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GENETIC ASPECTS OF SOME MILK CONSTITUENTS

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INTRODUCTION

In the past much more attention has been given to the quantitative aspects of milk production than to studies of milk quality which have largely been concerned with determinations of such major constituents as fat and total solids. Within the last 20 to 25 years, a deep interest in the variation of the chemical composition of milk has developed, and attention has begun to focus on the protein, lactose, solids not fat (S.N.F.) and mineral content of milk. In some areas of the world concern has arisen because milk supplies have failed to satisfy minimum standards for legal milk marketing, e.g. solids-not-fat.

Information on the inheritance of chemical constituents other than the fat of milk such as minerals is relatively sparse in comparison with the major constituents. The simple reason for this is the labor of analyzing sufficient samples to reach conclusions of statistical significance. Interest in the variation in these chemical constituents of cow's milk stems largely from the nutritional importance of milk in human diets, the growing conviction that the nutritional properties of milk and its competitive position with other food stuffs can be enhanced by increasing certain chemical constituents, the recognition of the fact that changes in milk composition reflect quantitative changes in the physiological and biochemical process of milk secretion, and another reason which can not be dismissed, that certain chemical constituents such as fatty acids play an important role in the flavour and palatability of milk and milk products.

In appraising the opportunity to improve the quality of milk, the important roles which both the genetic and environmental elements can play must be recognized and understood. Available information certainly indicates that there are breed and individual differences in the minor chemical constituents of milk. Unfortunately the studies that have been made are insufficiently systematic to enable precise definition of the extent of these differences.

In this study a special effort has been made to investigate the genetic influence on some constituents of cow's and ewe's milk. In cow's milk the inheritance of the potassium to lactose ratio was investigated. In ewe's milk the genetic influences on the variation in potassium to lactose ratio as well as potassium, lactose, sodium, and total solids contents were determined. The existence of the well known two blood potassium levels, high (HK) and low (LK), in sheep provide the basis of an hypothesis to study the physiology and synthesis of potassium and sodium in the milk, and its relation with the same minerals in the source of all fluids in the body, the blood. This may explain the mechanism of the secretion of potassium and sodium in the milk, and, if potassium in milk is inherited, do the same genes HK and LK of the blood control the potassium level in the milk? This observation has not been applicable to cattle, as it is already known that no great differences in the potassium level exist between different breeds, nor between the individuals of one breed, in their blood. Because of the great number of investigations which have been done on the correlation of haemoglobin (Hb) phenotypes of sheep with the potassium levels in blood, an attempt has been made to study the effect of the existence of different haemoglobin phenotypes in sheep blood on the secretion of potassium and sodium, in their milk.

The work to be described may be divided into two sections, the first dealing with the investigation into the hereditability of potassium to lactose ratio in dairy cattle and the second, investigations into the inheritance of potassium, lactose, sodium, total solids and potassium to lactose ratio in ewe's milk.

REVIEW OF LITERATURE

Cow's Milk

The nature and the causes of the variation in the chemical composition of milk may be divided into two parts, environmental influence and genetic influences. Earlier reviews of the factors affecting milk composition have been presented by Johansson & Claesson (1957), Larson (1958) and Tayler (1958). The fat content of milk has received the major share of attention since the beginning of this century and will not be reviewed here. This review will deal mostly with the factors affecting the solids-not-fat constituents of milk.

Solids Not Fat (S.N.F.) Constituents

I. Environmental influences

1. Season and climate

The influences of the season and climate are difficult to separate from nutritional factors. In addition when seasonal calving is practiced, studies, involving herd milk, suffer from the confusing effect of stage of lactation. Bailey (1953), Waite, White & Robertson (1956) in Europe, and Davis, Harland, Caster & Kellner (1947), Specht, Brunner Madden & Ralston (1956) and Wilcox, Peau, Mather & Bartlette (1959) in U.S.A., have shown that the S.N.F. content in June and July is rather consistently lower than in other months of the year. The lactose content generally is highest when the protein content is lowest and vice versa. Nevertheless, when the average composition is calculated for an entire lactation, each lactation extends over the greater part of the year and season of calving differences are usually small (Robertson, Waite and White, 1956).

Some work has definitely pointed out that S.N.F. can be lowered by high environmental temperatures. In controlled climatic chambers, Cobble & Herman (1951) found that the S.N.F. content decreased as the temperature rose above 90^{o}F, the chloride content increased and lactose content decreased. Lowering temperatures from 50 to 5^{o}F produced an increase in fat and S.N.F., but there was no appreciable increase in chloride or lactose content. Legates (1960), suggested that environmental temperatures from 30^{o}F to 70^{o}F do not appreciably influence the composition of milk. Likewise, variations in humidity do not appear to influence milk composition when the temperatures are below 75°F.

2. Stage of lactation

Stage of lactation becomes most important when the influence of certain factors on S.N.F. is being examined in short-term experiments. The content of total solids, solids-not-fat and protein drop rather precipitously after the first days of the lactation, reaching a low value by the second month. Most data show a reasonably constant level for S.N.F. during the second to the fifth month of lactation, with a gradual rise being displayed towards the end of the period (Bailey, 1952; Bartlett, 1934; Nicholson, Thomas, Willard & Brown, 1958 and Waite, White & Robertson 1956). The lactose content is highest at the beginning of lactation and declines linearly during the remainder of the lactation (Waite, White & Robertson, 1956). Gestation also can make an important contribution to the change in S.N.F. during the lactation period (Gorrie & Harvey, 1953). Bartlett (1934) and Wilcox, Peau, Mather & Bartlett (1959), found that the content of S.N.F. rose beginning with the fourth or fifth month of gestation. Bailey, (1952) working with the same herd as Bartlett, (1934) but at a more recent date, found that S.N.F.

showed a tendency to rise by the second and third month of pregnancy. It was particularly evident in the data reported by Wilcox, Peau, Mather & Bartlett, (1959), that the rise in S.N.F. during the later part of the lactation was practically negligible for those cows which were out of doors.

3. Age of the cow

The decline of S.N.F. percentage with advancing age or lactation number is approximately twice the magnitude of the decline in lactation fat percentage. A summary of five studies, Bailey (1952), Bartlett (1934), Robertson, Waite & White (1956), White & Drakeley (1927), and Wilcox, Peau, Mather & Bartlett (1959), has shown declines in solids-not-fat ranging from 0.21 to 0.45 during the first seven lactations. Politiek (1957) reported that the decline in S.N.F. with age in his data must be ascribed to a decrease in lactose content. This general observation agreed with data reported by Robertson, Waite & White (1956). However, their more detailed analysis indicated that while crude protein did not change much with age, the casein percentage declined during the first seven lactations almost as much as the lactose. Hence, there is circumstantial evidence that whey protein or non-protein nitrogen fractions increase with advancing lactation number.

The percentage of variance due to age influences for several milk constituents as found by Robertson, Waite & White (1956) are as follows: Milk yield 27%, fat percentage 5%, S.N.F. 18%, crude protein 4%, casein 11% and lactose 23%. All of the reported age changes must be considered in the light of the selection which has taken place in the population analyzed. In most cases selection probably was made on the basis of milk yield which has rather consistently shown small negative phenotypic correlations with milk constituents. The part played by age is further confused by the possible influence of udder deterioration through normal usage, and the increasing incidence of mastitis with advanced age (Legates, 1960).

4. Food changes and plane of nutrition

Reports of attempts to alter the fat content of milk through feeding are numerous, but current information on the influence of specific foodstuffs on S.N.F. content is most limited. There is reasonably abundant evidence to demonstrate that the percentage of S.N.F. is substantially influenced by the energy content of the diet (Rook, 1961).

Feeding rations with 25% less than the normal energy requirements results in a decrease in S.N.F., most of the decrease being attributable to a decrease in protein. In other experiments, feeding only 40% of a normal ration for 6 weeks at the beginning of the lactation resulted in a decrease in the average S.N.F. for the entire lactation, Flux & Patchell, (1954). Even reducing energy intake by 10% or 20% of normal requirements depressed the lactation average for protein percentage but no appreciable change resulted in lactose content (Flux & Patchell, 1954). Several other workers, Dijkstra, (1958) and Patchell (1957), have pointed out that under-feeding may reduce the S.N.F. percent by as much as 0.30 to 0.40%. Generally, the results from underfeeding have been in agreement in showing that the protein content is reduced somewhat more than is lactose.

Holmes, Reid, MacLusky, Waite & Watson (1957), have reported that S.N.F. increased rapidly from 8.3 to 8.6 in Ayrshires when concentrates in the ration were increased from 0 to 4.6 lb. per gallon of milk produced. Burt (1957) has also shown that the S.N.F. content may be increased by feeding above the normal British standards. However, feeding excess protein did not alter the protein content, but the non-protein nitrogen content was enhanced (Stein, 1957).

As was suggested earlier, some of the seasonal variations in S.N.F. may be traceable to changes in feeding. When cows are allowed fresh pasture the S.N.F. increases, mainly due to an increase in protein percentage. Politiek (1957), Rook & Rowland (1959) have reported that S.N.F. increased within four days after initiating grazing and the increase reached a peak after six days. The most important changes in protein was an increase in casein and the lactose content was not affected. Bartlett & Hutton (1959), have suggested that the increase in S.N.F. which occurs when cows are turned onto young pasture may be due to the estrogenic activity of certain grasses. Folley, Watson & Bottomley (1941) have shown that injected or implanted estrogens increased the total solids content of milk, but their results agree with Browning, Fountaine, Marion & Atkeson (1957) in reporting no significant effect from feeding diethylstilbestrol.

Although the information is not extensive, different sources of carbohydrate foods do not appear to influence the S.N.F. content (Bailey, 1952). Within reasonable limits, changing the relative proportion of concentrates to hay does not markedly alter S.N.F. percentage (Bailey, 1952). However in two trials with 69 cows Dijkstra (1958) & (1959), has reported that milk yield, S.N.F., and the protein content of milk were depressed when grass silage in contrast to hay was fed as the sole roughage.

5. Disease

Milk from cows affected by mastitis generally has been characterized by a fall in lactose and potassium (K) contents, with a compensatory increase in sodium (Na) and chloride (Cl) contents (Barry & Rowland, 1953), an increase in globulin content and, to a lesser content, in the content of serum albumin and proteoses, and a decrease in casein content (Rowland, 1938). Waite & Blackburn (1947) have suggested, on the basis of a survey of samples of bulk milk of individual cows that, for animals with sub-clinical mastitis, throughout the major part of the lactation, there is an association between total cell count in milk and the extent of changes in milk composition. There are two major types of cells in milk, polymorphs, which provide an indication of the extent of acute lobular mastitis, and epithelial cells which reflect the extent of post inflammatory involution (Blackburn & Macadam, 1954; Blackburn, Laing, Malcolm, 1955). Waite & Blackburn (1957) consider that an animal with a total cell count in its milk of less than 100,000/ml.

particularly when the polymorphs are low, is not affected by sub-clinical mastitis and that with an increase in cell count to 500,000/ml. there is a progressive reduction in the S.N.F. and lactose contents of the milk, but that above 500,000/ml. the effects are less pronounced and that casein content is not affected until counts approach 1,000,000/ml. It is further suggested that the distinctive differences between the effects associated with cell counts below and above 500,000/ml might be explained by two types of lesion. Up to this number, lesion may be mild but wide spread and have a considerable effect on milk composition, whereas higher numbers may reflect more severe lesions present in very few focii, so that the cell count will be high but, because of the small area of tissue involved, the effect on the composition will be small. McKenzie, Booker & Moore (1958) have also given evidence of an association of high total cell count in milk and a low content of S.N.F.

King (1955) has reported that a rise in body temperature accompanying certain disease conditions is associated with an increase in fat percentage and a decrease in milk yield and S.N.F. content.

II. Genetic influences

The current approach to the genetic improvement of quantitative traits such as the composition of milk, requires a thorough appraisal of the existing genetic and environmental relationships both between and within breeding groups. Breed differences in S.N.F. contents have long been recognized, but the economic emphasis on fat content and the lack of satisfactory field procedures for determining the composition of S.N.F. has affected the study of the variation within breeds.

1. Breed differences

Breed of the cow has a distinctive and general effect on milk composition. Many breed comparisons have been made either from selected populations where small numbers of animals have been used which may not therefore be representative of the breeds, yet these results have been used to indicate the likely differences in milk composition between breeds. Reliable averages for the fat and S.N.F. contents of the milk of the main dairy breeds in England and Wales are now available, however, from surveys carried out by the Milk Marketing Board (Table 1). More information on the differences between breeds in the detailed composition of their milk (Table 2) has been provided in an investigation by the National Institute for Research in Dairying in 1948 (Rowland & Rook, 1949) of the milk of representative selection of herds of the Ayrshire, Friesian, Guernsey, and Shorthorn breeds located in the Southern counties. An exhaustive review by Armstrong (1959) summarized the literature from Canada and U.S.A. bearing on the composition of milk from different dairy breeds, and the average values derived are included in Table 1.

TABLE 1

AVERAGE VALUES OF THE FAT AND S.N.F. CONTENTS OF THE MILK FROM THE MAIN BRITISH DAIRY BREEDS

Breed	M.M.B.1 (1945/1947) (Provan 1949)		M.M.B.2 (1957/1958) (M.M.B. 1958/59)		Armstrong (1959)	
	%Fat	%S.N.F.	%Fat	%S.N.F.	%Fat	%S.N.F.
Ayrshire	3.72	8.73	3.81	8.72	4.15	8.96
Friesian	3.45	8.58	3.62	8.65	3.49	8.61
Guernsey	4.41	8.93	4.54	8.94	4.99	9.32
Jersey	----	----	4.90	9.10	5.51	9.49
Shorthorn	3.65	8.68	3.70	8.75	----	----

TABLE 2

AVERAGE VALUES FOR DETAILED COMPOSITION OF MILK FOR FOUR MAIN BRITISH DAIRY BREEDS

Constituent %	Ayrshire	Friesian	Guernsey	Shorthorn
Fat	3.69	3.46	4.49	3.53
S.N.F.	8.82	8.61	9.08	8.74
Total protein (NX 6.38)	3.38	3.28	3.57	3.32
Casein (NX 6.38)	2.56	2.47	2.74	2.52
Lactose (Anhydrous)	4.57	4.46	4.62	4.51
Ash	0.74	0.75	0.77	0.76
Calcium (Ca)	0.116	0.113	0.130	0.121
Phosphorus (P)	0.093	0.090	0.102	0.096
Potassium (K)	0.151	0.158	0.154	0.152
Sodium (Na)	0.054	0.058	0.048	0.059
Chloride (Cl)	0.099	0.113	0.096	0.102

The information in Tables 1 and 2 shows that milk constituents also vary from breed to breed, while not varying as widely as percent of fat.

2. Intra-breed genetic variation

The probable response of a trait to selection pressure is a function of the nature and magnitude of its hereditary variation sometimes incompletely expressed as heritability, which also includes genetic and environmental intra-relationships. For dairy cattle heritability and genetic environmental inter-relationships are most conveniently estimated from daughter-dam regression and by an assessment of the variation between paternal half sisters. Identical twins have also been used recently to demonstrate the genetic variation in milk composition, but estimates of its heritable relationships are not comparable to results from daughter-dam and paternal half sisters analysis unless special experimental designs are used. Several reports each based on limited observations are now available and are shown in Table 3. The most complete study is the one reported by Robertson, Waite & White (1956) from 814 Ayrshire cows.

The particular value obtained for heritability in an investigation is clearly dependent on the degree of environmental uniformity achieved in the study (C.F. the high values for heritability obtained by Hansson & Bonnier, 1949; and Hancock, 1953) and on the accuracy of the estimates of the lactation averages of the individual animals (O'Connon & Lipton, 1960). The rate of improvement in milk quality possible by selection would therefore be increased if the milk composition characteristic of an individual animal could be assessed independently of non-genetic effects, due to stage of lactation, udder disease, and level and type of feeding.

TABLE 3

ESTIMATES OF HEREDITABILITY OF MILK CONSTITUENTS
(constituents %)

Authority	Fat	S.N.F.	Protein (Nx6.38)	Lactose Anhydrous
Robertson et. al. (1956)	0.32	0.53	0.48	0.36
Johnson (1957)	0.33	0.35	----	----
Politick (1957)	0.75	0.70	0.75	0.70
Lankamp (1959)	0.72	0.83	0.76	----
O'Connor (1959)	0.52	0.65	----	----
Wilcox et. al. (1959)	----	0.57	----	----
Von Krosigk et. al. (1960)	0.50	0.45	0.45	----

Evidence on the hereditability of other milk constituents not included in Table 3 is more scarce. Hansson (1948) conducted an experiment in Sweden with 3 pairs of identical twins. His results indicated little difference within the twin pairs in calcium and phosphorus contents of milk, but greater differences were obtained between non-twin pairs. In 1962, Comberg, Andreae & Meyer studied the mineral contents of milk of identical twin (MZ) cattle. They determined calcium, phosphorus, magnesium, sodium, and potassium in the milk of 6 pairs of MZ twins under similar feeding conditions and stage of lactation. The results showed considerable differences in content between the pairs of cows, the number of lactations having little effect. Comparative figures given from their results show clearly greater differences between pairs than within pairs. The intra-pairs correlations were calcium 0.77, phosphorus 0.76, magnesium 0.68, sodium 0.83, and potassium 0.91. From these results, the mineral contents of the milk would seem to be genetically controlled.

Inter-relationships of the concentrations of Milk Constituents

More clearly-defined relationships have been demonstrated between the major osmotically active constituents:

lactose, sodium, potassium, and chloride. Knowledge of such relationships might help in the understanding of the processes of milk secretion and in the explanation of natural variations in milk composition. Early work emphasized the close inverse relationship between the concentrations of lactose and chloride (Mathieu & Ferre, 1914), and the direct relationship between the concentrations of chloride and sodium (Jones & Davies, 1935). Observations by Black & Voris (1934), based on the analysis of milk taken from 12 Holstein Friesian animals at intervals throughout an entire lactation, confirmed these relationships, but indicated a low correlation between the concentrations of lactose and potassium ($r = 0.1767 \pm 0.0565$) and of potassium and sodium ($r = 0.2367 \pm 0.0550$). In a similar investigation with 12 Shorthorn cows over a period of 3 months in mid-lactation, Rook and Wood (1958) determined the constituents known to play a major part in the osmotic properties of milk, namely, sodium, potassium and lactose. From an analysis of 104 samples of milk they showed that the concentrations of lactose and potassium varied independently with that of sodium, and they obtained the following relationship when the constituents were expressed in mg/100 g milk water.

$$Na = 343.7 - 0.393\ k - 0.0411\ \text{lactose}$$

They further suggested that sodium in milk may be considered to be derived from two sources, a part associated with potassium and the remainder associated with lactose. Thus the water secreted in milk can be represented as a two phase system: in one, referred to as the sodium lactose phase, potassium is absent and sodium and lactose vary inversely; in the other a sodium-potassium phase, lactose is absent and sodium and potassium vary inversely.

By considering the effects of stage of lactation, mastitis and individuality, strictly quantitative relationships between the concentrations of the various constituents have been demonstrated. Barry & Rowland (1953) and Sutton (1954) showed that with advancing lactation and mastitis the progressive and proportionately similar decrease in lactose and potassium concentrations are paralleled in a quantitative manner, by increases in the concentrations of sodium and chloride.

An attempt to devise an index which would provide an assessment of the individual characteristics of milk of individual cows relatively free from non-genetic effects was made by Rook & Wood (1959). They showed that the potassium content was constant in the milk of the individual animals through the first four to five months of lactation, even during the period of transition from colostrum to normal milk when the changes in other constituents were large. The lactose contents of the milks showed marked increases during the first two to three weeks of lactation, but in the succeeding three to four months the values for each animal showed a constancy similar to that observed with potassium, and an inverse relationship between the potassium and lactose content has been demonstrated. From the inverse relationships between the values of potassium and lactose content obtained with different animals, they suggested that the ratio of the two hypothetical water phases (sodium, lactose phase and sodium potassium phase) in milk is fairly constant for an individual animal but varies considerably from animal to animal. They furthermore suggested that the concept of the water of milk arising in two ways is now seen to be consistent with the mechanism of the formation of milk within the cells of the alveoli. The sodium potassium phase corresponds to typical intracellular fluid and the sodium-lactose phase would arise by the synthesis within the cells of lactose together with proteins and fat coupled with the movement of the water into the cell to maintain osmotic equilibrium. The way in which the cell contents are expelled into the lumina of the alveoli was not established, but it is reasonable to suppose that at the moment of expulsion, the ratio of intracellular to the secretory fluid will be fairly constant in any individual and yet varies from animal to animal. An explanation of the constancy of the potassium content of the milk of individual animals and its variation between animals is thus afforded. Walsh & Rook (1964) have carried more important investigations on the potassium and lactose relationship and how it is altered by infection of the udder and stage of lactation. From Friesian animals in their first lactation, between the second and the fifth month of the stage of lactation and free from infections of the udder, they obtained the following general relationship.

$$Y = 7.4242 - 0.01095X$$

Where Y is the lactose in gm/100 gm of milk water and X is the potassium in mg/100 gm of milk water. The standard error of the regression coefficient was $\pm$ 0.00112 and the standard error of estimates was $\pm$ 0.144. These workers also found that lactose and potassium concentrations in milk from quarters damaged by bacterial infections or physical injury, or in the milk of an animal at an early or late stage of lactation are seldom the same as those found in milk from infection-free quarters in the middle part of the first lactation. Each of these effects tend in varying degrees, to cause a decrease in the concentrations of lactose and potassium and an increase of sodium. They also showed that the empirical relationship between lactose and potassium contents of milk secreted by healthy quarters of the udder of cows in the middle part of the first lactation appears to apply to most of Friesian cattle so far examined. Thus they suggested that if it could be shown that, while the concentrations of lactose and potassium are depressed by various physiological factors, the ratio of potassium to lactose is unaltered, this ratio would provide a basis for predicting a "Potential" lactose content in cattle of all ages irrespective of their stage of lactation or presence of infections of the udder.

Finally in a genetic study of the heritability of the potassium to lactose ratio of Friesian cattle, they suggested that the potassium to lactose ratio and the predicted "potential" for lactose content in the milk of individual animals are largely independent of the effects of environmental factors and physiological changes associated with stage of lactation, and serve to characterize the genetic potential for lactose content.

These results of Rook & Wood (1959) and Walsh & Rook (1964) suggested that the previous studies by Black & Voris (1934) and Barry & Rowland (1953) of the variations in the potassium and lactose contents of milks, have been based on analyses of milk samples obtained from animals varying widely in the age and stage of lactation or on comparisons of the composition of the milk from separate quarters of the udder of cows infected with mastitis: the data showed a direct or low relationship between the concentrations of potassium and lactose in the milk.

Ewe's Milk

In contrast with the abundant data available on the composition of cow's milk, information on ewe's milk is relatively sparse. This is particularly true of mineral elements such as potassium, sodium, magnesium, and the trace elements. Among the more extensive analyses which have been published are those of Niedig & Iddings (1919); Peirce (1934); Godden & Puddy (1935); Bonema (1939); Barnicoat, Logan & Grant (1949); Barnicoat, Marry, Roberts & Wilson (1957); El-Sokkary, Sirry & Hassen (1949); Perrin (1958); Nejim (1963); Ashton, Owen & Ingleton (1964); Ashton & Yousef (1966); and Yousef & Ashton (1967). Of these, only the last three references (with the exception of the work of Godden & Puddy), were obtained under conditions prevailing in Great Britain.

This review will deal only with the constituents which have been studied in this investigation, namely--lactose, potassium, sodium, and total solids.

Values given by various workers for lactose in ewes' milk have been quoted by Ashton, Owen & Ingleton (1964). These values varied between 4.1% reported by Perrin (1958) for New Zealand breeds, to 5.8% by Nejim (1963) for the Awassi breed in Iraq. The mean value for lactose is around 4.7% reported by most of the other workers i.e. Niedig & Iddings (1919); Peirce (1934); and Ashton, Owen & Ingleton (1964). With the exception of the results of Perrin (1958) and Nejim (1963) there is good agreement between the results quoted for lactose content. The lowest value for total solids was 16.3% obtained by Barnicoat et al. (1957) for the New Zealand Romney, the highest, 21.8% reported by Perrin (1958) in New Zealand breeds. The average for the other authors, quoted ranged between these two extremes.

The variation in the lactose % and total solids % in ewe's milk is smaller in comparison with the other major constituents (Ashton, Owen & Ingleton, 1964). Sartore (1959) studied the sodium and potassium contents of Sardinian sheep's milk during the lactation period. His results indicated that the stage of laction affected sodium and potassium concentrations in the milk. He reported the values given in Table 4.

TABLE 4

AVERAGE VALUES OF SODIUM AND POTASSIUM DURING THE STAGE OF LACTATION IN EWE'S MILK %.

Constituent	Beginning of Lactation	Mid-Lactation	End of Lactation
Sodium	0.0463	0.0362	0.0565
Potassium	0.136	0.119	0.155

Charton, Faye, Herry, Bernard & Gueslin (1962) studied the variation in sodium and potassium contents and their ratio in ewe's serum during the lactation. They found averages for sodium and potassium of 33.5 mg/liter and 144 mg/liter respectively for folded sheep and 36.4 mg/liter and 197 mg/liter for sheep at pasture. Age, growth, and lactation did not affect the variation in sodium or potassium, but sodium was affected by feeding. Ashton & Yousef (1966) studied the mineral constituents in the milk of Clun Forest ewes and found that the sodium content of the ewe's milk increased, whereas the potassium content decreased during the lactation with a reasonably constant period in the middle of the lactation. They reported a mean value for these elements of 0.046% and 0.168% for sodium and potassium respectively. The statistical analysis of their data showed significant differences between the sheep in these elements. There is a good deal of variation in the few results available for these elements in the literature probably owing to the inadequacy of the analytical methods available at the time. For sodium, Godden & Puddy (1935) and Konigs (1920) obtained values of about 0.05% and 0.03% respectively, while Godden & Puddy (1935), Konigs (1920), and Morrison (1951) give 0.13%, 0.18 and 0.19 for the percentage of potassium. Perrin (1958) reported a lactation average of 0.13% for potassium and 0.0431 for sodium, for the sheep on a high plane of nutrition and 0.135% and 0.039 for another group on a low plane of nutrition. These results of Perrin (1958) agree with the report of Charton et al. (1962) that the sodium content was affected by feeding.

No reports were found in the literature on the inheritance of the following constituents of ewe's milk: lactose, potassium, sodium, and total solids. The finding of differences between individual sheep by Ashton & Yousef (1966) in sodium and potassium, did however suggest that these might be inherited. Dassat & Sartore (1962) also found large differences between individual sheep for fat, protein and solids-not-fat and quote repeatabilities of 0.630, 0.606, and 0.805 respectively for these constituents.

Sheep's Blood

Potassium Levels

The work on potassium levels in sheep's blood was originally conducted in Great Britain by Evans (1954). He found that sheep may be classified into two distinct types. In one type the potassium concentration in their blood was high (about 36.0 m. eq./L) and sodium concentration correspondingly low, whereas in the other type the potassium concentration was relatively low (about 13.0 m. eq./L) and sodium concentration correspondingly high. The two types of animals have been called HK and LK respectively. The plasma potassium concentrations are the same in the two types of animals and the phenomenon is therefore entirely due to difference in the red cells. The same observation has been confirmed by Widdas (1954), Darcel & Avery (1960), and Poter & Suska (1962). After Evans' finding, Evans and King (1955) studied the basis of the inheritance of the potassium phenotypes in sheep. Their results of test matings indicated that the potassium phenotypes in sheep are inherited and controlled by a single gene pair, HK or LK with HK being recessive. They suggested that the balance between sodium and potassium in the red cells of British breeds of sheep investigated can be substantially modified by a single gene difference. These results were later confirmed by Kidwell, Bohman, Wade, Haveland & Hunter (1959); Darcel & Avery (1960); Kraay, Gaillard & Brouwer (1961); Sartore (1961); Meyer (1963); and Darsset & Bernoco (1966) on different breeds and crosses of sheep. Only the results obtained by Khattab, Watson & Axford (1964a) suggested that the HK and LK types were not clear cut. Although the distribution of whole blood potassium concentration in Welsh Mountain sheep showed marked bimodality, about 5% of the animals lay in the area where the tails of the two distributions merge. The matings data examined by them showed that the bimodality was due to one pair of genes, the LK was dominant to its allele HK. Neither gene controlled the character completely, but LK phenotypes showed much less variation than HK. It would seem that the results for 5% of the animals which lay in the area where the two tails of the two distributions merge and reported by Khattab et al. (1964) are due to experimental error and these animals could be of HK or LK type if the blood analysis were repeated and the sodium concentrations taken into consideration when identifying the types. Thus their suggestion that neither HK nor LK gene controlled the character completely should be ruled out.

Haemoglobin types

Harris & Warren (1955) found that if haemoglobin preparations from different adults of sheep are subjected to electrophoresis on filter paper at pH 8.6, three distinct types of animals may be recognized--those with a single component moving relatively rapidly (A) towards the anode, or a single component moving relatively slowly (B) or a mixture apparently consisting of both A and B components (AB). The three distinct types have been reported in different breeds and crosses of sheep by others; e.g. Darcel & Avery (1960); Teodor, Emann, Popa, Duica & Micle (1961); and Meyer (1963).

Evans, Harris & Warren (1957) indicated that sheep in Britain are of haemoglobin types A, AB, or B. The types are inherited and appear to be determined by two allelic genes each responsible for the formation of one kind of haemoglobin. They found that in general, Lowland breeds were predominantly haemoglobin B and Mountain and Hill breeds predominantly haemoglobin A. This suggests that haemoglobin types may be of some adaptive significance, but no obvious difference in any other characteristics of the sheep have been detected. Khattab, Watson & Axford (1964b) confirmed that the haemoglobin types are controlled by one pair of allelic genes and found that frequency of Hb.A varied from 0.378 to 0.454 in various ages and groups examined. Huisman, Van Vliet & Seben (1958) reached the same conclusion, but they gave the names of Hb.I for Hb.A and Hb.II for Hb.B. In a later communication by the same authors (1958, B), they further suggested that Hb.II in the Texel breed originated from European Mouflon and that HB.I may have originated from other types such as Lincoln and Leicesters which possess this haemoglobin.

<u>The Association between Potassium Levels and Haemoglobin Types</u>

Evans, King, Cohaen, Harris & Warren (1956) found no association between haemoglobin and potassium phenotypes.

They suggested that genes responsible for the two sets of red cell characteristics are probably situated at different loci. However both HK and LK individuals with haemoglobin A had a higher average value of whole blood potassium than those with haemoglobin B, haemoglobin AB animals being intermediate. Evans, Harris & Warren (1958A) again found that Mountain and Hill breeds of Britain tend to have rather high frequencies of haemoglobin B and low potassium. In Finnish, Iceland and Old Norwegian breeds Hb.A was very common, while in the Middle Eastern and African breeds (Awasi, Barki, Blackhead, Persian, Fulani, Masai and Rahmani) Hb.B predominates. LK was relatively infrequent in Scandinavian, Middle Eastern, and African breeds with the exception of Barki. The Merino flocks studied by the same authors were almost entirely LK but both types of Hb were fairly common. This last observation was confirmed by Evans (1961). He studied the gene frequencies of HK and Hb.A type in each of five strains of Merino. Strong non-peppin Merino had a highest frequency for HK of 0.16 and a highest mean for erythrocyte potassium of 15.7 m. eq./L. as compared with 0.05 and 12.0 respectively for other strains examined. Evans, Harris & Warren (1958B) have studied the relative frequency of Hb.A and HK genes within 33 British breeds. The great majority of breeds were polymorphic in respect of Hb and K types, and gene frequency varied greatly from breed to breed. They confirmed the previous suggestion of Evans, King, Cohaen, Harris & Warren (1956) that, although there was no correlation between the two sets of characters within breeds, there was a remarkable correlation between them from breed to breed. Breeds with a high frequency of Hb,A had a relatively high frequency of HK gene and vice versa. They further showed that the broad pattern of gene frequency distribution suggests that the two sets of characters have or have had some adaptive significance. Dassat & Bernoco (1966) have also confirmed that the two systems Hb types and K types are independent.

