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Influence of Daily Environmental Temperature Cycles on Composition of Cows' Milk

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SUMMARY

The effect of environmental temperature cycles on the composition of milk from Holstein and Jersey cows was investigated by analyzing milk samples from animals exposed to controlled diurnal temperature rhythms. The temperature cycles included ranges of 10-40° F, 40-70° F, 70-100° F, and 60-110° F. Duration of exposure at each temperature range varied from one to five weeks with a one week adjustment period at approximately 60° F separating the different temperature rhythms.

Increased percentages of butterfat and solids-not-fat occurred during both the high (70-100° F or 60-110° F) and low (10-40° F) temperature cycles. The total nitrogen content of the milk from both breeds was increased during the low temperature cycles. The chloride content was unaffected by low temperatures but increased values were associated with high temperature cycles and advancing lactation.

Changes in milk composition occurred rather slowly and thus trends for any particular temperature cycle were modified by the preceding cycle unless a suitable adjustment period was interposed between the different temperature ranges.

CONTENTS

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INTRODUCTION

Environmental conditions, particularly temperature, exert a profound influence not only on total milk production but also on the composition of milk. This poses a serious problem for the dairy industry since our increasing knowledge of nutrition is placing greater emphasis upon individual milk constituents and the need for a more uniform, highly nutritious product throughout the year. The adoption of minimum standards for butterfat and solids-not-fat by many communities illustrates some of the measures which are being taken to assure the consumer a high quality product. These standards were designed to protect the consumer against the sale of adulterated milk but tests have revealed that climatic conditions, notably during the hot summer months, many bring about the production of milk which does not meet these standards. Thus, the dairy industry must continually seek means for increasing the uniformity of milk production and milk composition.

The effect of various constant level temperatures below 50° F upon milk yield was studied by Ragsdale *et al.* (1949, 1950). As the environmental temperature was lowered from 50° F to approximately 5° F by 9° stages, each of two weeks duration, they found a gradual decrease in milk yield of the Jersey experimental cows, as compared to the Jersey controls. The decrease in production was most evident at temperatures below freezing. The same experimental conditions did not show an appreciable effect on milk yield of the Holstein cows. However, both the Holsteins and Jerseys showed a marked drop in milk yield when the environmental temperature was decreased rapidly from 50° F to 4° F. The composition of milk from these animals was studied by Cobble and Herman (1951), who observed that a decrease in ambient temperature from 50° to 5° F was accompanied by substantial increases in butterfat and total nitrogen percentages of the milk. The increases observed in these two milk constituents apparently were largely responsible for increases in total solids and solids-not-fat percentages with lowered environmental temperatures. The reduced temperatures exerted little, if any, influence upon the freezing point depression, specific gravity values, lactose, and chloride percentages.

Sementovskaya and Garkavi (1951) studied the effect of low environmental temperatures on milk yield by comparing the production of animals held at average temperatures of -0.2, -2.6, -1.6, and -13° C with control animals at temperatures ranging between 2.7 and 8.8° C. Under these conditions the experimental animals showed a decrease in milk yield and increase in butterfat percentage. At -13° C the milk yield decreased 16% while butterfat percentage increased 22%. In another trial, cows were kept at an average temperature of -4.91° C while receiving 25% more supplementary food than cows in the first trial; in this latter trial the decrease in milk yield amounted to only 4.8% with a 10% increase in fat percentage.

Tamarchenko *et al.* (1952) reported on another experiment designed to determine the effect of low temperatures on the chemical composition of milk. Twelve cows were kept for a preliminary 15-day period at 9.2° C, following which six of the animals were maintained at -2.4° C for 25 days with the remaining six animals serving as controls at 7.2° C. Milk of the experimental animals increased from 4.09 to 4.20 in butterfat percentage during the experimental period, compared to the preliminary period; that of the controls decreased from 4.25 to 4.07 percent. Milk yields and protein content remained unchanged in both groups.

High temperature and its effect on milk production and milk composition were studied by Riek and Lee (1948) who subjected four Jersey cows to temperatures ranging from 85 to 110° F for seven hours, twice a week. Under these conditions, they found that milk yield and butterfat percentage were not materially affected, even at the highest temperatures. In contrast, Ragsdale *et al.* (1948, 1949, 1950, 1951) found that approximately 80 to 85° F was a critical temperature range for Holsteins, Jerseys, and Brown Swiss since decreased production became evident at this point.

