RESPONSE OF COWS MILK COMPOSITION
TO CHANGES IN ENVIRONMENTAL TEMPERATURE

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TABLE OF CONTENTS

CHAPTER ONE

LIST OF TABLES

APPENDICES

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CHAPTER ONE

1.1 Introduction

The need for greater production of animal proteins in the developing countries stems from two factors. Protein deficiency among growing populations due to a wide gap between production and consumption and the continuing demand for the conventional proteins despite the availability of synthetic substitutes French 1970. Studies with regard to the nutritional properties of dairy products Henry 1957; McGillivray and Porter 1960. McGillivray and Gregory 1962 showed that the (protein) fraction of milk was well balanced in the essential amino acids enchancing their nutritive value.

Milk production at the desired levels has not been possible in humid and arid regions of the world due to a variety of technical problems chief of which have been the choice of dairy breeds and the availability of good quality pasture, Payne 1957. Cattle breeds indigenous to these regions are poor milk producers. They are slow developing, late maturing animals with short lactatious, long dry periods and poor milk let down; factors which probably contribute to their higher heat tolerance, a character incompatible with high milk yields Mahadevan and Marples 1961. In the United States of America Red Sindhi and Brahman breeds were used in cross breeding programmes aimed at evolving a heat tolerant high producing dairy breed for the gulf coast areas. The first generation Jersey Sindhi and Jersey Brahman crosses not only produced less milk than their contemporary pure Jerseys, but also lacked persistency and a suitable dairy temperament; which were in fact heritable. Brandon McDowell and Brown 1966. These observations do not preclude however the advantages of cross breeding for higher milk production in the tropics Legates 1966; Salazar 1968. Although early ventures using temperate breeds of cattle for milk production in the tropics have shown results of a disappointing nature Payne 1957, given near temperate conditions found in tropical uplands these breeds could respond well. Trail 1968; Yung Chen Chia 1968.

The problems associated with feeding in the tropics are reviewed by Payne 1966, Citing Hardison 1966, Milford and Minson 1963-64. Payne pointed out that tropical pasture species mature fast and thus contain a high crude fibre content which becomes a disadvantage to cattle under a certain degree of thermal stress. Feeding practices have to take into account an animal's heat tolerance, and where productive animals have to be kept on high planes of nutrition, rations low in crude fibre but high in crude protein, together with frequent feeding throughout the twenty four hours have been emphasized.

1.2(a) Thermoregulatory Responses of Cattle to Thermal Stress
Cardiovascular Responses

Changes in heart rate varied with the thermal intensity to which cattle were exposed. A decline in heart rate was observed under conditions of prolonged exposure to mild heat Worstell and Brody 1953. Exposure to severe heat however increased the heart rate of calves Bianca and Findlay 1962, Ingram and Whittow 1963. Heart rate was positively correlated with the metabolic rate Kibler and Brody 1949, Blaxter and Wood 1951. Consequently changes in the heart rate under various degrees of thermal stress could be attributed to this relationship, Bianca 1958 suggested that an increase in respiratory rate might be a contributory cause to an increase in the heart rate. In view of an increase in the excretion rate of nor adrenaline consequent to an increase in its secretion rate under thermal stress (Alvarez and Johnson 1970) it might appear as if this catecholamine by its direct action on the heart cause cardiac acceleration.

The blood volume of lactating cows Dale Bourge and Brody 1956 and of calves Bianca 1957 showed significant increases under thermal stress. Murti and Mullick 1961 reported seasonal variation in the blood volume of Indian buffaloes. In summer the blood volume was greater than in winter. Blood flow to skin areas where there were more arteriovenous anastamoses increased under high ambient temperatures Beakley and Findlay 1955, Whittow 1962. It is however not known whether mammary blood flow is altered due to an increase in blood flow to peripheral areas. A decrease in blood flow to the mammary gland would reduce the inflow of metabolites which would in turn result in an alteration in milk synthesis.

The changes that occur in the composition of blood under thermal stress are listed below.

(1) A decline in the haemotocrit value due to haemodilution
McDowell, Moody, Van Soest, Lehman and Ford 1969

(2) A decline in blood acetate mediated through a decline in blood thyroxine
Yousef and Johnson 1965

(3) A decline in plasma protein
McDowell et al. 1969

(4) A decrease in blood insulin
Kamal, Ibrahim, Seif and Johnson, 1970

(5) A decrease in blood glucose
Roussel Beatty, Ghoulson, Pinero and Waters 1971

(6) Changes in plasma free animo acids
Kamal, Ibrahim, Seif and Johnson 1970.

Precursors of almost all the milk constituents are taken up by the lactating mammary gland from the blood, Linzell 1968. Glucose and acetate fulfill two important functions in the mammary gland. They are partly metabolized, and the balance used up by the udder for the synthesis of all of lactose, a part of glycerol and short chain fatty acids. Annison and Linzell 1964. Amino acids are incorporated into milk proteins. It is not surprising to find changes in milk proteins, fat and lactose consequent to changes in their precursors in blood.

1.2(b) Respiratory Rate and Respiratory Evaporative Heat Loss

The first reaction observed in cattle exposed to a high ambient temperature is thermal polypnoea, Kamal 1964. It is an immediate response to dissipate excess body heat, being initiated by the stimulation of peripheral thermal receptors Bligh 1957 and probably of deep body receptors Rawson, Quick and Coughlin 1969.

Respiratory rates of Jersey, Holstein and Brown Swiss cows increased at 16°C, and that of Brahman cows at 24°C Worstell and Brody 1953; while respiratory rates as high as 200 per minute in cows Riek and Lee 1948 and 250 per minute in calves, Bligh 1957 have been observed. Respiratory ventilation increases due to the respiratory rate exceeding changes in the tidal volume, Bianca and Findlay 1952. Since respiratory vaporization depends partly on the movement of air within the respiratory tract an increase in respiratory ventilation increases respiratory evaporative heat losses. Kibler and Brody 1952 showed that respiratory vaporization rates varied from 50gm/m^2/hr for temperate breeds to 30gm/m^2/hr for tropical breeds of cattle. Hyperventilation has been shown to wash out excessive amounts of carbon dioxide leading to respiratory alkalosis accompanied by a rise in the pH of urine. Dale and Brody 1952, Bianca and Findlay 1962.

1.2(c) Sweating Rate and Cutaneous Evaporative Heat Loss

It has been proved that cattle sweat actively when under thermal stress, Knapp and Robinson 1954, McLean 1963; from sweat glands of an apocrine nature Findlay and Yang 1950, Hafez, Badreldin and Shafei 1955, which in the main had a thermoregulatory function, Fergusson and Dowling 1955, McDowell, McDaniel, Barrada and lee 1961. At 96°F the skin temperature of calves decreased consequent to sweat gland activity Klemm and Robinson 1955. The contribution of cutaneous vaporization to total vaporization was 80% while that of respiratory vaporization was 20%, Yeck and Stewart 1959. The amount of heat dissipated consequent to cutaneous vaporization therefore makes it the major avenue for dissipation of extra body heat in cattle under thermal stress. Sweat gland secretions were highly alkaline, and their concentrations of reducing sugars, lactic acid, inorganic phospherous, total protein and non-protein nitrogen were higher than for blood. Under conditions of thermal stress and thus of active sweating protein losses could be fairly high, Joshi, Joshi, McDowell and Sahu 1968. Although sweat glands serve a useful thermoregulatory function, they could to a certain degree affect production under thermal stress.

1.2(d) Food Intake and Digestion

High ambient temperatures had a depressing effect on the voluntary intake of all breeds of cattle. The temperatures at which this effect was manifested varied with different breeds, Worstell and Brody 1953; Davis and Merilan 1960, Robinson and Klemm 1953. Field observations showed that high ambient temperatures reduced the grazing time of beef cattle, Bonsma, Shchultz and Badenhorst 1940, Seath and Miller 1946.

Worstell and Brody 1953 found that the decline in voluntary intake coincided with the rise in body temperature implying that Brobeck's 1948 thermostatic theory on food intake was applicable to ruminants as well. Baile and Mayer 1968; Dinius Kavanaugh and Baumgardt 1970 experimenting with goats obtained data contrary to those of Worstell and Brody, and in fact contradicated Brobeck's theory. The rumen temperature being higher than the rectal temperature was suggested as a factor limiting intake by Brody, Dale and Stewart 1955. Temperature mediated decline in voluntary intake in ruminants has not been elucidated. There is evidence to show that lactating cows respond better to diets containing a lower percentage of fibre under thermal stress. Stott and Moody 1960 obtained a significant cow response in the fat corrected milk yields by decreasing hay and increasing concentrates in the diet. Respiratory rates and body temperatures declined as well. Similar observations were made by Leighton and Rupel 1956 and 1960, with diets low in fibre but high in proteins, and Breidenstein, Johnston, Hindery and Rusoff 1960 with diets containing 22 and 32% crude fibre at ambient temperatures of 23.9 and 35°C. Evidence to the contrary were obtained by

Rogerson 1960 and by Wayman, Johnson, Merilan and Berry 1962. Where the composition of the ration is concerned those with the least heat increment per 100 Kcal digested appear to give the best response at high ambient temperatures. Armstrong and Blaxter 1956 contended that the heat increment was greater when the proportion of acetic acid increased in the rumen. Rations containing a high percentage of crude fibre resulted in a higher proportion of acetic acid. Evidence in support of this contention was advanced by Shaw, Ensor, Telleghea and Lee 1960, Armstrong, Blaxter, Graham and Weinman 1958, Graham 1964, Leighton 1965.

Digestibility has been found to increase under hot environmental conditions, Blaxter and Weinman 1961, Davis and Merilan 1961. The apparent digestibility of proteins did not change in steers with elevated rectal temperatures, Vercoe 1969, McDowell et al., 1969 suggested that a decrease in the intake of digestible energy partly accounted for the increase in digestibility, while an increase in concentrates to roughage also contributed to the total digestibility of a mixed roughage and concentrate diet.

Wayman et al., 1962, Kibler, Johnson and Berry 1966, Johnson, Kibler, Berry, Wayman and Merilan 1966 demonstrated that the decline in voluntary intake of nutrients accounted for more than half the decline in milk yield under thermal stress.

1.2(e) Water Consumption

The amount of dry matter eaten and the severity of thermal stress seemed to govern the water consumption of cattle, Yousef, Hahn and Johnson 1968. Calves consumed more water at 27° than at 10°C, Johnson Ragsdale and Yeck 1960. Lactating cows consumed more water at a high ambient temperature, Ragsdale, Worstell, Thompson and Brody 1949. Under grazing conditions ambient temperature and water consumption were significently correlated, Harbin, Harbough, Neeley and Fine 1958.

A decrease in water consumption with increasing ambient temperatures Ragsdale, Worstell, Thompson and Brody 1949; Ragsdale, Thompson, Worstell and Brody 1951, was explained by the fact that the decline in intake of dry matter and the concurrent decrease in the milk yield collectively reduced water requirements for metabolism. Although there was an increase in the requirements of water for thermoregulation, this was offset by a decrease in the water requirements for metabolism.

An increase in the crude protein content of the diet increased the water consumption in cattle. Payne 1963. Rogerson 1963, found that a reduction of 12 to 4% crude protein in the diet decreased the intake of digestable energy by 60%, and heat production by 20% provided water was withheld.