Watson, Khattab & Axford (1963) found that the two loci controlling Hb types and erythrocyte potassium respectively have shown evidence of association in flock of Welsh Mountain sheep, an excess of Hb,B homozygotes occurring amongst HK animals. The imbalance extended to other phenotypes having the Hb,B gene but not to Hb,A homozygotes. Again Khattab, Watson & Axford (1964B) reported that sheep possessing Hb,A gene only had a significantly higher potassium concentration in their blood than the animals possessing

Hb.B gene only. AB types were intermediate in value, and this was in agreement with the results of Evans, King, Cohaen, Harris and Warren (1956), but Khattab et al. (1964) suggested that the nature of the variation reported by them was that such animals carrying the Hb.A and LK gene had the highest packed cell volumes and the most fragile erythrocytes; the differences in packed cell volumes were sufficient to account for changes in whole blood potassium concentration between the different phenotypes.

SECTION ONE

POTASSIUM TO LACTOSE RATIO AND ITS GENETIC

BASIS IN THE MILK OF DAIRY COWS

The object of this section is to investigate the finding of Walsh & Rook (1964) on the inheritance of the potassium to lactose ratio in cow's milk using another breed of dairy cattle and a different genetic relationship. This experiment includes an analysis of data of one egg, two egg twin cattle, pairs of half-sisters, and pairs of unrelated animals, all subjected to the same husbandry regime. As foreseen by Hutt (1930), Bonnier & Hansson (1948), Hancock (1951 & 1953), and Donald (1953 and 1959), one egg twins offer opportunities for economizing in experimental material when certain designs are appropriate. To avoid the objection that the variation between sets of twins may be influenced by various unknown non-genetic factors, the variation arising within uniformly treated and contemporary one-egg, two-egg, half-sisters and unrelated pairs has been compared.

Description of the Experiment

One hundred and two Ayrshire cows were used in the experiment. These were composed of 10 pairs of one-egg twins (MZ), 12 pairs of two-egg twins (DZ), 19 pairs of half-sisters (HZ), and 10 pairs of unrelated animals (U). All animals were under the same husbandry regime, in the first to the third lactation and in different stages of lactation. Such differences occurred approximately equally in each group and in any case should not affect the within pairs differences which are the main concern.

Thirty of the animals used in this experiment were in their first lactation and between the second to the fifth month of lactation. The data obtained from these animals have been chosen for calculating the lactose and potassium inter-relationship as previously recommended by Walsh & Rook (1964). The milk of each animal was sampled on one occasion at a morning milking. The samples were found to be free from mastitis and negative to the White Side test (Murphy & Hanson, 1941). Each sample was analyzed for: lactose, potassium, and total solids.

Methods of Analysis

1. Determination of the Lactose Content of Milk

The method described by Hinton & Macara (1927) was used as follows:

Twenty-five ml of milk were pipetted into a previously weighed glass basin and reweighed quickly to obtain the exact weight of the sample. The milk was transferred, using a glass rod, to a 200 ml flask. The basin was then washed by distilled water and the washings were transferred to the flask also. Five ml of zinc acetate solution (54.75 gm zinc acetate dissolved into 250 ml water to which 7.5 gm acetic acid were previously added) were added; 5 ml of potassium ferrocyanide (26.5 gm dissolved in 250 ml water) were also added. The flask was made up to the mark with distilled water and shaken well. The solution was filtered through a No. 12, 18.5 cm fluted filter paper into a dry clean beaker. Twenty-five ml of the filtrate were pipetted into a 250 ml concial flask, neutralized with N/10 NaOH using about 3 to 4 drops of phenolphthalein indicator and a further 3 ml of N/10 NaOH were added after neutralization. Fifty ml of N/20 Chloramine T (7.5 gm Chloramine T were dissolved in 1 liter distilled water) were added by pipette. 10 ml of potassium iodide were also added. The flask was stoppered and kept in the dark for 1-1/2 hour. After this period the stopper was removed and washed into the flask by distilled water and 10ml dilute acid added. The solution was then titrated with standard sodium thiosulphate solution using starch indicator. The lactose was calculated as follows:

$$\frac{\text{Blank - Titration X factor X 100}}{\text{weight taken}}$$

$$\text{Factor} = \text{N of } Na_2S_2O_3 \times \frac{127}{100} \times \frac{8}{0.705} \times \frac{100}{1}$$

2. Determination of the Potassium and Sodium* Content of Milk

The potassium was determined by the method of Have & Mulder (1957). This method employs flame-photometery and was carried out on milk simply diluted (1:400) with distilled water. It has been found by Ashton & Yousef (1966) that there were no significant differences between the results of potassium and sodium obtained by this method and the chemical methods.

Potassium and sodium were determined by comparison with standards containing Ca and P concentrations similar

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*Sodium was determined later in Section Two.

to those in milk and in which potassium and sodium were relatively related to each other.

3. Determination of the Total Solids Content of Milk

The total solids of milk were determined by evaporating thewater and weighing the residue.

Aluminum dishes about 44 mms in diameter and weighing about 1.2 gms were used. In these about 1 gm of milk was weighed accurately and rapidly on an automatic balance. After drying on a steam bath for 15 minutes, the dishes were placed in an air-oven maintained at the temperature of 100°C for three hours, weighed, replaced in the oven for a further hour and weighed again.

Results

The results of the analysis carried out on the 102 samples of milk are given in Table 1 of the Appendix. The mean values expressed per 100 g milk were as follows: Lactose, 4.66 gm; Potassium, 151 mg; total solids, 12.86 gm.

Lactose and Potassium Inter-relationship

The results of the analysis of milk samples of the thirty cows in the first lactation and between the second to the fifth month of lactation are given in Table 2 in the Appendix and were used for calculating the lactose and potassium inter-relationship. Rook & Wood (1959) found that the lactose and potassium content in milk of cows free from infections of the udder were shown to be constant from the second to about the fifth month of lactation, and an inverse relationship was demonstrated between the concentration for the lactose and potassium obtained with different animals.

The relationship between such values for lactose and potassium is shown in Fig. 1. Regression analysis gave the following highly significant ($P < 0.001$) relationship.

$$Y = 6.7900 - 0.00939X$$

Where Y is lactose gm/100 gm of milk water

X is potassium mg/100 gm of milk water

The standard error of estimate of lactose at a given value of potassium was $\pm$ 0.100, and the standard error of the regression coefficient was $\pm$ 0.008.

Genetic Basis of Potassium to Lactose Ratio in Ayrshire Cows

An analysis of variance between and within pairs in the different groups used in this experiment is summarized in Table 5.

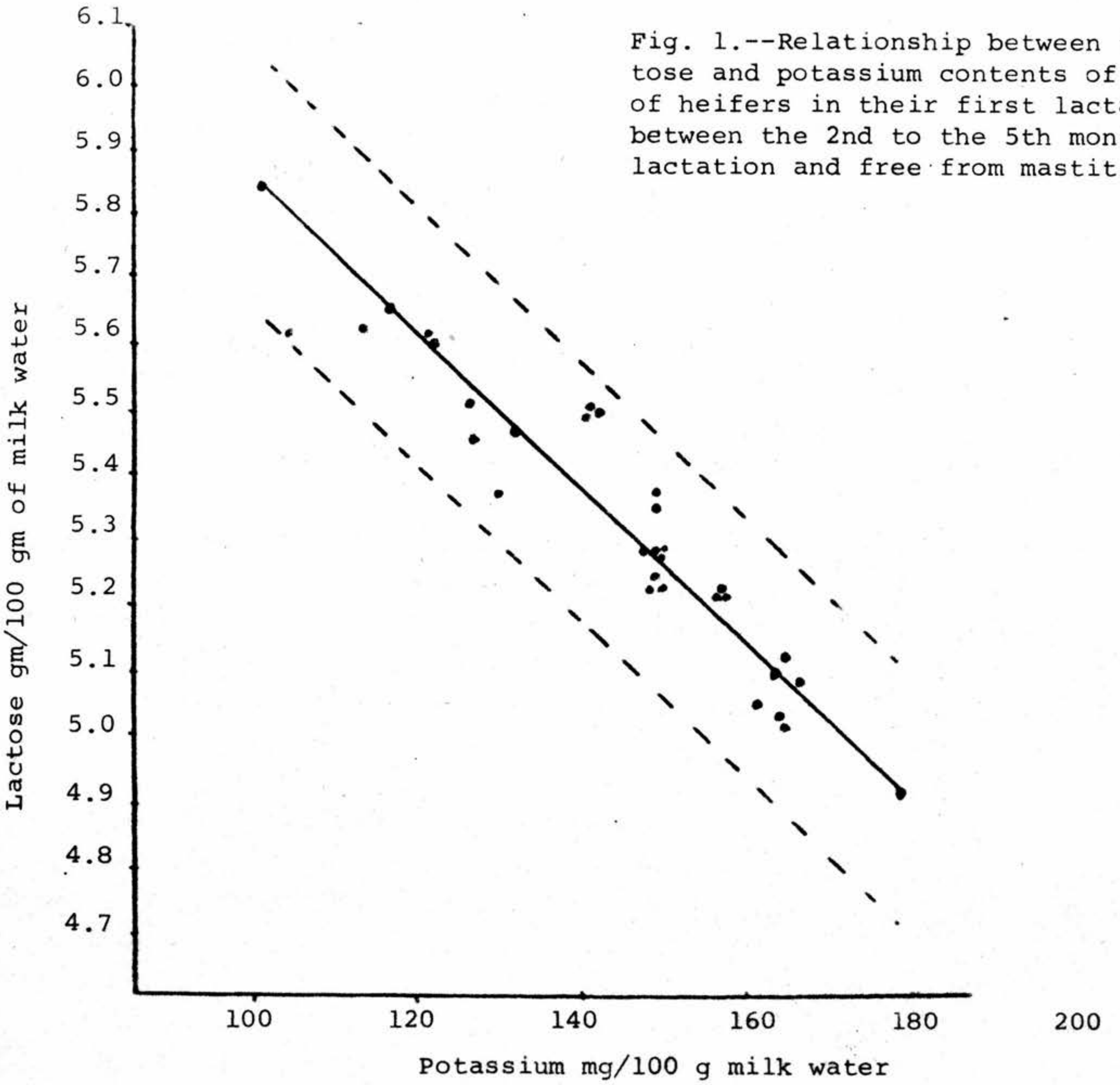


Fig. 1.--Relationship between the lactose and potassium contents of the milk of heifers in their first lactation, between the 2nd to the 5th month of lactation and free from mastitis.

TABLE 5

ANALYSIS OF VARIANCE BETWEEN AND WITHIN PAIRS OF ANIMALS FOR LACTOSE, POTASSIUM AND THE POTASSIUM TO LACTOSE RATIO

Source of Variance	MZ		DZ		HZ		U	
	d.f.	M.S.	d.f.	M.S.	d.f.	MM.S.	d.f.	M.S.
1. Lactose								
Between pairs	9	0.117	11	0.119	18	0.067	9	0.114
Within pairs	10	0.002	12	0.018	19	0.069	10	0.132
2. Potassium								
Between pairs	9	382.80	11	508.18	18	329.89	9	790.89
Within pairs	10	3.90	12	221.75	19	229.78	10	175.30
3. Potassium to Lactose Ratio								
Between pairs	9	31.34	11	45.84	18	24.95	9	57.08
Within pairs	10	0.34	12	13.13	9	23.45	10	17.17

Referring to the within-pairs variation in the table, the DZ groups were as expected more variable than the MZ groups. The HZ groups were more variable than DZ groups in lactose and the potassium to lactose ratio, but similar to the DZ groups in potassium content. The U groups were more variable than DZ, MZ, and HZ groups in lactose, but unexpectedly were more variable than the MZ group only, in potassium and the potassium to lactose ratio. The ratio of variance within and between sets of MZ indicates a wide variation between different pairs, but any one heifer tended to behave as her twin did. The variation between sets of DZ heifers in the lactose, potassium and potassium to lactose ratio was large enough to justify thinking that DZ twins had a tendency to behave similarly although not so markedly as MZ twins. No such tendency was evident among HZ heifers. Unfortunately the U heifers have behaved differently than expected in the potassium and potassium to lactose ratio. This may have arisen as a result of an experimental error, in selection of the animals and for this reason the results obtained from this group of animals will not be considered in the discussion.

Discussion

Rowland and Rook (1949) obtained average values of 12.41 gm/100 gm of milk, 4.57 gm/100 gm of milk and 151 mg/100 gm of milk for the total solids, lactose and potassium contents respectively, with Ayrshire dairy cattle. Their results for potassium is in close agreement with the mean value of 152 mg /100 gm of milk obtained in this experiment. The mean values of total solids and lactose contents obtained in this experiment are slightly higher than the average values for both constituents reported by them. The differences in the results of total solids and lactose contents could be explainable by the effect of the season, as foreseen in the literature that solids-not-fat contents in June and July are rather lower than in other months of the year. They may have taken their samples in that time of the year, but the samples used in this experiment were collected in November and December. It has been pointed out also by Holmes, Reid, MacLusky, Waite & Watson (1957) that solids-not-fat increased from 8.3 to 8.6 in Ayrshires when concentrates in the ration were increased, and the animals used in this experiment were receiving concentrates because they were kept indoor during the experiment.

Lactose and Potassium Inter-relationship

If it could be shown that, while the concentrations of lactose and potassium in milk are depressed by various physiological factors, the ratio of potassium to lactose is unaltered, this ratio would provide a basis for predicting a "potential" lactose content in cattle of all ages, irrespective of their stage of lactation or presence of infections of the udder. Barry & Rowland (1953) have shown that infections of the udder and advancing lactation cause similar reduction in the lactose and potassium content of milk. Walsh & Rook (1964) found that lactose and potassium concentrations in milk from quarters damaged by bacterial infections or physical injury, or in the milk of an animal at an early or late stage of lactation are seldom the same as those found in milk from infection-free quarters in the middle part of the first stage of lactation. Each of these effects tend to cause a decrease in lactose and potassium. They showed that the ratio of potassium to lactose content in milk is little affected by infection of the udder or by stage of lactation except during the first few days and the last two months of lactation, but comparable information on the effect of the age is not available.

In the herds of Ayrshire cows in which the performance of heifers is found to conform to the relationship obtained in the results ($Y = 6.7900 - 0.00939X$), the ratio of potassium to lactose content in the milk of each of the animals of the herd, can therefore be used to predict the "potential" value for potassium and lactose content defined by the above equation. Graphically the potential values will be determined by the intercept of the regression line of Fig. 1 with a second line extrapolated from the graph origin describing the given ratio of potassium to lactose as shown in Fig. 2. For lactose content the calculation would be made according to the formula:

$$\frac{6.7900}{1 + (0.00939)R}$$

Where R is the ratio of potassium content to lactose content found in the milk water.

Walsh & Rook (1964) obtained the following regression analysis for lactose and potassium content of Friesian cow's milk, between their second and fifth month in the first lactation.

$$Y = 7.4242 - 0.01095X$$

The standard error of estimate obtained by them was $\pm$ 0.144

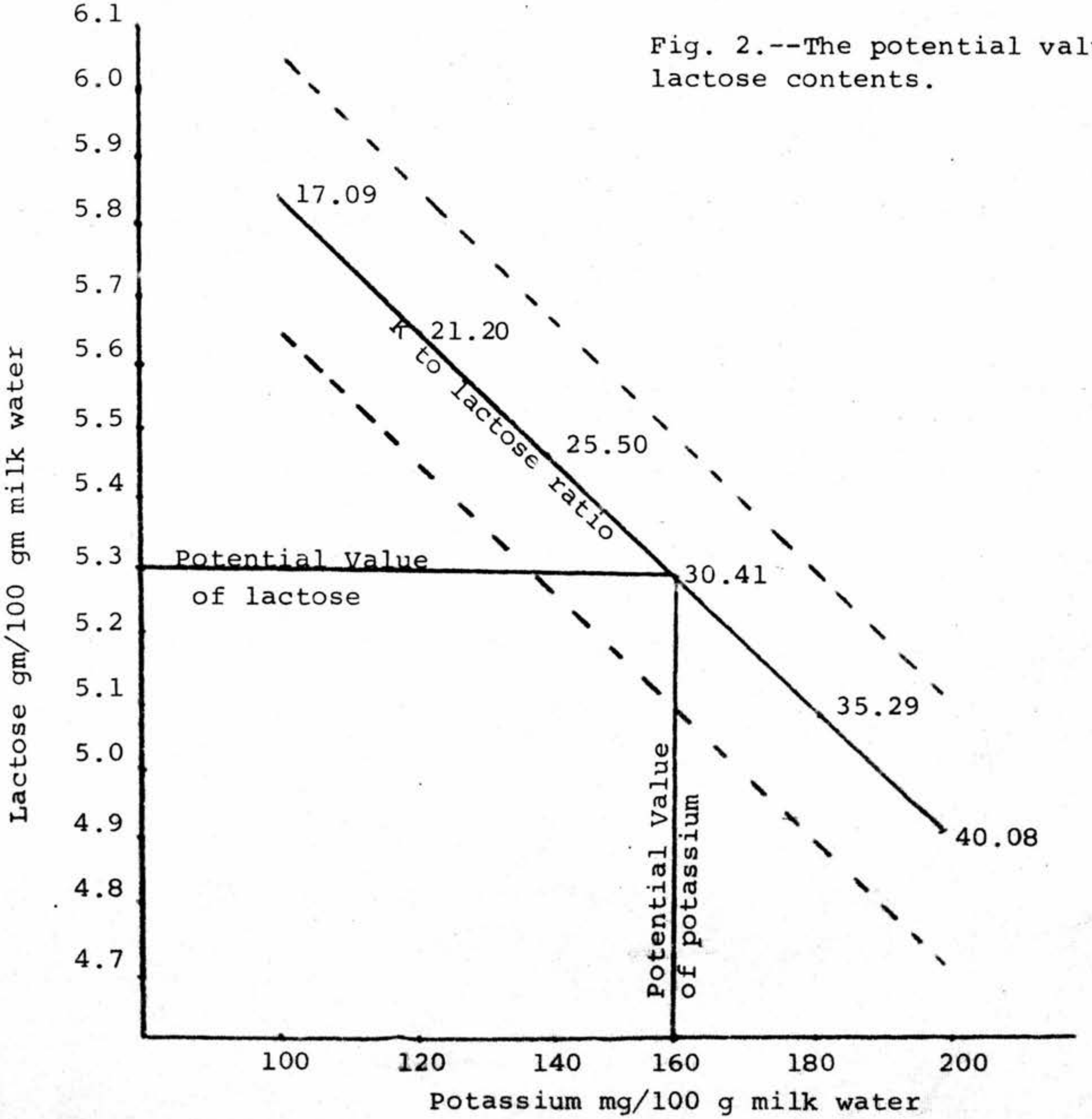


Fig. 2.--The potential value for lactose contents.

and the standard error of the regression coefficient was ± 0.00122. This equation differs from the equation obtained in this study. One explanation of this difference may be that it is due to a genetic difference between the two breeds studied, as the available information certainly indicates that there are breed differences in the mineral composition of milk (Rowland & Rook, 1949). It is to be expected that the formula for calculating the "potential" lactose in the Ayrshire is different than the formula obtained for Friesian cattle by Walsh & Rook (1964). They gave the following formula for calculating the "potential" lactose in the Friesian cattle.

$$\frac{7.4242}{1 + (0.01095)\ R}$$

These results of the lactose and potassium inter-relationship agree with the results of Walsh & Rook (1964) in the trend of the regression but not in the values.

Genetic Basis of the Potassium To Lactose Ratio of Milk

The variation within pairs of the four groups of animals, MZ, DZ, HZ, and U, as a first approximation (neglecting non-additive effects) can be represented by the following simple scheme (King & Donald, 1955).

Mean square within MZ pairs : $\sigma^2 MZ = e^2$

" " " DZ " : $\sigma^2 DZ = e^2 + 1/2\ g^2$

" " " HZ " : $\sigma^2 HZ = e^2 + 3/4\ g^2 + m^2$

" " " U " : $\sigma^2\ U = e^2 + g^2 + m^2$

It is assumed that e^2, the variance due to environmental effects is the same within DZ, HZ, and U pairs as within MZ pairs and that DZ, HZ, and U pairs are drawn from the same population in which the variance due to additive gene effects is g^2. It is further assumed that HZ and U pairs being non-twins have additional variance, m^2, not shown by twins. Each HZ pair has had two dams, and may suppose to be subject to maternal differences of various kinds not arising in twins produced by a single dam.

Values for e^2 and g^2 can be obtained from the first and the second equations as follows:

e^2 = Variance within MZ pairs

g^2 = 2 (Variance within DZ pairs--Variance within MZ pairs)

From the first three equations m^2 can be obtained as follows:

m^2 = variance within HZ pairs--Variance within MZ pairs - 3/4 x 2 (Variance within DZ pairs--Variance within MZ pairs)

= Variance within HZ pairs + 1/2 variance within MZ pairs - 3/2 Variance within DZ pairs.

For the lactose, potassium, and potassium to lactose ratio, values of e^2, g^2, and m^2 were obtained and given in Table 6. Each was then expressed as a percentage of the total variation.

TABLE 6

COMPONENT OF VARIANCE FOR LACTOSE, POTASSIUM, AND POTASSIUM TO LACTOSE RATIO

Source of Variance	Lactose		Potassium		Potassium to Lactose Ratio	
	M.S.*	%	M.S.	%	M.S.	%
e^2	0.002	2.60	3.90	1.19	0.34	1.14
g^2	0.032	41.56	425.70	129.50	25.58	85.72
m^2	0.043	55.84	-100.89	-30.69	3.92	13.14

*M.S. represents the mean square.

If this heritability in column g^2 was calculated from MZ and DZ pairs only, g^2 will be 94.12% for lactose, 99.10% for potassium, and 98.69% for the potassium to lactose ratio. This is to be expected and is in agreement with most of the work done on the heritabilities obtained from within and between sets of MZ and DZ only. Johannson (1958) has listed a number of possible causes for the higher estimates of hereditability obtained from twins, in comparison with the field data, as follows:

1. Genetic variance in twin data includes dominance epistatic and gene environment interaction contribution.

2. Variance between pairs of MZ twins includes some part of herd differences in genetic merit (to which might be added seasonal and other environmental differences).

3. Maternal influence makes MZ twins alike.

4. Field data come from heavily called herds.

5. Environmental variance is less within pairs of twins than within daughter dam pairs.

6. Control of feeding is much closer in experimental twin herds than on the commercial farms.

7. Measurement is more accurate in twin herds.

This list applies particularly to estimates of hereditability equivalent to intra-class correlations of MZ twins which require the use of variance arising between pairs. When h^2 is calculated from intra-pair variance of MZ and DZ twins, one of these possibilities, namely (2), is ruled out or almost so because non-pedigree DZ twins could show some part of breed difference.

There is no point in trying to assess the contribution to all remaining six factors on the present data. It can be accepted for the time being that factors 4, 5, 6, and 7 may help to reduce environmental variation and increase hereditabilities, but since all apply to all classes of pairs, no distinctions can be made among them. Attention must be concentrated on 1 and 3. If genetic variance includes non-additive genetic effects due to dominance and epistasis (1), then the variance within DZ should be higher than expected on a purely additive hypothesis. Since 3/4 or more of the non-additive effects will occur within DZ pairs, but only 1/2 the additive effects. Dominance and epistasis would tend to cancel any twin effect (m^2) by making DZ pairs more alike HZ pairs in respect of within pairs variance. This may have happened in the results for potassium.

Alternatively, or additionally, if twins are more alike than singles, partly as a result of some environmental circumstance peculiar to twins (3), then the series of classes of pairs should show an influx of within-pairs variation (m^2), when it changed from DZ to HZ. This is also what may have happened with the lactose and the potassium to lactose ratio.

Another possibility is that MZ and DZ pairs suffer a reduction in intra-pair variation because environmental conditions before and after the birth are more uniform than those experienced by single born calves. King & Donald (1955) reported that the mutual attachment shown by MZ pairs grazing may result in their having more uniform environment than even DZ pairs. Such an effect would lead to an underestimate of environmental differences between unrelated animals and to an overestimate of genetic differences. There remains one more factor which is possibly more important than all the foregoing. The assumption that all genetic and environmental differences act additively, neglects genotype-environment interactions. Should these interactions be important in producing the observed variability between unrelated animals, the use of one-egg twins will overestimate the genetic variance through inclusion of the whole of the variance due to interaction and part of the variance due to direct effect of environment (Lush, 1948).

The above several sources of variation which have been ignored and may have influenced the genetic variance would tend therefore to overestimate the additive genetic variation, but anyhow, whether or not estimates of g^2 which forms a large percentage of the total variation in twin data are seriously misleading owing to such omission is at present unknown.

Taken as a whole, however, the estimates of hereditabilities for lactose and potassium to lactose ratio agree reasonably well with the estimates of hereditabilities obtained previously. Robertson, Waite & White (1956) obtained a hereditability of 36.2% for the lactose from Ayrshire cows in comparison with the hereditability of 41.56 obtained in this investigation. Walsh & Rook (1964) obtained three estimates for the hereditability of the potassium to lactose ratio in Friesian heifers as follows:

1. From values for the MZ: $h^2 = 95\%$

2. By calculation of the within-herd regression of daughter group means on the record of their dams gave h^2 estimate at 95% ± 27

3. By repeating the record of the dam with each of her daughters in an analysis of co-variance of dam and daughter, giving h^2 estimate of 76% ± 24.

Comberg, Andreae & Meyer (1962) reported a hereditability of 91% for potassium obtained from an identical twin experiment.

There is a great variation in the maternal effect on the characters studied in this investigation. This may be because the maternal effects could be of primarily pre-natal origin for some characters and of post-natal origin for others. Therefore it is to be expected that m^2 could be varied from one character to another, or from one set of data to another obtained under different circumstances.

The results obtained for the potassium to lactose ratio in this experiment and the results obtained by Walsh & Rook (1964) with Friesian cattle, show that the potassium to lactose ratio of individual animals has the characteristics of a high genetic parameter and is highly independent of the effects of environmental factors and of physiological changes associated with age and stage of lactation. It also shows that this ratio could provide a basis for predicting potential values for lactose and potassium contents in cattle. The differences in the two formulas for the regression coefficients obtained in both experiments with Friesian and Ayrshire cattle may indicate that more studies are necessary to determine this relationship with other breeds to establish if this difference is due to breed differences or to an experimental error. If this difference was due to differences between breeds, then the formula obtained by Walsh & Rook would be used for predicting the potential values for lactose in the Friesian cattle only, and the formula obtained in this experiment would be used for predicting the potential values for lactose in the Ayrshire cattle only. On the other hand if this difference was due to an experimental error a correct formula could be obtained and would provide a basis for predicting the potential lactose content in cattle of all breeds irrespective of their ages, their stage of lactation, or the presence of infections of the udder.

~~This experiment furthermore provides further evidence that twins could be used with success to provide reasonable estimates for the hereditability of milk constituents, if certain designs are appropriate.~~

SECTION TWO

INVESTIGATION OF GENETIC ASPECTS OF SOME EWE'S MILK CONSTITUENTS

This investigation includes three separate experiments carried out to examine the genetic aspects of certain constituents of the milk of the ewe. The constituents considered were lactose, potassium, sodium and total solids. The ratio of potassium to lactose was also investigated. In the last experiment an attempt was made to correlate these constituents with blood levels of potassium, with haemoglobin types and with packed cell volumes.

Experiment A

Investigation of the effect of stage of lactation on the potassium, lactose, sodium, total solids content, and the potassium to lactose ratio of the milk of the ewe:

The object of this experiment was to establish if there was a period of the lactation over which the above constituents were relatively constant so that the effects of the stage of lactation could be avoided in the genetic studies in the later experiments.

Design of the Experiment

Thirty-five ewes were lambed before the normal lambing season. Among these ewes 24 were Finnish X Dorset (FXD) and the rest were of the Dorset Horn breed. The FXD ewes were two years old and the Dorsets were also two years old except for two of them which were six years old. All the animals were kept inside under one husbandry regime and were given concentrates and a basal diet of hay.

Milk samples were collected by hand milking at the end of a 3-1/2 to 4 hour interval during which the ewes were separated from their lambs. The samples were obtained every Wednesday during lactation weeks: 1, 2, 3, 4, 5, 6, 7, 8, and 9. For this reason there were differences in the time at which the first sample was taken from different ewes. For example, in the case of the ewe which was in the 1st day after lambing when the first sample was obtained from her, the second sample was collected at the 8th day and the third at the 15th day after lambing . . . etc. The samples were collected in this manner to get a complete curve for the milk constituents studied in this investigation from the 1st day after lambing to about the 63rd day of the lactation period. No colostrum samples were obtained and all samples were taken only from one side of the udder of each ewe. Some of the ewes were dried off before the 9th sample was obtained, and it was difficult to get enough milk for all the analyses from some ewes. The milk samples were found to be free from mastitis and negative to the Whiteside test prior to chemical analysis.

Method of Analysis

Lactose, potassium, sodium, and total solids content of each sample were determined as described in Section One. The potassium to lactose ratio was calculated according to the following formula:

$$\text{Ratio (R)} = \frac{\text{potassium (k) mg/100 gm of milk*}}{\text{lactose gm/100 gm of milk*}}$$

*Note: The constituents are expressed in terms of milk rather than milk water as for cows, because the total solids contents were not determined in some of the first few samples, and anyhow the value of potassium to lactose ratio will be the same if both terms of milk and milk water were used for any given sample.

Results

Tables 7, 8, 9, 10, and 11 give the mean values of lactose, potassium, sodium, total solid, and the potassium to lactose ratio respectively in ewe's milk. The tables were designed as follows:

1st sample	Samples from ewes between 1st day after lambing to 7th day
2nd sample	Samples from ewes between 8th day after lambing to 14th day
3rd sample	Samples from ewes between 15th day after lambing to 21st day
4th sample	Samples from ewes between 22nd day after lambing to 28th day
5th sample	Samples from ewes between 29th day after lambing to 35th day
6th sample	Samples from ewes between 36th day after lambing to 42nd day
7th sample	Samples from ewes between 43rd day after lambing to 49th day
8th sample	Samples from ewes between 50th day after lambing to 56th day
9th sample	Samples from ewes between 57th day after lambing to 63rd day

With reference to the general average of all the ewes, lactose was low in the first sample, about 4.84 gm/100 gm of milk, and increased during the second and the third samples up to 5.36. It was constant at this level for the next

TABLE 7

MEAN VALUES OF THE LACTOSE CONTENT OF EWE'S MILK DURING THE LACTATION

Breed or Cross	No. of Ewes	SAMPLES								
		1	2	3	4	5	6	7	8	9
Dorset	11	4.72	5.20	5.29	5.34	5.35	5.13	5.22	4.99	5.42
F X D	24	4.90	5.14	5.39	5.34	5.44	5.06	5.06	5.51	5.31
Ave.	35	4.84	5.16	5.36	5.34	5.41	5.11	5.11	5.35	5.22

Notes: 1. The mean values are given as gm/100 gm of milk.