This apparent disagreement in results might be explained by the differences in length of exposure to any given temperature since the latter studies were conducted with relatively long periods of exposure at each temperature level. Above the critical temperature range, in these latter experiments, milk yield was found to decline quite rapidly and virtually cease at 105° F. Accompanying the drop in milk yield at the higher environmental temperatures was an increased fat percentage which was partially attributed to a difference in mechanisms controlling fat and total milk production. Underfeeding is also known to raise the fat content of milk and with higher temperatures a definite decline in feed consumption was noted. Edwards (1951), in an experiment dealing with factors influencing the relationship between butterfat percentage and secretion of milk, showed that seasonal effects causing butterfat percentage to be low in May and high in November were independent of milk yields during these months.

Cobble and Herman (1951) found that environmental temperatures above 80° F were associated with alterations in the composition of milk from Holstein, Jersey, and Brown Swiss cows. Decreases were observed in solids-not-fat, total nitrogen, and lactose percentages while butterfat, total solids, and chloride percentages increased with higher environmental temperature levels. The specific gravity of milk was found to be lowered at the high temperatures, while the freezing point apparently was not affected due to compensating changes in the milk chloride and lactose content.

The majority of previous experiments determining the effect of environmental temperature upon milk composition have used either various constant temperature levels or an average of the uncontrolled daily temperatures. The first condition will seldom, if ever, be encountered under natural conditions. Thus, the information obtained, although valuable, does not necessarily represent the reaction to thermal stress as it occurs in nature. The other method, use of uncontrolled daily temperature averages, although representing the normal type of thermal stress, is subject to such great variation as to make it difficult to interpret the data. Thus, this present study was undertaken in an attempt to provide at least preliminary information on milk composition as affected by daily temperature cycles approximating the average conditions in the mid-west during winter, summer, spring, and fall (normal), and in the Imperial Valley in California.

METHODS

Data on the composition of milk, as influenced by diurnal environmental temperature cycles, were obtained through the use of the climatic laboratory at the University of Missouri. Constructional details have been described by Thompson (1954).

Temperatures used in the various experimental and adjustment periods are summarized in Table 1, and given in detail by Brody *et al.* (1955). The minimum and maximum temperatures referred to in Table 1 are those of 5 a.m. and 3 p.m., respectively, in the daily temperature cycle.

The fall experimental data were obtained from six cows, three each of the Holstein and Jersey breeds. Data for the spring experimental period were obtained from three Holstein and two Jersey cows. Holstein No. 184 had a heat stroke on May 1 and, upon removal from the laboratory, was also found to have acute diffuse streptococcal mastitis and a femoral blood clot. Jersey No. 564 aborted a 5-month fetus on May 7 and was removed from laboratory May 24. All animals were milked by machine twice daily. The animals were fed daily, 2 pounds of beet pulp, dry weight basis, and alfalfa *ad libitum.* Water was available at all times. 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 for each 4 pounds of milk produced daily.

Milk samples were collected every second day throughout the experimental and adjustment periods. Composite samples were made by taking aliquot parts of the morning and evening milkings. After collection of the milk samples,

TABLE 1--DIURNAL TEMPERATURE SCHEDULE

Temperature Condition	Diurnal Temperature Range °F.	Week 3 a.m. to 3 p.m.	Average Weekly Air Temp. °F.
		Fall	
Adjustment	**	Oct. 8 to 15	60
"Midwest Normal"	40 to 71	Oct. 15 to 22	58
	38 to 71	Oct. 22 to 29	54
	38 to 71	Oct. 29 to Nov. 5	56
"Midwest Cold"	6 to 32	Nov. 5 to 12	20
	10 to 39	Nov. 12 to 19	25
	12 to 39	Nov. 19 to 26	26
Adjustment	**	Nov. 26 to Dec. 3	64
"Midwest Hot"	70 to 100	Dec. 3 to 10	85
	70 to 101	Dec. 10 to 17	84
	73 to 101	Dec. 17 to 24	84
Adjustment	**	Dec. 24 to 31	65
"Imperial Valley"	39 to 110	Dec. 31 to Jan. 7	66
	49 to 110	Jan. 7 to 14	77
	48 to 112	Jan. 14 to 21	79
Adjustment	**	Jan. 21 to 28	64
		Spring	
Adjustment	**	Jan. 28 to Feb. 4	60
"Midwest Cold"	11 to 40	Feb. 4 to 11	30
	10 to 44	Feb. 11 to 18	26
	11 to 41	Feb. 18 to 25	24
	7 to 42	Feb. 25 to Mar. 4	21
	8 to 43	Mar. 4 to 11	21
Adjustment	*	Mar. 11 to 18	37
"Midwest Normal"	38 to 72	Mar. 18 to 25	55
	38 to 71	Mar. 25 to Apr. 1	54
	40 to 71	Apr. 1 to 8	55
	40 to 71	Apr. 8 to 15	55
	40 to 76	Apr. 15 to 22	55
"Imperial Valley"	59 to 112	Apr. 22 to 29	81
	60 to 111	Apr. 29 to May 7	84
Adjustment	**	May 7 to 13	63
"Midwest Hot"	64 to 102	May 13 to 20	84
	70 to 100	May 20 to 27	84
	68 to 100	May 27 to June 3	84