Water turnover of grazing cattle was greater in summer than in winter, MacFarlane and Howard 1966, Siebert and MacFarlane 1969. Since water turnover depends on the water actually consumed, water produced by metabolism, and the loss of water in urine, faeces and sweat, the increased water turnover in summer would result from an increase in water loss and to a compensatory increase in water consumed. Whereas requirements of water in temperate climates mainly stem from metabolic demands, in tropical climates they arise primarily from thermoregulatory demands, Bianca, Findlay and McLean 1965.

1.2(f) Energy Metabolism

Heat production in lactating cows declined by 30 - 40% when either exposed to ambient temperatures varying from 80 - 100°F or when their rectal temperatures increased from 101 - 106°F, Kibler Brody and Worstell 1949. The decline in heat production was closely associated with a rapid decline in voluntary intake, followed by a decline in milk yield and possibly to a decrease in thyroid activity. A gradually increasing ambient temperature (50 - 90°F over a period of two months) decreased the oxygen consumption of calves from 110 to 85 litres per hour. The oxygen consumption of normally fed calves increased from 83 to 107 litres/hr and that of fasting calves from 69 to 87 litres/hr when the ambient temperature was suddenly increased to 100°F, Kibler 1960. Blaxter and Wainman 1961 found an increase in heat production when two steers were suddenly exposed to an ambient temperature of 35°C. Low metabolic heat production associated with prolonged exposure to elevated ambient temperatures was due to a decline in oxygen consumption, Kibler 1960, and to a decline in thyroid activity, Blincoe and Brody 1955, Yousef, Kibler and Johnson 1967. Apparently all the following factors, a decline in voluntary intake, a decline in oxygen consumption, a decrease in thyroid activity and a decline in milk production seem to offset heat production by increased respiratory muscular exertion, Kamal 1964. However when the respiratory rates of cattle remain elevated, respiratory muscular activity would be expected to utilize some part of the total intake of energy despite a decline in heat production consequent to the factors considered above. A significant decrease in the utilization of feed energy for productive purposes and an increase in the utilization of feed energy for heat production were observed in ad libitum fed lactating cows at 31°C, Kibler, Johnson and Berry 1966. McDowell et al., 1969 contended that the energy requirements of cattle increased under thermal stress, due to an increase in the expenditure of energy. The authors cited Consalazio and Shapiro 1964 in this regard who found that an extra expenditure of energy occurred under thermal stress consequent to heat transport by blood, increased sweat gland activity and an increased metabolic rate. Under thermal stress the energy intake of ad libitum fed cows decreased due to a decline in intake of dry matter and according to Kibler et al., 1966 and McDowell et al., 1969 an increased proportion of this was utilized for non productive purposes. The efficiency of utilization of energy for productive purposes then declined. When lactating cows were maintained at high ambient temperatures on the same level of gross energy that they voluntary took under normal ambient temperatures the decline in milk yield was markedly less, Kibler et al., 1966. This implied that maintaining them on the same level of energy did not stress them further, and allowing energy for non productive purposes, more energy was available for production. However under these circumstances force fed cows gained body weight, which meant that of the energy available for production a greater proportion was used for gains in body weight. Such a shift in intermediary metabolism seems possible in the light of evidence by Weldy, McDowell, Van Soest and Bond 1964; Gengler Martz, Johnson, Krause and Hahn 1970 who showed that the acetate to propionate ratio in the rumen declined under thermal stress. The general opinion is that a change in rumen metabolism favouring a decrease in the acetate to propionate ratio favours body weight gains rather than milk with a high fat content. For a discussion reference is made to the review by Van Soest 1963. The observations of Kibler et al., 1966 tend to support this shift in that force fed cows under conditions of thermal stress showed gains in body weight. Subsequent investigations however tend to show increased lipolysis under thermal stress due to declines in blood glucose and plasma insulin (See 1.2(a)) and to an increased secretion of corticoids. (See 1.2(g)). The animals used by Kibler et al., 1966 consumed more water under control feeding, and could have increased their body water content, and probably gut fill as well. Under these circumstances the body weight changes could have occurred consequent to a higher body water content, a greater gut fill and to a retention of energy due to lipogenesis offsetting lipolysis in the adipose tissue.

1.2(g) Endocrine Responses

Thyroid activity was negatively correlated with the ambient temperature. A rise in the ambient temperature lowered thyroid activity, Blincoe and Brody 1955, Johnson and Ragsdale 1960, Lundgren and Johnson 1964. Whereas thyroid secretion and turnover rates decreased, plasma 17 hydroxy corticosterone increased in heat stressed cows, Thompson, Johnston, Breidenstein, Guidry, Banerjee and Barnett 1963. Subsequently Kotby and Johson 1967 showed that ACTH increased immediately on exposure to $90^{\circ}F$, but declined on prolonged exposure. Wegner and Stott and Wersma and Stott 1969 reported findings contrary to those of Kotby and Johnson 1967. They found ACTH to be elevated over a period of 2 - 3 months of heat exposure. During this period blood progesterone level was high and leucocytes in the milk increased. Similar changes were observed with parenteral administration of ACTH. Neither blood levels of somatotrophin nor of prolactin of lactating cows exposed to high ambient temperatures have been measured.
Proppe and Gale 1970 found a decline in serum somatotrophin associated with other thermoregulatory responses such as cutaneous vadodilatation and a fall in oxygen consumption in baboons whose preoptic and anterior hypothalamic regions in the brain were heated. Blood insulin declined at high ambient temperatures, Kamal, et al., 1970. Thyroxine somototrophin and adrenal corticoids increased under cold stress. Cold acclimation resulted in an increase in thyroxine and adrenaline enhanced the calorigenic action of thyroxine, Swanson 1965. The release of I^{131} increased together with its peripheral utilization, adrenals hyphertrophied increasing the secretion of corticoids and pituitary ACTH remained elevated in cold acclimation. Endocrine

adjustments of guinea pigs exposed to moderately cold temperatures was characterized by a sustained augmentation of pituitary, thyroid and adrenal functions, D'Angelo 1960. Thyroxine metabolism was slow and decreased progressively in cattle exposed to high ambient temperatures, Yousef and Johnson 1966a. The authors 1966(b) suggested that the calorigenic action of somatotrophin was enhanced by thyroxine. Yousef, Kibler and Johnson 1967 a & b contended that the calorigenic effect of thyroxine somatotrophin and adrenal corticoids declined in cows exposed to high ambient temperatures, presumably due to a decline in all the hormones and a lack of synergicism necessary for calorigenesis when compared with cold exposure.

1.3 Rumen Characteristics

The concentration of volatile fatty acids of thermally stressed cows declined. A decline in acetic acid largely accounted for the total decline in the volatile fatty acids of thermally stressed cows under conditions of uncontrolled feeding, Weldy, McDowell, Van Soest and Bond 1964, while acetic and propionic acids accounted for a decline in controlled fed cows, Kelly, Martz and Johnson 1966. A rise in the rumen temperature decreased the percentage of acetic acid and increased that of propionic and butyric acids, Gengler, Martz, Johnson, Krause and Hahn 1969. The decrease in the concentration of volatile fatty acids was however due to thermal stress rather than to an increase in the rumen temperature. Diets lacking in physical fibrousness (more concentrates to roughage, chopped or pelleted roughage) produced more propionic acid when compared with acetic and butyric acids. Storry and Rook 1966, Storry and Sutton 1969. Under these conditions rumen pH decreased, together with the digestion of cellulose, Storry and Sutton 1969. Storry 1970 suggested that an initial decrease in the flow of saliva to the rumen reduced its pH, due to a decrease in the buffering action in the rumen. An acid pH subsequently reduced the cellulytic organisms in the rumen. Cows that were exposed to a high ambient temperature showed lower values for rumen pH, Misra, Martz, Stanley, Johnson, Campbell and Hilderbrand 1970. A decline in the volume of saliva entering the rumen may be suggested as being the contributory cause for a decline in rumen pH under thermal stress simply because cattle salivate under thermal stress and this saliva is subsequently lost. Consequently the change in rumen fermentation will be similar to that which occurs on diets lacking physical fibrousness. The oxidation reduction protential which was a measure of the activity of rumen micro-organisms decreased under thermal stress, Misra et al., 1970 and would in all probability have decreased the concentration of volatile fatty acids. An increase in lactic acid and the decrease in volatile fatty acids were highly indicative of a preferential growth of amylolytic organisms to cellulytic organisms consequent to changes in the rumen pH under thermal stress.

Whereas the concentration of Ammonia in the rumen was independent of ambient temperatures, the decline in its concentration post feeding tended to be slower under thermal stress, Misra et al., 1970. The authors citing the evidence of Bloomfield, Kearley, Creach and Muhrer 1963 suggested that the slow rate of decline post feeding under thermal stress was due to a slow rate of absorption in an acid medium. A slow rate of decline of Ammonia post feeding may also mean that its utilization for protein synthesis by the rumen micro-organisms has declined All the cellulose digesting bacteria utilized ammonia in preference to preformed amino acids for protein synthesis, Blackburn 1965. A decrease in cellulytic organisms in the rumen would at least in part explain a slow decline in ammonia post feeding under thermal stress. The circumstantial evidence points out to the fact that there might be a greater loss of dietary proteins and a greater decrease in bacterial proteins, bringing about an overall decrease in the availability of protein to the animal. When viewed with proteolysis, and subsequent protein losses in the urine, Vercoe 1969, and in sweat, Joshi et al., 1968, a protein deficiency under thermal stress might be expected with concurrent decreases of protein in products like milk.

1.4(a) Productive Responses

Milk Yield and Composition

The secreting bovine mammary gland is extremely complex in its synthetic processes such that optimal conditions are a prerequisite for maximal yields with least changes in the composition. Data from perfusion experiments with caprine mammary glands have shown the importance of flow rate of metabolites to the gland. For both yield and composition to be normal in perfused mammary glands the rate of flow of metabolites had to be the same as in the intact gland, Hardwick and Linzell 1960, Hardwick, Linzell and Price 1961. The metabolism of the whole body is geared to aid the secreting mammary gland. Under different physiological conditions milk yield and composition deviate from the normal, Linzell 1968. In view of optimal conditions being a prerequisite to the lactating mammary gland, changes in rumen metabolism, intermediatry metabolism, cardiovascular system, blood composition and endocrine balance consequent to thermal stress must necessarily bring about concurrent changes in milk yield and composition Kamal 1964.

Early findings on the direct effects of the climatic environment on milk yield and composition are reviewed by Payne 1954. Data from the Missouri climatic laboratory up to 1953 have been summarized by Worstell and Brody 1953. Studies at the Missour climatic laboratory have examined the effects of each climatic variable on milk yield. The milk yield of all breeds of cows used in the trials declined under conditions of a constant wet bulb temperature but elevated dry bulb temperatures. However the effective temperatures varied from temperate to tropical breeds. At high ambient temperatures the decline in milk yield of early lactation was relatively greater than that of late lactation, Johnson, Kibler, Ragsdale and Shanklin 1960. Also the decline in high producing cows was greater than in low producing cows, Johnson, Hahn, Kibler and Merilan 1962. With identical twins, fed the same rations, but managed under two different climatic environments, Payne and Hancock 1957 showed that the set of twins managed under hot environmental conditions, produced on an average less milk, butterfat and solids not fat. Climatic physiological studies in Tasmania, Rees 1964, showed the same effects on milk yield and composition in addition to depressions in total acidity and freezing point depression. Data of Rees 1964 have been obtained from very short exposure periods to varying ambient temperatures without intervening control periods. Consequently carry over effects could have been interpreted as treatment effects.