2. The data which these means represent are given in the Appendix, Table 3.

TABLE 8

MEAN VALUES OF THE POTASSIUM CONTENT OF EWE'S MILK DURING THE LACTATION

Breed or Cross	No. of Ewes	SAMPLES								
		1	2	3	4	5	6	7	8	9
Dorset	11	166	145	129	119	113	118	114	117	127
F X D	24	160	129	124	113	118	125	131	126	133
Ave.	35	162	134	126	115	116	123	123	123	130

Notes: 1. The mean values of potassium content are given as mg/100 gm of milk.

2. The data which these means represent are given in the Appendix, Table 4.

TABLE 9

MEAN VALUES OF SODIUM CONTENT OF EWE'S MILK
DURING THE LACTATION

Breed or Cross	No. of Ewes	SAMPLES								
		1	2	3	4	5	6	7	8	9
Dorset	11	22.5	26.4	30.5	32.7	35.3	35.3	41.1	46.4	48.4
FXD	24	23.8	27.4	32.7	33.0	36.2	36.7	42.2	45.5	49.8
Ave.	35	23.4	27.1	32.0	32.9	35.9	36.2	41.8	45.8	49.2

Notes: 1. The mean values of sodium content are given as mg/100 gm milk.

2. The data which these means represent are given in the Appendix, Table 5.

TABLE 10

MEAN VALUES OF TOTAL SOLIDS CONTENT OF EWE'S MILK
DURING THE LACTATION

Mean	No. of Ewes	SAMPLES								
		1	2	3	4	5	6	7	8	9
--	35	16.6	17.1	16.6	17.1	17.9	18.1	18.5	19.1	18.6

Notes: 1. The mean values of total solids content are given as gm/100 gm of milk.

2. The data which these means represent are given in the Appendix, Table 6.

MEAN VALUES OF POTASSIUM TO LACTOSE RATIO OF EWE'S MILK DURING THE LACTATION

Breed or Cross	No. of Ewes	SAMPLES								
		1	2	3	4	5	6	7	8	9
Dorset	11	35.6	28.1	24.5	22.3	21.1	22.8	22.0	23.8	24.3
F X D	24	34.0	25.5	23.5	21.2	21.9	23.0	25.7	23.3	25.7
Ave.	35	34.5	26.3	23.8	21.5	21.7	22.9	24.5	23.5	25.1

Notes: 1. The potassium to lactose ratio was calculated as follows:

$$\frac{\text{k mg/100 gm of milk}}{\text{lactose gm/100 gm of milk}}$$

2. The data which these means represent are given in the Appendix, Table 7.

three weeks, but afterwards fluctuated until the last sample. In the Dorset ewe's milk, the lactose content took the same trend as the general average except that it reached a constant level a week earlier. The lactose content in the F X D ewe's milk took exactly the same trend as the general average. Fig. 3 shows that the approximate time during which the lactose content is approximately constant in ewe's milk is between the 3rd and the 6th weeks after lambing. The average potassium content was high in the first sample, about 162 mg/100 gm of milk, but decreased to about 134 in the second sample. The potassium concentration in the 3rd sample was

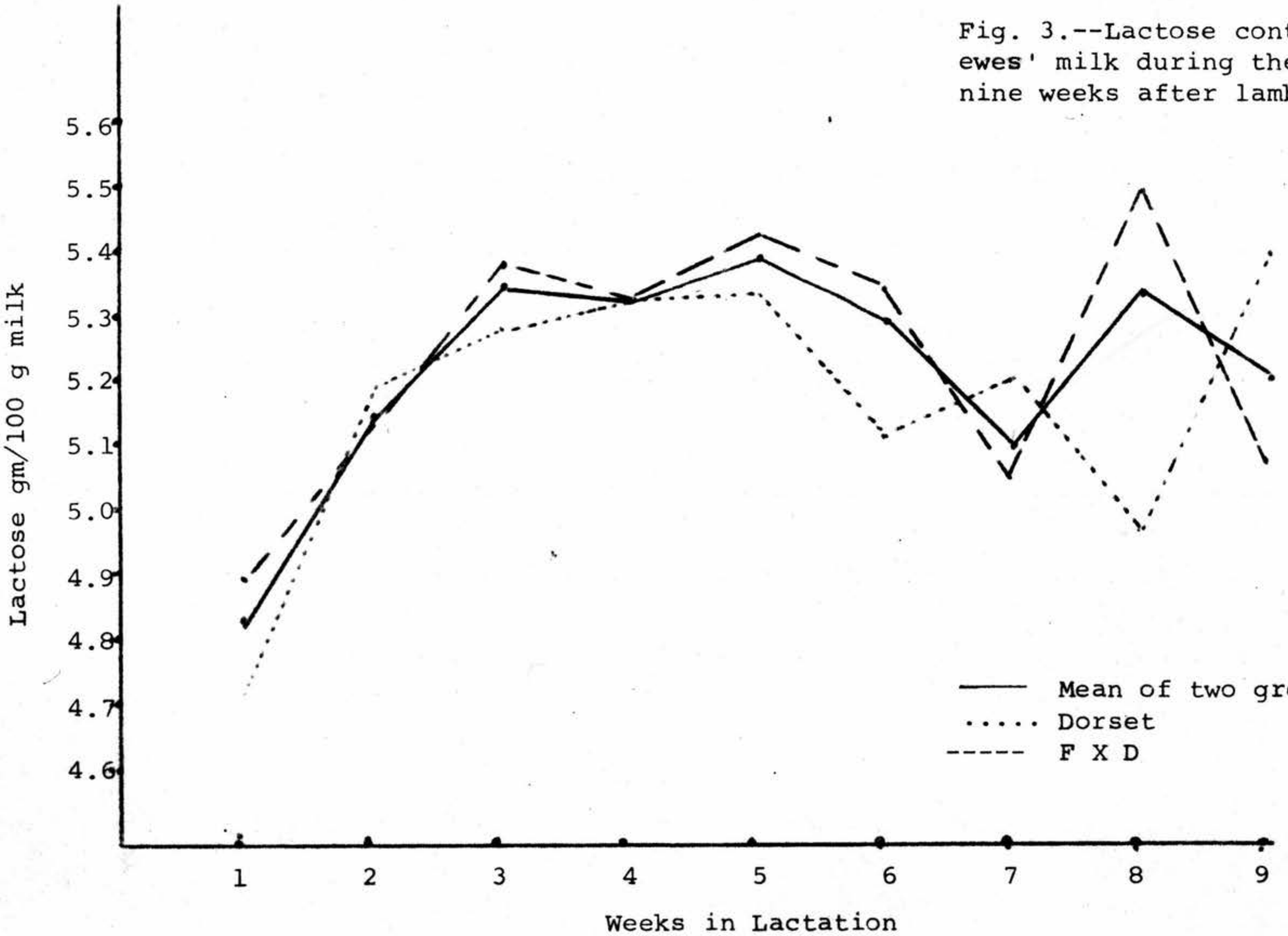


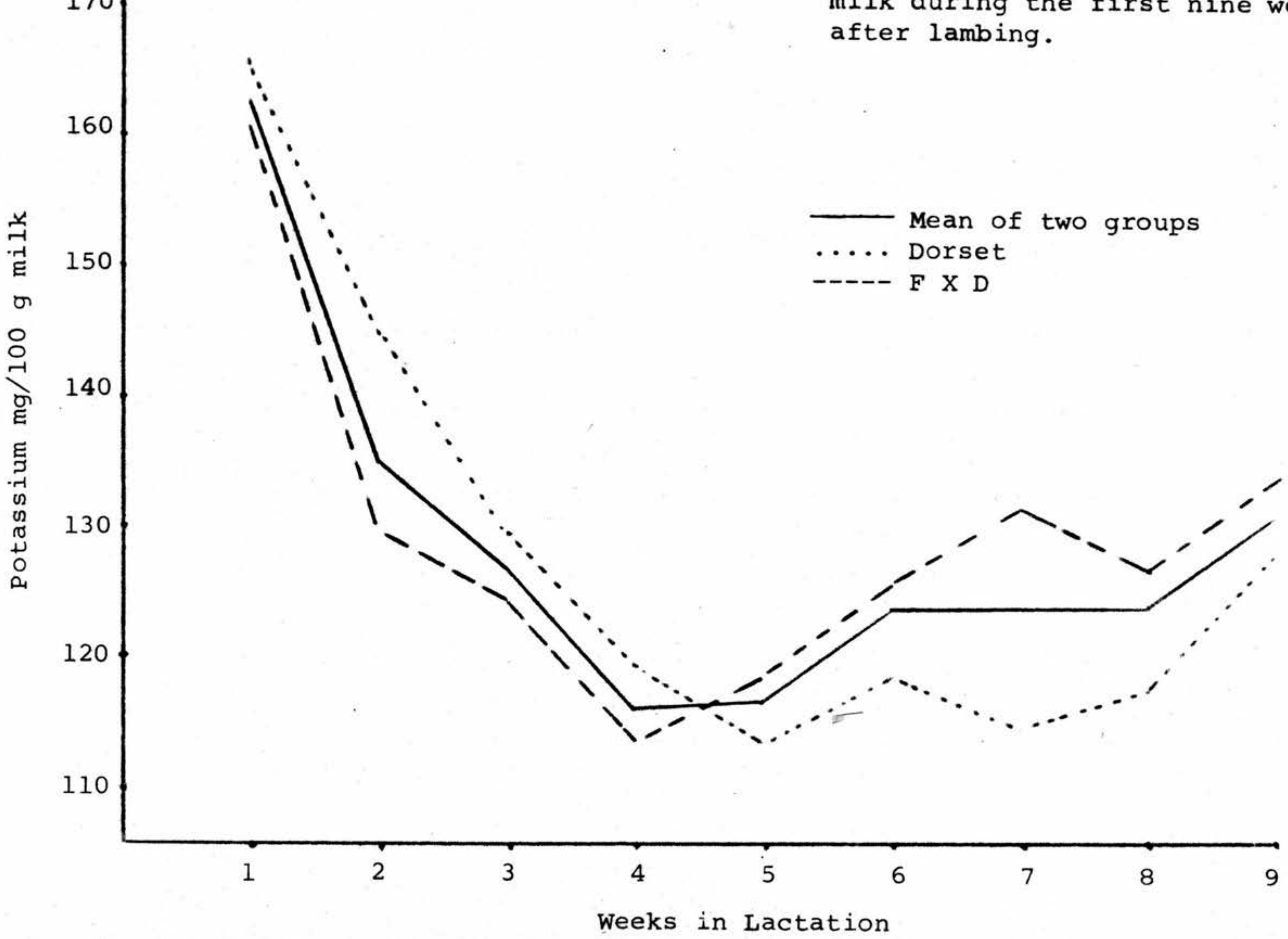
Fig. 3.--Lactose content of ewes' milk during the first nine weeks after lambing.

similar to the concentration in the 6th sample and the 4th was similar to the 5th sample. The content was constant after the 6th sample until the last one. The Dorset ewe's milk had a high content of potassium in the first sample and it decreased in the second and the third samples, afterwards the concentrations were constant until the last sample. The potassium content in the F X D ewe's milk follows the same trend as the general average of the two groups. The main decrease in the potassium content was in the second sample.

Fig. 4 shows that the potassium content of ewe's milk was approximately constant from the 3rd week to about the 8th week after lambing. The overall average for sodium content of the milk of both groups of ewes was low in the first sample and increased continuously during the stage of lactation. The main increase was in the second sample and in the last three weeks. The Dorset and F X D ewe's milk were identical in the sodium trend during the lactation period and both are similar to the overall average trend during the stage oflactation.

Fig. 5 shows that sodium content in ewe's milk increases continuously during the stage of lactation, but

Fig. 4.--Potassium content of ewes' milk during the first nine weeks after lambing.



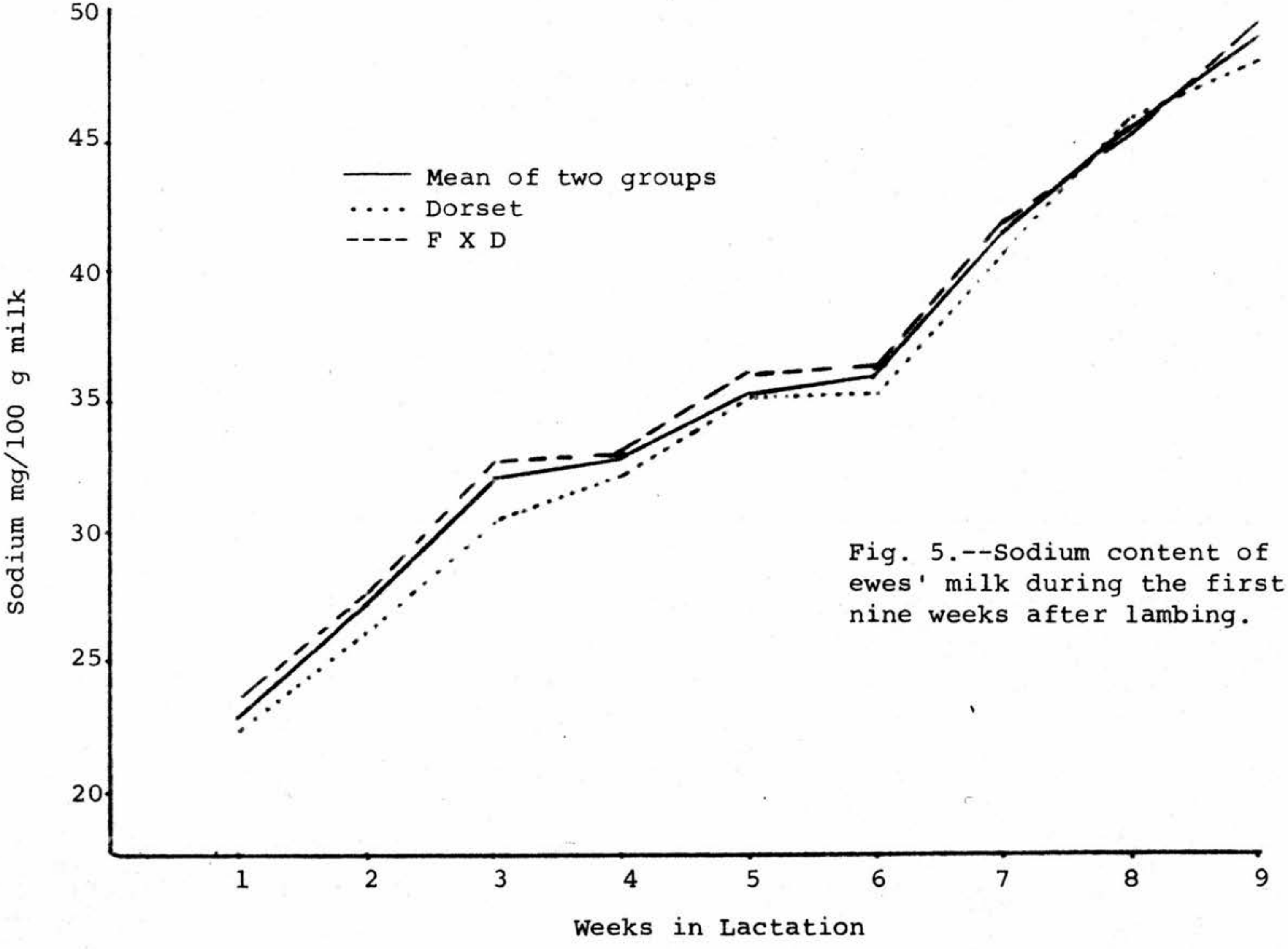


Fig. 5.--Sodium content of ewes' milk during the first nine weeks after lambing.

differences between the 3rd sample to about the 6th sample were smaller than the differences between the other samples. It was not decided to determine the total solids content until a few samples had been collected and already analyzed; for this reason the results of the total solids of some ewes were not included in the 1st, 2nd, and the last samples.

As a whole the total solids of ewe's milk increased in the second sample and decreased in the 3rd sample; afterwards it increased continuously until the 8th sample and decreased again in the last sample.

Fig. 6 shows that unlike the individual constituents already discussed the total solids content of ewe's milk is not approximately constant during any particular period of the lactation. The potassium to lactose ratio in ewe's milk followed the same trend during the lactation as the potassium. The ratio was 34.5 in the first sample and decreased to 26.3 in the second sample. It remained below this level until the end of the lactation ranging from 21.5 to 25.1. The differences between the 3rd, 4th, 5th, and 6th samples were smaller in comparison with differences between the other samples.

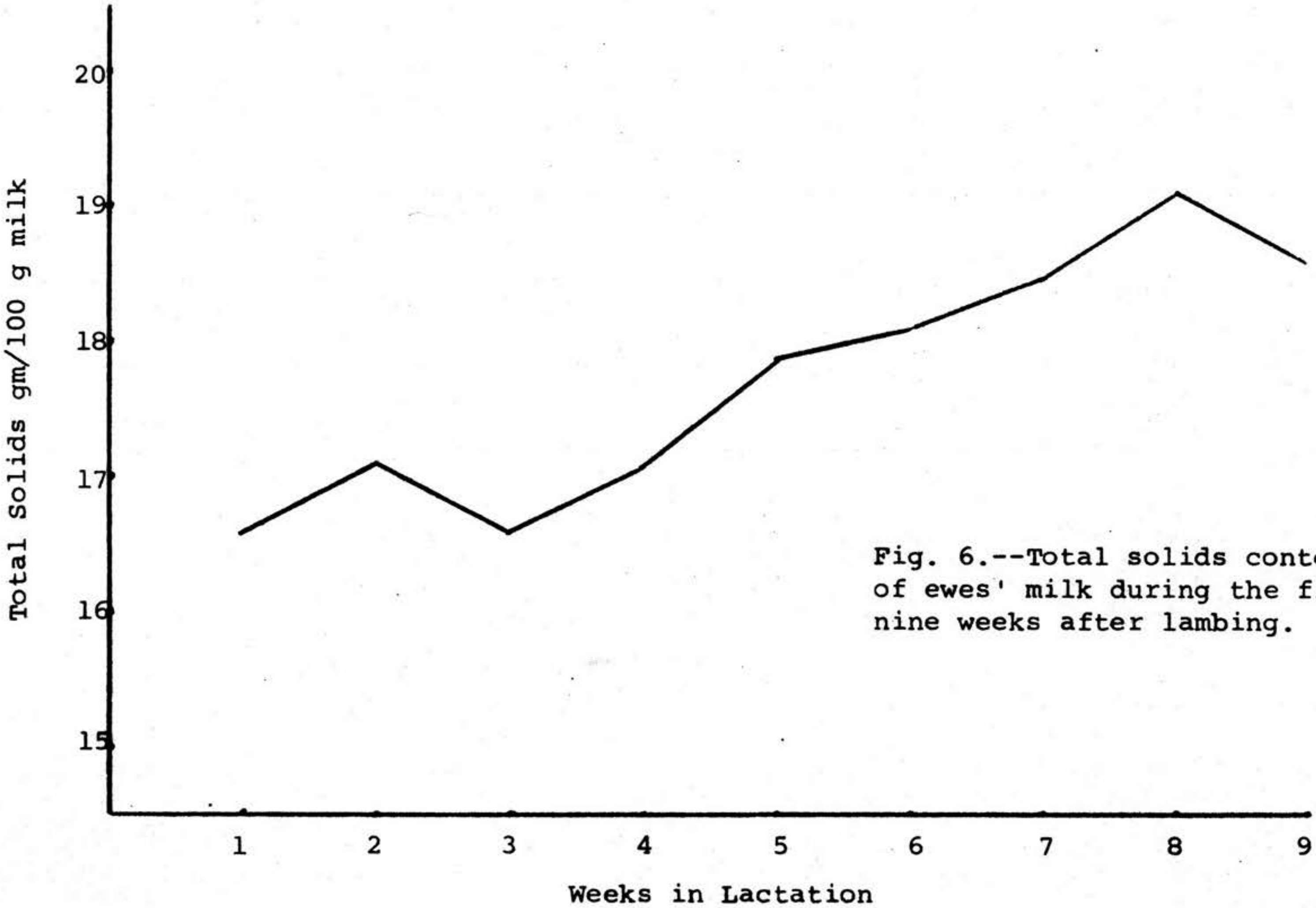


Fig. 6.--Total solids content of ewes' milk during the first nine weeks after lambing.

Fig. 7 shows that the potassium to lactose ratio of ewe's milk reaches an approximately constant value between the 3rd to about the 6th week after lambing. Fig. 8, 9, and 10 show the potassium to lactose ratio in the groups of ewes studied plotted against the actual day of the lactation on which the samples were taken. Again the period from the 20th to about the 35th day of the lactation is less variable than any other time during the lactation period, and the two groups of animals agree reasonably well in this matter.

The Repeatability of Potassium to Lactose Ratio of Ewe's Milk

One of the most important statistics in the analysis of milk production is the correlation between performance at different times or different stages of lactation of the same animal, often given the name "Repeatability." This measures the proportion of the variation between animals within herds which is common to the samples concerned and therefore includes all hereditary differences which affect both samples alike as well as some environmental similarities. It is an upper limit of the hereditability of the character. The repeatability is calculated as follows:

$$\frac{\sigma^2 \text{ sheep}}{\sigma^2 \text{ sheep} + \sigma^2 \text{ error}}$$

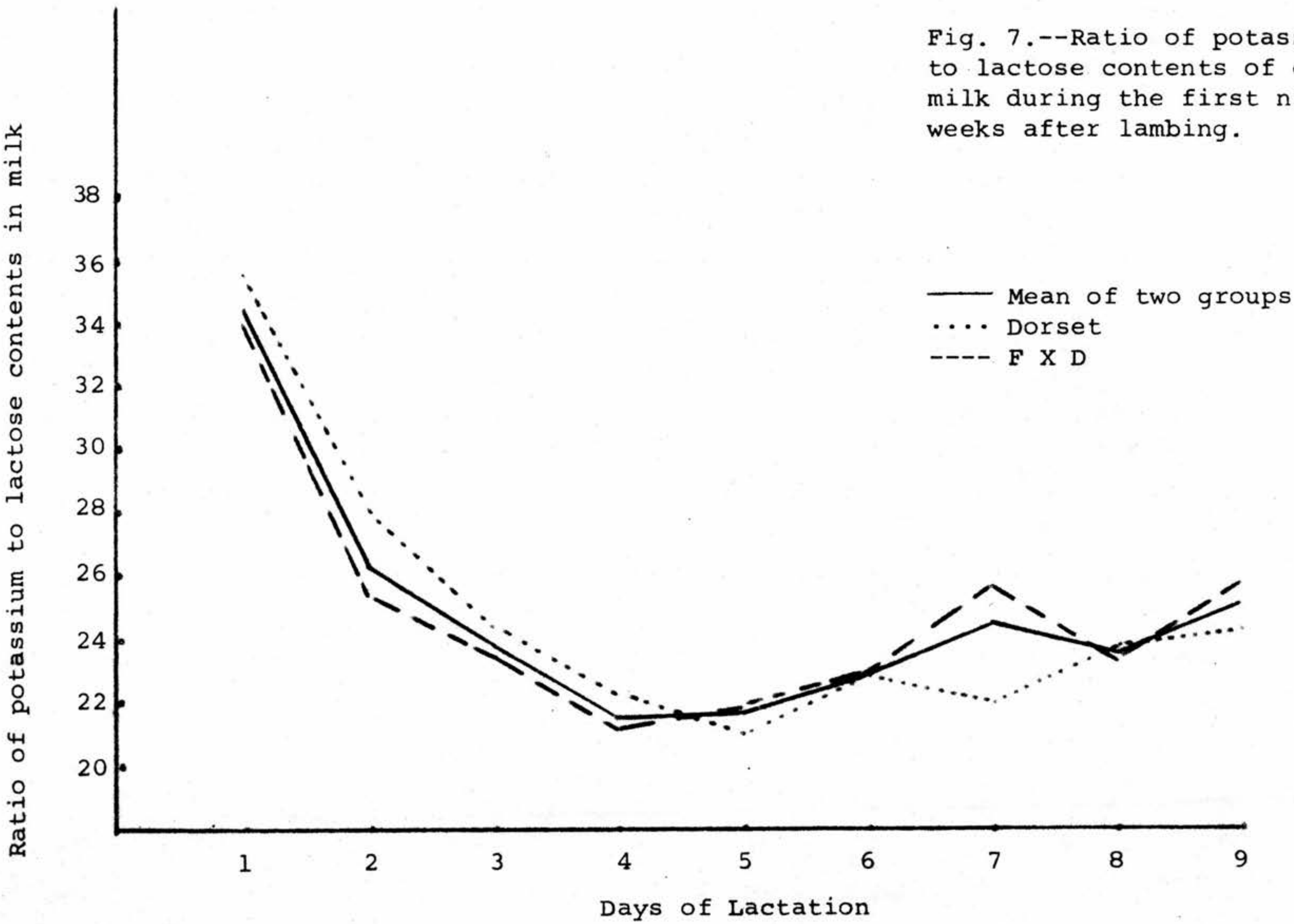
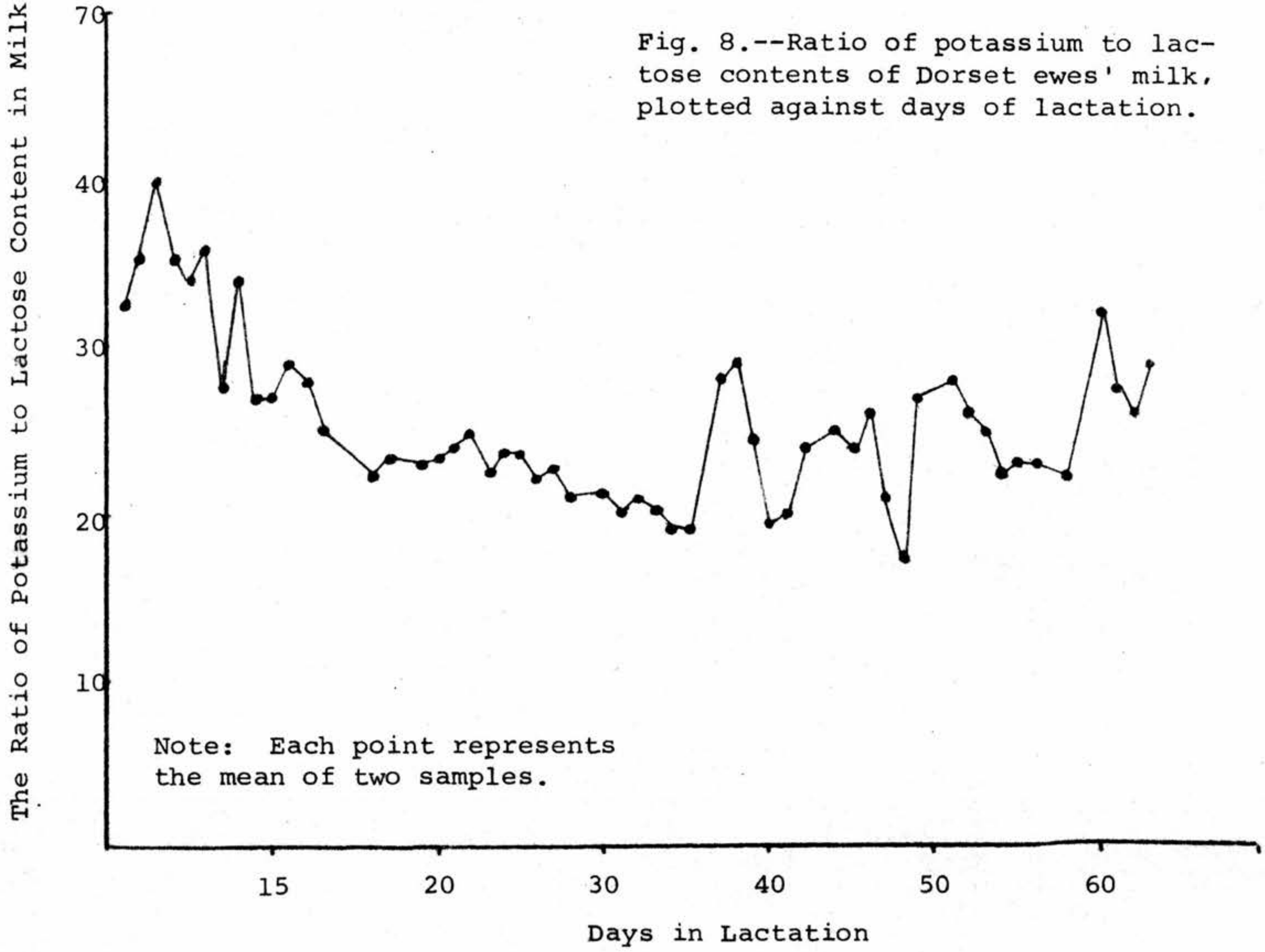


Fig. 7.--Ratio of potassium to lactose contents of ewes' milk during the first nine weeks after lambing.



Note: Each point represents the mean of two samples.

Fig. 8.--Ratio of potassium to lactose contents of Dorset ewes' milk, plotted against days of lactation.

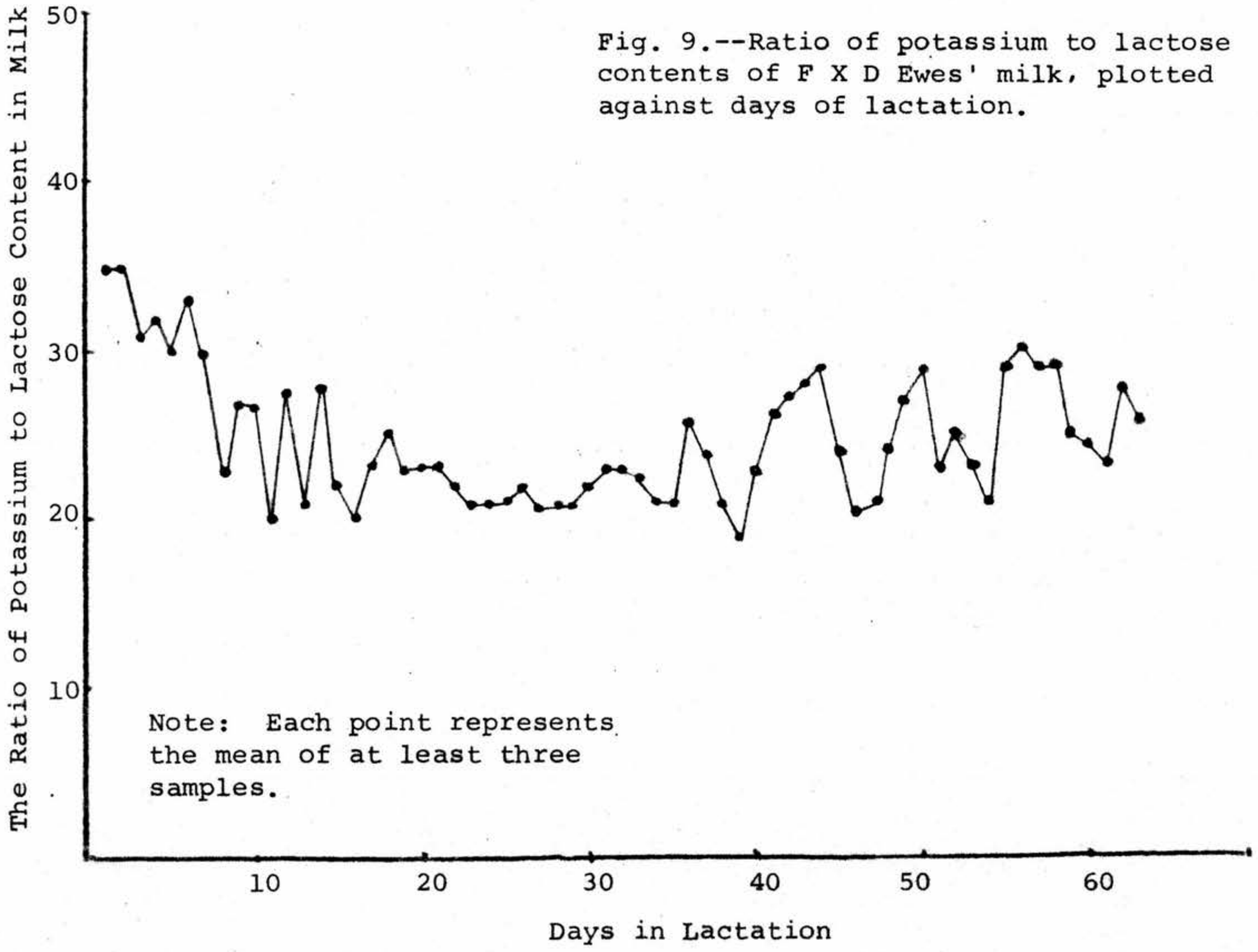


Fig. 9.--Ratio of potassium to lactose contents of F X D Ewes' milk, plotted against days of lactation.

