsdale, A. C., and C. W. Turner. 1922. The stage of lactation as a factor in the variation of the per cent in fat in cow's milk. *J. Dairy Sci.*, 5:22-26.

Ragsdale, A. C., D. M. Worstell, H. J. Thompson and Samuel Brody. 1949. Environmental physiology with special reference to domestic animals. Influence of temperature, 50° to 0° F., and 50° to 95° F., on milk production, feed and water consumption and body weight in Jersey and Holstein cows. *Mo. Agr. Exp. Sta. Res. Bul. 449.*

Regan, W. M., and G. A. Richardson. 1938. Reactions of the dairy cow to changes in environmental temperature. *J. Dairy Sci.*, 21:73-79.

Rhoads, A. O. 1936. The influence of environmental temperature on the respiratory rhythm of dairy cattle of tropics. *J. Agr. Sci.*, 26:35-44.

Richardson, G. A. 1949. Variations in the compositional quality of milk. *Can. Dairy and Ice Cream J.*, 28:36-37.

Riek, R. F., and D. H. K. Lee. 1948. Reactions to hot atmospheres of Jersey cows in milk. *J. Dairy Res.*, 15:219-226.

Riddle, O., G. C. Smith, R. W. Bates, C. S. Moran, and E. L. Lahr. 1936. Action of anterior pituitary hormones on basal metabolism of normal and hypophysectomized pigeons and on a paradoxial influence of temperature. *Endocrin.*, 20:1-16.

Rowland, S. J. 1944. The occurrence in winter of milk with a low content of solids-not-fat. *J. Dairy Res.*, 13:261-266.

Seath, D. M., and G. D. Miller. 1946. The relative importance of high temperatures and high humidity as factors influencing respiration rate, body temperature and pulse rates in dairy cows. *J. Dairy Sci.*, 29:465-472.

Seath, D. M., and G. D. Miller. 1947. Heat tolerance comparisons between Jersey and Holstein cows. *J. An. Sci.*, 6:24-34.

Shaffer, P. A., and M. Somogyi. 1933. Copper idometric reagents for sugar determination. *J. Biol. Chem.*, 100:695-713.

Sharp, P. F., and R. G. Hart. 1936. The influence of the physical state of the fat on the calculations of solids from the specific gravity of milk. *J. Dairy Sci.*, 19:683-695.

Sharp, P. F., and E. B. Struble. 1935. Period of lactation and the direct titratable chloride value of milk. *J. Dairy Sci.*, 18:527-538.

Sinha, K. C., and F. C. Minett. 1947. Application of water to the body surface of water buffaloes and its effect on milk yield. *J. An. Sci.*, 6:258-264.

Smith, J. A. B., G. R. Howat, and S. C. Ray. 1938. The composition of the blood and milk of lactating cows during inanition with a note on an unidentified constituent present in certain samples of abormal milk. *J. Dairy Res.*, 9:310-322.

Spielman, A. A., T. M. Ludwick and W. E. Petersen. 1941. Effect of diethylstilbestrol on milk secretion. (Abstract) *J. Dairy Sci.*, 24:499.

Starr, P., and R. Roskelley. 1940. A comparison of the effect of cold and thyrotropic hormone on the thyroid gland. *Am. J. Physiol.* 130:549-556.

Thompson, H. J., D. M. Worstell and Samuel Brody. 1949. Environmental physiology with special reference to domestic animals. V. Influence of temperature, 50° to 105° F., on water consumption in dairy cattle. *Mo. Agr. Exp. Sta. Res. Bul. 436.*

Tocher, J. F. 1925. *Variations in the composition of milk.* Scotland Board of Health, Edinburgh.

Turner, C. W. 1936. Factors affecting the composition of milk. *Mo. Agr. Exp. Sta. Bul. 365.*

Vanlandingham, A. H., C. E. Weakley, Jr., E. N. Moore, and H. O. Henderson. 1941. Mastitis. 1. The relationship of the development of mastitis to changes in the chlorine lactose and casein number of milk. *J. Dairy Sci.*, 24:383-398.

Van Rensburg, S. W. J. 1946. Low solids-not-fat content of milk in South Africa. *Farming in S. Africa*, 21:217-228.

Weaver, E., and C. A. Matthews. 1928. The influence of temperature and certain other factors upon the percentage of fat in milk. *Ia. Agr. Exp. Sta. Res. Bul. 107.*

White, G. C., and H. F. Judkins. 1918. Variations in fat, solids-not-fat, and total solids in cow's milk. *Storrs Agr. Exp. Sta. Bul. 94.*

Wolf, Opal, and Ray Greep. 1937. Histological study of thyroid gland of hypophysectionized rats exposed to cold. *Proc. Soc. Exp. Biol. and Med.*, 36:856-860.