The effects of humidity on milk yield were only manifested at ambient temperatures above 24°C, when an increase in humidity resulted in greater declines in the milk yield, Yeck and Stewart 1959, Johnson Ragsdale, Berry and Shanklin 1963. Milk yields of Holstein, Jersey and Brown Swiss cows declined by 32, 18 and 15% respectively on increasing the humidity from 40 to 90% at 29°C, Yeck and Stewart also found that the decline in milk yield was less at high wind velocities when compared with low wind velocities at the same ambient temperature. Brody, Ragsdale, Thompson and Worstell 1954 contended that high yielding large dairy cows benefitted more from the effects of high wind volocities under thermal stress. Analysis of data from trials at Missouri by Cobble and Herman 1951 showed the following changes in milk yield and composition due to thermal stress.

A decline in milk yield.
A decline in the fat percentage up to 90°F,
and an increase above 90°F.
A decrease in SNF and total nitrogen.
A decrease in lactose.
An increase in chloride
No change in the freezing point.

Changes in the fatty acids of milk fat were characterized by a decline in short chain acids C_4 - C_{12}, and an increase in C_{16} and $C_{18:0}$. The increase in $C_{18:0}$ resulted in a decline in $C_{18:1}$ Richardson, Johnson, Gehrke and Goerlitz 1961. High ambient temperatures caused declines in total phosphorous, and magnesuim. Citric acid declined only during early lactation. The changes in sodium or sodium to potassium ratio were not significant, Kamal, Johnson and Ragsdale 1961.

The depressing effect of high ambient temperatures and humidities on milk production has still not been solved fully. Experimental findings of Wayman et al., 1962, Johnson et al., 1966 implied that the primary effect of thermal stress was mediated through a decline in intake and therefore due to underfeeding effects. When the intake of gross energy was maintained under thermal stress the decline in milk yield was smaller when compared with ad libitum feeding. However the milk yields of control fed cows were below their yield under normal ambient temperatures, which also implied that temperature mediated changes in the endocrine balance by their effects on metabolism or on golactopoesis or both accounted for the balance. In view of these observations underfeeding effects, and endocrine effects on metabolism and galactopoesis have to be considered to explain the overall changes in milk yield and composition under thermal stress. Data on underfeeding cows after calving by Flux and Patchell 1954 on milk yield and composition are considered, because of their relevance to studies with high ambient temperatures which in the main used cows with already established lactations. Underfeeding after calving caused a decline in milk yield, fat yield and SNF%. A decrease in the SNF% was due to declines in both protein % and lactose%. The changes under thermal stress are similar to those of underfeeding. As seen earlier 1.2(g) the changes in the endocrine balance were an increase in ACTH and adrenal corticorids, a decrease in thyroxine, probably from under-feeding effects, Blincoe and Brody 1955, Kibler 1960 or from direct effects, Lundgren and Johnson 1964, and insulin, Kamal, et. al., 1970 A probable decrease in somatotrophin, Proffe and Gale 1970 and an increase in nor adrenaline, Alvarez and Johnson 1970.

The possible effects of endocrine changes together with other changes such as a decline of blood glucose and acetate on metabolism and udder metabolism are summarised.

(1) An increase in corticorids, catecholamines and a decrease in insulin favour lipolysis in adipose tissue, with a release of long chain fatty acids, which would be incorporated in milk fat increasing the long chain fatty acids.

(2) An increase in corticorids would increase gluconeogenesis and decrease protein precursors to the gland with a concurrent decline in milk protein. Regan and Richardson 1938 observed a decline in casein under thermal stress.

(3) A decline in glucose and acetate would reduce udder metabolism, reduce lactose synthesis and the synthesis of short chain fatty acids. The decrease in acetate may arise due to changes in the rumen, a decline in thyroxine, Yousef and Johnson or to both.

The possible effects on golactopoesis are based on the findings of Cowie and Tindall 1961, Cowie, Knaggs and Tindall 1963. Data on hypophysectomized goats showed that prolactin tri-iodothyronine insulin and dexamethasone restored milk yields to normal levels. These hormones were considered essential for golactopoesis. Presuming that the same hormones are essential for the bovine, under thermal stress galactopoesis could be affected by a decline in insulin somatotrophin and thy roxine and enhanced secretion of ACTH which has been shown to decrease milk yield, Flux, Folley and Rowlands 1955.

This experiment was carried out to examine some of the responses in cows milk yield and composition due to an elevated dry bulb temperature. Responses examined were rectal temperature and respiratory rate as measures of thermal stress, water intake, milk yield and composition, cells in milk and osmolarity, rumen characteristics with regard to pH and volatile fatty acids, and changes in the composition of milk fat. Since the responses were to be examined at a constant level of intake cows were paired and the control cows within pairs were controlled fed to ensure the same level of intake, see 2.4

Wayman, et al., 1962, Kibler 1966, Johson, et al., 1966 compared the responses in milk yield of cows on two levels of intake at the same high ambient temperature. Their results proved that the decline in milk yield was due to a decline in voluntary intake and to other factors, and that the former accounted for more than half the decline. In this experiment a comparision of the responses was made on cows maintained on the same level of intake but at two different ambient temperatures, and consequently examining whether the cows exposed to the high ambient temperature showed a greater decline in milk yield and changes in composition due to changes other than a decline in voluntary intake.

Water intake and osmolarity were measured to examine possible effects of haemodilution on the water content of milk. Since changes in rumen fermentation are reflected in milk yield and composition, particularly the fat moiety and body weight changes, rumen pH and volatile fatty acids were examined with a view to relating any alterations to possible changes in the composition of milk fat. Daily AM and PM milk samples were subject to the Wisconsin Mastitis

Test in order to observe changes in the cells in milk and thus corticorid activity and their related effects on milk composition.

CHAPTER TWO

Materials and Methods

2.1 Animals

2.2 Housing and Management

2.3(a) Feed

(b) Feeding During the Experimental Period

2.4 Measurement of Respiratory Rate and Rectal Temperature

2.5 Milking

2.6 Sampling and Tests

(a) Milk Composition

(b) Cell Content

(c) Osmolarity

(d) Fatty Acid Composition of Milk Fat

2.7 Sampling Rumen Liquor and Tests

(a) pH

(b) Concentration of Volatile Fatty Acids

(c) Proportions of Volatile Fatty Acids

2.8 Statistical Analysis of Data

2.1 Animals

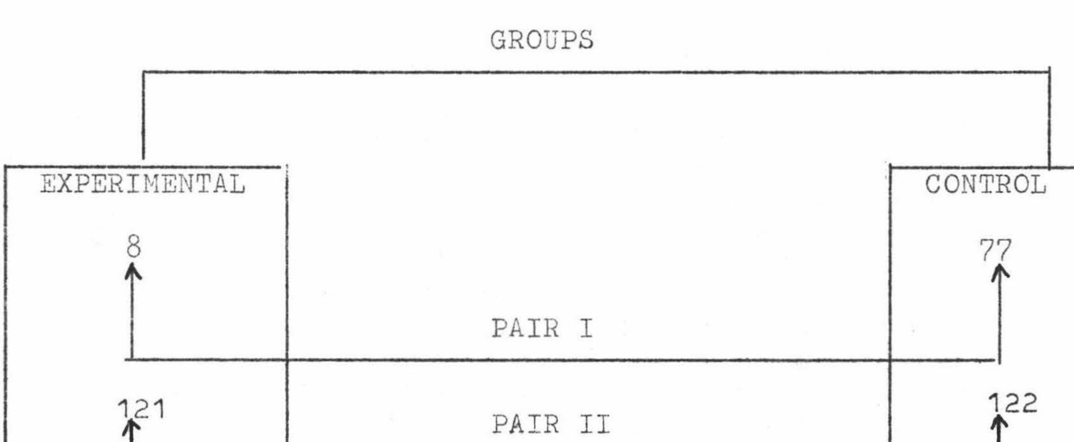
Four lactating non pregnant cows from Massey University dairy herd which had been fitted with rumen fistulae in the previous year were used in the experiment. Particulars of the cows are given in the table below.

Cow No.	Breed	Bodyweight**	**Stage of Lactation
8	FRxJ	783 Lb	16 weeks post Partum
77	J	732	9 weeks post Partum
121*	J	791	9 weeks post Partum
122*	J	842	15 weeks post Partum

* Monozygous Twins

** At beginning of experiment

The four cows were divided into two groups, and to maintain the same level of intake during the experimental period see 2.3(b) cows in the two groups were paired. The use of a pair of monozygous twins in the experiment resulted in the other two cows being randomly paired.



2.2

Both groups of cows were initially kept in two temperature controlled rooms ($\pm$ $1^{o}C$) in individual cow stands fitted with food bins and water troughs. At the end of a preliminary period of 29 days the room temperature of the experimental group was increased to $30^{o}C$. It remained at $30^{o}C$ until day 54, when it was returned to $15^{o}C$. Measurements continued until day 62

DURATION OF THE EXPERIMENT 62 DAYS

DAY 0 TO DAY 29	DAY 30 TO DAY 54	DAY 55 TO DAY 62
Control Group, Experimental Group: $15^{o}C$	Control Group $15^{o}C$, Experimental Group $30^{o}C$	Control Group, Experimental Group: $15^{o}C$

2.3(a) Feed

Cows were fed dried grass from day 0 through to day 64 of the experiment. A proximate analysis of a sample of the dried grass is given below.

Acid Detergent fibre	28.1%
Crude Protein	14.9%
Ether Extract	9.7%
Ash	9.3%
Nitrogen Free Extract (By difference)	34.2%

An apparent digestibility of 73.0 (A.W. Davey unpublished data) was obtained using four sheep. Particulars are given below.

No. of Sheep	Intake	Digestibility
10	1245 gm	73.4
2	1157 gm	70.0
A	1245 gm	74.7
13	945 gm	73.3

The digestible organic matter calculated from the above figures for organic matter and digestibility was 63.2% Using the approximation that 1 gram of digestible organic matter is equivalent to 3.6 Kcal of metabolizable energy, and maintenence requirements under stall feeding conditions at 11500 Kcal of metabolizable energy Blaxter 1964, the requirements of dried grass for maintenence were estimated at 7.0lbs.

Requirements for production were estimated by assuming that 0.35lb of digestible organic matter was required to produce one pound of fat corrected milk. The cows were fed 1 pound in excess of their requirements thus estimated. No 8 and 121, 30lb and no 77 and 122 29lb of dried grass respectively. Approximately half of the daily ration was offerred to each cow at 600 hrs, and the balance at 1600 hours before milking.

2.3(b) Feeding During the Experimental Period

During the experimental period the cows were fed in pairs and the intake of the Pair controlled at the level consumed by the member with the lowest voluntary intake. Pair 1 is taken as an example and pair feeding is illustrated in the table given below.