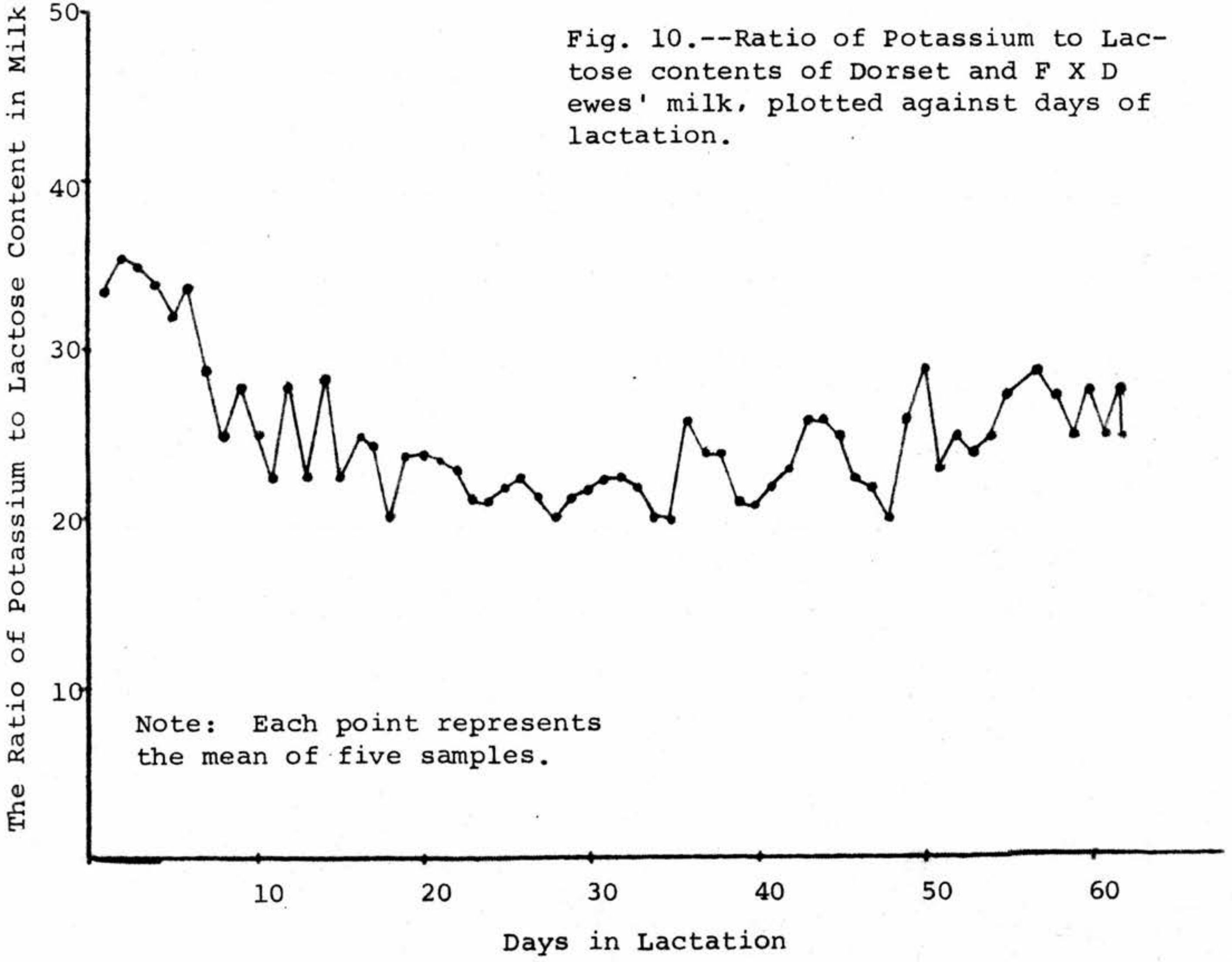


Fig. 10.--Ratio of Potassium to Lactose contents of Dorset and F X D ewes' milk, plotted against days of lactation.

Note: Each point represents the mean of five samples.

σ^2 sheep is the component of variance between the sheep and σ^2 error is the component of variance within the sheep.

An analysis of variance of the potassium to lactose ratio of ewe's milk in the 3rd, 4th, 5th, and 6th weeks after lambing was carried out as given in Table 12. The repeatability of the four samples of all animals was calculated from the table of analysis of variance as follows:

σ^2 error = 9.97

σ^2 sheep = $\frac{1}{4}$(Between sheep variance - error) = 10.22

Repeatability = $\frac{10.22}{20.19}$ = 0.45

TABLE 12

ANALYSIS OF VARIANCE OF POTASSIUM TO LACTOSE RATIO OF EWE'S MILK IN THE 3rd, 4th, 5th, AND 6th WEEKS OF LACTATION

Source of Variance	d.f.	M.S.	F.	P.
Between Weeks	3	41.32	4.14	1%
Between Breeds	1	2.54	1	
Between Sheep/breeds	33	50.84	5.10	0.1%
Error (within sheep)	102	9.97		

It was decided to use the 3rd and 6th week of lactation in later experiments and for comparable results the correlation was calculated between the 3rd and 6th samples of the F X D ewes only, as they were of a similar age. The repeatability of the potassium to lactose ratio was 0.7999. Table 13 gives the analysis of variance which was used in calculating this repeatability.

TABLE 13

ANALYSIS OF VARIANCE OF POTASSIUM TO LACTOSE RATIO OF F X D EWES IN THE 3rd AND 6th SAMPLES

Source of Variance	d.f.	M.S.
Between Samples	1	439.94
Between Sheep	23	51.82
Within Sheep (error)	23	5.76

σ^2 Error = 5.76

σ^2 Sheep = 23.03

Repeatability = $\frac{23.03}{28.79}$ = 0.80

The value of 0.7999 expresses the degree to which the potassium to lactose ratio of the F X D ewe's milk would be expected to be consistent from the 3rd to the 6th sample.

Discussion

This experiment has demonstrated the effect of the stage of lactation on ewe's milk constituents studied, namely lactose, potassium, sodium, total solids, and the potassium to lactose ratio. It certainly indicates a smaller variation in these constituents between the 3rd to about the 6th week after lambing than at any other time during lactation. These results agree reasonably well with the results obtained by Perrin (1958) in New Zealand. She obtained a smaller variation in these contents in mid-lactation than any other period of the lactation.

The mean values obtained in this experiment are compared with the mean values obtained by other investigators in Table 14.

The data in Table 14 emphasises the great variability in the levels of these constituents found by different workers. This may be due to many factors: genetical and environmental, such as breed differences, different management, and the different methods of analysis available at the time of the investigation.

TABLE 14

MEAN VALUES OF LACTOSE, POTASSIUM, SODIUM, AND TOTAL SOLIDS OF EWE'S MILK

Author	Breed or Cross	Total Solids	Lac-tose	k	Na
Abderhalden(1908)	Various	----	----	80	64
Neidig & Iddings (1919)	Various	----	4.7	----	----
Könings(1920)	German breeds	----	----	180	30
Peirce(1934)	Merino	18.9	4.7	----	----
Godden & Puddy (1935)	Cheviot	19.3	4.8	126	50
Bonsma(1939	Various	16.6	----	----	----
Barnicoat et al. (1949)	N.Z. Romany	16.3	4.4	----	----
El-Sokkary et al. (1949)	Rahmany & Awsemg	19.4	----	----	----
Morrison(1951)	Various	----	----	190	----
Perrin(1958)	N.Z. breeds				
	H.P.N.	23.0	4.0	124	48
	L.P.N.	20.5	4.1	121	38
Ashton et al. (1964)	Clun Forest	16.9	4.7	----	----
Ashton & Yousef (1966)	Clun Forest	----	----	168	46
Results obtained (1967)	Dorset		5.15	127.5	35.4
	F X D	17.7	5.27	128.7	36.1

Notes: Total solids expressed as gm/100 gm of milk.
Lactose " " gm/100 gm of milk.
Potassium (k) " " mg/100 gm of milk.
Sodium (Na) " " mg/100 gm of milk.
H.P.N. means high plain of nutrition.
L.P.N. means low plain of nutrition.

Ashton, Owen & Ingleton (1964) pointed out that lactose was variable in Clun Forest ewes with a coefficient of variation between ewes of about 4%. The total solids of this breed showed also variation between ewes. They furthermore suggested that in sheep as in dairy cows individual animals may produce milk which tends either to be comparatively rich or poor in certain major milk constituents. Ashton & Yousef (1966) showed that the content of potassium and sodium in ewe's milk varied significantly between the ewes. This is in agreement with the highly significant differences obtained in this experiment between ewes within breeds in Table 12.

The repeatability of 0.5061 and 0.7999 obtained in this experiment for the potassium to lactose ratio express the upper limit of the hereditability of this character in ewe's milk. It suggests that the potassium to lactose ratio in ewe's milk is inherited and further experiments are needed to obtain more information about other factors which might affect this character and to examine the inheritance of the other constituents.

Experiment B

The inheritance of lactose, potassium, sodium, total solids and potassium to lactose ratio in ewe's milk.

Design of the Experiment

This experiment involved the use of two different breeds of ewes with a wide range of age and sires, to study the variation of the above constituents related to the effect of age differences and different sires within ages.

There were 96 Clun ewes, divided into 6 groups according to the ages which vary from one to six years and again divided into 22 groups according to the sires of the animals. Eleven ewes were of the Suffolk breed, to give a mean for these constituents only. All the animals were under one husbandry regime, out on grass, received less concentrates than the ewes in Experiment A, and were lambed in the normal lambing season.

A list of the identity of each ewe used in this experiment is given in the Appendix, Tables 8 and 9.

Two milk samples were obtained from each animal, the first in the 3rd week after lambing and the second in the 6th week. The milk samples were collected as described in Experiment A and were treated by the same procedure prior to chemical analysis for lactose, potassium, sodium, and total solids.

<u>Results</u>

The mean values of the milk constituents of Clun ewes studied in this experiment were as follows: lactose, 4.85 and 4.76; potassium, 129.71 and 123.96; sodium 31.8 and 36.5; and total solids 17.0 and 18.1 in the 3rd and 6th weeks of lactation respectively.

Table 15 gives the average of these constituents in the Clun ewe's milk in different ages.

The lactose and potassium contents decreased very slightly after the two-year-old group until the four-year-old group, and started to increase again very slightly in the last two groups. The highest levels for lactose and potassium were obtained from the two-year-old group, and the lowest levels from the four-year-old group. The total solids and potassium to lactose ratio were constant in the different groups of animals, but there were differences between the groups in the sodium contents.

Table 16 gives the mean values of the milk constituents of different groups of ewes under different sires and

TABLE 15

MEAN VALUES OF CONSTITUENTS IN THE MILK OF CLUN EWES OF DIFFERENT AGES

Age of Ewe in years	No. of Ewes	Average No. of Lamb Sucked	Date of the Sample	Lactose	Potassium k mg/100 gm	Sodium Na mg/100 gm	Total Solids T.S. gm/100 gm	Raio k/lactose
1	12	1.00	1) 3rd wk.	4.89	131.47	30.93	15.89	26.78
			2) 6th wk.	4.75	124.27	36.27	17.12	26.11
2	31	1.45	1	4.97	136.13	32.13	16.94	27.50
			2	4.86	127.23	36.39	18.53	26.51
3	32	1.31	1	4.79	124.75	31.25	17.37	26.23
			2	4.75	120.38	36.13	18.25	25.85
4	5	1.80	1	4.63	118.40	31.20	17.02	25.84
			2	4.61	109.60	37.60	17.44	23.88
5	9	1.56	1	4.68	128.89	31.56	17.52	27.54
			2	4.60	129.78	36.00	17.87	28.46
6	4	2.00	1	4.87	129.00	37.00	17.78	26.45
			2	4.65	131.00	40.00	18.10	28.18
Group Means	96	1.52	1	4.81	128.11	32.34	17.09	26.72
			2	4.70	123.71	37.06	17.89	26.50

Note: The data which these means represent are given in the Appendix, Table 10.

TABLE 16

MEAN VALUES OF MILK CONSTITUENTS OF CLUN EWES UNDER DIFFERENT AGES AND SIRES

Age	1 Year Old					2 Years			3 Years	4 Years				5 Years					6 Years				Average
Sire	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	22 Group
No. of Animals	4	5	1	4	1	12	9	10	32	1	2	1	1	1	3	2	1	1	1	1	2	1	d96
No. of Lambs Suckled	1	1	1	1	1	1.67	1.56	1.10	1.31	2.00	2.00	1	2.00	2.00	1.67	2.00	1	1	1	2	2	2	1.47
Potassium 1	139	125	108	136	140	139	132	136	125	108	116	96	156	144	140	138	120	100	100	120	114	168	127.27
2	131	121	104	123	140	127	125	130	120	108	100	96	148	148	127	122	144	120	132	128	128	140	125.34
Lactose 1	4.95	4.76	4.19	5.148	5.02	4.91	5.05	4.98	4.79	4.48	4.93	4.70	4.13	5.22	4.64	4.83	4.15	4.27	4.95	5.25	4.64	4.93	4.77
2	4.75	4.72	4.20	4.86	5.02	4.81	4.78	4.99	4.75	4.67	4.73	4.69	4.23	5.07	4.38	4.42	4.56	4.94	4.89	4.38	4.77	4.67	4.69
Ratio 1	27.05	26.22	25.80	27.20	27.80	28.53	26.16	27.46	26.23	24.10	23.50	24.40	37.70	27.50	30.17	28.70	28.90	23.40	20.20	22.80	24.45	34.10	26.74
2	27.70	25.38	24.70	25.38	27.80	26.73	26.38	26.35	25.85	23.10	21.10	20.10	34.00	29.10	29.17	28.45	31.50	24.20	26.90	29.20	26.80	29.90	26.81
Sodium 1	29.0	31.2	36.0	31.0	32.0	32.0	31.1	33.2	32.0	30.0	32.0	32.0	28.0	32.0	32.0	36.0	28.0	32.0	32.0	40.0	36.0	36.0	32.22
2	38.0	36.0	36.0	35.0	36.0	36.0	36.0	37.2	36.1	40.0	38.0	36.0	36.0	36.0	36.0	36.0	36.0	36.0	36.0	36.0	42.0	40.0	36.83
Total Solids 1	15.57	15.40	17.20	16.23	17.00	16.43	17.87	16.71	17.37	16.30	16.50	19.10	17.60	15.30	17.33	18.95	19.20	17.30	16.00	18.30	18.45	15.90	17.07
2	17.10	17.18	18.30	16.78	17.10	18.07	19.98	17.79	18.25	16.70	16.35	19.80	18.00	15.90	17.43	19.50	19.30	18.00	16.30	19.00	18.70	16.00	17.80

Note: The data which these means represent are given in the Appendix, Table 10.

ages. It appears from this table that sires have an effect on some of the constituents, namely potassium and sodium.

The data obtained from this experiment were subjected to the following statistical analysis tests:

1. Analysis of Variance

The following tables 17 A and B indicate that potassium and sodium contents of Clun ewe's milk are the only two constituents which are affected by the variation between the ewes in the ages and sires, but the lactose, total solids, and potassium to lactose ratio were not affected by this variation. The data again have been classified in a "hierarchical" way, assuming that there is not any statistically significant interaction between the factors on which the classification has been based.

The general scheme of variance-analysis is given in Table 18. σ_a^2, $\sigma^2 s$, and $\sigma^2 w$ are the components of variance according to ages, sires and "error" respectively. The k values have been calculated as given by King & Henderson (1954).

The proportion of variance components in the total phenotypic variance, σt^2 has been calculated as follows: Assuming $\sigma t^2 = \sigma w^2 + \sigma s^2 + \sigma a^2$, then we get $\sigma w^2/\sigma t^2$,

TABLE 17

ANALYSIS OF VARIANCE OF CLUN EWE'S MILK

	d.f.	Mean Squares				
A. Corrected Mean Squares (M.S.)						
		Lactose	Potassium	Sodium	Total Solids	K/L Ratio
Between ages	5	3374.4	89877	35517	833.1	2006.6
Between sires within ages	16	1813.9	56098	8659	5930.9	3201.7
Between sheep within sires and ages	74	2195.3	14624	4682	4403.0	2458.9
B. F Values						
	F^{5}_{16}	1.861	1.60	4.10^{xx}	1.40	<1
	F^{5}_{74}	1.511	6.14^{xx}	7.59^{xx}	1.89	<1
	F^{16}_{74}	<1	3.83^{xx}	1.84^{x}	1.34	1.30

Notes: x = significant at 5% level.
xx = significant at 1% level.

$\sigma s^2/\sigma t^2$ and $\sigma a^2/\sigma t^2$. The results are given in Table 19 for milk lactose, potassium, sodium, total solids, and potassium to lactose ratio respectively. Table 19 indicates that half of the variance in the potassium content of ewe's milk is due to the difference between ewes, the other half

TABLE 18

THE GENERAL SCHEME OF VARIANCE-ANALYSIS

Source of Variation	Degrees of Freedom	Expected (M.S.)
Between Ages	a - 1	$\sigma_w^2 + k_2\sigma s^2 + k_3\sigma a^2$
Between Sires/Ages	isi-a	$\sigma w^2 + k_1\sigma s^2$
Within sheep "error"	n - isi	σw^2

Notes: a = number of ages.
Si = number of sires within ages.
n = total number of individuals.

TABLE 19

PERCENTAGE OF CONTRIBUTION OF SOME FACTORS TO THE TOTAL VARIANCE OF MILK CONSTITUENTS

Character	Lactose	Potassium	Sodium	Total Solids	K/L Ratio
Source of Variation:					
Ages	0.04	8.49	24.66	3.36	----
Sires/ages	----	38.64	13.53	7.93	7.23
Within Sheep	99.96	52.86	61.80	88.70	92.77

being due to the effects of the age and sire of the ewe. Sixty percent of the variance in the sodium content of the ewe's milk was due to the difference between the individual ewes and the remainder was due to the effects of the ages and the sires of the ewes. The variance in the lactose, total solids and the ratio of potassium to lactose content of ewes' milk was mostly due to differences between the ewes only. The differences between the individual ewes includes genetic influences accompanied by some permanent environmental factors. The variance between ages is an environmental difference, but the variance between sires is about 1/4 of the heritability and is entirely a genetic difference.

2. The repeatability of Clun ewe's milk constituents

To measure the proportion of the variation between the animals within herds which is common to the samples concerned and therefore includes all hereditary differences which affect both samples alike as well as some environmental similarities, the repeatability of these characters was estimated as in Table 20. These results indicate that the repeatability of the total solids of ewe's milk is greater than that of the other constituents studied in this experiment;

TABLE 20

REPEATABILITY OF CLUN EWE'S MILK CONSTITUENTS

Source of Variation	d.f.	Lactose	Potassium	Sodium	Total Solids	K/Lactose Ratio
Between sheep	95	2193.1	25569.8	6553.6	4867.1	2560.2
Within sheep "error"	95	615.9	12460.0	3367.5	356.6	630.2
Repeatability		0.5614	0.3447	0.3211	0.8634	0.6049

it also indicates that the repeatability of the potassium and sodium are lower than that of the other characters.

3. The phenotypic correlation between the milk constituents studied in the experiement

Table 21 gives the correlations between the lactose, potassium, sodium, and total solids contents and the potassium to lactose ratio of the Clun ewe's milk.

There were low negative not significant correlations between total solids and sodium on the one hand and the other milk constituents on the other. There was a negative correlation also between the potassium and lactose content but this correlation was not significant. The only significant

TABLE 21

CORRELATIONS BETWEEN CLUN EWE'S MILK CONSTITUENTS

	Potassium	Lactose	K/Lactose Ratio	Sodium
Lactose	-0.130			
K/Lactose ratio	0.749^{xx}	-0.466^{xx}		
Sodium	-0.073	-0.106	-0.049	
Total Solids	-0.122	-0.100	-0.026	-0.110

Notes: x = d.f. 95
xx = significant at 1%

correlations were those between lactose and potassium concentrations on the one hand and their ratio on the other.

4. <u>The effect of number of lambs suckling the ewe</u>

The ewes used in this experiment were divided into two groups, one group with only one lamb suckling each ewe and the other with two lambs suckling each ewe. It seems that the group which had more than one lamb produced more potassium and lactose in the milk in the 3rd week, but the concentration of lactose decreased again in the 6th week. Table 22 gives the "P" values of the differences between the two groups of animals in the milk constituents studied.

TABLE 22

"P" VALUES OF THE DIFFERENCES IN THE MILK CONSTITUENTS BETWEEN THE TWO GROUPS OF ANIMALS (1 LAMB OR 2 LAMBS SUCKLING)

Constituents	3rd Week	6th Week
Potassium	+1.7146++	+0.5767
Lactose	+0.9589+	-1.8029++
K/lactose ratio	+0.9200+	+0.8547+
Sodium	-0.5062	-0.5636
Total solids	-0.1453	-0.0251

Notes: d.f. = 95
+ = significant at 5%
++ = significant at 1%

The Suffolk ewes which were used in this experiment gave the following mean values in the third and sixth week after lambing respectively: potassium, 128.0 and 133.0; lactose, 4.75 and 4.74; potassium to lactose ratio, 27.3 and 27.0; sodium 32.0 and 36.4; and total solids, 16.1 and 16.5. The data which these means represent are given in the Appendix, Table 11.

Discussion

A third experiment was carried out to confirm the results of the previous experiment and to extend its scope.

For this reason the foregoing results are briefly discussed here and a general discussion on all aspects will follow after the third experiment.

The mean values for the potassium, sodium, and total solids contents of Clun and Suffolk ewe's milk obtained in this experiment are in good agreement with the mean values for the same constituents in the milk of Dorset and F X D ewes used in the first experiment. The values for lactose and potassium and for potassium to lactose ratio are rather different in both experiments.

This experiment indicates that there are certain genetic effects operating on all the constituents studied and the repeatabilities of these characters were determined. There are also considerable environmental effects on the levels of both potassium and sodium of the Clun ewe's milk. The number of lambs suckling (one or two lambs) has no consistent effect on the variations in the composition of the Clun ewe's milk studied in this experiment.

The correlations between the milk constituents were calculated, and it seems from this experiment that the constituents studied varied independently of each other.

Experiment C

I. The inheritance of lactose, potassium, sodium, total solids and the potassium to lactose ratio of ewe's milk.

II. The correlation between the above milk constituents and some blood characters.

Design of the Experiment

This experiment like the previous one was designed to study the differences in the above milk constituents between crosses, between ages of ewes, and between ewes sired by different rams. The second aim of the experiment was to study the correlations between some milk constituents on the one hand and the blood characters on the other, namely packed cell volume,potassium types, and haemoglobin types.

One hundred thirty ewes were used in this experiment. They were of five different crosses, divided into ten age groups and again divided into nineteen groups sired by different rams. A list of the identity of the ewes is given in the Appendix, Tables 12, 13, 14, 15, and 16. All ewes were lambed in the normal lambing season and were again under the same husbandry regime as that described in Experiment B. Milk samples were collected twice from each ewe in the third and the sixth weeks after lambing. The samples were treated and analysed for lactose, potassium, sodium, and total solids as previously described. One blood sample was taken from each ewe and analysed for the following characters:

1. Packed cell volumes
2. Sodium and potassium in plasma volumes
3. Sodium and potassium in whole blood volumes
4. Haemoglobin types, A, AB, and B.

Methods of Analysis

1. Milk samples were analysed as previously described in Section One.
2. The blood analyses were carried by the following procedures.

Packed cell volume

The blood samples were transferred into Hawksley Micro-Hoematocrit centrifuge tubes and spun for 12 minutes. The results were read in percent packed cell volume (PCV%) with a Hawksley Micro-Hoematocrit Reader.

Sodium and potassium plasma volumes

The plasma was obtained by centrifuging the blood samples. Of the plasma, 0.25 ml was transferred into a 50 ml volumetric flask. The volumetric flask was then filled to the mark with distilled water and the samples were then passed through an EEL flame photometer.

The standard solution used for sodium determination was prepared by dissolving 0.634 gm NaCl in one litre of distilled water to serve as stock solution. Of this stock, 40 ml solution were again diluted to one litre with distilled water. The standard solution for potassium was prepared by dissolving 0.477 gm KCl in one litre of distilled water, then 20 ml of this solution were diluted to one litre with distilled water.

Sodium and potassium were calculated into m. eq/ litre by the following formulae:

$$\text{m.eq Na/L} = \frac{\text{flamephotometer Reading X 40}}{23}$$

$$\text{m.eq K/L} = \frac{\text{flamephotometer Reading X 20}}{39}$$

Sodium and potassium in whole blood volumes

Before the samples were centrifuged for obtaining the plasma, 0.25 ml from each of the blood samples was diluted to 50 ml in a volumetric flask with distilled water. The rest of the analysis and calculating m.eq Na/Land m.eq K/L were carried out as the same procedure in the determinations of sodium and potassium plasma volumes.

Potassium in whole packed cell volumes

The potassium in whole packed cell volumes was calculated by the following formula:

$$\text{m.eq K/P.C.V.} = \frac{100}{\text{PCV}}\left[\text{m.eq/L whole blood potassium} - \frac{\text{m.eq/L plasma potassium X(100-PCV)}}{100}\right]$$

Haemoglobin types

The haemoglobin was subjected to electrophoresis at pH 8.9 by the following procedure:

The whole blood samples were washed three times in 0.09% NaCl solution, centrifuged after each wash and the supernatant was sucked off. In the third wash the samples were spun for 10 minutes and the supernatant sucked off. The equal volumes of distilled water were added to the washed packed cells (2/1 distilled/WPC) to cause haemolysis. An electrolyte buffer was prepared by adding Tris, 40.4 gm (Tri Hydroxymethyl) Methylamine; EDTA, 40.0 gm; and Boric acid, 3.0 gm, to two litres of distilled water.

Seventy-five ml of the above electrolyte buffer were transferred to a 250 ml volumetric flask and made up to the volume with distilled water. Thirty gm approximately of hydrolyzed starch were put into a Buchner flask with 55 ml gel buffer and swirled. The rest of the buffer in the volumetric flask was heated and added to the starch. The mixture was swirled and then connected to the suction pump to remove air bubbles and then poured into the gel plates.

The electrophoresis was set up at 300 volts, about 30 MA, the inserts removed after 1-2 minutes and the samples were run for about 2-1/2 hours. The haemoglobin types were taken direct from the gel as follows:

- B	AB	A +
moving slowly	intermediate	moving fast

Note: The blood analysis methods are the standard methods used by the Blood Typing Department at the A.B.R.O. Edinburgh.

Results

Table 23 gives the mean values for potassium, lactose, sodium, and total solids and potassium to lactose ratio of milk from five different crosses. It is quite noticeable that there is a wide variation between the different crosses in both potassium contents and the potassium to lactose ratio, but the mean values for the other constituents, lactose, sodium, and total solids are rather similar for the different crosses used in this experiment.

TABLE 23

MEAN VALUES OF POTASSIUM, LACTOSE, SODIUM, TOTAL SOLIDS, AND POTASSIUM TO LACTOSE RATIO IN MILK FROM DIFFERENT CROSSES

Crosses	No. of Lambs Suckled	No. of Ewes	Potassium mg/100 gm Milk	Lactose gm/100 Milk	K/Lactose Ratio	Sodium mg/100 Milk	Total Solids gm/100 gm Milk
BL X BF	1.50	16	x 113.25	4.94	23.08	33.25	16.74
(Border Leic x Black Face)			xx 109.25	4.50	24.59	37.50	18.02
F X BF	1.90	29	111.72	4.78	23.53	33.79	16.51
(Finnish x Black Face)			110.76	4.56	24.28	38.48	17.78
M X BF	1.13	31	123.10	4.65	26.33	32.39	16.28
(Merino x Black Face)	1		124.65	4.64	26.80	36.77	17.59
C X BF	1.58	32	118.23	4.79	24.88	34.15	16.46
(Clun x Black Face)			114.15	4.62	24.84	37.23	17.83
D X BF	1.43	28	129.43	4.87	26.76	34.29	15.85
(Dorset x Black Face)			125.93	4.76	26.68	38.29	17.03
Groups	1.51	130	119.15	4.81	24.92	33.57	16.37
Mean			116.95	4.62	25.44	37.65	17.65

Notes: The data which these means represent are given in the Appendix, Tables 17, 18, 19, 20, and 21.

x The first value is the mean value of the samples collected in the 3rd week after lambing.

xx The second value is the mean value of the samples collected in the 6th week after lambing.

The next two tables, Table 24 and Table 25, give the mean values of the milk constituents studied in this experiment for ewes of different ages within different crosses and for ewes of different sires within different ages and different crosses. It is obvious that there are a variation between the different groups of animals in potassium content and the potassium to lactose ratio, but the lactose, sodium, and total solids remain similar between these different groups.

In an analysis of variance of the data obtained in this experiment there are highly significant differences in the potassium content and the potassium to lactose ratio between ages within crosses and between sires within ages and crosses as given in Tables 26A and B.

The data obtained in this experiment were again classified in a "hierarchical" way, assuming that there is not any statistically significant interaction between the factors on which the classification has been used. The general scheme of analysis of variance is given in Table 27. The proportion of variance components in the total phenotypic variance of σt^2 has been calculated as follows:

Assuming: $\sigma t^2 = \sigma w^2 + \sigma s^2 + \sigma a^2 + \sigma c^2$,

then: $\sigma w^2/\sigma t^2$; $\sigma s^2/\sigma t^2$; $\sigma a^2/\sigma t^2$; and $\sigma c^2/\sigma t^2$.