** Constant temperature of about 60°F.

* The 10° to 40° diurnal temperature range was gradually increased during the week to a range of 40° to 70°F.

formaldehyde was added as a preservative and the samples were then cooled to 40° F. The determinations for all constituents were made within 48 hours after collection of the samples. Daily milk production records were kept.

Analytical methods for determination of total solids, butterfat percentage, solids-not-fat, specific gravity, and total nitrogen are those described in detail by Cobble and Herman (1951).

Briefly, the analytical methods used to obtain duplicate determinations for all constituents were:

Total solids: Milk samples were heated to 112° F and cooled to 86° F. Two ml. of each sample were placed on flat aluminum pans containing a thin layer of quartz sand (pan and sand preheated three hours to get constant weight) and heated in an oven for 2½ hours at 101° C. The samples were then allowed to cool for 15 minutes in a desiccator prior to obtaining constant weights on an analytical balance.

Butterfat: The standard Babcock procedure was used to determine butterfat percentages on milk samples heated and cooled for total solids determinations.

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

Specific Gravity: A specially adapted Westphal balance was used to determine the specific gravity of milk samples heated and cooled for total solids determinations.

Lactose: The Lippich polarizer, with procedures as given by the Association of Official Agricultural Chemists (1945), was used in making lactose determinations on milk.

Chlorides: A modification of the methods outlined by Sharp and Struble (1935) and Sanders (1939) was used in chloride determinations. Seventeen and one-half ml. of milk were pipetted into a 200 ml. Erlenmeyer flask and 20 ml. of silver nitrate solution were added and mixed with the milk. The silver nitrate solution was composed of 8.624 grams silver nitrate, 350 ml. concentrated nitric acid, 525 ml. of a saturated solution of ferric ammonium sulfate, and distilled water to give a volume of one liter. The excess silver nitrate in the mixture was then titrated with a potassium thiocyanate solution (4.9325 grams KSCN per liter).