EXPERIMENTAL COW No. 8	CONTROL COW No. 77
DAY O	DAY O
30lb of dried grass were weighed at 1800 hrs for day 1	29lb of dried grass were weighed at 1800 hrs for day 1
DAY I	DAY I
Approximately half of the dried grass weighed on Day O was offered at 600 hrs before milking. Balance of the grass was offered at 1600 hrs before milking. 30lb of dried grass were weighed at 1800 hrs for Day 2	Approximately half of the dried grass weighed on Day O was offered at 600 hrs, before milking. Balance of the grass was offered at 1600 hrs before milking. 29lb of dried grass were weighed at 1800 hrs for Day 2
DAY 2	DAY 2
Grass refused from day 1 was weighed at 5.30 hrs. Four 50 gm samples from the refusals were placed in the oven. Approximately half of the grass weighed on day 1	Approximately half of the dried grass weighed on day 1 was offered at 600 hrs before milking. Four 50 gm samples from the balance were placed in the oven. The dry matter

was offered at 600 hrs before milking. The dry matter percentage of the four 50 gm samples was determined at 1500 hrs and the dry matter refused from day 1 was determined. The balance grass was offered at 1600 hrs before milking. 30lb of grass were weighed at 1800 hrs for day 3

percentage of the four 50 gm sample was determined at 1500 hrs. Using this dry matter percentage the weight of grass equivalent to the dry matter refused by 8 was determined. This weight of grass was deducted from the balance of the grass offered at 1600 hrs before milking. 29lb of grass were weighed at 1800 hrs for day 3

The quantity of dry matter refused by experimental cow no 8 on day 1 was deducted from the dry matter offered to control cow no 77 on day 2. Cow 77 was consequently a day behind 8 in the intake of the same quantity of dry matter.

2.4 Measurement of Respiratory Rate and Rectal Temperature

Rectal temperatures were measured twice daily at 5.45 hrs and 15.45 hrs before feeding using a thermister (Thermophil Ultrakust Co. West Germany). This was calibrated against a mercury in glass thermometer ($\pm$ 0.05^{o}C)

Respiratory rates were recorded at 5.45 and 15.45 hrs on several days, during the preliminary, experimental and post experimental periods. The respiratory rate was measured by observing the movements of the right flank.

2.5 Milking

The cows were milked twice daily at 600 and 1600 hrs using a portable bucket type milking machine, and the weight of the milk from each cow recorded at each milking.

2.6 Sampling and Tests

(a) Milk Composition

Approximately 300 ml of milk from each cow at each milking were collected in clean dry bottles after stirring and stored at 3°C. The composition of these samples were subsequently determined using a MK 1 Grabb Parsons Infra Red Milk Analyser (Munford 1968)

Approximately 20 ml samples from each cow at each milking were also collected in clean dry bottles for the determination of the cell content and osmolarity.

(b) Cell Content

The cell content of milk was determined by the Wisconsin Mastitis Test as described by Holmes 1971.

(c) Osmolarity

Osmolarity was measured using a cryoscope. Advanced Instruments Philadelphia; as miliosmoles per litre in duplicate for each sample.

(d) Fatty Acid Composition of Milk Fat

20 ml samples were collected from each cow on the days given below for separation of milk fat.

Period	Day of Collection	Time of Collection	Day of Separation
Preliminary Period	6	*16.45 Hours	
	7	6.45 Hours	7
	29	*16.45 Hours	
	30	6.45 Hours	30
Experimental Period	36	*16.45 Hours	
	37	6.45 Hours	37
	44	*16.45 Hours	
	45	6.45 Hours	45
	49	*16.45 Hours	
	50	6.45 Hours	

*STORED AT 3°C

20 ml aliquots were treated with 20 ml of ethanol and a lesser quantity of diethyl ether and filtered. Separation of fat from the filtrate was done in a vacuum evaporator and later in a separating funnel using petroleum ether. The separated fat was stored at 3°C until further use.

The stored milk fats were analysed as methyl ethers of the fatty acids prepared by the method of van Wigngaarden 1967, in a Varian Aerograph series 1200 gass chromatograph using a 8' x $\frac{1}{8}$" stainless steel column packed with chromosorb W(DCMS) 60/80 mesh coated with 12.5% diethyl glycol succuiate (Analab). The following conditions were used:

Nitrogen flow	25 ml/min
Hydrogen flow	25 ml/min
Injector temperature	210°C
Detector temperature	210°C

Temperature programme. Initial 60°C, 2°C/minute from sample injection 4°C/minute until 175°C and then isothermal at 175°C until methyl linoleate separated out. Recordings were made using a Leeds and Northrup Speedomax model 207S recorder with a strip chart integrator (Disc Instrument California U.S.A.) Fatty acid proportions were calculated from the disc integrator tracing as molar percentages without correction for the molecular weight difference of the free acids and the methyl esters.

2.7 Sampling Rumen Liquor and Tests

Period	Day of Sampling	Sampling Times			
Preliminary	11	5.30 Hrs	900 Hrs	1200 Hrs	1500 Hrs
	25				
Experimental	39				
	46				
	53				

Approximately 200 gm of rumen contents were removed through the fistula, strained through two layers of cheese cloth into a labelled container.

(a) pH

The pH of the rumen liquor was determined immediately using a pH meter (type PHM 23d. Copenhagen NV) and the rumen liquor returned to the container which was then stored at 3^{o}C until required for steam distilation.

(b) Concentration of Volatile Fatty Acids

The concentration of volatile fatty acids of each sample was determined by steam distilation in a Markham Still in duplicate. (Markham 1942). A 5 ml aliquot of rumen liquor was placed in the still with one ml of 10N H_2SO_4 saturated with MgSO4 (McAnnlly 1944) and distilled until approximately 70 ml of the distilate were obtained. Carbon dioxide was bubbled through the distilate for 2 - 3 minutes and then titrated against 0.05N NaoH using 1 - 2 drops of phenol phthalein as indicator. A further 1 ml of 0.IN Naoh was added and the solution evaporated to a sludge in a 250 ml beaker. The sludge was stored at 3°C until required for separation by chromatography. Determinations were repeated where the difference between duplicates was greater than 1%. Davey 1964.

(c) Proportions of Volatile Fatty Acids

The sludge was evaporated to dryness and reconstituted with 1 ml of distilled water. Duplicate samples were mixed and the volatile fatty acids separated in a Varian Aerograph Series 1200 gas chromatograph using a stainless steel column 6' x $\frac{1}{8}$" packed with 20% FFAP on 60/80 mesh chromosorb W. The following conditions were maintained.

Oven temperature 145°C (conditioned to 160°C overnight)

Injector temperature	170°C
Detector temperature	170°C
Hydrogen flow	25 ml/min
Nitrogen flow	25 ml/min

The gases were bubbled through a solution of formic acid prior to entry into the column. The volatile fatty acid proportions were calculated from a disc integrator tracing as molar percentages correction factor used. Relative to Sodium butyrate

$$\text{Acetate} = \frac{209.7702}{\text{Acetate area relative to Butyrate (100\%)}}$$

$$\text{Proprionate} = \frac{119.6865}{\text{Propionate area relative to Butyrate (100\%)}}$$

Isovaleric and valeric acids taken as C_5 were assigned respective factors equal to 100% for Butyrate. The molar percentages that differed by more than 1% were determined in replicate. Volatile fatty acid proportions were expressed as milimoles per 100 ml of rumen liquor.

2.8 Statistical Analysis of Data

All experimental data were subject to analysis of variance. Since experimental and control cows were pair fed, variation within pairs were analysed into the following sources. Treatment within pairs, Period within pairs and Residual.

The experimental period was divided into four periods for the analysis of data with regard to daily water consumption, daily milk yield, osmolarity of milk, fat, protein, lactose percentages and their respective yields, and into three periods with regard to rumen pH, volatile fatty acids, and fatty acids of milk.

Differences between preliminary and experimental period means for all the measurements were suitably coded; and measurements for the four and three periods analysed with 15 and 11 degrees of freedom.

CHAPTER THREE

Results

3.1 Respiratory Rate

3.11 Rectal Temperature

3.12 Food Intake

3.13 Water Consumption

3.14 Rumen Characteristics

3.15 Milk Yield

3.16 Fat Percentages, Yield of Fat and Molar Percentages of Milk Fatty Acids.

3.17 Protein Percentages and Yield

3.18 Lactose Percentages and Yield

3.19 Osmolarity

3.20 Cell Content in Milk

3.21 Body Weight Changes

3.1 Respiratory Rate

The experimental cows exibited thermal polypnoea, salivation and discomfort on day 30 when the room temperature was increased to 30°C. As shown in table 1 respiratory rates of the experimental cows remained elevated during the experimental period. Between experimental cows, no 121 showed a higher mean respiratory rate when compared with no 8.

Table 1

Respiratory Rates

Pairs	Cow No.	Respirations/Minute			
		Preliminary Period Means		Experimental Period Means	
1	8	24	(6)	84	(10)
	77	24	(6)	22	(6)
2	121	28	(6)	104	(10)
	122	26	(6)	22	(6)

The number of observations within each mean is given in paranthesis.

3.11 Rectal Temperatures

Elevated rectal temperatures in the experimental cows were observed at 15.45 hrs on day 30. The mean daily rectal temperatures are given in table 1.11. Both experimental animals showed elevated rectal temperatures during the experimental period. As with the respiratory rate, cow no 121 showed a higher rectal temperature when compared with no 8.

Table 1.11

Daily Rectal Temperatures ^{o}C

Pairs	Cow No.	Preliminary Period		Experimental Period	
		A.M.	P.M.	A.M.	P.M.
1	8	37.65 (15)	37.22 (15)	38.33 (15)	38.50 (15)
	77	37.65 (15)	37.80 (15)	37.50 (15)	37.70 (15)
2	121	37.80 (15)	37.85 (15)	39.10 (15)	39.11 (15)
	122	37.68 (15)	37.72 (15)	37.65 (15)	37.71 (15)

The number of observations within each mean is given in paranthesis.

3.12 Food Intake

Daily intake of dry matter is shown in table 1.12. Paired feeding in this experiment could be considered as having effectively controlled intake during the experimental period. The intake of experimental cow no 121 declined more when compared with no 8.

Table 1.12

Intake of Dry Matter (Lb)

Pairs	Cow No.	Preliminary Period	Experimental Period			
			Periods			
			I	II	III	IV
1	8	26.0(14)	21.6(6)	23.7(6)	23.8(6)	24.2(6)
	77	25.0(14)	20.6(6)	22.7(6)	22.9(6)	23.4(6)
2	121	26.0(14)	20.5(6)	18.5(6)	21.7(6)	21.6(6)
	122	25.0(14)	19.9(6)	17.6(6)	20.9(6)	20.9(6)

The number of observations within each mean is given in paranthesis.

3.13 Water Consumption

Experimental cows increased their daily consumption of water during the experimental period as shown in table 1.13. Differences in water consumption (Preliminary-Experimental Period Means) are given table 1.14, and were highly significant. Cow no 8 consumed more water when compared with no 121 during the experimental period.

Table 1.13

Daily Water Consumption Lb.

Cow No.	Group	Preliminary Period Means	Experimental Period Means			
			I	II	III	IV
8+ 121	Experi-mental	130.5 (23)	176(6)	1799(6)	202(6)	174(6)
77+ 122	Control	135.5 (23)	120.5(6)	105.5(6)	117.5(6)	130.5(6)

The number of observations within each mean is given in paranthesis.