TABLE 24

MEAN VALUES OF THE MILK CONSTITUENTS OF DIFFERENT GROUPS OF EWES OF DIFFERENT AGES WITHIN DIFFERENT GROUPS

Crosses	Age	No. of Ewes	Mean of Suckling	Potassium mg/100 gm Milk	Lactose gm/100 gm. Milk	K/Lactose Ratio	Sodium mg/100gm Milk	Total Solids gm/100 gm/Milk
BL X BF	2	9	1.44	123.11	4.95	24.87	32.89	16.68
				113.78	4.50	25.19	36.89	18.08
	3	7	1.57	100.57	4.93	20.77	33.71	16.81
				103.43	4.49	23.81	38.29	17.94
FX BF	2	15	1.93	116.53	4.63	25.34	33.87	16.05
				112.00	4.44	25.25	38.93	17.09
	3	14	1.86	106.57	4.95	21.60	33.71	17.00
				109.43	4.69	23.24	38.00	18.50
M X BF	2	13	1.08	117.85	4.64	25.26	31.38	16.52
				116.92	4.72	24.90	36.31	17.75
	3	18	1.17	126.89	4.66	27.09	33.11	16.11
				130.22	4.62	28.17	37.11	17.48
C X BF	2	14	1.43	113.86	4.87	23.27	35.71	16.81
				109.43	4.66	23.63	38.00	18.17
	3	12	1.75	123.33	4.67	26.76	32.33	16.06
				119.67	4.58	26.25	36.33	17.43
D X BF	2	14	1.36	131.43	4.90	27.03	33.71	16.15
				127.14	4.82	26.62	37.43	17.36
	3	14	1.50	127.43	4.84	26.50	34.86	15.56
				124.71	4.70	26.71	39.14	16.69

TABLE 25

MEAN VALUES OF THE MILK CONSTITUENTS IN DIFFERENT GROUPS OF EWES OF DIFFERENT SIRES WITHIN AGES AND CROSSES

Crosses	Age in Years	Sire	No. of Animals	No. Lambs Suckling	k	lac-tose	Ratio	Na	T.S.
BL X BF	2	1	7	1.57	123.86	5.00	24.57	31.43	16.97
					108.57	4.48	24.36	36.00	18.61
	2	2	2	1.00	124.00	4.78	25.90	38.00	15.73
					132.00	4.59	28.10	40.00	16.55
	3	3	7	1.57	100.57	4.93	20.77	33.71	16.81
					103.43	4.49	23.81	38.29	17.94
F X BF	2	4	6	1.83	116.00	4.59	25.38	31.33	15.73
					112.27	4.62	24.38	40.00	16.55
	2	5	9	2.00	116.00	4.65	25.31	35.56	16.26
					111.56	4.32	25.83	38.22	17.46
	3	6	8	1.88	105.00	5.07	20.79	34.50	17.35
					108.50	4.74	22.73	38.50	18.98
	3	7	6	1.83	108.67	4.80	22.68	32.67	16.53
					110.67	4.62	23.93	37.33	17.90
M X BF	2	8	10	1.00	135.60	4.67	28.85	32.80	16.49
					137.20	4.67	29.26	37.20	17.75
	2	9	8	1.38	116.00	4.66	29.90	33.50	15.64
					121.50	4.56	26.80	37.00	17.15
	3	10	6	1.00	117.33	4.48	25.75	31.33	16.52
					114.00	4.56	25.15	36.67	17.85
	3	11	7	1.14	118.29	4.78	24.84	31.43	16.51
					119.43	4.86	24.69	36.00	17.66
C X BF	2	12	8	1.75	125.00	4.69	27.31	31.50	16.18
					123.50	4.62	26.95	35.50	17.35
	2	13	4	1.75	120.00	4.65	25.65	34.00	15.83
					112.00	4.50	24.85	38.00	17.58
	3	14	7	1.57	109.43	4.83	22.39	37.14	16.83
					100.00	4.59	22.04	38.29	18.50
	4	15	7	1.29	118.29	4.91	24.16	34.29	16.79
					118.86	4.73	25.21	37.71	17.84
D X BF	2	16	6	1.50	131.33	4.90	27.12	33.33	16.10
					128.67	4.91	26.43	37.33	17.45
	2	17	8	1.25	131.50	4.90	26.96	34.00	16.19
					126.00	4.77	26.80	37.50	17.30
	3	18	9	1.44	136.44	4.77	28.72	34.67	15.43
					134.89	4.61	29.27	39.11	16.66
	3	19	5	1.60	111.20	4.96	22.50	35.20	15.78
					106.40	4.87	22.10	39.20	16.76
Means of 2/3 Groups		19	130	1.49	119.18	4.79	24.98	33.70	16.29
					117.36	4.64	25.41	37.78	17.55
Total Average of Animals			130	1.50	119.74	4.79	25.11	33.57	16.33
					117.83	4.63	25.55	37.66	17.61

TABLE 26

ANALYSIS OF VARIANCE OF THE DATA OBTAINED IN EXPERIMENT C

Source of Variances	d.f.	Potassium	Lactose	K/Lactose Ratio	Sodium	Total Solids
A. Corrected M.S.						
Between crosses	4	287500	2184.0	10067.5	27384.0	6095.0
" ages within crosses	5	119651	3176.0	17961.8	29807.0	6981.8
Between sires/ ages & crosses	9	108011	1645.0	5378.8	18878.0	2957.7
Between sheep/ sires/ages & crosses	111	24132	1694.0	11835.4	21435.0	3305.6
B. F Values						
	F^4_5	2.66	<1	1.26	<1	<1
	F^5_9	1.10	1.99	1.48	1.57	2.36'
	F^4_{111}	11.91^{++}	1.28	5.48**	1.27	1.84
	F^5_{111}	4.95^{++}	1.87	4.33^{++}	1.39	2.11
	F^9_{111}	44.47^{++}	<1	2.93^{++}	<1	≤1

$^{++}$Significant at >1% level.

TABLE 27

THE GENERAL SCHEME OF ANALYSIS OF VARIANCE OF EXPERIMENT C

Source of Variation	Degrees of Freedom	Expected (M.S.)
Crosses	C - 1	$\sigma w^2 + k_4\sigma s^2 + k_5\sigma a^2 + k_6\sigma c^2$
Ages/crosses	$\Sigma iai - C$	$\sigma w^2 + k_2\sigma s^2 + k_3\sigma a^2$
Sires/ages/crosses	$\Sigma i\Sigma csij - ai$	$\sigma w^2 + k_1\sigma s^2$
Within sheep "error"	$n - \Sigma i\Sigma csij$	σw^2

Notes: c is the number of crosses.
ai is the number of ages in i^{th} cross.
sij is the number of sires considered in j^{th} year of ith cross.
σw^2, σs^2, σa^2, and σc^2 are the components of variance according to "error," sires, ages, and crosses resp.
k values were calculated as described by King & Henderson (1954).

The results of the percentage of contribution of these factors to the total variance of the milk constituents studied are given in Table 28. Half of the variance in potassium content, 70% of the variance in the potassium to lactose ratio, and most of the variance in lactose, sodium, and total solids contents of the milk samples used in this experiment were due to differences between the individual ewes. These differences, as previously mentioned in Experiment B,

TABLE 28

PERCENTAGE OF CONTRIBUTION OF SOME FACTORS TO THE TOTAL VARIANCE OF THE MILK CONSTITUENTS IN EXPERIMENT C

Character	Potassium	Lactose	K/Lactose Ratio	Sodium	Total Solids
Source of variation:					
Crosses	13.47	-----	3.11	-----	-----
Ages/crosses	5.83	6.25	6.41	2.90	7.83
Sires/ages/crosses	28.23	-----	20.83	-----	-----
Within sheep "error"	52.47	93.75	69.64	97.10	92.17

includes genetical and permanent environmental factors. The differences between the crosses have a considerable effect on the variation between the individual ewes in the potassium and potassium to lactose ratio only. The different ages within crosses have a fairly small effect on the variation between the individual ewes in these milk constituents. This may be due to the small difference between the ewes used in this experiment; all were in their third and fourth year of age. The differences between sires within ages and crosses have a fairly large effect on the variations in the potassium content and potassium to lactose ratio, but this source of variance has no effect on the other constituents. This indicates that both potassium content and the potassium to lactose ratio are inherited to a greater extent than the other constituents studied.

<u>The repeatability of the Milk Constituents Studied in Experiment C</u>

The repeatability of potassium, lactose, sodium, total solids, and the potassium to lactose ratio of the milk samples studied in this experiment is given in Table 29.

TABLE 29

THE REPEATABILITY OF THE MILK CONSTITUENTS STUDIED IN EXPERIMENT C

Source of Variance	d.f.	Potassium	Lactose	K/Lactose Ratio	Sodium	Total Solids
Between sheep	129	141852.9	1763.6	2575.3	21765.5	3510.3
Within sheep "error"	129	14629.1	896.3	765.2	4522.8	239.9
Repeatability		0.4465	0.3266	0.5418	0.6559	0.8720

From these results it seems that total solids is more highly repeatable than the other constituents, but anyhow it indicates that there are certain genetic influences on all the constituents studied in this experiment.

The phenotypic correlations between the Milk Constituents

Table 30 gives the correlations between the milk constituents studied in this experiment.

TABLE 30

THE CORRELATIONS BETWEEN THE MILK CONSTITUENTS

	Potassium	Lactose	K/Lactose Ratio	Sodium
Lactose	-0.045			
K/Lactose ratio	-0.778++	-0.323++		
Sodium	-0.205+	+0.037	-0.189+	
Total solids	-0.104	-0.031	-0.078	-0.047

Notes: + = significant at 5% level.
++ = significant at 1% level.

The total solids content were negatively and not significantly correlated with any of the milk constituents studied. The correlation between potassium and lactose was not significant and indicates that the contents of lactose and potassium in ewe's milk vary independently from each other at least at this stage of lactation. Potassium was correlated with sodium at the 5% level. Lactose was not correlated with the sodium content indicating that lactose and sodium contents in these samples vary independently of each other. Finally there was a high correlation between the potassium and lactose contents on the one hand and the potassium to lactose ratio on the other.

The Effect of Number of Lambs Suckling the Ewe

The ewes used in this experiment were divided into two groups, one group which had only one lamb and the other with two lambs suckling. The number of lambs suckling significantly decreases the potassium and the potassium to lactose ratio, but the effect on the other constituents was not consistent. Thus the effect on lactose was significant at 1% level in the 3rd week samples and not significant in the 6th week samples. There was no significant difference between the two groups of ewes in the contents of total solids.

Table 31 gives the "P" values of the differences between the two groups of animals in the milk constituents studied.

Blood Characters and Its Correlation with the Milk Constituents

The results of the blood analysis of the ewes used in this experiment, packed cell volume (PCV), potassium in

TABLE 31

"P" VALUES OF THE DIFFERENCES IN THE MILK CONSTITUENTS BETWEEN THE TWO GROUPS OF ANIMALS (1 LAMB OR 2 LAMBS SUCKLING)

Constituents	3rd Week Samples	6th Week Samples
Potassium	-2.6686^{++}	-3.0143^{++}
Lactose	$+2.0574^{++}$	-0.3769
K/Lactose ratio	-3.0025^{++}	-2.6178^{++}
Sodium	+0.5143	$+0.9841^{+}$
Total solids	-0.2809	-0.3763

Notes: + = significant at 5% level.
++ = significant at 1% level.

whole packed cell volume (KWPC), potassium and sodium in whole blood, potassium phenotypes and haemoglobin phenotypes are given in the Appendix Tables 22, 23, 24, 25, and 26. Sheep used in this experiment may be classified into two distinct types according to the potassium and sodium concentrations in their blood. In one type the potassium concentration is relatively high (about 30.1 m.eq/L) and the sodium concentration correspondingly low about (99.8 m.eg/L). Whereas in the other type the potassium concentration is relatively low (about 11.1 m.eq/L) and the sodium concentration correspondingly high (about 110.5 m.eq/L).

The two types of animals have been called Hk and Lk respectively. Fifty-five ewes were of Hk type and 75 were of Lk type (Fig. 11).

Table 32 indicates that although the potassium and sodium concentrations in the blood of the two types are different they produced milk containing similar concentrations of potassium and sodium.

TABLE 32

MEAN VALUES OF THE BLOOD ANALYSIS AND THE CORRESPONDING VALUES OF POTASSIUM AND SODIUM IN THE MILK

Cross	Blood (k) Type	No. of Animals	Hoematocrit (PCV)%	Potassium in WPC	Sodium in Whole Blood	Potassium Whole Blood	Sodium in Milk	Potassium in Milk
				m.eq/L	m.eq/L	m.eq/L	mg/100 g milk	
BL X BF	Hk	5	33.3	54.0	98.1	29.8	35.6	110.8
	Lk	11	34.6	14.3	111.6	10.8	35.5	111.1
FX BF	Hk	11	31.9	64.1	101.4	31.2	36.9	106.5
	Lk	18	31.4	15.1	110.3	10.8	95.7	114.1
M X BF	Hk	11	32.7	63.1	100.4	30.4	33.8	125.8
	Lk	20	33.6	15.5	113.7	11.3	35.0	122.8
C X BF	Hk	9	32.9	56.1	101.0	28.9	35.4	114.0
	Lk	17	33.5	15.8	106.9	11.3	35.8	118.1
D X BF	Hk	18	33.1	61.1	98.3	30.2	36.3	125.8
	Lk	10	34.0	14.6	109.9	11.1	36.4	129.1
Groups	Hk	55	32.8	59.7	99.8	30.1	35.6	116.6
Mean	Lk	75	33.4	15.1	110.5	11.1	35.7	119.0

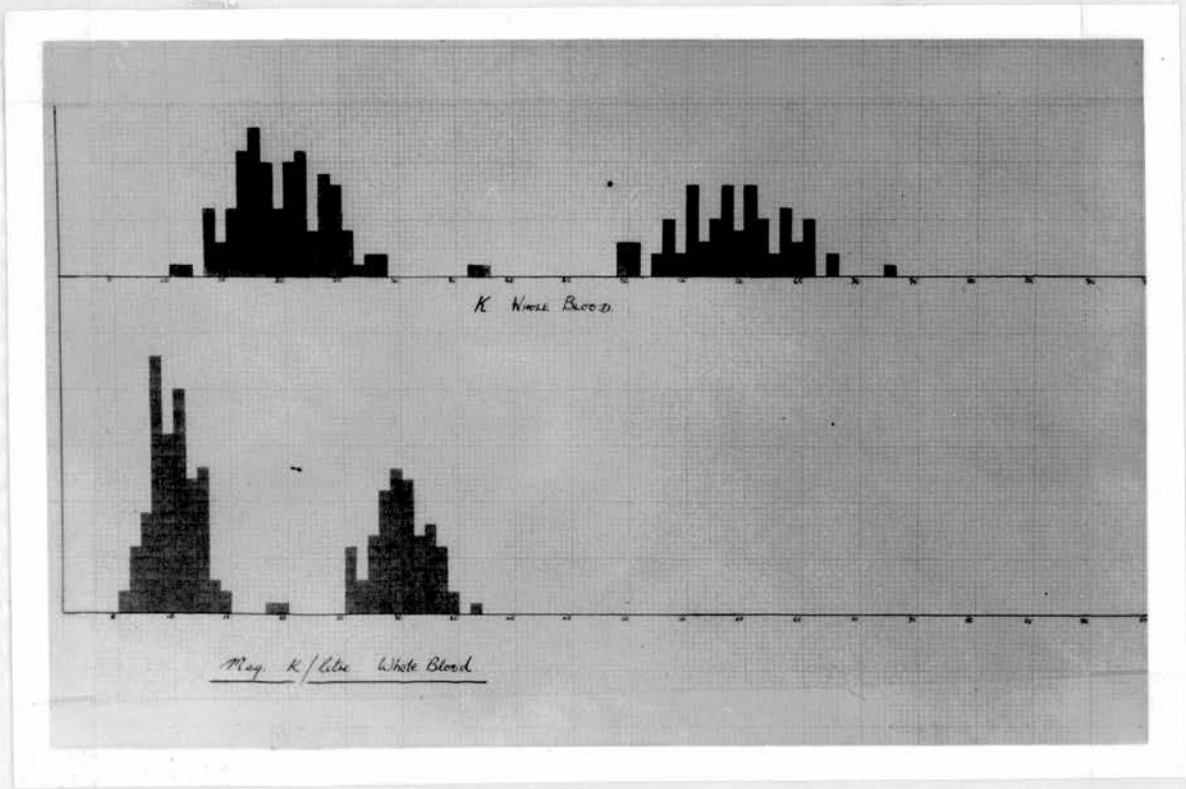


Fig.11.

Potassium contents of whole blood of ewes used in Exp.C.

The correlations between the blood characters and the milk constituents studied are given in Table 33. The results

TABLE 33

THE CORRELATIONS BETWEEN THE MILK AND BLOOD CONSTITUENTS

Milk Constituents	Week of Lactation	Blood			
		PCV	KWPC	Na in Whole Blood	K in Whole Blood
Potassium	3	-0.166	0.059	-0.017	0.055
	6	-0.121	0.021	-0.033	-0.024
Lactose	3	0.129	0.015	0.001	0.040
	6	0.171[x]	-0.105	0.059	0.045
K/Lactose Ratio	3	-0.205[x]	0.041	-0.030	0.024
	6	-0.185[x]	0.069	-0.061	00.001
Sodium	3	0.165	0.081	-0.112	0.138
	6	0.153	0.050	-0.098	0.099
Total Solids	3	-0.024	-0.005	0.076	0.001
	6	-0.041	0.069	0.054	0.0749

[x]Significant at 5% level.

indicate that potassium in whole packed cells and sodium and potassium in whole blood are not correlated with any of the milk constituents studied. The lack of correlation may suggest that the levels of potassium and sodium in the two fluids--blood and milk--are independent of each other and it may be that the mammary gland has a selective action in regard to some minerals among them potassium and sodium. It also indicates that the genes responsible for the blood potassium levels have no effect on the milk potassium, and that potassium in milk is subjected to a different group of genes. The only significant correlation was that between the potassium to lactose ratio in milk and the packed cell volumes. There was also a doubtful correlation between the lactose in milk and the packed cell volume.

The sheep may be classified again according to their haemaglobin types into haemoglobin A, AB, and B types. The distribution of these types in regard to the packed cell volume and the potassium in whole packed cells are shown in Figs. 12 and 13. Table 34 gives the mean values for blood characteristics, namely packed cell volume, potassium in whole packed cells, and potassium and sodium in whole blood on the one hand and the milk potassium, sodium, and potassium to lactose ratio on the other, in the different haemoglobin types.

Table 34 indicates that the milk of sheep of haemoglobin A or B type is similar in potassium content and potassium to lactose ratio although the milk of sheep of

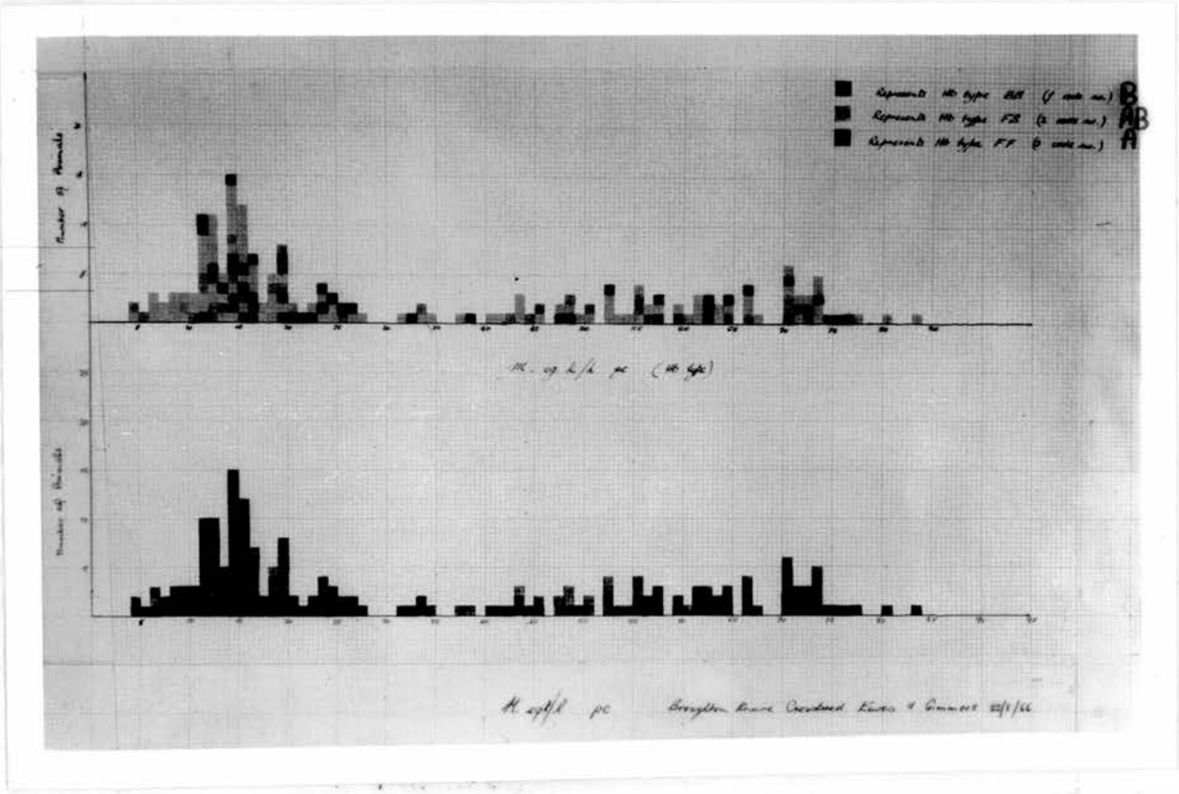


Fig. 12.

Haemoglobin types of ewes used in Exp. C. distributed in the potassium levels.

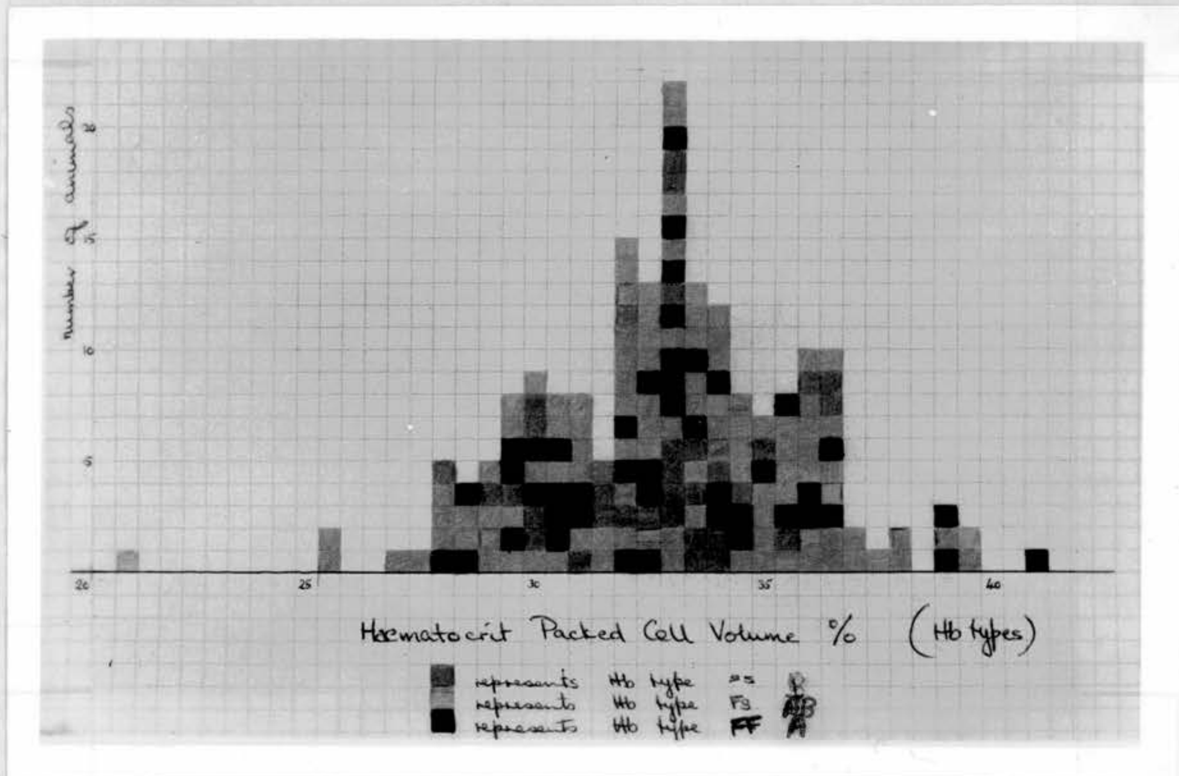


Fig. 13.

Haemoglobin types of ewes used in Exp. C. distributed in the packed cell volumes.

haemoglobin AB contains more potassium and has a higher potassium to lactose ratio than the milk of the other two types.

TABLE 34

THE MEAN VALUES OF BLOOD CHARACTERS AND MILK CONSTITUENTS IN DIFFERENT HAEMOGLOBIN TYPES

Haemo-globin Type	No. of Ewes	PCV %	KWPC m.eq/L	k in whole blood m.eq/L	Na in whole blood m.eq/L	k/Lactose Ratio in milk	k in Milk mg/100 gm milk	Na in Milk
A	27	32.7	38.1	20.7	104.8	24.5	114.1	35.5
AB	73	32.9	37.2	20.7	105.0	25.8	121.2	35.9
B	30	34.5	36.3	19.6	108.0	23.6	112.0	36.9

Table 35 gives the "P" values of the differences in the milk constituents studied between the groups of animals (haemoglobin A and B). It indicates that there are no differences between both types of animals except for sodium content which appears, from Table 34, to be higher in the milk of the animals of haemoglobin B type.

Table 36 gives the "P" values of the differences in the milk constituents studied between the animals homozygotous for haemoglobin A and B on one hand, and on the other hand the animals heterozygous for haemoglobin AB.

TABLE 35

"P" VALUES OF THE DIFFERENCES IN THE MILK CONSTITUENTS STUDIED BETWEEN THE TWO GROUPS OF ANIMALS OF HAEMOGLOBIN A&B

	3rd Week Samples	6th Week Samples
Potassium	+0.4710	-0.2545
Lactose	+0.3386	-0.0948
K/Lactose ratio	+0.5737	-0.2196
Sodium	+0.9808+	-0.9362+
Total solids	0.0971	-0.4348

+Significant at 5% level.

TABLE 36

"P" VALUES OF THE DIFFERENCES IN THE MILK CONSTITUENTS STUDIED BETWEEN THE ANIMALS OF HOMOZYGOTES GENES OF HAEMOGLOBIN A AND B ON THE ONE HAND, AND THE HETEROZYGOTES GENES OF HAEMOGLOBIN AB ON THE OTHER

	3rd Week Samples	6th Week Samples
Potassium	+1.5983+	+2.0833++
Lactose	-0.0849	-0.1664
K/Lactose ratio	+1.2967+	+2.1423++
Sodium	+1.2381+	+0.3016
Total solids	-1.3644+	-1.0036+

+Significant at 5% level; ++significant at 1% level.

These values indicate that there is more milk potassium and a higher potassium to lactose ratio but less total solids in the heterozygotes group than the homozygotes group. The lactose contents were similar in the different types of animals and sodium concentrations were higher in the group of animals carrying haemoglobin B only.

These results suggest that the milk constituents studied in this investigation are independent in their inheritance of the effect of homozygotes genes of haemoglobin A or B, but the presences of AB haemoglobin could effect some of the milk compositions as described above.

Discussion

The mean values of the milk constituents obtained in this experiment are in good agreement with the mean values of the same constituents obtained in Experiment B. As in Experiment B the mean values of lactose and potassium to lactose ratio are different from the mean values of both characters obtained in Experiment A. This difference might be due to breed differences or to the fact that the animals used in Experiment A were under different husbandry regime than the regime used in experiments B and C. In the first experiment the animals were kept indoors and received concentrated foods but in the other two experiments the animals were out of doors on grass and received less concentrates.

The components of variance of the milk constituents obtained in this experiment agree reasonably well with the components of variance of the same milk constituents in the previous experiment. Half of the variance of the potassium contents in both experiments was due to differences between the individual ewes. The differences in the ages of the ewes had a considerably greater effect on the variation of sodium contents in Experiment B than in Experiment C and this may be due to the fact that the age differences between the ewes used in Experiment C were small (one year). There is agreement in both experiments B and C regarding the source of variations in the levels of lactose, total solids, and the potassium to lactose ratio. The repeatabilities obtained in both experiments are in close agreement with regard to the total solids, potassium, lactose, and potassium to lactose ratio. Sodium was more highly repeatable in Experiment C than in Experiment B.

Although a correlation has been found in Experiment C between potassium and sodium contents, this correlation is very small and less than that usually found in cow's milk. These phenotypic correlations indicate that the milk constituents studied in this experiment vary independently from each other.

There is a difference between the effect of the number of lambs suckled on the milk constituents observed in this experiment and the effect observed in the previous experiment. It may therefore be that the number of lambs suckled has no consistent effect on the milk constituents studied. It could be due to the better treatment of ewes with twin lambs or to the more frequent emptying of the udder, or it may be that other environmental factors such as health of the animal, size of the mammary gland, or metabolic factors could have additive influences on the milk constituents.

Finally, it has been proved by many workers (see the review of sheep's blood) that sheep may be classified into two types according to the potassium and sodium concentrations in their blood. In one type, the potassium concentration is high and the corresponding value for sodium is low; this type is called Hk. In the other type the potassium concentration is low and the corresponding value for sodium is high; this type is called Lk. The two types of blood potassium are inherited and controlled by a pair of genes Hk and Lk with Lk being dominant over the Hk gene. This difference in sheep's blood affords a good basis to show whether the potassium in milk is inherited by the same genes as that of blood or not. The results obtained certainly indicated that both types of sheep have only one level of potassium in their milk and suggest that the potassium and sodium in milk are inherited by different groups of genes, and that the mammary gland acts in a selective manner towards both elements, or it may be that the genes of Hk and Lk have some effect on the membrane of the red cells in blood and allow certain concentrations of potassium and sodium in the blood plasma which go to the mammary gland. The latter suggestion is more probable than the first one as it is known that the blood plasma in sheep has one level of potassium and sodium although the red cells may be Hk or Lk in type.

The haemoglobin types which also are inherited appear to be independent in their inheritance from the inheritance of the milk constituents studied, but the presences of AB haemoglobin increased the potassium and potassium to lactose ratio in the milk and the presence of B haemoglobin increased the sodium concentrations. These results suggest that more work is needed to study the correlation between the different haemoglobin types and the constituents of great economic importance in milk such as fat and proteins. It also suggests that the possibility of improving the levels of the milk constituents studied by looking into the blood potassium types is not worth while.

GENERAL DISCUSSION

In Experiments A, B, and C the genetic effects on potassium, lactose, sodium, total solids, and the potassium to lactose ratio of ewe's milk were studied. It has been found that these characters are repeatable in different experiments and different breeds and crosses. The effects of breeds and crosses, age of the ewe, sire of the ewe, number of lambs suckled from the ewe, stage of lactation, the existence of two different types of whole blood potassium--Hk and Lk--and the existence of different types of haemoglobin were studied in relation to their effects on the variations in the above milk constituents. The possibility of using the potassium to lactose ratio in predicting a potential lactose content of ewe's milk as in cow's milk will be discussed.

The Genetic Basis of the Ewe's Milk Constituents Studied

As previously mentioned one of the most important statistics in the analysis of milk production is the correlation between performance at different times or different stages of lactation of the same animal. This correlation is often given the name of "Intra-class correlation or Repeatability." The repeatability in this case measures the proportion of the variation between animals within herds which is common to the samples concerned and therefore includes all hereditary differences which effect both samples or stage of lactation. This value of repeatability expresses the upper limits of the herditability of the character. The repeatabilities obtained for the milk constituents studied in this investigation are given in Table 37.

TABLE 37

THE REPEATABILITIES OF THE MILK CONSTITUENTS STUDIED IN EXPERIMENTS B AND C

Constituent	Repeatability in Experiment B	Repeatability in Experiment C
Potassium	0.35	0.45
Lactose	0.56	0.33
K/Lactose ratio	0.60	0.54
Sodium	0.32	0.66
Total solids	0.86	0.87

The particular value obtained for repeatability in an investigation is clearly dependent on the degree of environmental uniformity achieved in the study. This may have been the cause of obtaining a different repeatability for sodium and lactose in both experiments. The only repeatabilities found in the literature on ewe's milk were reported by Dassat and Sartore (1962). They gave values of 0.63, 0.61, and 0.81 for fat, protein, and solids-not-fat respectively.