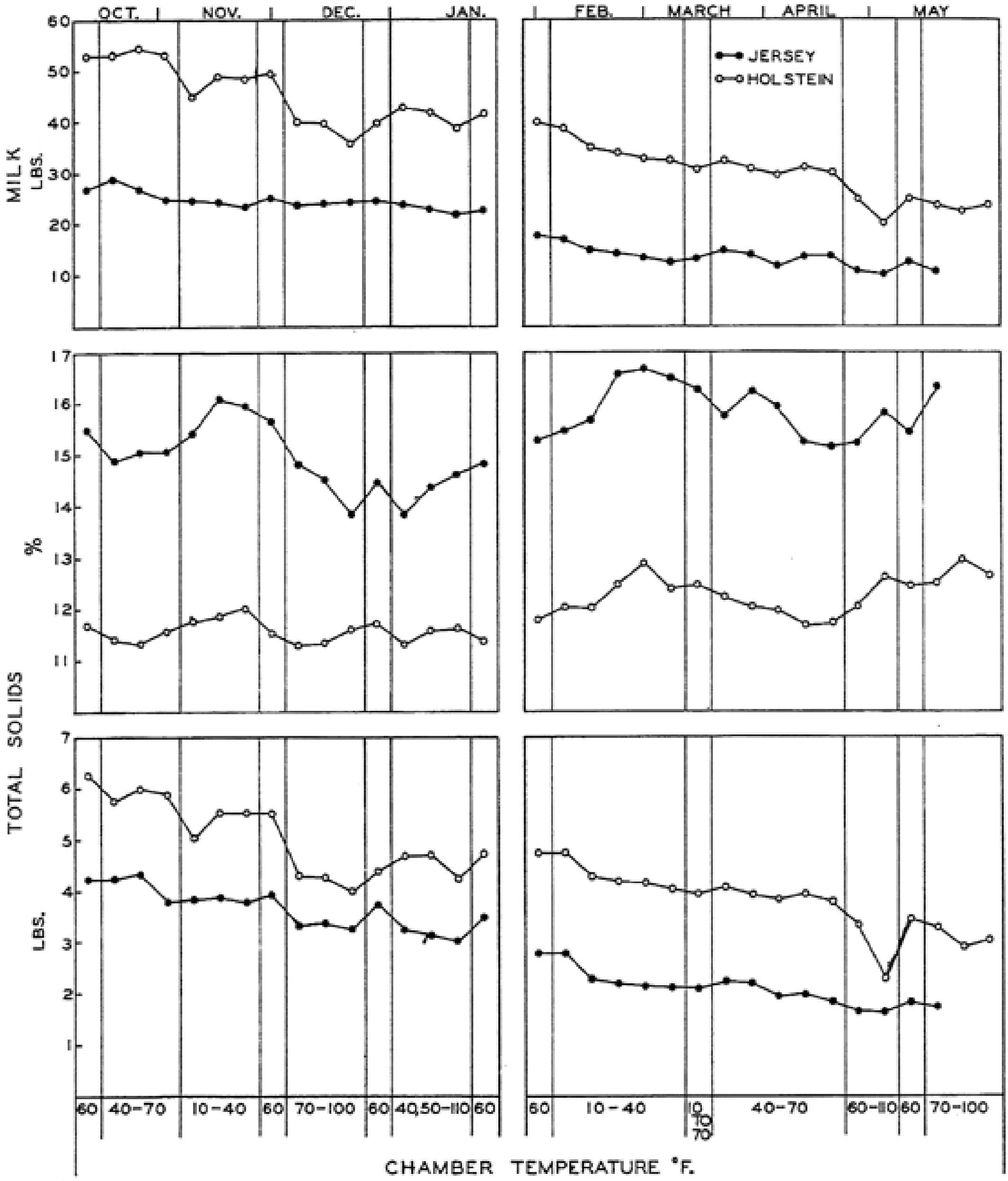
Total Nitrogen: The standard Kjeldahl method for determining total nitrogen was used in all determinations (association of Official Agricultural Chemists, 1945).

RESULTS AND DISCUSSION

Milk Production

The average milk production of Jersey and Holstein cows subjected to various diurnal temperature cycles is shown in Figure 1. The Jerseys, possibly

Figure 1—The influence of various diurnal environmental temperature cycles on the milk production and total solids content of Holstein and Jersey milk.



because of the lower production levels, show very little response in milk production to different temperature cycles; the Holsteins appear to be more affected by temperature changes. Effect of the stress due to change in temperatures was most evident when cold (10 to 40° F) and normal (40 to 70° F) cycles were followed by either 70 to 100° F or 60 to 110° F temperature ranges.

Total Solids

Exposure of lactating cows to different diurnal environmental temperatures resulted in changes in the total solids percentages of their milk (Figure 1). The effect was most pronounced for the Jerseys with only slight changes for Holsteins. Exposure to both high and low temperature cycles increased the total solids percentages of the milk when these test periods were preceded by suitable adjustment periods. The length of this "normal" period probably varies with animals and test conditions but from the data obtained in March and April during the 40 to 70° F cycle it appears that at least four weeks were needed for the total solids percentage to reach an approximately normal value in these experiments. When the adjustment or normal period between low and high temperature cycles was of short duration, the total solids percentage declined temporarily to below normal before resuming the upward trend associated with exposure to high temperature cycles. The rather uniform trend downward in pounds of total solids and milk production (Figure 1) for the Jerseys, when considered with the fat and solids-not-fat percentages (Figure 2), seems to indicate that much of the changes in total solids percentage may have been due to changes in the fluid balance of the Jerseys rather than a direct effect upon the secretion of these milk constituents. The picture for the Holsteins is complicated by variations in total milk production accompanying the changes in other constituents.

Butterfat

The changes in percentage of fat (Figure 2) in the milk of Jersey cows with different temperature ranges reflected trends which were similar to the trends in total solids percentages. However, changes in the milk fat percentages of the Holsteins could not be attributed definitely to the effect of changes in environmental temperature. This may be due to the gradual increase in milk fat percentage with advancing lactation which would tend to mask any small changes due to environmental conditions.