Table 1.14

Daily Water Consumption Lb.
Preliminary-Experimental Period Means

Group	Cow No.	Differences				Treatment Effects	Period Effects
		Periods					
Experimental	8	-61	-62	-77	-34		
	121	-30	-36	-66	-53	$P<0.01$	N.S.
Control	77	-22	-12	0	-14		
	122	-52	72	36	24		

3.14 Rumen Characteristics

Changes in rumen pH from 0 through to 9 hrs post feeding are given in table 1.15 and show that the decline in the experimental cows during the experimental period was greater when compared with the control cows. This indicated a more acid medium in the rumen of experimental cows.

Table 1.15

Rumen pH

Sampling Time	Group	Preliminary Period	Experimental Period		
			I	II	III
5.45 Hrs	Experimental	6.88	6.20	6.58	6.50
	Control	6.58	6.58	7.15	7.15
900 Hrs	Experimental	6.64	5.98	6.28	6.15
	Control	6.32	6.65	6.45	6.28
1200 Hrs	Experimental	6.44	6.00	6.20	6.25
	Control	6.39	6.50	6.28	6.28
1500 Hrs	Experimental	6.43	6.15	5.70	6.10
	Control	6.45	6.78	5.90	6.40

The differences (Preliminary-Experimental period means) shown in table 1.16 were significant only at zero hours post feeding.

Table 1.16

Changes in Rumen pH

Preliminary-Experimental Period Means

Sampling Time	Group	I	II	III	Effect of Treatment	Effect of Periods
5.45 Hrs	Experimental	0.68	0.30	0.38	$P<0.01$	N.S.
	Control	-0.27	-0.57	-0.57		
900 Hrs	Experimental	0.66	0.36	0.49	N.S.	N.S.
	Control	-0.33	-0.13	0.04		
1200 Hrs	Experimental	0.44	0.24	0.16	N.S.	N.S.
	Control	-0.11	0.11	0.11		
1500 Hrs	Experimental	0.28	0.73	0.33	N.S.	N.S.
	Control	-0.03	0.55	0.05		

Table 1.17

Molar Proportions of Volatile
Fatty Acids of Rumen Liquor

Acid	Group	*Preliminary Period	*Experimental Period		
			I	II	III
Acetic	Experimental	68.26	67.25	67.41	67.65
	Control	67.93	68.75	68.57	69.90
Propionic	Experimental	18.37	17.81	18.40	18.10
	Control	18.14	17.41	17.61	17.29
Butyric	Experimental	11.19	11.09	11.17	11.37
	Control	11.27	11.42	11.64	11.68

*Means from samples 0, 3, 6, 9 hours Post Feeding. Changes in the molar proportions of the volatile fatty acids are given in table 1.18

Table 1.18

Changes in Molar Proportions of Volatile Fatty Acids of Rumen Liquor
Preliminary-Experimental Period Means'

Acid	Group	I	II	III	Effect of Treatment	Effect of Periods
Acetic	Experimental	1.01	0.85	0.61		
	Control	-0.82	-0.64	-1.97		
Propionic	Experimental	0.56	-0.03	0.27		
	Control	0.73	0.53	0.85		
Butyric	Experimental	0.10	0.02	0.18		
	Control	-0.15	-0.37	-0.14		

As shown in table 1.19 the concentration of acetic, propionic and butyric acids were higher in control cows during the same period when compared with the experimental cows.

Table 1.19

Molar Concentrations of Volatile Fatty Acids of Rumen Liquor

Acids	Group	Preliminary Period	Experimental Period		
			I	II	III
Acetic	Experimental	8.32	6.72	13.17	10.72
	Control	7.45	7.91	15.08	12.18
Propionic	Experimental	2.20	1.63	3.75	3.04
	Control	2.08	2.10	4.00	3.17
Butyric	Experimental	1.28	0.98	2.20	1.74
	Control	1.19	1.43	2.70	1.97

The differences (Preliminary-Experimental Period Means) of molar concentration of volatile fatty acids are given in table 1.20 Treatment effects were only significant with regard to acetic acid, while period effects were significant for all three acids.

Table 1.20

Changes in the Molar Concentration of Volatile Fatty Acids of Rumen Liquor. Preliminary-Experimental Period Means

Acid	Group	Differences			Treatment Effects	Period Effects
		I	II	III		
Acetic	Experimental	1.60	-4.85	2.40	$P<0.05$	$P<0.01$
	Control	-0.46	-7.63	-4.73		
Propionic	Experimental	0.57	-1.55	-0.84	N.S.	$P<0.05$
	Control	-0.02	-1.92	-1.09		
Butyric	Experimental	0.30	-0.92	-0.46	N.S.	$P<0.05$
	Control	-0.24	-1.51	-0.78		

Table 1.21

DAILY MILK YIELD Lb									
PRELIMINARY PERIOD MEANS				EXPERIMENTAL PERIOD MEANS					
Pairs	Cow No	Daily Milk Yield Lb		Pairs	Cow No	Daily Milk Yield Lb			
						Periods			
1	8	26.71	(14)	1	8	20.21 (6)	23.28 (6)	23.10 (6)	23.26 (6)
	77	23.08	(14)		77	18.11 (6)	16.97 (6)	17.58 (6)	18.50 (6)
2	121	25.50	(14)	2	121	21.61 (6)	17.93 (6)	16.83 (6)	16.83 (6)
	122	22.58	(14)		122	20.23 (6)	17.80 (6)	16.10 (6)	14.76 (6)

The number of observations within each mean is given in parenthesis

Table 1.22

DAILY FAT CORRECTED MILK YIELD									
PRELIMINARY PERIOD MEANS				EXPERIMENTAL PERIOD MEANS					
Pairs	Cow No	Daily Fat Corrected Milk Yield		Pairs	Cow No	Daily Corrected Milk Yield			
						Periods			
	8								
	8	32.57	(14)		8	25.32 (6)	26.50 (6)	29.39 (6)	27.67 (6)
1				1					
	77	30.02	(14)		77	23.99 (6)	22.84 (6)	24.66 (6)	25.48 (6)
	121	32.73	(14)		121	26.36 (6)	20.72 (6)	20.05 (6)	19.38 (6)
2				2					
	122	28.81	(14)		122	25.16 (6)	22.51 (6)	21.36 (6)	19.30 (6)

The number of observations within each mean is given in parenthesis

3.15 Milk Yield

The daily milk yields declined in both experimental and control cows during the experimental period. Data on daily milk yields and daily fat corrected milk yields are given in tables 121 and 122.

The mean decline in daily milk yield and fat corrected milk yield are shown in tables 1.23 and 1.24. Experimental cows showed a greater decline in milk yield during experimental period 1. The mean decline in daily milk yield of the control cows showed an increase during experimental periods II, III and IV, and it could be seen that during these periods the mean decline in daily milk yield did not differ between the experimental and control cows.

Differences in the decline with regard to mean daily fat corrected milk yield were however greater between the experimental and control cows during the whole of the experimental period, and appeared to arise as a consequence of a higher fat percentage in the control cows. The declines in both daily milk yield and fat corrected milk were not

Table 1.23
Decline in the Daily Milk
Yield.Lb.

Preliminary-Experimental Period Means						
Groups	Periods					
	I	II	III	IV	Treatment Effects	Period Effects
Experimental	5.19	5.50	6.14	6.06	N.S.	N.S.
Control	3.66	5.45	6.03	6.08		

Table 1.24

Decline in the Daily Fat Corrected Milk Yield.Lb.

Preliminary-Experimental Period Means						
Groups	Periods					
	I	II	III	IV	Treatment Effects	Period Effects
Experimental	6.81	9.04	7.94	9.63	N.S.	N.S.
Control	4.84	6.74	6.41	7.04	N.S.	N.S.

significantly different. Declines in both milk yield and fat corrected milk yield were greater in cow no 121 when compared with no 8.

3.16 Fat Percentages. Yield of Fat and Molar Percentages of Milk Fatty Acids

Data on fat percentages are shown in table 1.25

Table 1.25

Fat Percentage

Milking Time	Group	Preliminary Period	Experimental Period			
			I	II	III	IV
A.M.	Experimental	4.84 (14)	4.89(6)	4.18(6)	4.63(6)	4.41(6)
	Control	5.34 (14)	5.27(6)	5.49(6)	5.72(6)	5.48(6)
P.M.	Experimental	7.47 (14)	6.62(6)	6.25(6)	6.62(6)	6.55(6)
	Control	6.89 (14)	6.86(6)	7.15(6)	7.42(6)	7.52(6)

The number of observations within each mean is given in parenthesis

The declines in fat percentage (Preliminary-Experimental Period Means) are given in table 1.26. A.M. fat percentage was significantly different when data from periods II, III and IV only were analysed, (see Appendix table VI) but the decline in P.M. fat percentage was significantly different when data from all four periods were analysed. In the experimental cows the fat percentage declined significantly due to the effect of the high ambient temperature.

Table 1.26

Change in the Fat Percentage
(Preliminary-Experimental Means)

Milking Time	Group	Differences				Effects of Treatment	Effects of Periods
		I	II	III	IV		
A.M.	Experimental	0.05	0.66	0.21	0.43	$P<0.05$	N.S.
	Control	0.07	-0.15	-0.38	-0.14		
P.M.	Experimental	0.85	1.22	0.85	0.92	$P<0.05$	N.S.
	Control	0.03	-0.26	-0.53	-0.63		

Daily fat yields declined in both groups of cows during the experimental period, table 1.27

Table 1.27

Daily Fat Yield Lb.

Fat Yield Lb.	Group	Preliminary Period	Experimental Period			
			I	II	III	IV
	Experimental	1.49 (14)	1.17(6)	1.03(6)	1.11(6)	1.04(6)
	Control	1.36 (14)	1.13(6)	1.06(6)	1.08(6)	1.05(6)

The number of observations within each mean is given in parenthesis

The decline in daily fat yield was significantly greater in the experimental cows when compared with the control cows despite slightly higher milk yields, table 1.28

Table 1.28

Decline in Daily Fat Yield Lb.

(Preliminary-Experimental Period Means)

Group	Differences				Effects of Treatment	Effects of Periods
	I	II	III	IV		
Experimental	0.32	0.46	0.38	0.45	$P<0.01$	N.S.
Control	0.23	0.30	0.28	0.31		

Fatty acids of milk fat were analysed as short chain C_6 - C_{14} (C_4 did not separate out clearly) medium chain C_{16} and long chain $C_{18:0}$; $C_{18:1}$; $C_{18:2}$ and $C_{18:3}$ acids. Data with regard to these are presented in table 1.29

Table 1.29

Molar Percentages of Milk Fatty Acids

Acid	Group	Preliminary Period	Experimental Period		
			I	II	III
C_6-C_{14}	Experimental	59.17 (4)	55.69(2)	50.30(2)	55.57(2)
	Control	59.28 (4)	62.55(2)	51.49(2)	59.92(2)
C_{16}	Experimental	15.81 (4)	14.58(2)	17.03(2)	18.12(2)
	Control	13.64 (4)	13.23(2)	17.97(2)	15.93(2)
$C_{18:0}$+18:1	Experimental	25.29 (4)	29.17(2)	28.94(2)	28.66(2)
+18:2+18:3	Control	24.99 (4)	23.72(2)	28.36(2)	24.67(2)
$C_{18:0}$	Experimental	9.46 (4)	10.21(2)	11.28(2)	10.98(2)
	Control	9.59 (4)	9.56(2)	10.25(2)	8.69(2)

The number of observations within each mean is given in paranthesis.