Source of Variations of the Ewe's Milk Constituents Studied in this Investigation

1. Breeds and Crosses

There is noticeable a significant variation at 1% between the crosses in both potassium and potassium to lactose ratio in Experiment C. Table 38 gives the mean values for potassium, lactose, sodium, total solids, and the potassium to lactose ratio of all breeds and crosses studied in the previous experiments.

A. Potassium Content:

The highest level of potassium was obtained for the Suffolk ewe's milk followed by D X BF, Clun, F X D, M X BF, Dorset, C X BF, and F X BF; the lowest value was obtained from BL X BF ewe's milk. These results are in close agreement with the potassium results obtained from New Zealand

TABLE 38

MEAN VALUES FOR EWE'S MILK CONSTITUENTS OF THE BREEDS AND CROSSES STUDIED IN SECTION TWO

Experiment	Breed or Cross	No. of Ewes	Potassium mg/100 gm	Lactose gm/100 gm	K/Lactose Ratio	Sodium mg/100 gm	Total Solids gm/100 gm
A	Dorset	11	123.5	5.21	23.7	32.9	17.1
	F X D	24	124.5	5.23	23.3	34.7	17.5
B	Clun	96	127.0	4.81	26.6	34.2	17.1
	Suffolk	11	130.5	4.75	27.2	34.2	16.3
C	BL X BF	16	111.0	4.72	23.9	35.4	17.4
	F X BF	29	111.5	4.67	23.9	35.4	17.2
	M X BF	31	124.0	4.65	26.6	34.6	17.0
	C X BF	26	116.0	4.71	24.9	35.7	17.2
	D X BF	28	127.5	4.82	26.7	36.3	16.5

Notes: 1--These values represent the mean of the 3rd and 6th weeks samples.
2--Dorset is the Dorset Horn breed.
3--F X D is Finnish X Dorset Ham cross.
4--Clun is Clun Forest breed.
5--BL X BF is Border Leicister X Black face cross.
6--F X BF is Finnish X Black face cross.
7--M X BF is Merino X Black face cross.
8--C X BF is Clun Forest X Black face cross.
9--D X BF is Dorset Ham X Black face cross.

by Perrin (1958). She reported values of 124 and 121 mg/100 gm of milk for ewes on high and low planes of nutrition respectively. Godden & Puddy (1935) reported a value of 126 mg/100 gm of milk for the Cheviot ewes. Sartore (1959) obtained a value of 119 mg/100 gm of milk for Sardinian ewe's milk in mid-lactation. Other values ranging from 80 to 190 mgk/100 gm of milk were reported by other investigators including Abderhalden (1908), Königs (1920), Morrison (1951), Charton, Faye, Harry, Bernard & Bueslin (1962), and Ashton & Yousef (1966). These values can be accepted as reasonable mean values for the potassium concentrations in the milk of the ewes with regard to the breed studied, age of the ewe, and stage of lactation which, from the results of this investigation definitely have an affect on the potassium concentration of ewe's milk. Differences in the methods of analysis used by different investigators might have affected the results obtained to some extent.

B. Lactose Content:

There is only a small variation in the lactose contents of the different groups of animals studied in this section with the exception of the results obtained from the Dorset and F X D ewes, which have higher values for lactose than the other breeds and crosses. The difference between the Dorset, F X D ewes and the remaining groups may have occurred as a result of different lambing seasons and feeding systems. Dorset and F X D ewes were lambed before the normal lambing season, kept indoors during the lactation and received concentrated foods. Burt (1957) obtained an increase in solids-not-fat percent when additional concentrates amounting to 25% more than the production requirement were given to cows on a basal diet of hay.

The results obtained for lactose contents except in Dorset and F X D ewes, show fairly close agreement with the results obtained by other investigators including Neidig & Iddings (1919), Peirce (1934), Godden & Puddy (1935), Barnicoat et al. (1949), and Ashton, Owen & Ingleton (1964). They obtained values of 4.7, 4.7, 4.8, 4.4, and 4.7 percent respectively. Perrin (1958) obtained comparatively low figures for lactose of 4.0 and 4.1, but it is interesting to note that her figure for chloride is correspondingly high, which may indicate some udder infections. From all these figures it is conceivable that the breed has no effect on the lactose content of ewe's milk. In Experiment C there were no significant differences between the different crosses in lactose content.

C. Sodium Content:

There is little variation between the sodium concentration found in the milk of different breeds and crosses used in this study. However, in the few results published in the literature, there is a wide variation in the sodium level quoted for ewe's milk. These sources include, Abderhalden (1908), Königs (1920), Godden & Puddy (1935), Perrin (1958), Charton et al. (1962), and Ashton & Yousef (1966). They obtained values of 64, 30, 50, 48, 38, 34, & 36 and 46 mg/100 gm of milk respectively. Sartore (1959) reported a value of 36 mg Na/100 gm of milk in mid-lactation, which is in close agreement with the results of the samples obtained in the 6th week after lambing in this investigation.

There were no significant differences between the different crosses used in Experiment C. Thus the variations in the results of sodium content in the published literatures may be due to differences in the ages of the animals. Experiment B shows that age is an effective source of variance in the sodium content of ewe's milk. It may also be due to the plane of nutrition and Charton et al. (1962) reported that the sodium level of ewe's milk was affected by feeding. It could also be due to the stage of lactation as it is very clear from Experiment A that it effects the sodium content. The difficulty involved in the past in the determination of sodium in biological material such as milk could also influence these results.

D. Total Solids Content:

The total solids contents are approximately similar in the different groups of ewe's studied in this investigation and range from 16.3 to 17.5 gm/100 gm of milk. These values are in close agreement with the results of Peirce, (1934), 18.9; Bonsma (1939), 16.6; Barnicoat, 16.3 and Ashton, Owen & Ingleton (1964), 16.9. With regard to the different breeds and crosses, ages of the ewes used in this investigation and in the previous literature, it is conceivable that breeds, crosses, and ages have a very little effect on the variation in the total solids contents of ewe's milk. Some higher values for total solids such as 23.0 mg/100 gm of milk have been reported by Perrin (1958) when a high plane of nutrition was introduced into the husbandry regime of the ewes.

E. The Potassium to Lactose Ratio:

The highest value was obtained for the Suffolk ewes and the lowest for the BL X BF ewes, with the exception of the pre-lambing season groups which gave a lower ratio as a result of higher values of lactose. There is a significant difference between the different crosses used in the potassium to lactose ratio.

It is interesting to note that this ratio in the results of Perrin (1958) was high, namely 31.0 and 29.5 and, as previously mentioned, that she gave low figures for lactose of 4.0 and 4.1 gm/100 gm of milk and a high figure for chlorine which may indicate the presence of some udder infection.

2. Stage of Lactation

Table 39 summarizes the effect of the stage of lactation on the milk constituents studied in this investigation.

TABLE 39

MEAN VALUES FOR POTASSIUM, LACTOSE, SODIUM, TOTAL SOLIDS AND POTASSIUM TO LACTOSE RATIO OF EWE'S MILK DURING THE STAGE OF LACTATION

Constituents	Weeks After Lambing								
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th
Potassium	162	134	126	115	116	123	123	123	130
Lactose	4.84	5.16	5.36	5.34	5.41	5.11	5.11	5.35	5.22
Sodium	23.4	27.1	32.0	32.9	35.9	36.2	41.8	45.8	49.2
Total Solids	16.6	17.1	16.6	17.1	17.9	18.1	18.5	19.1	18.6
K/Lactose ratio	34.5	26.3	23.8	21.5	21.7	21.7	22.9	24.5	25.1

Note: Potassium and sodium contents as mg/100 g, Lactose, and total solids as gm/100 gm.

The potassium decreased in the first two weeks and was reasonably constant up to the 8th week when it increased again. The same trend was reported by Sartore,(1959) when he studied the sodium and potassium contents of Sardinian sheep's milk during the lactation period. His results indicated that potassium was high at the beginning of the lactation, decreased in the middle, and increased again at the end. Ashton & Yousef (1966) reported that the potassium contents in Clun Forest ewe's milk decreased continuously during the lactation period but the decrease in mid-lactation was much smaller than the decrease at the beginning or the end of the lactation. Rook & Wood (1959) showed that the potassium content of cows' milk was constant in the milk of individual animals through the first four to five months of lactation, even during the period of transition from colostrum to normal milk when changes in other constituents were large. It seems that sheep's milk differs from cows' milk in the effect of stage of lactation on the potassium content. In sheep's milk the potassium content sharply decreased in the first two weeks after lambing. Both milks are in a close agreement in that there is a constant level of potassium in the first half of the lactation period.

The lactose content increased during the first two weeks of lactation and apparently was constant up to the 9th week. Ashton, Owen & Ingleton (1964) reported a constant value of lactose in three different groups of Clun Forest ewes from the beginning of the third week after lambing up to the 9th week, but they did not give any information about the first two weeks of lactation. The lactose trend in cow's milk reported by Rook & Wood (1959) is in close agreement with the above trend in ewes' milk. They found that lactose contents of cows' milk showed marked increases during the first two to three weeks of lactation, but in the succeeding three to four months the values for each animal showed a constancy similar to that observed with potassium.

The sodium content was increased continuously during the lactation. The period between the 3rd and the 6th week after lambing was less variable in the sodium concentration than any other period of the lactation. The same trend was reported by Ashton & Yousef (1966). They found that the sodium content of Clun ewe's milk was constantly increasing during the whole period of lactation. The steady increase in sodium with advancing lactation is characteristic of cow's milk (Ling, 1956).

The total solids seems to have no pronounced trend during the lactation period, but the period from the 3rd to the 6th week of lactation is less variable than the early or late periods. The same trend for the total solids was reported by Ashton, Owen & Ingleton (1964) and Perrin (1958).

The potassium to lactose ratio decreased during the first two weeks and was apparently constant up to the end of the 9th week after lambing. Fairly similar results could be obtained from the figures of lactose and potassium of ewe's milk given by Perrin (1958); from these figures the potassium to lactose ratio in the two groups of animals used by her are as follows:

Days of Lactation	1st Group High Plane of Nutrition	2nd Group High Plane of Nutrition
3 - 6	31.2	39.5
7 - 27	21.2	18.7
28 - 48	-----	20.5
49 - 69	25.8	23.3

Walsh & Rook (1964) found that the potassium to lactose ratio in cows' milk decreased in the first two to three weeks of lactation and was fairly constant up to the fourth or the fifth month. These results are in close agreement with the results obtained in this investigation on ewes' milk.

3. Ages of the Ewes

The ages of the ewes have a significant effect on the potassium and sodium levels in their milk. The potassium increased in the 2-year-old group, decreased in the 3- and 4-year-old groups, and increased again in the older groups. The differences between the 5- and 6-year-old group was not significant at the 5% level and there were no significant differences between these two groups and the 2-year-old group. The sodium increased very slightly in the 2-year-old group, stabilized in the 3- and 4-year-old group, and then increased in the older groups. These results are not in agreement with the results obtained by Charton, Fraye, Herry, Bernard & Gueslin (1962). They reported that age growth and lactation did not effect the variation in sodium or potassium of ewes' milk. The other milk constituents--lactose, total solids, and the potassium to lactose ratio--were not affected significantly by the age of the animal.

4. Sires of the Ewes

There were significant differences between the ewes sired by different rams in the potassium, sodium, and potassium to lactose ratio of the milk, but no such differences were obtained in the other milk constituents studied in this investigation.

5. The Individuality of the Ewes

It is conceivable that most of the variations in lactose, total solids, and sodium are due to differences between the individual ewes. These differences between the ewes are mostly genetic differences but also include some environmental factors such as the health of the animal, metabolic effects and the interactions between the genetic and environmental factors. The variations in the potassium and potassium to lactose ratio are divided into two parts. Half is due to differences between the individual ewes and the other half is divided between the effects of different sires, different crosses, different ages, and the interactions between these factors.

6. Number of Lambs Suckled from Each Ewe

There is a difference between the effect of the number of lambs suckled from the ewe, on the milk constituents, observed in Experiments B and C. It may therefore be that the number of lambs suckled from the ewe has no consistent effect on the milk constituents studied. This difference between the ewes with two lambs and the ewes with one lamb may be due to the better treatment of the ewes' with twin lambs or to the more frequent emptying of the udder, or it may be that the environmental factors such as health of the animal, size of the mammary gland, or metabolic factors could have additive influences on the milk constituents.

7. The Existence of Different Types of Potassium and Haemoglobin in the Blood

From comparisons of the results of analysis of ewes' blood and milk, it is shown that the potassium and sodium concentrations in blood have no effect on potassium and sodium concentrations in the milk. The potassium and sodium concentrations in the milk of both Hk and Lk phenotypes were the same and no correlations between these phenotypes and any of the milk constituents were obtained.

In view of the facts obtained in this study about the lack of correlation between blood and milk potassium, and sodium, the secretion of these two elements could be explained by a selective action on the part of the mammary gland.

The haemoglobin types which are inherited appear to be independent in their inheritance from the inheritance of the milk constituents studied in this investigation, but the presence of AB haemoglobin increased significantly the potassium and potassium to lactose ratio in the milk, and the presence of B homozygotes haemoglobin increased the sodium concentration. These results suggest that more work is needed to study the effect of the different haemoglobin types on the constituents of great economic importance such as fat and proteins.

The Phenotypic Correlations Between the Milk Constituents

This investigation on ewes' milk indicates that the milk constituents, namely lactose, potassium, sodium, and total solids vary independently from each other, at least in the 3rd and 6th weeks of lactation. These results certainly do not agree with the results obtained for cows' milk in this study and the results reported by Rook & Wood (1958) and Walsh & Rook (1964). In cows' milk there are highly negative correlations between lactose and potassium, lactose and sodium, and between potassium and sodium. This difference between ewes' and cows' milk ~~may be an additive characteristic of ewes' milk, and~~ suggests that the potassium to lactose ratio of ewes' milk is not of any importance and could not be used in predicting a potential value for lactose in ewes' milk as it can in cows' milk.

CONCLUSION

This study is concerned with some genetic aspects of some milk constituents of cows and ewes.

A. Cows' Milk

In this experiment 102 Ayrshire cows were used. These were composed of 10 pairs MZ, 12 pairs DZ, 19 pairs HZ, and 10 pairs U animals. The inheritance of lactose, potassium, and potassium to lactose ratio was investigated.

An analysis of variance between and within pairs of cows of each group indicated that DZ pairs were more variable than MZ pairs, and HZ pairs were more variable than MZ and DZ pairs, with regard to within-pairs variance in lactose and potassium to lactose ratio. The DZ pairs were more variable than the MZ pairs and more alike the HZ pairs with regard to the potassium contents.

Table 40 gives the components of variance as a percentage of the total variance calculated from MZ, DZ, and HZ pairs. This table indicates that potassium and potassium to lactose ratio are highly inherited and largely independent of environmental effects.

TABLE 40

COMPONENT OF VARIANCE AS PERCENTAGE OF THE TOTAL VARIANCE CALCULATED FROM MZ, DZ, AND HZ PAIRS FOR COWS' MILK CONSTITUENTS

	$\hat{e}^2$ Environmental Effects	$\hat{g}^2$ Genetic Effects h^2	$\hat{m}^2$ Maternal Effects
Lactose	2.60	41.56	55.84
Potassium	1.19	129.50	-30.69
K/Lactose ratio	1.10	85.72	13.14

The lactose and potassium inter-relationship for the milk of the animals in their first lactation and in the second to about the fifth month of lactation can be represented by the following highly significant ($P < 0.01$) regression equation:

$$Y = 6.79 - 0.00939X$$

Where Y is lactose gm/100 gm of milk water

X is potassium mg/100 gm of milk water.

The potential value for lactose content in Ayrshire cows can be obtained from the following equation:

$$\text{Potential Value of Lactose} = \frac{6.79}{1 + (0.00939)R}$$

where R is the potassium (mg/100 gm milk water) to lactose (gm/100 gm milk water) ratio.

B. Ewes' Milk

The investigation on ewes' milk included three separate experiments to examine the genetic aspects of some milk constituents, namely lactose, potassium, sodium, total solids, and potassium to lactose ratio. The first experiment was designed to study the effect of stage of lactation on the above milk constituents to establish if there was a period of lactation over which these constituents were relatively constant and so to avoid the effect of stage of lactation in the genetic studies in the following experiments. The second experiment involved the use of two different breeds with a wide range of ages and sires to study the differences in the above milk constituents between different ages of ewes and between ewes sired by different rams. In the last experiment five different crosses have been used to study the differences in the milk constituents between different crosses, between ages of ewes and between ewes sired by different rams. The second aim of this experiment was to study the correlations between milk potassium and sodium on the one hand and on the other the blood potassium types and the haemoglobin types in an attempt to investigate the secretion of both elements in ewes' milk. The effect of number of lambs suckling on the milk composition was investigated in the last two experiments.

The results obtained from the first experiment have shown that the milk constituents studied are relatively constant in the period from the 3rd week to about the 6th week after lambing. It has been found that to avoid most of the variation in these constituents due to the stage of lactation, samples should be taken within that period.

The differences between ewes in ages and sires have affected the concentrations of the potassium and sodium in the milk, but have no effect on lactose, total solids and potassium to lactose ratio in the second experiment.

The differences between crosses, ages within crosses, and sires within ages and crosses, were a source of variation between the individual ewes in the potassium and potassium to lactose ratio in the third experiment.

Most of the variation in the concentrations of lactose, sodium, and total solids was apparently due to variations between the individual ewes. This variation was due partly to genetic and partly to environmental factors and to their interactions.

The number of lambs suckling had no consistent effect on the milk constituents studied.

The repeatabilities obtained for the milk constituents studied were as follows:

Factor	Experiment B	Experiment C
Potassium	0.4465	0.3447
Lactose	0.3260	0.5614
K/Lactose ratio	0.5418	0.6049
Sodium	0.6559	0.3211
Total solids	0.8720	0.8634

The milk constituents studied--potassium, sodium, lactose, and total solids--have been shown to vary independently of each other during the 3rd to about the 6th week after lambing.

No correlation was found between the blood potassium and sodium on the one hand, and the milk potassium and sodium on the other. It is conceivable that the levels of the two characters in the two fluids are inherited by two different groups of genes.

The two different blood potassium types of ewes have given similar levels of potassium and sodium in their milk. It seems, however, that the mammary gland could act in a selective manner towards the blood potassium and sodium.

The presence of heterozygotes AB haemoglobin increases the potassium and potassium to lactose ratio in the milk, but the presence of homozygotes BB haemoglogin increases the sodium content.

Ewe's milk quality could be improved for the constituents studied by selection on a milk analysis basis, but no advantage could be obtained by looking into the blood potassium types.

Finally, the potassium to lactose ratio of ewe's milk is not of any importance and could not be used in predicting a potential value for lactose.

REFERENCES

1. Abderhalden, E. (1908)
   Textbook of physiological chemistry in thirty lectures. P. 366. 1st ed. Trans. Hall, W. T. Defren, G. New York: Wiley.

2. Armstrong, T. V. (1959)
   J. Dairy Sci., 42:1.

3. Ashton, W. M., Owen, J. B. and Ingleton, J. W. (1964)
   J. Agric. Sci. Camb., 63:85.

4. Ashton, W. M. and Yousef, I. M. K. (1966)
   J. Agric. Sci. Camb., 67:77.

5. Bailey, G. L. (1952)
   J. Dairy Res., 19:89, 102, 109 and 169.

6. Barnicoat, C. R., Logan, A. G. and Grant, A. T. (1949)
   J. Agric. Sci. Camb., 39:237.

7. Barnicoat, C. R., Marry, P. E., Roberts, E. M. and Wilson, G. S. (1957)
   J. Agric. Sci. Camb., 48:9.

8. Barry, J. M. and Rowland, S. J. (1953)
   Biochem. J., 54:575.

9. Bartlett, S. (1934)
   J. Dairy Res., 5:113.

10. Bartlett, S. and Hutton, J. B. (1959)
    Inter. Dairy Congr., 1:135.

11. Black, A. and Voris, L. (1934)
    J. Agric. Res., 48:1025

12. Blackburn, P. S. and Macadam, I. (1954)
J. Dairy Res., 21:31.

13. Blackburn, P. S., Laing, C. M. and Malcolm, J. F. (1955)
J. Dairy Res., 22:37.

14. Bonnier, G. and Hansson, A. (1948)
Heredity 2:1

15. Bonsma, F. (1939)
Publ. Univ., Pretoria, Agric., Series 1. No:48.

16. Burt, A. W. A. (1957)
Dairy Science Abstr. 19:436.
J. Dairy Res. 24:283.

17. Charton A., Faye, P., Harvy, A., Bernard, C. and Gueslin, M. (1962)
Rec. Méd., Wét, 138(8):625.

18. Cobble, J. W. and Herman, H. A. (1951)
Missouri, Agric. Expt. Sta. Res. Bull.:485.

19. Comberg, G., Andreae, U. and Meyer, H. (1962)
Z. Tier., Zücht Biol., 78(1):5.

20. Darcel, C. Le.Q and Avery, R. J. (1960)
Canad. J. Comp. Med., 24:27.

21. Dassat, P. and Sartore, G. (1962)
Atti, Ass., Genet., ital., 7:136.

22. Dassat, P. and Bernoco, D. (1965)
Atti, Soc. ital. Sci., Vet., 19:195.

23. Dassat, P. and Bernoco, D. (1966)
Atti, Ass., Genet., ital., 11:210.

24. Davis, R. N., Harland, F. G., Gaster, A. B. and Kellner, R. H. (1947)
J. Dairy Sci., 30:425.

25. Davis, J. G. and MacDonald, J. F. (1952)
Richmonds Dairy Chemistry, 5th ed., Charles Griffin & Co. London.

26. Donald, H. P. (1953)
J. Dairy Res., 20:355.

27. Donald, H. P. (1959)
X Int. Congr. Genetics (Montreal 1958), 1:225.

28. Dijkstra, N. D. (1958)
Verslag. Landbouwk. onderzoek. Minist. Landbouwk. S. Grav., 64:2.

29. Dijkstra, N. D. (1959)
Verslag. Landbouwk. onderzoek. Minist. Landbouwk. S. Grav., 65:14.

30. El. Sokkary, A. M., Sirry, I. and Hassen, H. A. (1949)
J. Agric. Sci. Camb., 39:287.

31. Evans, J. V. (1954)
Nature (London), 174:931.

32. Evans, J. V. and King, J. W. B. (1955)
Nature (London), 176:171.

33. Evans, J. V., King, J. W. B., Cohaen, B. L., Harris, H. and Warren, F. L. (1956)
Nature (London), 178:849.

34. Evans, J. V., Harris, H. and Warren, F. L. (1957)
Biochem, J., 65:92.

35. Evans, J. V., Harris and Warren, F. L. (1958)
Nature (London), 182:320.

36. Evans, J. V., Harris and Warren, F. L. (1958)
Proc. Roy. Soc. B., 149:249.

37. Evans, J. V. (1961)
Aust. J. Biol. Sci., 14:247.

38. Folley, S. J., Watson, H. M. S. and Bottomely, A. C. (1941)
J. Dairy Res., 12:1.

39. Folley, S. J. (1949)
Biochemical Aspects of Mammary gland function. Biol. Revs. Camb. Phil. Soc., 24:316.

40. Flux, D. S. and Patchell, M. R. (1954)
J. Agric. Sci., Camb., 45:246.

41. Godden, W. and Puddy, C. A. (1935)
J. Dairy Res., 6:307.

42. Gorrie, G. and Harvey, W. R. (1953)
Proc. 34th Ann. Meet. Western, Div., A. D. S. A. p. 71.

43. Hancock, J. (1951)
N. Z. J. Sci. Tech., 33A:17.

44. Hancock, J. (1953)
N. Z. J. Sci. Tech., 35A:67.

45. Hansson, A. (1948)
Acta agric. Suec., 3:59

46. Hansson, A. and Banner, G. (1949)
Acta. Agric. Suec., 3:179.

47. Harris, H. and Warren, F. L. (1955)
Biochem. J. 60, xxix.

48. Have, A. J. V. and Mulder, H. (1957)
The Neatherland Milk and Dairy Journal. 11:128.

49. Hinton, C. L. and Macara, T. (1927)
Analyst, 52:668.

50. Hill, R. L. (1916)
J. Am. Ved. Med. Assoc., 49:1483.

51. Holmes, W., Ried, D., MacLusky, D. S., Waite, Rand Watson, J. H. (1957)
J. Dairy Res., 24:1.

52. Huisman, J. H. J., Van Vliet, G. and Sebens, T. (1958)
Nature (London), 182:171.

53. Huisman, J. H. J., Van Vliet, G. and Sebens, T. (1958)
Nature (London), 182:172.

54. Hutt, F. B. (1930)
J. Hered., 21:339.

55. Johansson, I. and Claesson, O. (1957)
Vol. 3. Chap. 21. Progress in Physiology of farm animals. Butterworth Scientific Publications, London.

56. Johansson, I. (1959)
Xth, Int. Congr. Genetics (Montreal) 1958. 1:236.

57. Johnson, K. R. (1957)
J. Dairy Sci., 40:723.

58. Jones, T. S. J. and Davis, W. L. (1935)
Biochem. J., 29:978.

59. Khattab, A. G. H., Watson, J. H. and Axford, R. F. E. (1964)
J. Agric. Sci., Camb., 63:81.

60. Khattab, A. G. H., Watson, J. H. and Axford, R. F. E. (1964)
J. Agric. Sci., Camb., 63:173.

61. Kidwell, J. F., Bohman, V. R., Wade, M. A., Haveland, L. H. and Hunter, J. E. (1959)
J. Hered., 50:275.

62. King, J. L. P. (1955)
Vet. Record., 67:432.

63. King, S. C. and Henderson, C. R. (1954)
Poultry Sci., 33:147.

64. King, J. W. B. and Donald, H. P. (1955)
J. Dairy Res., 22:1.

65. King, J. W. B., Evans, J. V., Harris, H. and Warren, F. L. (1959)
J. Agric. Sci., Camb., 51:342.

66. Königs, C. (1920)
Chem. Mensch. Nahr., Berlis 2:27.

67. Kraag, G. J., Gailland, B. D. E. and Brouwer, E. (1961)
Tijdschr. Diergeneesk., 86:937.

68. Lankamp, H. (1959)
Z. Tierz. Züicht Biol., 73:60.

69. Larson, B. L. (1958)
J. Dairy Sci., 41:440.

70. Legates, J. E. (1960)
J. Dairy Sci., 43:1527.

71. Ling, E. R. (1956)
A Textbook of Dairy Chemistry Vol. 1. London: Chapman and Hall Ltd.

72. Lush, J. L. (1948)
The Genetics of Populations. Mimeographed, Ames.

73. Mathieu, L. and Ferré, L. (1914)
Ann. Falsif., Paris, 7:12.

74. Mckenzie, D. A., Booker, E. M. K. and Moore, W. (1958)
J. Dairy Res., 25:52.

75. Meyer, H. C. (1963)
Z. Tierz. Züicht Biol., 79:275.

76. Milk Marketing Board (U.K.)
Survey 1 (1945/47)
Survey 2 (1957/58) (1958/59)

77. Morrison, F. B. (1951) Feeds and Feeding, p. 1123. 21st ed. New York: The Morrison Publishing Company.

78. Murphy, J. M. and Hanson, J. J. (1941) Cornell. Vet. 31(1), 47.

79. Nejim, H. T. (1963) J. Dairy Res., 30:81.

80. Nicholson, W. S. Jr., Thomas, W. R., Willard, H. S. and Bown, D. S. (1958) J. Dairy Sci., 41:232.

81. Niedig, R. E. and Iddings, E. J. (1919) J. Agric. Res., 17:19.

82. O'Connor, L. K. (1959) Inter Dairy Congr. (1959) 1, 158.

83. O'Connor, L. K. and Lipton, J. (1960) J. Dairy Res. 27:389.

84. Patchell, M. R. (1957) N. Z. J. Sci., Tech., 38:682.

85. Pater, K. and Suska, F. (1962) Boczn. Nauk. Vol. B,51:75.

86. Paterson, W. E. (1944) Physiol. Revs., 24:340.

87. Peirce, A. W. (1934) Aust. J. Exp. Biol. Med. Sci., 12:7.

88. Perrin, D. R. (1958) J. Dairy Res., 25:70.

89. Politick, R. D. (1957) Dissertation. Agr. Coll. of Wageningen. Netherland.

90. Robertson, A., Waite, R. and White, J. C. D. (1956)
J. Dairy Res., 23:82.

91. Rook, J. A. F. (1961)
Dairy Sci. Abst., 23:251.

92. Rook, J. A. F. and Rowland, S. J. (1959)
Inter. Dairy Congr. 1. 204.

93. Rook, J. A. F. and Wood, M. (1959)
Nature (London) 184:647.

94. Rook, J. A. F. and Wood, M. (1958)
Nature (London) 181:1284.

95. Rowland, S. J. (1938)
J. Dairy Res., 9:47.

96. Rowland, S. J. and Rook, J. A. F. (1949)
Rep. nat. Inst. Res. Dairy, Reading, p. 42.

97. Sartore, G. (1959)
Ann. Fac. Agr. Univ. Sassari (Studi Sassaresi III) 7; p. 61.

98. Simms, H. S. (1931)
The Inter. Dairy Congress (Copenhagen) Vol. 2:50.

99. Specht, L. W., Brunner, J. R., Madden, D. W. and Ralston, N. P. (1956)
J. Dairy Sci., 39:1337.

100. Stein, J. F. (1957)
Dissertation, Pennsylvania, State University.

101. Sutton, W. J. L. (1954)
Thesis: Ohio, State University.

102. Tayler, W. J. (1958)
J. Dairy Sci., 41:440.

103. Teodor, Emann, Popa [L], Duica [S] and Micle [S] (1961)
VIIIth Inter. Congr. Animal Prod. [Hamburg] 1: 18.

104. Waite, R., White, J. C. D. and Robertson, A. (1956)
J. Dairy Res. 23:65.

105. Waite, R., and Blackburn, P. S. (1957)
J. Dairy Res., 24:328.

106. Walsh, J. P. and Rook, J. A. F. (1964)
Nature (London) 204:353.

107. Watson, J. H., Khattab, A. G. H. and Axford, R. F. E (1963)

In Genetics Today
Proc XIth Inter. Congr. Genetics [The Hague]
Vol. 1, Abstr. 270.