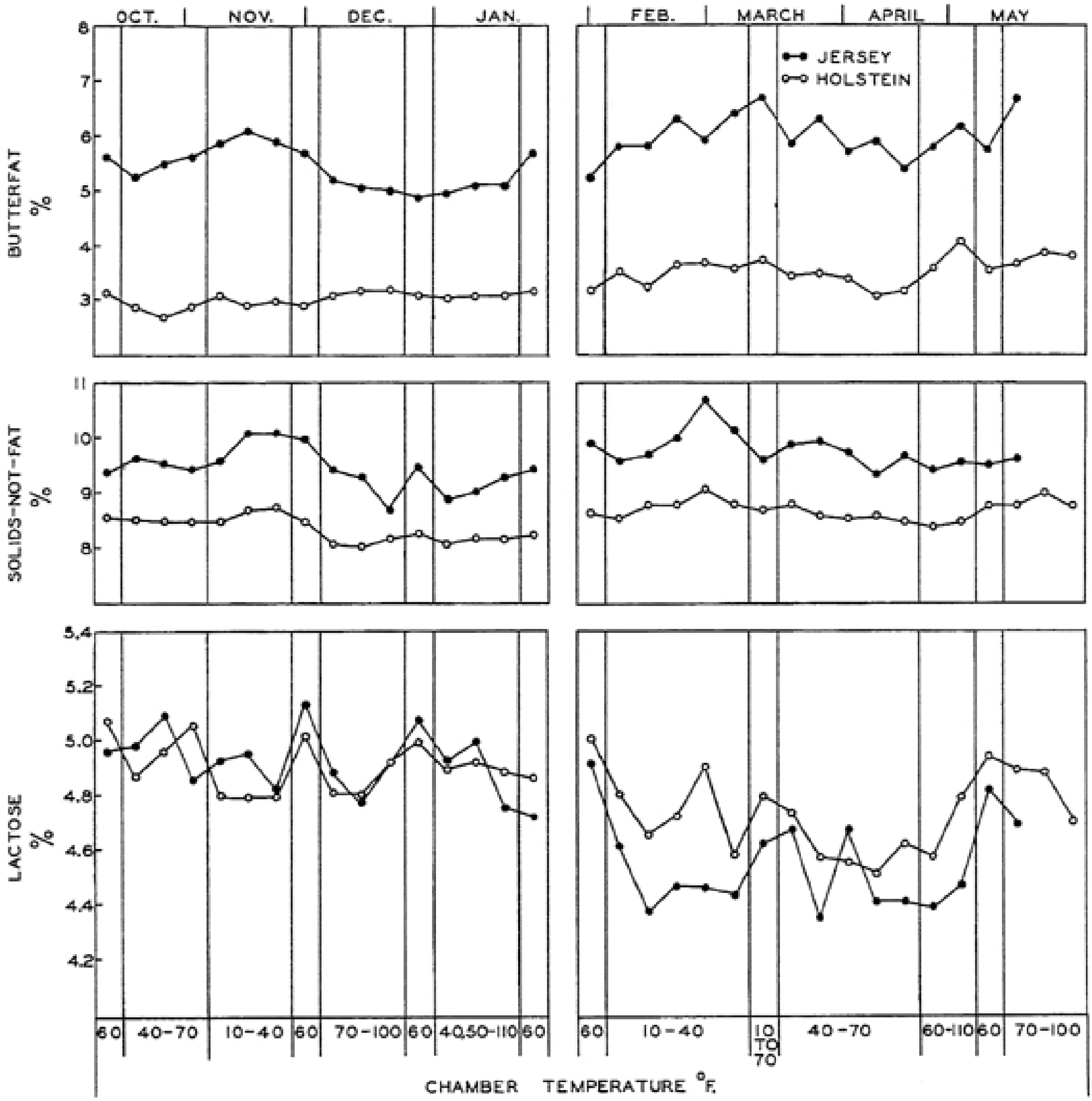
Solids-not-fat

During the cold cycles, the general trend of changes in solids-not-fat percentages (Figure 2) of both the Holstein and Jersey cows was similar to that observed in total solids percentages, with maximum changes occurring in the Jersey milk.

Lactose

The percentages of lactose were quite variable for both the Jersey and Holstein cows (Figure 2) and the changes could not be definitely associated with any particular diurnal temperature rhythm. The gradual decrease in lactose per-

Figure 2—The influence of various diurnal environmental temperature cycles on the butterfat, lactose, and solids-not-fat content of Holstein and Jersey milk.