Changes in the fatty acids are given in table 1.30. The high ambient temperature decreased C_6-C_{14} acids, and increased C_{18} significantly. Effects on all of the C_{18} acids were significant at the 10% level, while those on C_{16} were not significant.

Table 1.30

Changes in the Molar Percentages of Milk Fatty Acids

Preliminary-Experimental Period Means

Acid	Group	Differences			Effects of Treatment	Effects of Periods
		I	II	III		
C_6-C_{14}	Experimental	3.48	8.87	3.60	$P<0.05$	N.S.S
	Control	-3.27	7.79	-0.64		
C_{16}	Experimental	1.23	-1.22	-2.31	N.S.	N.S.
	Control	0.41	-4.33	-2.29		
$C_{18:0}$+18:1	Experimental	-3.88	-3.65	-3.37	$P<0.10$	N.S.
+18:2+18:3	Control	1.27	-3.37	0.32		
C_{18}	Experimental	-0.75	-1.82	-1.52	$P<0.05$	N.S.
	Control	0.03	0.66	0.90		

3.17 Protein Percentages and Yield

Protein percentages are shown in Table 1.31

Table 1.31

Protein Percentage Fat Free Serum

Time of Milking	Group	Preliminary Period	Experimental Period			
			I	II	III	IV
A.M. Protein	Experimental	3.77 (14)	3.33(6)	3.41(6)	3.47(6)	3.44(6)
Per-centages	Control	3.74 (14)	3.36(6)	3.64(6)	3.68(6)	3.74(6)
P.M. Protein	Experimental	3.85 (14)	3.49(6)	3.48(6)	3.57(6)	3.57(6)
Per-centages	Control	3.74 (14)	3.34(6)	3.62(6)	3.77(6)	3.83(6)

The number of observations within each mean is given in paranthesis

The declines in protein percentages given in table 1.32 showed that the effect of the high ambient temperature was significant on both A.M. and P.M. protein percentages.

Table 1.32

Decline In Protein Percentage Fat Free Serum

Preliminary-Experimental Period Means

Protein Percentage	Group	Differences				Temperature Effect	Period Effect
		I	II	III	IV		
A.M.	Experimental	0.55	0.36	0.30	0.33	P<0.01	N.S.
	Control	0.38	0.10	0.06	0		
P.M.	Experimental	0.36	0.37	0.28	0.28	P<0.05	N.S.
	Control	0.30	0.12	-0.03	-0.09		

Daily protein yields are presented in Table 1.33

Table 1.33

Daily Protein Yield Lb.

Group	Preliminary Period	Experimental			
		I	II	III	IV
Experimental	0.93 (14)	0.69(6)	0.68(6)	0.67(6)	0.66(6)
Control	0.79 (14)	0.60(6)	0.59(6)	0.59(6)	0.69(6)

The number of observations within each mean is given in parenthesis.

Table 1.34

Declines In Daily Protein Yield Lb.
Preliminary-Experimental Period Means

Group	Differences				Treatment Effects	Period Effects
	I	II	III	IV		
Experimental	0.24	0.25	0.26	0.27	N.S.	N.S.
Control	0.19	0.20	0.20	0.10		

The decline in daily protein yield were not significantly different as shown in table 1.34

3.18 Lactose Percentage and Yield

Lactose percentages are given in Table 1.35

Table 1.35

Lactose Percentage Fat Free Serum

Milking Time	Group	Preliminary Period	Experimental Period			
			I	II	III	IV
A.M.	Experimental	5.42 (14)	5.46(6)	5.38(6)	5.42(6)	5.45(6)
	Control	5.42 (14)	5.49(6)	5.46(6)	5.38(6)	5.48(6)
P.M.	Experimental	5.48 (14)	5.39(6)	5.32(6)	5.36(6)	5.39(6)
	Control	5.47 (6)	5.38(6)	5.34(6)	5.34(6)	5.37(6)

The number of observations within each mean is given in parenthesis

Daily lactose yields are shown in table 1.36

Table 1.36

Daily Yield of Lactose Lb.

Group	Preliminary Period	Experimental Period			
		I	II	III	IV
Experimental	1.34 (14)	1.07(6)	1.04(6)	1.02(6)	1.01(6)
Control	1.14 (14)	0.98(6)	0.88(6)	0.86(6)	.85(6)

Table 1.37

Decline in Lactose Percentage Fat Free Serum
Preliminary-Experimental Period Means

Milking Time	Group	Differences				Temperature Effects	Period Effects
		I	II	III	IV		
A.M.	Experimental	-0.04	0.04	0	-0.03	N.S.	N.S.
	Control	0.03	0.06	0.14	0.04		
P.M.	Experimental	0.09	0.16	0.12	0.09	N.S.	N.S.
	Control	0.09	0.13	0.13	0.10		

Table 1.38

Decline In Daily Lactose Yield Lb.
Preliminary-Experimental Period Means

Group	Differences				Temperature Effects	Period Effects
	I	II	III	IV		
Experimental	0.27	0.30	0.32	0.33	N.S.	N.S.
Control	0.16	0.26	0.28	0.29		

The decline in lactose percentages and daily lactose yield were not significantly altered by the high ambient temperature

3.19 Osmolarity

Means for osmolarity of daily A.M. and P.M. milk samples during the preliminary and experimental periods are shown in table 1.39

Table 1.39

Osmolarity of Daily A.M. and P.M. Milk Samples: Miliosmoles/Lit

Group	Preliminary Period	Experimental Period			
		I	II	III	IV
Experimental	280 (14)	274.5(6)	274.5(6)	276.5(6)	277.5(6)
Control	279 (14)	277 (6)	277.5(6)	277.5(6)	277 (6)

In table 1.40 the declines in osmolarity (Preliminary-Experimental Period Means) are given. It could be observed that the decline was greater in the experimental cows when compared with the control cows. The declines however were not significantly different Appendix table XIV

Table 1.40

Decline in Osmolarity of Daily Milk Samples Preliminary-Experimental Period Means

Group					Effects of Treatment	Effects of Periods
Experimental	5.5	5.5	3.5	2.5	N.S.	N.S.
Control	2	1.5	1.5	2		

The correlation coefficient of 0.6032 (P 0.05) between osmolarity and water intake showed that changes in osmolarity was at least in part due to the water consumed.

3.20 Cell Content in Milk

Results with regard to the cell content of milk are given in table 1.41. These show that the cell content did not change in the experimental cows during the experimental period, and the high ambient temperature had no significant effects on the cell content of milk.

Table 1.41

Cell Content of Milk in CM

Group	Preliminary Period	Experimental Period			
		I	II	III	IV
Experimental	3.25 (14)	3.25(6)	3.50(6)	3.26(6)	3.25(6)
Control	3.75 (14)	3.50(6)	3.25(6)	3.75(6)	3.50(6)

3.21 Body Weight Changes

Body weight changes are shown in table 1.42. The control cows lost more body weight when compared with the control cows during the experimental period. These differences in body weight changes are discussed in relation to water consumption and probable changes in fat metabolism in section 4.13a

Table 1.42
Body Weight Changes Lb.

Group	Body Weight Lb.		Body Weight Changes By Difference Lb.
	Beginning of Experiment	End of Experiment	
Experiment	787	780	7
Control	787	734	53

CHAPTER FOUR

Discussion

4.1 Thermoregulatory Responses

4.11 Rumen Characteristics

4.12 Milk Yield

4.13 Milk Composition

(a) Fat

(b) Protein

(c) Lactose

(d) Osmolarity

(e) Cell Content

Summary

Conclusions

4.1 Thermoregulatory Responses

The thermoregulatory responses discussed in chapter one are elicited to maintain thermal balance under conditions of thermal stress. These would in the main depend not only on the degree of stress, but also on the animal's heat tolerance. Thermal polypnoea, an increas in water consumption, a decrease in the voluntary intake, active sweating are immediate visible responses to thermal stress, and the rectal temperature is a measure of their efficiency in maintaining thermal balance. Adjustments in the endocrine balance, energy metabolism, and changes in blood consituents are delayed responses, Kamal 1964. An elevated rectal temperature of cows consequent to various disease conditions decreased the solids not fat percentage, King 1956. Changes in the concentration of rumen volatile fatty acids were due to an elevated body temperature rather than to an increase in the rumen temperature, Gengler et al., 1970. These observations imply that some of the responses that occur under thermal stress could be due to a variation in the body temperature. Although rectal temperature by itself is a convenient measure of thermal stress, a combination of rectal temperature and other parameters such as respiratory rate, voluntary intake and water consumption would give a better assessment of thermal stress, and show the variation in responses between cows to the same high environmental temperatures. Winchester and Morris 1956 found that water consumption per unit of dry matter ingested remained constant from 10 to 40^{o}C, but increased above 40^{o}C in all breeds of cattle. Under normal ambient temperatures water consumption was governed by the quantity and quality of food ingested and the metabolic demands for water (see section 1.2e). Water consumed in a hot environment was governed by the heat intensity in addition to the quality and quantity of food ingested, Yousef, Hahn and Johnson 1968.

Results of this experiment showed that water consumption increased at the high ambient temperature. The decline in water consumption by the control cows was due to a decline in both intake of dry matter and milk yield (see 3.13). An increase in water consumption of the experimental cows despite a decline in intake of dry matter and milk yield was obviously due to a greater demand for water, for thermoregulation. The increase in water consumption observed in this experiment are in accordance with the findings of Ragsdale et al., 1949 and McDowell et al., 1969. However all of this extra water consumed apparently was not shunted for evaporative cooling. Although measurements were not made, visual observations showed that the volume and frequency of mictuirition of the experimental cows were greater when compared with the control cows, Anderson 1955, Dalton 1964, found that an increase in water consumption by ruminants subsequently resulted in diuresis. The higher rectal temperatures and respiratory rates, together with a significantly higher water consumption of the experimental cows in the present experiment showed that they were experiencing a certain degree of thermal stress, and conform to the observations made by a number of workers which were discussed in section 1.2. When heat tolerance is considered as a function of thermoregulatory responses, a lower heat tolerance is associated with a greater increase in the responses. It was observed in the discussion of experimental results that between experimental cows no 121 showed higher values for rectal temperature respiratory rate, and lower values for the intake of dry matter during the experimental period when compared with no 8 which consumed more water during the experimentalperiod as shown in table 1.14. This difference could probably have been due to a greater utilization of water for cutaneous evaporative cooling, because no 8 showed a lower respiratory rate and rectal temperature. On the basis of these measurements cow no 121 appeared to be stressed more at the ambient temperature of 30°C, and consequently less heat tolerant.