108. White, M. K. and Drakeley, T. J. (1927)
J. Agric. Sci. Camb., 17:420.

109. Widdas, W. F. (1954)
J. Physiol., 125.

110. Wilcox, C. J., Peau, K. O., Mather, R. E. and Bartlette, J. W. (1959)

J. Dairy Sci., 42:1132.

111. Von Krosigk, C. M., Young, J. O. and Richardson, G. A. (1960)

J. Dairy Sci., 43:877.

112. Yousef, I. M. K. and Ashton, W. M. (1967)
J. Agric. Sci., Camb., 68:103.

APPENDIX

APP. TABLE 1

LACTOSE, POTASSIUM, AND TOTAL SOLIDS CONTENTS, AND POTASSIUM TO LACTOSE RATIO OF COWS' MILK

Cow No. and Group		Lactose gm/100 gm	Potassium mg/100 gm	Total Solids gm/100 gm	K/Lactose Ratio
<u>MZ Group</u>					
1	A[x]	4.20	173	11.39	41.1
	B[x]	4.20	173	11.47	41.1
2	A	4.67	178	12.18	38.2
	B	4.73	185	12.30	39.1
3	A	4.78	197	11.56	41.3
	B	4.85	194	11.63	40.1
4	A	4.97	179	12.98	36.1
	B	4.90	178	13.04	36.4
5	A	4.37	145	13.14	33.2
	B	4.43	148	13.20	33.4
6	A	4.81	176	13.50	36.6
	B	4.76	178	13.70	37.4
7	A	4.42	177	11.39	40.1
	B	4.36	181	11.48	44.1
8	A	4.81	165	14.33	34.4
	B	4.78	166	14.41	34.8
9	A	4.90	161	14.10	32.7
	B	4.80	162	14.70	33.8
10	A	4.66	156	12.29	33.6
	B	4.70	153	12.49	32.7
<u>DZ Group</u>					
1	A	4.22	172	12.34	40.8
	B	4.37	154	12.99	35.3
2	A	4.36	155	13.23	35.7
	B	4.35	168	12.71	38.5

App. Table 1 (continued)

Cow No. and Group		Lactose gm/100 gm	Potassium mg/100 gm	Total Solids gm/100 gm	K/Lactose Ratio
DZ Group (continued)					
3	A	4.46	122	11.31	27.2
	B	4.67	174	12.03	37.2
4	A	4.57	140	13.52	30.6
	B	4.33	157	13.67	36.3
5	A	4.81	137	12.71	27.6
	B	4.66	141	13.01	30.2
6	A	4.79	133	13.34	27.6
	B	4.50	148	13.94	32.8
7	A	4.51	134	13.84	29.5
	B	4.38	149	13.01	33.9
8	A	4.90	118	11.21	24.1
	B	4.87	135	11.91	27.6
9	A	5.04	137	12.78	27.2
	B	5.20	116	13.14	22.4
10	A	4.67	145	12.13	31.1
	B	4.93	131	11.69	26.6
11	A	4.83	108	14.13	22.4
	B	4.85	100	13.81	20.6
12	A	4.89	129	14.32	26.4
	B	4.64	149	14.56	32.1
HZ Group					
1	A	4.42	156	12.13	35.2
	B	4.78	154	13.01	32.2
2	A	4.63	174	13.34	37.6
	B	4.40	162	12.19	36.9
3	A	4.69	144	11.23	30.7
	B	4.60	151	12.14	32.8
4	A	4.78	126	14.34	26.4
	B	4.29	149	14.97	34.7

App. Table 1 (continued)

Cow No. and Group		Lactose gm/100 gm	Potassium mg/100 gm	Total Solids gm/100 gm	K/Lactose Ratio
HZ Group (continued)					
5	A	5.15	126	14.32	24.5
	B	4.67	186	13.31	39.8
6	A	4.47	154	11.23	34.5
	B	4.98	134	11.94	26.9
7	A	4.04	175	12.34	43.4
	B	4.75	146	11.29	30.7
8	A	4.63	144	14.34	31.2
	B	4.09	116	14.89	40.5
9	A	4.69	114	14.31	24.4
	B	4.66	132	13.43	28.3
10	A	4.52	162	11.23	36.1
	B	4.68	142	12.01	30.2
11	A	4.81	162	14.32	33.7
	B	4.32	167	13.47	38.6
12	A	4.83	160	12.10	33.2
	B	4.91	164	11.17	33.5
13	A	4.09	164	13.01	40.2
	B	4.66	156	13.93	33.6
14	A	4.88	133	14.31	27.3
	B	5.18	124	15.41	23.8
15	A	4.67	141	13.21	30.1
	B	4.93	110	12.34	22.4
16	A	4.46	148	11.03	33.1
	B	4.68	144	11.94	30.8
17	A	4.85	143	12.87	29.5
	B	4.60	156	12.01	34.3
18	A	4.45	157	11.93	35.2
	B	4.57	141	12.87	30.9

App. Table 1 (continued)

Cow No. and Group		Lactose gm/100 gm	Potassium mg/100 gm	Total Solids gm/100 gm	K/Lactose Ratio
HZ Group (continued)					
19	A	4.58	140	13.34	30.6
	B	4.39	159	12.53	36.3
U Group					
1	A	4.40	152	13.12	34.5
	B	4.16	165	12.03	39.6
2	A	4.74	153	14.34	32.4
	B	4.28	174	13.11	40.5
3	A	4.56	170	11.01	37.4
	B	4.77	167	12.14	34.8
4	A	4.82	170	12.13	35.3
	B	4.96	145	13.43	29.1
5	A	5.43	131	14.12	24.2
	B	4.44	144	15.21	32.4
6	A	4.78	122	11.23	25.4
	B	4.95	92	12.01	18.5
7	A	5.48	133	13.11	24.3
	B	4.51	115	11.91	25.4
8	A	5.16	123	14.13	23.8
	B	4.61	141	13.29	30.6
9	A	4.65	153	11.13	32.8
	B	4.41	165	12.14	37.5
10	A	4.50	160	12.34	35.6
	B	4.53	140	13.47	30.9

x

A&B = one pair of animals.

APP. TABLE 2

POTASSIUM AND LACTOSE CONTENTS AND THEIR RATIO IN AYRSHIRE COWS' MILK IN THE FIRST LACTATION AND BETWEEN THE 2ND TO THE 5TH MONTH OF LACTATION

Cow No.		Potassium mg/100 g Milk Water	Lactose g/100 g Milk Water	K to Lactose Ratio
1	xA	195	4.74	41.1
	xB	195	4.74	41.1
2	A	162	5.29	30.6
	B	182	5.02	36.3
3	A	152	5.51	27.6
	B	162	5.36	30.2
4	A	126	5.62	22.4
	B	116	5.63	20.6
5	A	133	5.52	24.1
	B	152	5.51	27.6
6	A	152	5.51	27.6
	B	172	5.23	32.8
7	A	162	5.28	30.7
	B	172	5.23	32.8
8	A	133	5.46	24.4
	B	152	5.38	28.3
9	A	184	5.09	36.1
	B	161	5.32	30.2
10	A	162	5.38	30.1
	B	126	5.62	22.4
11	B	162	5.29	30.6
	C	182	5.02	36.3
12	A	178	5.05	35.2
	B	162	5.25	30.9
13	A	183	5.13	35.6
	B	162	5.24	30.9

App. Table 2 (continued)

Cow No.		Potassium mg/100 g Milk Water	Lactose g/100 g Milk Water	K to Lactose Ratio
14	A	137	5.38	25.4
	B	104	5.62	18.5
15	A	172	5.23	32.8
	B	188	5.02	37.5
Mean		159.37	5.29	

[x]A&B one pair of animals.

APP. TABLE 3

LACTOSE (gm/100 gm of milk) IN THE MILK OF EWES USED IN EXPERIMENT A DURING THE FIRST NINE WEEKS AFTER LAMBING

Ewe No.	1st Week	2nd Week	3rd Week	4th Week	5th Week	6th Week	7th Week	8th Week	9th Week
FXD									
41	5.10	5.13	5.73	5.39	4.88	4.86	5.02	4.51	----
46	4.55	4.74	5.07	4.63	5.09	5.11	5.12	----	6.14
47	4.95	4.12	4.88	5.34	5.53	5.33	4.09	5.03	----
48	4.64	4.23	5.38	4.91	5.72	5.47	4.68	4.99	4.58
52	5.15	5.30	5.80	6.38	5.34	5.32	6.67	7.80	----
53	4.92	5.70	5.22	5.24	5.86	5.87	5.04	6.80	----
54	5.29	5.37	5.16	5.68	5.79	5.79	4.64	5.74	----
57	4.87	4.89	5.27	5.13	4.98	5.80	5.97	5.38	5.99
62	4.51	4.77	5.95	5.40	5.00	5.28	5.04	5.15	4.87
63	4.62	5.38	5.19	5.47	5.25	5.26	5.11	5.12	5.21
73	5.31	5.13	5.53	5.57	5.82	5.60	4.70	6.03	----
74	4.89	4.88	5.15	5.07	5.03	5.26	5.24	5.02	4.39
75	6.10	5.38	5.15	5.14	5.77	5.69	5.22	5.58	----
76	4.74	4.79	5.07	5.50	5.08	4.95	4.91	4.96	----
82	4.44	5.38	5.32	5.36	5.54	5.79	4.85	5.85	----
84	3.99	5.59	5.96	5.72	5.19	5.30	4.68	6.17	----
88	4.73	5.02	5.52	5.50	5.54	5.43	4.33	6.23	----
89	4.57	4.94	5.34	5.46	6.00	5.54	5.53	5.61	7.40
91	4.55	4.61	5.31	4.96	4.43	4.68	4.33	4.42	4.26
93	4.79	5.11	5.90	4.67	5.53	4.97	6.54	6.10	5.06
94	3.76	5.32	5.32	5.19	5.71	5.72	4.26	5.13	----
100	4.17	6.07	5.06	5.16	5.63	5.79	3.95	4.99	----
102	4.08	4.61	5.09	5.80	5.65	5.90	5.60	4.71	5.23
218	5.21	6.89	5.97	5.45	5.31	4.70	6.00	----	----
Dorset									
1009	4.41	5.23	5.54	5.12	5.93	5.44	5.33	4.90	6.92
1010	4.46	5.12	5.67	5.66	5.22	5.68	5.66	----	6.08
100	5.11	4.57	5.37	5.08	5.62	4.92	4.69	5.65	----
105	4.73	4.92	5.10	5.79	5.12	5.41	4.47	4.66	4.20
106	4.71	5.06	5.60	5.29	5.40	4.92	4.47	5.01	4.79
108	5.00	5.16	4.75	5.19	4.72	4.88	5.37	5.26	5.59
139	4.57	5.11	5.11	5.12	5.60	5.06	5.07	4.42	4.81
141	4.43	6.13	5.26	5.68	5.69	5.71	5.66	4.96	5.11
143	5.07	6.49	5.44	5.75	5.64	5.68	6.36	5.32	5.00
148	4.52	4.62	4.92	5.16	4.89	4.03	5.25	4.67	4.96
154	4.88	4.83	5.38	4.92	4.99	4.68	5.06	5.00	3.96

APP. TABLE 4

POTASSIUM (mg/100 gm of milk) CONTENT OF EWES' MILK USED IN EXPERIMENT A DURING THE FIRST NINE WEEKS AFTER LAMBING

Ewe No.	1st Week	2nd Week	3rd Week	4th Week	5th Week	6th Week	7th Week	8th Week	9th Week
FXD									
41	160	152	192	132	100	108	104	108	---
46	160	;08	104	104	104	120	128	---	128
47	168	116	116	104	140	112	108	140	---
48	168	140	108	80	96	96	128	132	144
52	148	88	88	100	108	88	108	88	---
53	140	104	108	104	112	128	120	120	---
54	168	116	100	104	144	144	140	140	---
57	224	156	180	104	100	120	108	144	184
62	152	148	108	92	104	100	128	140	132
63	192	144	184	96	92	108	104	104	108
73	160	152	128	132	140	132	140	108	0--
74	140	156	140	152	124	132	120	144	128
75	168	140	148	116	160	160	128	156	---
76	160	160	140	176	148	116	148	156	---
82	148	104	116	104	112	140	160	108	---
84	148	104	132	104	120	140	112	128	---
88	152	104	108	108	120	126	144	128	---
89	172	120	120	104	104	120	132	120	132
91	156	164	128	108	108	116	128	128	156
93	160	124	128	96	108	120	176	112	100
94	148	108	108	116	148	140	168	132	---
100	140	148	96	116	112	128	120	108	---
102	160	132	116	108	104	192	112	120	120
218	148	104	88	144	128	112	88	---	---
Dorset									
1009	176	140	132	120	116	160	128	128	232
1010	172	140	116	108	104	160	112	---	116
100	148	164	128	104	104	116	128	132	---
105	148	144	108	116	108	100	96	108	108
106	156	176	116	96	116	108	128	120	120
108	208	128	156	116	72	96	84	104	108
139	176	176	176	192	168	104	104	104	104
141	168	148	104	116	116	156	140	128	148
143	140	132	116	140	128	128	128	130	---
148	172	144	144	128	116	88	104	120	112
154	164	100	120	72	96	80	100	100	92

APP. TABLE 5

SODIUM (mg/100 gm of milk) CONTENT OF EWES' MILK USED IN EXPERIMENT A DURING THE FIRST NINE WEEKS AFTER LAMBING

Ewe No.	1st Week	2nd Week	3rd Week	4th Week	5th Week	6th Week	7th Week	8th Week	9th Week
FXD									
41	24	24	28	32	32	32	44	44	--
46	24	28	32	36	36	36	40	--	48
47	20	28	32	32	36	36	40	44	--
48	24	24	32	32	36	36	40	48	48
52	24	30	36	36	40	40	40	48	--
53	24	28	32	32	36	36	44	48	--
54	24	28	36	36	36	36	44	48	--
57	20	24	32	32	36	40	48	48	54
62	24	24	32	32	36	36	44	44	54
63	24	28	28	32	36	36	40	40	48
73	24	28	32	32	36	36	40	40	--
74	24	28	32	32	36	36	40	48	48
75	20	28	32	32	36	36	40	48	--
76	24	28	32	32	36	36	40	44	--
82	28	28	36	36	36	40	44	44	--
84	24	24	32	36	36	40	44	44	--
88	24	28	32	32	36	36	40	44	--
89	20	30	32	32	36	36	44	44	48
91	24	30	28	32	36	36	44	44	48
93	24	28	32	28	36	36	40	44	48
94	24	28	32	28	36	36	40	44	--
100	28	28	40	40	36	40	48	48	--
102	24	24	32	32	36	36	44	48	54
218	28	32	40	46	40	40	44	--	--
Dorset									
1009	24	24	28	30	32	32	40	44	44
1010	24	24	28	30	32	32	44	--	48
100	24	28	32	32	36	36	40	48	--
105	20	24	32	36	36	36	40	44	48
106	24	30	32	32	36	36	40	48	48
108	28	30	28	32	36	36	40	48	48
139	20	24	28	32	36	32	36	44	48
141	20	24	32	32	36	36	44	48	50
143	24	30	32	36	36	36	44	48	--
148	20	28	32	36	36	36	40	44	54
154	20	24	32	32	36	40	44	48	48

APP. TABLE 6

TOTAL SOLIDS (gm/100 gm of milk) CONTENTS OF EWES' MILK USED IN EXPERIMENT A DURING THE FIRST NINE WEEKS AFTER LAMBING

Ewe No.	1st Week	2nd Week	3rd Week	4th Week	5th Week	6th Week	7th Week	8th Week	9th Week
FXD									
41	----	----	17.8	16.8	18.0	18.0	18.0	29.9	20.5
46	----	16.9	19.1	18.6	19.1	21.7	20.5	----	21.0
47	14.7	16.4	20.2	20.4	23.5	20.7	23.1	29.7	----
48	----	----	19.6	17.4	19.0	19.8	20.2	19.8	20.2
52	19.5	19.8	17.2	18.4	17.9	24.6	24.6	24.6	----
53	16.6	17.0	15.1	15.5	20.4	23.7	18.8	19.3	----
54	----	17.1	15.3	17.0	18.6	17.1	18.1	18.8	----
57	----	----	15.6	18.9	15.8	15.9	14.6	18.4	17.4
62	----	----	17.7	16.0	15.8	16.7	19.3	16.4	17.1
63	----	----	15.6	16.7	16.3	15.9	14.5	19.4	18.5
73	17.5	17.8	14.3	14.9	17.7	15.6	16.0	18.0	----
74	----	----	17.6	16.3	16.3	17.4	20.3	16.5	17.9
75	16.1	14.6	14.4	16.5	16.6	16.4	15.9	18.4	----
76	----	----	15.5	14.3	13.3	14.8	21.2	14.1	----
82	15.3	17.9	16.1	20.4	21.8	19.4	18.9	18.1	----
84	13.8	14.6	17.1	16.7	17.8	18.6	19.0	19.3	----
88	18.0	16.8	15.6	17.2	16.7	20.0	17.0	17.7	----
89	----	15.8	14.7	14.9	13.8	15.8	14.7	15.5	14.9
91	----	----	17.1	17.2	16.5	17.2	19.3	17.7	17.3
93	----	17.5	14.7	17.0	15.8	17.4	17.4	18.6	19.5
94	16.2	18.8	18.1	17.1	19.2	19.0	18.4	18.4	----
100	15.9	21.3	18.9	14.4	20.1	17.2	19.0	20.3	----
102	----	18.2	17.4	17.5	23.1	22.5	18.2	----	18.0
218	18.8	16.2	15.3	17.3	23.7	15.8	16.5	----	----
Dorset									
1009	----	16.5	16.8	15.8	16.4	17.8	18.3	18.9	18.6
1010	----	----	18.1	18.7	18.4	23.7	21.1	----	21.0
100	----	----	14.3	14.5	16.3	16.2	18.1	17.2	----
105	----	----	18.4	19.0	19.6	19.1	21.1	18.2	20.5
106	----	----	17.2	16.5	16.6	16.2	18.3	16.6	17.6
108	----	----	16.9	17.4	17.0	16.7	17.8	17.9	18.2
139	----	----	16.0	18.4	15.6	15.6	19.2	18.1	18.2
141	17.5	17.9	14.4	15.6	18.2	16.2	16.8	18.2	----
143	15.9	14.1	16.1	19.5	17.7	15.8	17.8	18.3	----
148	----	----	16.3	18.0	15.9	16.7	16.4	20.4	18.1
154	----	----	17.9	17.9	18.1	19.3	20.2	20.5	19.7

APP. TABLE 7

RATIO OF POTASSIUM TO LACTOSE CONTENT OF EWES' MILK USED IN EXPERIMENT A DURING THE FIRST NINE WEEKS AFTER LAMBING

Ewe No.	1st Week	2nd Week	3rd Week	4th Week	5th Week	6th Week	7th Week	8th Week	9th Week
FXD									
41	31.4	29.6	40.6	24.5	20.5	22.2	20.7	23.9	----
46	35.2	22.6	20.5	22.5	20.4	23.4	25.0	----	20.8
47	33.9	28.2	23.8	19.5	25.3	21.0	26.4	27.8	----
48	36.2	33.1	20.1	16.3	16.8	17.6	27.4	26.5	31.4
52	28.7	16.6	15.2	15.7	20.2	16.5	16.2	11.3	----
53	28.5	18.2	20.7	19.8	19.1	21.8	23.8	17.6	----
54	31.8	21.6	19.4	18.3	24.9	24.9	30.2	24.4	----
57	46.0	31.9	34.2	20.3	20.0	20.7	18.1	26.8	30.8
62	33.7	31.0	18.2	17.0	20.8	18.9	25.4	27.2	27.1
63	41.2	26.8	35.5	17.5	17.5	20.5	20.4	20.3	20.7
73	30.1	29.6	23.1	23.7	24.1	23.6	29.8	17.9	----
74	28.6	32.0	27.2	30.0	24.7	21.1	22.9	28.7	29.2
75	27.5	26.0	28.7	22.6	27.7	28.1	24.5	28.0	----
76	33.8	33.4	27.6	32.0	29.1	23.4	30.1	31.5	----
82	33.3	19.3	21.8	19.4	20.2	24.2	33.0	18.5	----
84	37.1	18.6	22.1	18.2	23.1	26.4	23.9	20.7	----
88	32.1	20.7	19.6	19.6	21.7	23.2	33.3	20.5	----
89	37.6	24.3	22.5	19.0	17.3	21.7	23.9	21.4	17.8
91	34.3	35.6	24.1	21.8	24.5	24.8	29.6	29.0	36.6
93	33.4	24.3	21.7	20.6	19.5	24.1	26.9	18.4	19.8
94	39.4	20.3	20.3	22.4	25.9	24.5	39.4	25.7	----
100	33.6	24.4	19.0	22.5	20.0	22.1	30.4	21.6	----
102	39.2	28.6	22.8	18.6	18.4	32.5	20.0	25.5	22.9
218	28.4	15.1	14.7	26.4	24.1	23.8	14.7	----	----
Dorset									
1009	39.9	26.8	23.8	23.4	19.6	29.4	24.0	26.1	33.5
1010	38.6	27.3	20.5	19.1	19.9	28.2	19.8	----	19.1
100	29.0	35.9	23.8	20.5	18.5	23.6	27.3	23.4	----
105	31.3	29.3	21.2	20.0	21.1	18.5	21.5	23.2	25.7
106	33.1	34.0	20.7	18.1	21.5	22.0	28.6	24.0	25.1
108	40.[illegible]	24.8	32.8	22.4	15.5	19.7	15.6	19.8	19.3
139	38.5	34.4	34.4	37.5	30.0	20.5	20.5	25.8	21.6
141	37.9	24.1	19.8	20.4	20.4	27.3	24.7	25.8	29.0
143	27.6	20.3	21.3	24.3	22.7	22.5	20.1	24.4	----
148	41.6	31.2	29.3	24.8	23.7	21.8	19.8	25.7	22.6
154	33.6	20.7	22.3	14.6	19.2	17.1	19.8	20.0	23.2

APP. TABLE 8

IDENTITY OF CLUN EWES USED IN EXPERIMENT B

Serial No.	Ewe No.	Age	Dam	Sire	Number Suckling
1	53013	1	23001	801	1
2	53021	1	13010	801	1
3	53216	1	23104	801	1
4	53302	1	13136	801	1
5	53016	1	23112	802	1
6	53046	1	23028	802	1
7	53116	1	33199	802	1
8	53239	1	33010	802	1
9	53242	1	33088	802	1
10	53069	1	3088	803	1
11	53162	1	23157	804	1
12	53272	1	33100	804	1
13	53360	1	43084	804	1
14	53373	1	33171	804	1
15	53231	1	3031	805	1
16	43007	2	93021	801	2
17	43010	2	3120	801	1
18	43039	2	93047	801	2
19	43046	2	3124	801	2
20	43052	2	93003	801	2
21	43068	2	3116	801	1
22	43079	2	93011	801	1
23	43080	2	3003	801	2
24	43131	2	3018	801	2
25	43178	2	3135	801	1
26	43192	2	3062	801	2
27	43205	2	3142	801	2
28	43037	2	13069	802	2
29	43084	2	93008	802	2
30	43085	2	23008	802	1
31	43086	2	23008	802	1
32	43123	2	23094	802	2
33	43149	2	93002	802	2
34	43210	2	23015	802	1
35	43293	2	93026	802	1

App. Table 8 (continued)

Serial No.	Ewe No.	Age	Dam	Sire	Number Suckling
36	43307	2	13025	802	1
37	43019	2	13045	806	1
38	43020	2	13045	806	1
39	43100	2	23183	806	1
40	43128	2	23073	806	1
41	43157	2	13094	806	1
42	43175	2	93037	806	1
43	43222	2	23081	806	1
44	43232	2	13121	806	1
45	43236	2	23072	806	1
46	43248	2	23041	806	2
47	33018	3	3037	807	2
48	33028	3	23183	807	1
49	33046	3	3036	807	1
50	33052	3	13124	807	2
51	33072	3	3107	807	1
52	33076	3	3142	807	1
53	33116	3	3010	807	1
54	33124	3	3120	807	1
55	33125	3	3120	807	2
56	33126	3	93025	807	2
57	33133	3	3092	807	1
58	33136	3	3019	807	1
59	33151	3	3117	807	1
60	33157	3	3099	807	2
61	33158	3	3015	807	2
62	33171	3	3093	807	1
63	33177	3	93017	807	1
64	33202	3	3088	807	2
65	33204	3	3001	807	2
66	33206	3	93021	807	1
67	33207	3	3037	807	1
68	33215	3	3064	807	2
69	33216	3	3095	807	1
70	33217	3	3095	807	1

App. Table 8 (continued)

Serial No.	Ewe No.	Age	Dam	Sire	Number Suckling
71	33234	3	13099	807	1
72	33240	3	93031	807	2
73	33257	3	23089	807	1
74	33259	3	93043	807	1
75	33260	3	93043	807	1
76	33268	3	3070	807	2
77	33270	3	13070	807	1
78	33275	3	3038	807	1
79	23008	4	93048	808	2
80	23034	4	3031	809	2
81	23112	4	93035	809	2
82	23014	4	3015	810	1
83	23072	4	3091	812	2
84	13010	5	3117	808	2
85	13049	5	93041	813	2
86	13126	5	93005	813	1
87	13134	5	3028	813	2
88	13069	5	3050	814	2
89	13100	5	93033	814	2
90	13073	5	3082	815	1
91	13078	5	93022	816	1
92	13124	5	93028	817	1
93	03032	6	3065	818	2
94	03085	6	3026	819	2
95	03107	6	3063	819	2
96	03088	6	3019	820	2

APP. TABLE 9

POTASSIUM, LACTOSE, POTASSIUM TO LACTOSE RATIO, SODIUM AND TOTAL SOLIDS CONTENTS OF CLUN EWES' MILK USED IN EXPERIMENT B

Serial No. of Ewe	Potassium		Lactose		Potassium to Lactose R		Sodium		Total Solids	
	3rd Week	6th Week	3rd Week	6th Week	3rd Week	6th Week	3rd Week	6th Week	3rd Week	6th Week
Clun:										
1	148	144	4.88	4.68	30.3	30.7	28.	36	15.3	16.9
2	168	140	5.63	5.08	26.2	27.5	28	36	16.0	17.3
3	120	96	4.85	4.82	24.7	19.9	28	40	16.1	18.3
4	120	144	4.44	4.40	27.0	32.7	32	40	14.9	15.9
5	144	140	5.19	5.18	27.7	27.0	32	36	14.8	15.9
6	132	128	4.54	4.55	29.1	28.1	28	36	15.3	16.8
7	100	100	4.69	4.69	21.3	21.3	32	36	11.9	14.8
8	116	108	4.87	4.57	23.8	22.7	32	36	17.8	19.3
9	132	128	4.52	4.61	29.2	27.8	32	36	17.2	19.1
10	108	104	4.19	4.20	25.8	24.7	36	36	17.2	18.3
11	156	148	4.80	4.90	32.5	30.2	28	32	15.9	15.9
12	120	108	5.98	4.87	20.0	22.1	32	36	15.8	16.0
13	160	144	4.40	4.62	36.3	31.1	32	36	16.3	16.9
14	108	92	5.38	5.06	20.0	18.1	32	36	16.9	18.3
15	140	140	5.02	5.02	27.8	27.8	32	36	17.0	17.1
16	128	116	5.07	5.08	25.2	22.8	32	40	14.1	16.3
17	140	116	5.07	5.19	27.6	22.3	36	36	16.2	18.2
18	132	104	5.26	4.90	25.0	21.1	28	32	16.4	17.2
19	160	156	4.13	3.62	38.7	43.9	28	36	18.0	19.3
20	160	128	4.67	4.36	34.2	29.3	36	36	19.6	22.0
21	144	140	4.98	4.99	28.9	28.1	32	36	15.2	16.1
22	140	140	4.99	4.63	28.0	30.2	32	36	18.3	19.8
23	128	129	4.85	4.84	26.3	24.8	32	36	15.5	16.3
24	116	120	4.78	5.22	24.2	22.9	32	36	16.0	18.1
25	140	132	4.97	5.20	28.1	25.3	32	36	16.4	18.9
26	128	116	5.14	4.70	24.9	24.6	32	36	16.8	19.3
27	156	132	4.97	4.99	31.3	26.4	32	36	14.6	15.3
28	148	144	5.44	5.45	27.2	26.4	32	36	18.2	19.2
29	140	128	5.04	5.06	27.7	31.5	28	36	18.4	20.1
30	144	128	4.53	4.00	31.7	32.6	36	36	18.1	20.3
31	148	144	5.20	5.09	28.4	28.2	32	36	17.3	19.4
32	120	120	5.23	5.04	22.9	23.8	32	36	17.1	19.6
33	140	132	4.93	4.89	28.3	27.0	28	36	17.9	19.8
34	128	96	4.99	4.90	25.6	19.5	28	36	16.8	18.3
35	116	128	4.89	4.80	23.7	26.6	28	36	18.7	20.4
36	104	104	5.22	4.76	19.9	21.8	36	36	18.3	22.0
37	156	140	5.33	4.84	29.2	28.9	32	36	15.7	15.9
38	128	108	5.12	4.99	25.1	21.6	36	40	17.7	17.9

App. Table 9 (continued)

Serial No. of Ewe	Potassium		Lactose		Potassium to Lactose R		Sodium		Total Solids	
	3rd Week	6th Week	3rd Week	6th Week	3rd Week	6th Week	3rd Week	6th Week	3rd Week	6th Week
Clun:										
39	128	120	4.52	5.04	28.3	23.8	32	36	15.9	18.0
40	128	168	4.13	4.25	30.9	39.5	32	36	15.3	16.4
41	128	120	4.99	4.87	25.6	24.6	40	44	13.8	14.9
42	156	148	4.98	4.97	31.3	29.8	36	40	16.2	16.9
43	120	116	4.98	5.19	24.0	22.3	32	36	20.5	23.0
44	116	108	5.38	5.29	21.5	20.4	28	32	18.9	20.3
45	160	140	4.64	4.72	34.4	29.6	32	36	17.4	18.3
46	140	132	5.75	5.74	24.3	23.0	32	36	15.7	16.3
47	128	132	5.40	4.92	23.7	26.8	32	36	17.1	18.3
48	120	108	5.27	4.87	22.7	22.1	28	36	17.0	17.2
49	108	96	4.60	4.37	23.4	21.9	32	40	17.7	17.9
50	128	96	4.91	4.64	26.0	20.6	32	36	14.3	15.6
51	120	144	4.81	4.47	24.9	32.2	32	36	17.1	18.1
52	116	128	4.37	4.73	26.5	27.0	32	40	17.5	17.9
53	120	116	4.72	5.04	25.4	23.0	32	36	18.3	19.6
54	148	120	5.20	4.44	28.4	27.0	32	36	17.6	17.5
55	132	156	5.25	4.90	25.1	31.8	32	36	17.2	17.3
56	116	92	5.44	5.19	21.3	17.7	28	32	21.3	21.4
57	120	116	4.62	4.73	25.9	24.5	32	36	16.7	17.8
58	120	96	5.24	5.12	22.4	18.7	32	36	16.3	18.2
59	120	140	3.91	4.51	30.6	31.0	32	36	19.6	20.1
60	148	116	4.60	4.50	33.1	25.1	32	36	16.2	18.3
61	116	108	4.62	4.63	25.1	23.3	28	36	16.4	17.5
62	140	120	4.85	5.01	28.8	23.9	36	36	16.9	17.4
63	100	100	4.94	4.95	20.2	20.2	32	36	20.0	20.1
64	128	132	4.51	4.42	28.3	29.8	32	40	15.3	15.4
65	116	104	4.86	4.51	23.8	23.0	36	36	18.5	19.3
66	144	144	4.62	4.62	31.1	31.1	24	36	17.2	18.3
67	132	116	5.11	4.85	25.8	23.9	32	36	16.8	19.1
68	104	92	4.93	4.61	21.0	19.9	32	36	16.5	18.0
69	116	120	5.09	5.14	22.8	23.4	28	36	16.3	18.3
70	148	140	4.40	4.41	33.6	31.7	32	36	16.8	18.0
71	120	128	5.29	5.32	22.6	36.0	24	36	17.9	17.9
72	168	168	4.21	4.24	39.9	39.6	28	32	18.3	18.9
73	104	104	5.02	4.55	20.7	22.8	32	36	21.5	21.0
74	92	104	4.29	4.92	21.4	21.1	32	36	21.0	22.0
75	128	108	4.09	4.78	31.2	22.5	32	36	15.0	17.1
76	156	148	5.16	4.51	30.2	32.8	32	36	15.9	18.3
77	116	132	4.65	5.43	24.9	24.3	32	36	16.5	16.8
78	120	128	4.17	4.50	28.7	28.4	36	36	15.1	15.4
79	108	108	4.48	4.67	24.1	23.1	32	40	16.3	16.7
80	116	96	4.91	4.75	23.6	20.2	32	40	16.0	16.3
81	116	104	4.95	4.71	23.4	22.0	28	36	16.1	16.4