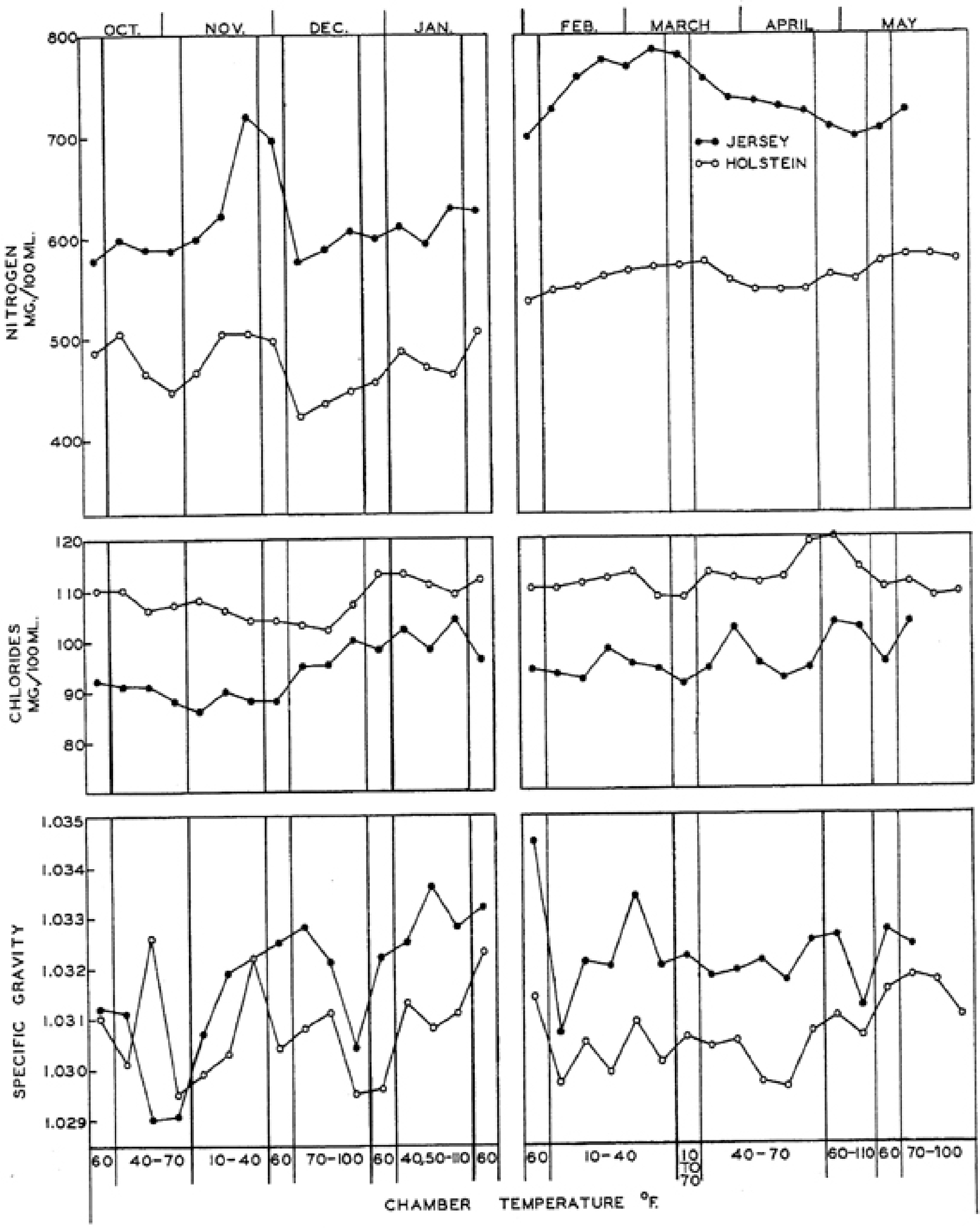


centages until near the end of lactation was characteristic of both breeds.

Nitrogen

The greatest changes in the percentages of nitrogen in the milk of both Holstein and Jersey cows occurred during the cold diurnal cycles (Figure 3). However, a slight upward trend in nitrogen percentage was also observed during the hot diurnal cycles.

Figure 3—The influence of various diurnal environmental temperature cycles on the specific gravity, nitrogen, and chloride content of Holstein and Jersey milk.



Chlorides

Chloride content of the milk (Figure 3) was not appreciably affected during the cold diurnal cycles. It increased during the "hot" temperature cycles.

Specific Gravity

The specific gravity values of milk from both Holstein and Jersey cows (Figure 3) were rather variable during the course of these experiments. Changes could not be associated definitely with changes in diurnal temperature cycles.

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