4.11 Rumen Characteristics

The hydrogen ion concentration of rumen liquor from experimental cows was low during the whole of the experimental period when compared with control cows. Rumen pH was significantly different only at zero hours post feeding, and this difference could be explained partly by the observed differences in feeding behaviour. Whereas the control cows consumed their ration offered at 1600 hours within a short period of time, the experimental cows probably continued to feed during the night. Mishra et al., 1970 found significantly lower values for rumen pH in thermally stressed cows; due to a significant increase in the concentration of lactic acid. According to Storry 1970 a decline in rumen pH could be due to a diminished secretion of saliva and subsequent buffering capacity of rumen digesta. Since the concentration of lactic acid was not measured in this experiment it is not known whether its concentration did increase on a diet of dried grass. As seen in section 3.1 however, experimental cows incurred a loss of saliva during the experimental period. A decrease in the volume of saliva entering the rumen, and a reduction in the buffering capacity of digesta in the experimental cows could be suggested as a probable cause to their low rumen pH when compared with the control cows. Changes in pH towards lower values resulted in a marked fall in the rate of cellulose digestion, Storry and Sutton 1969 and a reduction in protozoa, Chalupa, Odell, Kutches and Lanker 1967, but in a greater population of amylolytic organisms and a reduction in VFA producing organisms, Mishra et al., 1970. In this experiment the concentrations of volatile fatty acids were higher and that for acetic acid significantly higher (see table and appendix table III) in the rumen liquor of control cows when compared with the experimental cows, Weldy et al., 1964. Kelly et al., 1968 found that high ambient temperatures depressed the volatile fatty acids. The results of this experiment are in agreement with the above findings. Whereas Weldy et al., attributed this decline to a decrease in acetic acid, Kelly et al., explained their results on the basis of a greater decline in propionic acid. In this respect the present experimental results agree more closely with the observations of Weldy et al. Kelly et al., suggested that the difference between acetate to propionate ratio obtained by them and that obtained by Weldy et al., was due to ration differences. Since these observations point to the fact that a high ambient temperature depresses those acids predominantly produced by a particular feeding regime, acetic acid would be depressed more than the other volatile fatty acids on an all roughage ration such as the one used in this experiment producing more acetic acid, Rook 1964. This is evident from the fact that the differences with regard to propionic and butyric acids between experimental and control cows were not significant. The findings of Weldy et al., also showed that propionic acid was not altered and that of Kelly et al., that no significant changes in butyric acid occured under thermal stress.

When examining the effect of a high ambient temperature on rumen metabolism three main factors have to be considered.

1 Systemic changes in body temperature

2. Local changes in rumen temperature and changes in rumen pH

3. The effect of food

Gengler et al., 1970 found that the decrease in the concentration of volatile fatty acids was due to an increase in the body temperature rather than to an increase in rumen temperature. The same authors observed that an increase in the rumen temperature increased the molar proportions of propionic and butyric acids and decreased the molar proportions of acetic acid. At high ambient temperatures rumen pH decreased as observed in this experiment and by Mishra et al., 1970. In summarising the observations of a number of workers Storry 1970 contended that a decrease in the rumen pH decreased acetic acid and increased propionic acid. An increase in rumen temperature and a decrease in rumen pH have similar effects on rumen fermentation by bringing about a decrease in acetic acid and an increase in propionic acid. It could be observed that an increase in rumen temperature acting synergistically with a decrease in rumen pH is more likely to alter the volatile fatty acid proportions than rumen temperature per se under thermal stress. Care has however to be exercised in making a generalisation due to food effects, as seen earlier. A diet producing more propionic acid in the rumen will show a greater decrease in propionic acid due to an increase in the body temperature, but an increase in propionic acid due to a change in the rumen temperature and pH. An all roughage diet producing more acetic acid will show a greater decrease in acetic acid due both to an increase in the body temperature and an increase in the rumen temperature together with a decrease in rumen pH.

4.12 Milk Yield

Since the level of intake within a pair depended on the amount of food voluntarily refused by the experimental cow (see 2.3) this experiment in fact examined the response in milk yield and composition due to temperature mediated changes other than those in voluntary food intake. Results with regard to the decline in daily milk yield and daily fat corrected milk yield, table 1.23 and 1.24 showed that the different ambient temperatures had no significant effect on milk production, and are in agreement with the findings of Wayman et al., 1962, Kibler et al., 1966 and Johnson et al., 1966, that the major factor responsible for a decline in the milk yield of lactating cows at high ambient temperatures is indeed a decline in the voluntary intake.

Cow no 8 in this experiment showed a recovery in the milk yield after an initial decline in period 1 of the experimental period. The mean daily milk yield during the whole of the experimental period however was below the preliminary period mean. Experimental cow 121 showed a steady decline during the same period and considering the differences in thermoregulatory responses (see section 4.1) it appeared as if she was less heat tolerant when compared with no 8. Differences with regard to milk yield as being due to a variation in heat tolerance have been observed by Payne and Hancock 1957, Johnson, Ragsdale, Berry and Shaklin 1962.

4.13(a) Fat

The high ambient temperature had a significant effect on the fat percentage and fat yield, in that the experimental cows had significantly lower a.m. and p.m. fat percentages and daily fat yield. Cobble and Herman 1951 observed a decline in the fat percentage in milk of cows exposed to temperatures up to 32°C. Since the high ambient temperature in this experiment was 30°C, the results obtained are in accordance with the findings of the above authors.

According to Decaen and Adda 1966 the lactation period of cows could be separated into two phases. There was a 70% increase in the amount of short chain fatty acids, a 30% decrease in the long chain acids with little variation in palmitic (C_{16}) acid during the first 8 weeks of lactation. For the remainder of the lactation period the compositions were stable despite changes in the total fat content. In the final stages however long chain acids contributed 25% and C_{16} 30% to the total fatty acids. Cows used in this experiment were over 8 weeks in their lactation, and were expected to be steady with regard to the fatty acid composition. According to Decaen and Adda the short chain group of acids (C_4 - C_{14}) varied in a reciprocal manner to long chain C_{18} + $C_{18:1}$ acids, while C_{16} showed very little variation. Consequently the acids were considered as members of three groups C_4 - C_{14}; C_{16}, and C_{18} + $C_{18:1}$

The short chain fatty acids C_6 - C_{14} were significantly higher in the control cows when compared with the experimental cows. Appendix table IX . Palmitic acid was not significantly different, but the experimental cows showed slightly higher molar percentages during experimental perids 1 and 3. These results are in accordance with the findings of Richardson et al., 1961.

The higher molar proportions of short chain fatty acids in the milk of control cows could be explained on the basis of a greater substrate availability to the mammary gland for their synthesis. The following presumption is however made; that the control cows had a higher concentration of blood acetate due to a higher concentration of acetate in the rumen, and to a higher blood thyroxine level Yousef and Johnson 1965. Since the uptake of acetate by the mammary gland was related to its concentration in the arterial blood McClymont 1951 and the presumption made, the uptake of acetate by the mammary gland and subsequent synthesis of short chain fatty acids would have been greater in the control cows. Long chain fatty acids $C_{18:0} + C_{18:1} + C_{18:2} + C_{18:3}$ taken as a group was significantly different between the control and experimental cows at the 10% level Appendix table X, but in table 1.30 it could be seen that the experimental cows showed a higher molar percentage and also that the molar percentage of control cows increased during experimental periods II + III. $C_{18:0}$ alone was significantly higher Appendix tableXI in the experimental cows when compared with the control cows. A similar trend was observed with regard to the long chain fatty acids under thermal stress by Richardson et al., 1961. They also found that under thermal stress an increase in C_{18} was followed by a decrease in $C_{18:1}$.

Short chain fatty acids contribute nearly 40% to the total milk fatty acids in ruminants, Linzell 1968. Since the short chain fatty acids were significantly higher in the control cows, it was highly suggestive that the higher fat percentages was due to this difference.

The increase in long chain fatty acids of both experimental and control cows table 1.30 indicate an enhanced uptake of either plasma lipo proteins, chylomicra or unesteritied fatty acids. At a decreased level of intake however, the chylomicra could not be expected to increase above the normal feeding level, but an increase in the plasma unesterified fatty acids is expected under the two physiological conditions in the present experiment. A greater increase observed in the experimental cows could be due both to under feeding and probable hormonally induced lipolysis consequent to thermal stress. Although non esterified fatty acids have been observed to be important precursors of milk fat, Bishop, Davies, Glascock and Welch, 1949, Lascelles, Hardwick, Linzell and Mepham 1964, Barry, Bartley, Linzell and Mepham 1963 and an increase in their concentration in plasma under starvation, Hartmann and Lascelles 1965, opinions regarding their contribution to milk fat under starvation seem to vary. Lauryssens, Verbeke and Peeters, 1961 and Barry et al., 1963 suggested a greater contribution of unesterified fatty acids to milk fat under starvation; but Hartmann and Lascelles 1965 found only a doubtful uptake of these acids by the mammary gland despite an increase in their concentration in the plasma. These observations agree with the contention of Storry 1970 that the relative contributions of the various pathways to total milk fatty acids under different physiological and nutritional conditions have not been fully elucidated. The findings of Richardson et al., 1961 however indicate a greater contribution of plasma lipids to milk fat under thermal stress. Under the present circumstances the experimental results also indicate a greater contribution of plasma lipids to milk fat in both control and experimental cows either in the form of lipoproteins or free fatty acids. The contribution appears greater in the experimental cows when compared with the controls. Van Soest 1963 pointed out that changes in the fatty acid composition of milk fat under both conditions of underfeeding and thermal stress were similar; and the present experiment did show this similarity in that short chain acids tended to decrease and long chain acids tended to increase from preliminary period levels. However the changes in both short and long chain fatty acids in the experimental cows were comparatively greater and show that significantly lower fat percentages were due mainly to significantly lower molar percentages of C_6 - C_{14} fatty acids and probably to a decrease in de novo synthesis. Since Decaen and Adda 1966 showed a reciprocal increase in C_{16} and C_{18} acids towards the end of lactation both underfeeding and thermal stress show drying off effects. The experimental cows showed a greater drying off effect when compared with the controls

At the end of the experiment the control cows showed a greater loss in body weight probably due to mobilization of body reserves for milk production and milk fat synthesis. Higher molar proportions of C_{16} and C_{18} acids in the milk fat of experimental cows were suggestive of lipolysis due to thermal stress. Since the experimental cows consumed more water and according to Pitts 1968 variability of body water in relation to body weight is a function of adipose tissue, and that the body water contents of animals in hot dry and hot wet climates was generally above 70% due to a low body fat content, McFarlane 1968 the differences in body weights could be explained on the basis of a higher body water content of experimental cows when compared with the control cows.

4.13(b) Protein

Significant differences were only observed in the protein percentages and not in the protein yield. The experimental cows showed significantly lower a.m. and p.m. protein percentages when compared with controls. Cobble and Herman 1951 and Richardson 1960 citied by Johnson 1965 found a decrease in the total nitrogen while Richardson observed an increase in non protein nitrogen as well. A decrease in casein under thermal stress was shown by Regan and Richardson 1938.

This decrease in total nitrogen probably stems from a decline in protein synthesis consequent to a reduction in amino acids reaching the mammary gland. Blood levels of Tyrosine, Methionine, ornithine and aspartic acid decreased at 32°C, Kamal et al., 1970. There is reason to believe that this decline in amino acids occurs due more to systemic changes than to those in rumen protein metabolism. The amount of protein ingested by both control and experimental cows within pairs during the experimental period was the same. According to Vercoe 1969 the apparent digestibility of proteins did not alter under thermal stress. Consequently proteins reaching the small intestines could be expected to be the same in both cows unless microbial protein synthesis in the rumen was affected under thermal stress (see section 1.3). The free amino acids in the plasma were more indicative of a constant inflow of hydrolysed microbial protein than of dietary protein Purser 1970.

On the other hand increased gluconeogenesis could decrease amino acids to the lactating mammary gland. Corticoids have been observed to increase under thermal stress, Thompson et al., 1963 and corticoids have been observed to increase gluconeogenesis in cows, Baird and

Heitzman 1970, Stockl and Jochle 1971. With increased gluconeogenesis plasma amino acids increased Bethial, Fiegelson and Fiegelson 1964, but there was an increase in the availability of amino acids to the liver, Kaplan and Shimiznes 1963, Lardy, Shrago, Young and Paetkan 1964, Baird and Heitzman 1970, and an inhibition of protein synthesis by peripheral tissues. Segal 1964, Sutherland and Hahnes 1965, and Uete 1966. The secretory tissue of the lactating mammary gland in this respect may be considered to behave like other peripheral tissues. In thermally stressed cows a part of the total digestible energy intake was used for non-productive purposes (see section 1.2f). Rook and Line 1961 obtained an increase in plasma amino nitrogen and a concurrent increase in casein, α lactalbumin and β lactoglobulin when the plane of energy nutrition of lactating cows was increased. A decrease in the protein percentage occurred when cows were underfed after calving, Flux and Patchell 1954. Protein losses in urine, Vercoe 1969, and sweat, Joshi et al., 1969 have been suggested as probable causes to a decrease in productive performance under thermal stress. The significant differences in protein percentages observed between experimental and control cows practically on the same level of intake of digestible organic matter could be attributed to an increase in gluconeogenesis as suggested by Johnson 1965, a decrease in energy for protein synthesis, and a greater loss of protein or to all three of them in the experimental cows.

4.13(c) Lactose

A decline in the lactose percentage in both experimental and control cows showed that the effect of treatment was not significant on the lactose percentage of milk. Results of Cobble and Herman 1951 showed only a small decrease in lactose in the milk of thermally stressed cows. The decline in S.N.F.% observed in the milk of cows underfed after calving was due in part to a decrease in the lactose percentage, Flux and Patchell 1954. From the experimental results it may be suggested that the effect of changes mediated by a high ambient temperature other than that in the voluntary intake are not significant on the lactose percentage when compared with either the fat or protein percentages.

4.13(d) Osmolarity

The differences in osmolarity between experimental and control cows were not significant, appendix table XIV . Cobble and Herman 1951 found that a decline in lactose resulted in an increase in the chloride content of milk under thermal stress. Since lactose and chlorides accounted for nearly 75 - 77% of the total freezing point depression of milk, Cole and Mead 1955, Dharmarajan, Rao, Menon and Dastur 1950, no apparent change in the freezing point depression was observed by Cobble and Herman. Due to a very small variation in the lactose percentage in the present experiment, that observed in osmolarity between experimental and control cows was also small and not significant. Rees 1964, however showed changes in the freezing point depression due to thermal stress. An increase in water consumption and mictuirition would have resulted in haemodilution and a greater turnover of body water, as found by McDowell et al., 1969. The correlation indicated changes in osmolarity due to an increase in water consumption and this effect was not significantly great probably due to a higher frequency of drinks and subsequent mictuirition. Aschaffenburg 1955 demonstrated a marked variation in the depression of freezing point of blood and unusually large morning-evening differences in the freezing point depression of milk when cows were offered water over a single period of one hour each day. The small differences in osmolarity in this experiment appeared to be due to the increase in water consumption by the experimental cows, rather than to changes in the lactose percentage.

4.13(e) Cell Content

Results of the Wisconsin Mastitis test showed that treatment had no significant effects on the cell content of milk. It could be seen that milk samples of both experimental and control cows in showing practically the same reaction to the test appeared to have the same cell contents. There is evidence to show that corticoid activity increases under thermal stress, Thompson et al., 1963, Kotby and Johnson 1967, Wegner and Stott 1968 accompanied by Leucocytosis, Wersma and Stott 1969. The latter authors also found that leucocytosis resulted in an increase of leucocytes in milk. Convey, Miller and Tucker 1971 however observed that leucocytosis resulting from the parenteral administration of a synthetic corticoid was not followed by an increase of leucocytes in milk up to 10 hours from the time of administration. The present experimental results suggested that the temperature to which the experimental cows were exposed, did not stress them sufficiently to elicit changes in the cell content of milk.

Summary

A comparison in the responses to milk yield and composition was made between cows within pairs at the same level of intake of nutrients at ambient temperatures of 15 and 30°C. The results showed that

(1) Milk yields and fat corrected milk yields between cows within pairs were not significantly different and that the main factor responsible for a decrease in milk yield at a high ambient temperature was the temperature mediated decline in the voluntary inatke of nutrients confirming earlier findings of Wayman et al., Kibler et al., and Johnson et al.

(2) The higher ambient temperature decreased the protein percentage, and fat percentage of milk, molar proportions of short chain fatty acids, and increased the molar proportions of long chain fatty acids of milk fat. It had no significant effects on the lactose percentage, osmolarity and the cell content of milk.

(3) The higher ambient temperature also decreased rumen pH, total volatile fatty acids, and significantly reduced the concentration of acetic adic in the rumen on a diet of dried grass.

(4) The temperature mediated changes other than those in the voluntary intake of nutrients had significant effects on milk composition but not on milk yield.

(5) The higher temperature, elicited thermoregulatory responses such as an increase in the respiratory rate and water consumption, and elevated the rectal temperatures.

(6) A cow variation in both thermoregualtory and lactation response to a high ambient temperature.

The possible ways in which these changes are manifested are discussed.

Conclusions

The overall effect of a high ambient temperature on milk yield and composition is mediated through a decline in voluntary intake and other changes due to variation in physioligical functions and endocrine balance. Evidence tends to show that this a drying off effect due to a reduction of metabolites to the mammary gland and also on galoctopoesis.

From the point of view of practical feeding the composition of the diet must ensure an intake of energy and protein above normal levels due to the extra cost of energy and protein losses under thermal stress to maintain lactation.

Investigations have shown that ground and chopped herbage and concentrates are diets ensuring the normal intake of energy under thermal stress. These in the main alter rumen fermentation resulting in the production of more propionic acid. The effect of a high ambient temperature on rumen fermentation is also in the same direction. Propionic acid as a specific energy source however has been found to be less efficiently metabolized for milk production resulting in low butter fat percentages. These observations imply that maintenance of the intake of energy under thermal stress has to be done at the cost of the fat percentage. Since a high ambient temperature also reduces the fat and protein percentages independent of under feeding milk produced under hot environmental conditions would be expected to have low fat and protein percentages.

In terms of milk production in hot wet and arid regions the effect of high ambient temperatures must be viewed in respect of the stage of lactation and the production potential.

To off set the effect of a high ambient temperature on lactation the aim would be to ensure that high producing cows are not exposed to thermal stress from parturition to at least mid lactation. Adjustment of calving dates to the coolest months of the year and grazing time to the cooler parts of the day together with supplementary feeding indoors during the hotter parts of the day may be suggested.

Appendix Table I

Daily Water Consumption

Analysis of Variance

Source	df	SS	MS	F	Results
Treatment	1	19113	19113	17.48	<0.01
Periods	3	636	212		N.S.
Treatment x Period	3	1021	340		N.S.
Residual	8	8750	1093		
TOTAL	15				

Appendix Table II

Rumen pH Zero Hours Post Feeding

Analysis of Variance

Source	df	SS	MS	F	Results
Treatment Within Pairs	2	2.6155	1.3078	54.04	<0.01
Period Within Pairs	4	0.2917	0.0729	3.01	N.S.
Residual	4	0.0967	0.0242		
TOTAL	10				

Appendix Table III

Acetic Acid Millimoles %

Analysis of Variance

Source	df	SS	MS	F	Results
Treatment Within Pairs	2	25.4784	12.7382	9.0696	<0.05
Period Within Pairs	4	104.8083	26.2020	18.6544	<0.01
Residual	4	5.6186	1.4046		
TOTAL	10				

Appendix Table IV

Propionic Adic Millimoles %

Analysis of Variance

Source	df	SS	MS	F	Results
Treatment Within Pairs	2	0.2676	0.1338	0.6061	N.S.
Period Within Pairs	4	8.9950	2.2487	10.1110	<0.05
Residual	4	0.8898	0.2224		
TOTAL	10				

Appendix Table V

Butyric Acid Millimoles %

Analysis of Variance

Source	df	SS	MS	F	Results
Treatment Within Pairs	2	0.73	0.365	3.363	N.S.
Period Within Pairs	4	3.49	0.8	7.931	<0.05
Residual	4	0.44	0.11		
TOTAL	10				

Appendix Table VI

A.M. Fat Percentage

Analysis of Variance

Source	df	SS	MS	F	Result
Treatment Within Pairs	2	1.34	0.67	14.88	<0.05
Periods Within Pairs	4	0.29	0.072	1.6	
Residual	4	0.18	0.045		
TOTAL	10				

Appendix Table VII

P.M. Fat Percentage

Analysis of Variance

Source	df	SS	MS	F	Result
Treatment Within Pairs	2	4.8620	2.4310	8.8272	<0.05
Period Within Pairs	6	3.3964	0.5661		
Residual	6	1.6525	0.2754		
TOTAL	15				

Appendix Table VIII

Daily Fat Yield

Analysis of Variance

Source	df	SS	MS	F	Results
Treatment Within Pairs	2	1.0913	0.5456	18.247	<0.01
Period Within Pairs	6	1.2142	0.2024		
Residual	6	0.1792	0.0299		
TOTAL	15				

Appendix Table IX

Molar Percentages of C_6 - C_{14} Milk Fatty Acids

Analysis of Variance

Source	df	SS	MS	F	Results
Treatment Within Pairs	2	76.0894	38.0447	7.1907	<0.05
Period Within Pairs	4	232.7658	58.1914	10.9986	N.S.
Residual	4	21.1634	5.2908		
TOTAL	10				

Appendix Table X

Molar Percentages of $C_{18:0} + C_{18:1} + C_{18:2} + C_{18:3}$ Milk Fatty Acids

Analysis of Variance

Source	df	SS	MS	F	Result
Treatment Within Pairs	2	49.1958	24.5979	6.48	$P<0.10$
Period Within Pairs	4	14.6181	3.6545		
Residual	4	15.7802	3.7950		
TOTAL	10				

Appendix Table XI

Molar Percentage of C_{18} Milk Fatty Acid

Analysis of Variance

Source	df	SS	MS	F	Results
Treatment Within Pairs	2	6.3296	3.1648	7.4888	<0.05
Period Within Pairs	4	5.3974	1.3494	3.122	N.S.
Residual	4	1.6904	0.4226		
TOTAL	10				

Appendix Table XII

A.M. Protein Percentage

Analysis of Variance

Source	df	SS	MS	F	Results
Treatment Within Pairs	2	0.2522	0.1261	12.36	<0.01
Period Within Pairs	6	0.3049	0.0508	4.98	N.S.
Residual	6	0.0610	0.0102		
TOTAL	15				

Appendix Table XIII

P.M. Protein Percentage

Analysis of Variance

Source	df	SS	MS	F	Results
Treatment Within Pairs	2	0.2754	0.1377	5.34	<0.05
Period Within Pairs	6	0.2600	0.0433	1.67	N.S.
Residual	6	0.1550	0.0258		
TOTAL	15				

Appendix Table XIV

Osmolarity of Milk Milliosmoles/Lit

Analysis of Variance

Source	df	SS	MS	F	Results
Treatment Within Pairs	2	32	16	5.65	N.S.
Period Within Pairs	6	14	2.33		N.S.
Residual	6	17	2.83		
TOTAL	15				

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