App. Table 9 (continued)

Serial No. of Ewe	Potassium		Lactose		Potassium to Lactose R		Sodium		Total Solids	
	3rd Week	6th Week	3rd Week	6th Week	3rd Week	6th Week	3rd Week	6th Week	3rd Week	6th Week
Clun:										
82	96	96	4.70	4.69	20.4	20.1	32	36	19.1	19.8
83	156	144	4.13	4.23	37.7	34.0	32	36	17.6	18.0
84	144	148	5.22	5.07	27.5	29.1	28	36	15.3	15.9
85	104	120	4.82	4.65	21.5	25.8	32	36	16.2	16.2
86	120	116	4.45	4.51	26.9	25.7	32	36	16.7	16.7
87	196	144	4.65	3.99	42.1	36.0	32	36	19.1	19.4
88	148	128	4.60	3.74	32.1	34.2	32	36	20.8	21.0
89	128	116	5.05	5.09	25.3	22.7	32	36	17.1	18.0
90	120	144	4.15	4.56	28.9	31.5	36	36	19.2	19.3
91	100	120	4.27	4.94	23.4	24.2	28	36	17.3	18.0
92	100	132	4.95	4.89	20.2	26.9	32	36	16.0	16.3
93	120	128	5.25	4.38	22.8	29.2	32	36	18.3	19.0
94	100	128	4.48	4.73	22.3	27.0	40	44	17.5	18.0
95	128	128	4.81	4.80	26.6	26.6	40	40	19.4	19.4
96	168	140	4.93	4.67	34.1	29.9	36	40	15.9	16.6

APP. TABLE 10

POTASSIUM, LACTOSE, POTASSIUM TO LACTOSE RATIO, SODIUM AND TOTAL SOLIDS OF SUFFOLK EWES' MILK USED IN EXPERIMENT B

Serial No. of Ewe	Potassium		Lactose		Potassium to Lactose R		Sodium		Total Solids	
	3rd Week	6th Week	3rd Week	6th Week	3rd Week	6th Week	3rd Week	6th Week	3rd Week	6th Week
1	104	106	4.69	4.71	22.2	21.2	32	36	15.7	16.3
2	144	140	4.84	4.86	29.7	28.8	32	36	15.1	15.4
3	132	140	4.80	4.51	27.5	31.0	36	36	15.2	15.9
4	120	116	4.84	4.95	24.7	23.4	28	36	14.9	15.2
5	176	156	4.33	4.81	40.6	32.4	36	36	19.7	18.9
6	132	104	4.79	4.83	27.5	21.5	32	36	15.6	16.1
7	120	116	5.34	5.55	23.8	20.9	32	36	16.1	16.8
8	128	120	4.11	4.12	31.1	29.1	32	36	15.8	15.9
9	104	128	4.78	4.75	21.7	26.9	32	40	15.8	15.7
10	140	160	4.85	4.51	28.8	35.4	32	36	15.6	16.0
11	108	120	4.85	4.53	22.2	26.4	28	36	17.2	19.0

APP. TABLE 11

IDENTITY OF THE EWES USED IN EXPERIMENT C
CROSS 1: BORDER LAISETER X BLACK FACE (BL X BF)

Serial No.	Ewe No.	Age	Dam	Sire	No. of Suckling
1	42068	2	22052	301	1
2	44012	2	17	301	2
3	44035	2	32	301	2
4	44136	2	126	301	2
5	44209	2	130	301	1
6	44210	2	121	301	1
7	44241	2	34	301	2
8	42010	2	12001	302	1
9	44150	2	94	302	1
10	32075	3	2016	303	2
11	32076	3	92168	303	1
12	32004	3	12090	303	2
13	32019	3	12062	303	2
14	32031	3	12004	303	2
15	32055	3	92026	303	1
16	32070	3	92057	303	1

APP. TABLE 12

IDENTITY OF THE EWES USED IN EXPERIMENT C

CROSS 2: FINNISH X BLACK FACE (F X BF)

Serial Number	Ewe No.	Age	Dam	Sire	Number Suckling
17	42060	2	12120	401	1
18	44025	2	84	401	2
19	44026	2	84	401	2
20	44160	2	129	401	2
21	44178	2	199	401	2
22	44185	2	61	401	2
23	44005	2	107	402	2
24	44006	2	107	402	2
25	44060	2	104	402	2
26	44112	2	24	402	2
27	44117	2	26	402	2
28	44132	2	134	402	2
29	44143	2	59	402	2
30	44155	2	201	402	2
31	44183	2	82	402	2
32	32011	3	12076	403	2
33	32013	3	82056	403	2
34	32029	3	12036	403	1
35	32032	3	12102	403	2
36	32046	3	2075	403	2
37	32058	3	92005	403	2
38	32061	3	92171	403	2
39	32065	3	92081	403	2
40	32017	3	2114	404	2
41	32018	3	2114	404	1
42	32028	3	92082	404	2
43	32039	3	12127	404	2
44	32040	3	12127	404	2
45	32049	3	82133	404	2

APP. TABLE 13

IDENTITY OF THE EWES USED IN EXPERIMENT C
CROSS 3: MERINO X BLACK FACE (M X BF)

Serial No.	Ewe No.	Age	Dam	Sire	Number Suckling
46	42072	2	12002	503	1
47	44242	2	39	503	1
48	44244	2	198	503	1
49	44245	2	174	503	1
50	44246	2	174	503	1
51	44247	2	23	503	1
52	42001	2	22088	504	1
53	44056	2	92068	504	1
54	44094	2	13	504	1
55	44102	2	186	504	1
56	44196	2	123	504	1
57	44197	2	123	504	1
58	44238	2	182	504	1
59	34013	3	119	501	1
60	34041	3	189	501	1
61	34064	3	56	501	1
62	34065	3	205	501	1
63	34139	3	91	501	1
64	34253	3	117	501	1
65	34266	3	23	501	1
66	34267	3	200	501	1
67	34275	3	94	501	1
68	34283	3	22	501	1
69	34026	3	107	502	2
70	34095	3	20	502	1
71	34110	3	12	502	1
72	34116	3	114	502	2
73	34151	3	76	502	1
74	34241	3	17	502	1
75	34268	3	71	502	2
76	34277	3	101	502	1

APP. TABLE 14

IDENTITY OF THE EWES USED IN EXPERIMENT C
CROSS 4: CLUN X BLACK FACE (C X BF)

Serial No.	Ewe No.	Age	Dam	Sire	Number Suckling
77	42039	2	22051	603	1
78	44047	2	173	603	1
79	44071	2	50	603	2
80	44104	2	54	603	1
81	44195	2	149	603	2
82	44211	2	169	603	2
83	44212	2	169	603	2
84	44003	2	41	604	1
85	44029	2	142	604	1
86	44030	2	142	604	2
87	44069	2	77	604	2
88	44101	2	15	604	1
89	44109	2	202	604	1
90	44110	2	202	604	1
91	34027	3	129	601	2
92	34093	3	13	601	2
93	34094	3	13	601	1
94	34189	3	134	601	2
95	34190	3	134	601	2
96	34198	3	45	601	1
97	34235	3	69	601	2
98	34245	3	21	601	2
99	34053	3	16	602	2
100	34054	3	16	602	2
101	34141	3	112	602	2
102	34173	3	40	602	1

APP. TABLE 15

IDENTITY OF THE EWES USED IN EXPERIMENT C
CROSS 5: DORSET X BLACK FACE (D X BF)

Serial Number	Ewe No.	Age	Dam	Sire	Number Suckling
103	44059	2	14	701	1
104	44091	2	119	701	2
105	44092	2	119	701	2
106	44114	2	176	701	1
107	44120	2	92057	701	1
108	44128	2	133	701	2
109	44062	2	114	703	1
110	44100	2	73	703	2
111	44130	2	197	703	1
112	44152	2	43	703	1
113	44163	2	147	703	1
114	44206	2	141	703	1
115	44217	2	172	703	1
116	44230	2	101	703	2
117	34005	3	41	701	1
118	34009	3	106	701	1
119	34010	3	106	701	1
120	34145	3	59	701	2
121	34158	3	15	701	1
122	34160	3	167	701	1
123	34194	3	99	701	2
124	34213	3	11	701	2
125	34217	3	65	701	2
126	34049	3	26	702	1
127	34112	3	61	702	1
128	34175	3	165	702	2
129	34199	3	74	702	2
130	43218	3	151	702	2

APP. TABLE 16

COMPOSITION OF BL X BF EWES' MILK

Serial No. of Ewe	Potassium		Lactose		Potassium to Lactose R		Sodium		Total Solids	
	3rd Week	6th Week	3rd Week	6th Week	3rd Week	6th Week	3rd Week	6th Week	3rd Week	6th Week
1	88	92	5.01	5.06	17.6	18.2	28	36	14.1	15.8
2	132	116	5.49	4.51	24.0	25.7	32	36	18.6	19.4
3	140	132	5.24	4.60	26.7	28.7	32	36	16.4	18.2
4	144	92	4.98	4.16	28.9	22.1	36	40	15.1	18.4
5	120	96	4.65	3.94	25.8	24.4	28	32	17.2	18.0
6	104	100	4.62	4.63	22.5	21.6	32	36	17.6	18.8
7	132	132	4.98	4.43	26.5	29.8	32	36	19.8	23.7
8	116	116	4.82	4.39	24.0	26.4	36	36	17.3	18.5
9	132	148	4.74	4.79	27.8	29.8	40	44	14.0	13.9
10	92	100	5.19	4.67	17.7	21.4	36	40	16.4	17.3
11	104	128	4.76	4.55	21.8	28.1	32	36	17.0	17.3
12	128	108	5.05	4.75	25.3	22.7	28	32	15.0	16.4
13	60	92	5.17	4.51	11.6	20.5	40	44	18.3	20.5
14	68	72	5.37	4.13	12.7	17.4	36	44	18.0	18.4
15	132	108	4.27	4.52	30.9	29.7	32	36	17.0	18.9
16	120	116	4.73	4.32	25.4	26.9	32	36	16.0	16.8

APP. TABLE 17

COMPOSITION OF F X BF EWES' MILK

Serial No. of Ewe	Potassium		Lactose		Potassium to Lactose R		Sodium		Total Solids	
	3rd Week	6th Week	3rd Week	6th Week	3rd Week	6th Week	3rd Week	6th Week	3rd Week	6th Week
17	128	108	4.40	4.29	29.0	25.2	36	40	15.0	15.3
18	120	60	4.23	4.60	28.3	13.0	32	56	17.1	18.6
19	128	132	4.58	4.83	27.9	27.3	32	36	15.9	16.1
20	104	128	4.49	4.86	23.1	26.3	32	36	13.4	14.6
21	100	116	5.15	4.79	19.4	24.2	28	36	15.8	16.4
22	116	132	4.70	4.36	24.6	30.3	28	36	17.2	18.3
23	116	128	5.09	4.70	22.8	27.2	32	36	15.3	16.8
24	140	100	4.23	4.32	33.0	23.1	40	40	15.7	16.2
25	116	76	5.15	3.13	22.5	24.3	40	48	17.3	17.7
26	120	116	4.58	4.51	26.2	25.7	28	32	15.3	16.4
27	72	84	4.69	4.55	15.3	18.5	40	40	15.7	16.8
28	128	116	4.15	4.34	30.8	26.7	40	40	16.9	20.7
29	120	148	4.39	4.52	27.3	32.7	32	32	18.3	18.0
30	92	96	4.64	4.66	19.8	20.6	36	40	16.0	17.3
31	148	140	4.91	4.16	30.1	33.7	32	36	15.8	17.2
32	128	92	4.70	5.02	27.2	18.3	32	36	15.4	15.9
33	100	72	5.06	4.67	19.8	15.4	40	44	16.8	20.7
34	116	116	5.21	5.03	22.2	23.1	32	36	18.3	20.5
35	116	132	4.87	4.89	23.8	27.0	32	36	17.9	18.6
36	88	128	4.96	4.82	17.7	24.9	32	36	16.7	17.9
37	88	132	5.15	4.40	17.1	29.7	40	40	18.4	20.4
38	96	88	5.21	4.24	18.4	20.9	36	44	17.3	18.0
39	108	108	5.37	4.81	20.1	22.5	32	36	18.0	19.8
40	104	108	5.14	4.62	20.2	23.4	32	36	18.1	19.7
41	120	116	4.80	4.79	25.0	24.2	32	36	18.3	20.1
42	116	108	4.57	4.51	25.3	23.9	32	36	15.4	16.7
43	104	116	4.72	4.42	22.0	26.0	32	36	17.0	17.6
44	100	104	4.99	4.75	20.0	22.7	36	40	16.1	17.9
45	108	108	4.58	4.65	23.6	23.2	32	40	14.3	15.4

APP. TABLE 18

CCOMPOSITION OF M X BF EWES' MILK

Serial of the Ewe	Potassium		Lactose		Potassium to Lactose R		Sodium		Total Solids	
	3rd Week	6th Week	3rd Week	6th Week	3rd Week	6th Week	3rd Week	6th Week	3rd Week	6th Week
46	120	108	4.28	4.71	28.0	22.9	32	36	14.1	15.6
47	120	120	4.74	4.74	25.3	25.3	32	36	15.9	17.0
48	140	156	4.29	4.27	32.6	36.5	28.	32	17.1	18.5
49	104	100	4.67	4.68	22.2	21.6	28	36	17.2	18.3
50	116	100	4.41	4.49	23.2	22.3	32	40	17.8	18.9
51	104	100	4.47	4.49	23.2	22.3	36	40	17.0	18.8
52	148	144	4.50	4.58	32.9	31.4	28	36	16.0	16.5
53	108	104	4.80	4.91	22.5	21.2	28	32	15.3	16.6
54	128	116	5.01	5.00	25.5	23.2	28	36	16.1	17.5
55	96	116	4.91	4.94	19.5	23.7	36	36	16.3	17.4
56	100	100	5.04	5.03	19.8	19.9	36	40	16.2	17.4
57	128	124	4.76	4.78	26.9	25.9	32	36	18.1	19.2
58	120	132	4.47	4.80	36.8	27.5	32	36	17.6	19.0
59	140	140	4.94	4.85	26.7	28.9	44	44	15.8	16.2
60	116	116	4.59	4.69	25.2	24.7	32	36	16.0	17.2
61	144	140	4.94	4.79	29.1	29.2	32	36	15.7	17.0
62	140	140	5.09	4.39	27.5	31.9	32	36	16.8	17.7
63	156	148	4.80	4.83	32.4	30.6	32	36	15.2	16.8
64	148	148	4.51	4.51	32.8	32.8	32	36	18.0	19.1
65	140	132	4.50	4.57	31.1	28.9	32	36	20.1	22.2
66	128	168	4.29	4.74	29.8	34.0	32	36	16.3	17.7
67	116	108	4.51	4.54	25.7	23.8	28	40	15.1	16.4
68	128	132	4.53	4.74	28.2	27.8	32	36	15.9	17.2
69	116	116	4.70	4.17	24.6	27.8	32	36	17.0	17.9
70	132	140	4.66	4.68	28.3	29.9	32	36	14.3	15.9
71	96	128	4.11	4.37	23.3	29.3	36	36	16.2	17.8
72	104	104	5.00	5.09	20.8	20.4	32	36	15.3	16.5
73	148	148	4.94	4.33	29.9	34.2	36	40	14.8	16.1
74	128	116	4.36	4.38	29.3	26.5	32	36	15.3	16.6
75	100	120	4.80	4.81	20.8	24.9	32	36	17.1	18.8
76	104	100	4.67	4.68	22.2	21.4	36	40	15.1	17.6

APP. TABLE 19

COMPOSITION OF C X BF EWES' MILK

Serial No. of Ewe	Potassium		Lactose		Potassium to Lactose R		Sodium		Total Solids	
	3rd Week	6th Week	3rd Week	6th Week	3rd Week	6th Week	3rd Week	6th Week	3rd Week	6th Week
77	104	132	4.72	4.41	22.0	29.9	32	36	17.5	21.8
78	116	104	4.40	4.70	26.3	22.1	40	40	16.5	17.7
79	100	68	4.74	4.73	21.0	14.4	32	40	16.9	18.1
80	108	108	4.98	3.89	21.7	27.8	32	36	22.0	23.0
81	116	88	5.43	4.83	20.2	18.2	44	36	14.2	15.0
82	106	104	4.19	4.69	23.8	22.2	36	36	16.0	17.8
83	116	96	5.33	4.88	21.7	19.7	44	44	14.7	16.1
84	116	128	5.09	4.70	22.8	27.2	32	36	17.3	18.0
85	116	108	5.18	5.20	22.3	20.7	44	44	17.8	18.9
86	104	100	4.97	4.99	20.9	20.0	28	36	18.0	18.2
87	120	116	4.82	4.37	24.9	26.5	32	36	15.3	16.8
88	128	148	5.36	4.56	23.8	32.4	36	40	15.8	16.8
89	128	132	4.65	4.94	27.5	26.7	36	36	15.3	16.8
90	116	100	4.30	4.34	26.9	23.0	32	36	18.0	19.4
91	116	92	5.86	5.01	19.8	18.4	28	32	15.8	16.2
92	116	108	4.49	4.52	25.8	23.9	36	40	15.1	16.5
93	156	148	5.10	5.13	30.5	28.5	28	32	17.3	18.9
94	156	148	4.63	4.00	33.7	37.0	28	32	14.3	15.7
95	120	132	3.14	4.82	38.2	27.4	32	36	16.0	16.5
96	128	128	4.72	4.36	27.1	29.4	32	36	18.0	19.5
97	104	128	4.71	4.63	22.0	27.6	36	40	14.9	16.1
98	104	104	4.84	4.45	21.4	23.4	32	36	18.0	19.4
99	128	132	5.21	4.56	24.3	28.9	28	36	14.0	15.8
100	104	120	4.32	4.59	24.0	26.1	36	36	16.2	17.8
101	104	104	4.08	4.57	25.4	22.8	32	36	17.1	18.8
102	144	92	4.98	4.26	28.9	21.6	40	44	16.0	17.9

APP. TABLE 20

COMPOSITION OF D X BF EWES' MILK

Serial No. of Ewe	Potassium		Lactose		Potassium to Lactose R		Sodium		Total Solids	
	3rd Week	6th Week	3rd Week	6th Week	3rd Week	6th Week	3rd Week	6th Week	3rd Week	6th Week
103	160	156	5.12	5.14	31.2	30.4	32	36	16.2	17.7
104	96	92	4.77	4.77	20.6	19.3	40	44	15.3	16.8
105	132	132	5.86	5.86	22.5	22.5	32	36	18.2	19.5
106	128	124	3.97	3.99	32.2	31.1	32	36	15.5	16.9
107	128	128	4.86	4.86	26.3	26.3	32	36	15.4	16.8
108	144	140	4.81	4.83	29.9	29.0	32	36	16.0	17.0
109	132	148	5.05	4.56	26.1	32.5	36	36	16.1	17.5
110	168	148	5.46	4.57	30.7	32.4	44	44	16.0	17.3
111	116	116	5.63	5.63	20.6	20.6	28	36	16.0	16.0
112	128	116	4.31	4.40	29.6	26.4	32	36	16.9	17.2
113	148	144	4.61	4.63	32.1	31.1	32	36	15.3	16.9
114	104	100	4.49	4.51	23.1	22.2	32	36	16.0	17.1
115	140	128	4.45	4.45	31.4	28.8	36	40	16.7	18.4
116	116	108	5.23	5.30	22.1	20.4	32	36	16.5	18.0
117	132	128	4.94	4.96	26.7	25.0	44	44	16.0	17.3
118	172	168	4.64	4.50	37.0	37.3	36	40	16.3	17.4
119	132	128	5.15	4.83	25.5	26.5	40	44	15.2	16.7
120	156	160	4.31	4.26	36.2	37.6	32	40	14.9	15.5
121	156	158	4.73	4.73	32.9	32.9	32	36	15.4	16.9
122	104	92	4.49	4.14	23.1	22.2	32	36	16.0	17.2
123	128	140	4.63	4.43	27.6	31.6	32	36	15.0	16.5
124	140	144	4.99	4.69	28.1	30.7	32	36	15.0	16.7
125	108	96	5.04	4.91	21.4	19.6	32	40	15.1	15.7
126	100	96	5.10	5.19	19.6	18.5	40	44	15.0	15.8
127	88	100	4.72	4.79	18.6	20.9	36	40	15.2	16.8
128	120	116	4.39	4.57	27.3	25.4	32	36	15.9	17.1
129	140	116	5.13	4.36	27.2	26.6	32	36	17.0	17.2
130	108	104	5.45	5.46	19.8	19.1	36	40	15.8	16.9

APP. TABLE 21

BLOOD CHARACTERS OF BL X BF EWES

Serial No. of Ewe	Packed Cell Volume (PCV)	Plasma Values		k. Whole Packed Cells (KWPC)	Whole Blood		Blood Pheno-type	Hb Pheno-type
		Na	k		Na	k		
1	32.5	100.9	9.2	10.7	106.1	9.7	6	2
2	33.0	121.7	7.2	18.1	113.1	10.8	6	3
3	35.0	118.3	7.7	19.4	109.6	11.8	6	2
4	33.5	114.8	26.7	37.4	99.1	30.3	9	2
5	37.5	125.2	11.3	13.9	116.5	12.3	6	2
6	36.0	116.5	22.0	54.8	97.4	33.8	9	3
7	35.5	114.8	9.2	15.1	120.0	11.3	6	2
8	31.5	106.1	8.2	11.3	116.5	9.2	6	3
9	37.0	128.9	11.3	4.2	106.1	8.7	6	2
10	35.5	120.0	44.4	56.1	97.4	29.2	9	3
11	36.0	123.5	7.2	12.4	111.3	12.3	6	2
12	32.5	107.8	5.1	24.1	118.3	11.3	6	2
13	38.0	121.7	8.2	16.3	106.1	11.3	6	2
14	33.5	116.5	6.2	15.1	107.8	9.2	6	3
15	29.5	116.5	15.4	60.5	102.6	28.7	9	2
16	32.0	120.0	11.8	61.2	93.9	27.6	9	2

The following notes apply to all ewes' blood characters.

6 in blood phenotype means Low potassium type.
9 in blood phenotype means High potassium type.
1 in Hb phenotype means (A) type ~~potassium~~ Fast type.
2 in Hb phenotype means (AB) type ~~potassium~~ Mixed type.
3 in Hb phenotype means (B) type ~~potassium~~ Slow type.

APP. TABLE 22

BLOOD CHARACTERS OF F X BF EWES

Serial No. of Ewe	Packed Cell Volume (PCV)	Plasma Values Na	Plasma Values k	k.Whole Packed Cells (KWPC)	Whole Blood Na	Whole Blood k	Blood Phenotype	Hb Phenotype
17	21.0	104.3	7.7	14.8	113.1	9.2	6	2
18	32.5	116.5	7.2	11.8	106.1	9.7	6	1
19	28.5	121.7	6.7	11.9	107.8	8.2	6	1
20	32.5	118.3	7.2	8.7	107.8	7.7	6	2
21	33.0	123.5	7.7	9.2	106.1	8.2	6	2
22	29.5	118.3	10.3	13.6	107.8	11.3	6	1
23	30.0	121.7	7.2	18.5	113.1	10.8	6	3
24	33.5	121.7	22.9	22.9	107.8	11.8	6	2
25	33.0	128.7	8.7	11.7	116.5	9.7	6	1
26	35.0	120.0	9.2	19.4	118.3	12.8	6	1
27	33.0	125.2	12.3	10.8	107.8	11.8	6	3
28	31.5	121.7	18.9	48.4	102.6	28.2	9	3
29	31.0	123.5	9.7	6.4	106.1	8.7	6	2
30	30.5	121.7	9.7	13.3	106.1	10.8	6	1
31	36.0	116.5	8.2	10.9	106.1	9.2	6	2
32	32.5	121.7	9.7	74.0	102.6	30.6	9	3
33	33.5	107.8	17.9	66.3	106.1	32.8	9	2
34	30.5	120.0	16.4	70.1	104.3	32.8	9	1
35	30.0	123.5	7.7	14.3	113.1	9.7	6	2
36	31.0	121.7	8.3	23.0	114.8	12.8	6	1
37	33.0	113.1	11.3	71.6	97.4	31.2	9	2
38	28.5	121.7	12.3	69.8	100.9	28.7	9	2
39	30.0	113.1	18.9	47.9	100.9	27.6	9	1
40	33.0	118.3	14.4	71.9	102.6	33.4	9	1
41	36.0	121.7	11.8	31.5	118.3	18.9	6	1
42	30.0	120.0	10.8	19.1	107.8	13.3	6	1
43	33.0	111.3	18.5	61.8	100.9	32.8	9	1
44	32.0	116.5	16.9	61.5	95.7	31.2	9	1
45	33.5	114.8	19.5	62.1	100.9	33.8	9	1

APP. TABLE 23

BLOOD CHARACTERS OF M X BF EWES

Ewes' Serial No. of	Packed Cell Volume (PCV)	Plasma Values Na	Plasma Values k	k.Whole Packed Cells (KWPC)	Whole Blood Na	Whole Blood k	Blood Phenotype	Hb Phenotype
46	33.5	104.3	9.7	14.5	109.6	11.3	6	2
47	31.0	126.0	8.7	10.3	121.7	9.2	6	2
48	30.5	120.9	18.5	57.1	106.1	30.3	9	1
49	35.5	114.8	10.8	16.4	114.8	12.8	6	1
50	34.5	118.3	9.5	11.7	123.5	10.3	6	2
51	31.0	116.5	7.2	7.2	121.7	7.2	6	2
52	29.5	111.3	18.5	56.8	107.8	29.8	9	2
53	36.5	130.4	8.7	14.5	125.2	10.8	6	1
54	33.0	118.3	22.0	51.6	102.9	31.8	9	1
55	32.0	126.9	8.2	11.3	113.1	9.2	6	2
56	32.5	125.2	7.7	10.7	114.8	8.7	6	1
57	29.0	120.0	17.9	18.9	107.8	28.2	6	3
58	35.0	121.7	9.2	15.2	121.7	11.3	6	2
59	34.0	123.5	7.2	19.2	114.8	11.3	6	1
60	32.0	123.5	5.6	10.6	111.3	7.2	6	1
61	33.0	126.9	8.2	17.6	116.5	11.3	6	2
62	30.5	120.0	16.4	70.1	104.3	32.8	9	1
63	32.5	125.2	6.2	13.9	113.1	8.7	6	1
64	34.5	114.8	9.2	73.0	92.2	31.2	9	1
65	36.5	130.4	7.2	14.0	107.8	9.7	6	1
66	39.0	126.9	6.7	13.1	102.6	9.2	6	2
67	39.0	121.7	8.2	16.1	118.3	11.3	6	1
68	30.0	125.2	6.7	13.4	120.0	8.7	6	3
69	33.5	123.5	9.7	72.0	97.4	30.6	9	3
70	31.0	149.5	13.8	51.8	104.3	25.6	9	2
71	31.0	123.5	7.7	75.4	102.6	28.7	9	1
72	34.0	123.5	13.3	58.5	95.7	28.7	9	1
73	29.0	130.4	9.2	44.7	99.1	19.5	6	2
74	35.5	130.4	6.2	16.5	95.7	9.7	6	2
75	36.0	130.4	12.8	63.9	88.7	31.2	9	2
76	36.0	120.0	16.9	64.0	102.6	33.8	9	1

APP. TABLE 24

BLOOD CHARACTERS OF C X BF EWES

Serial No. of Ewe	Packed Cell Volume (PCV)	Plasma Values Na	Plasma Values k	k.Whole Packed Cells (KWPC)	Whole Blood Na	Whole Blood k	Blood Pheno-type	Hb Pheno-type
77	33.0	113.1	8.1	8.1	111.3	9.2	6	2
78	36.0	121.7	28.2	53.2	106.1	37.2	9	2
79	30.0	128.7	23.1	41.8	102.6	28.7	9	3
80	35.5	121.7	10.8	17.8	111.3	13.3	6	2
81	36.5	120.0	10.8	9.4	106.1	10.3	6	3
82	35.5	116.5	11.8	14.6	113.1	12.8	6	2
83	35.5	121.7	11.6	11.6	114.8	10.8	6	2
84	30.0	128.7	23.1	41.8	102.6	28.7	9	3
85	35.0	106.1	24.6	33.2	90.4	27.6	6	2
86	34.0	118.3	19.5	49.8	95.7	29.8	9	2
87	32.5	125.2	23.6	42.7	109.6	29.8	9	2
88	34.0	125.2	10.8	15.2	114.8	12.3	6	2
89	33.0	116.5	26.2	52.2	104.3	34.8	9	2
90	25.5	109.6	18.5	54.2	100.9	27.6	9	2
91	31.0	121.7	5.6	15.6	113.1	8.7	6	3
92	33.5	128.7	6.7	14.2	114.8	9.2	6	2
93	33.0	126.9	6.2	12.3	111.3	8.3	6	3
94	33.0	123.5	5.6	13.5	104.3	8.2	6	3
95	33.0	130.4	5.1	11.5	106.1	7.2	6	3
96	33.5	132.1	5.1	65.9	104.3	56.0	9	3
97	33.0	125.2	6.2	21.6	93.9	11.3	6	2
98	30.0	126.9	6.7	25.3	93.9	12.3	6	3
99	36.0	121.7	10.3	72.8	93.9	32.8	9	2
100	32.0	125.2	7.2	23.1	104.3	12.3	6	2
101	33.0	114.8	13.8	13.8	102.6	8.7	6	3
102	38.0	123.5	11.8	69.6	90.4	33.8	9	2

APP. TABLE 25

BLOOD CHARACTERS OF D X BF EWES

Serial No. of Ewe	Packed Cell Volume (PCV)	Plasma Values		k.Whole Packed Cells (KWPC)	Whole Blood		Blood Pheno-type	Hb Pheno-type
		Na	k		Na	k		
103	31.5	121.7	25.6	40.5	107.8	30.3	9	2
104	33.0	114.8	24.1	52.2	116.5	33.4	9	2
105	36.5	120.0	8.7	13.1	106.1	10.3	6	2
106	34.0	113.1	22.0	43.2	92.2	29.2	9	2
107	32.5	114.8	22.0	47.5	99.1	30.3	9	2
108	29.0	123.5	8.7	10.5	111.3	9.2	6	2
109	32.0	126.9	21.0	54.7	106.1	31.8	9	2
110	32.0	113.1	25.6	34.3	106.1	28.7	6	2
111	33.0	126.9	7.2	4.1	114.8	6.2	6	3
112	28.0	113.1	6.7	13.8	116.5	8.7	6	2
113	34.5	125.2	8.2	5.3	111.3	7.2	6	3
114	31.5	116.5	22.0	44.8	100.9	29.2	9	3
115	32.0	118.3	18.5	55.3	106.1	30.3	9	3
116	36.5	116.5	8.2	9.5	120.0	8.7	6	2
117	34.0	121.7	11.3	76.3	100.9	33.4	9	3
118	36.5	121.7	16.9	60.4	95.7	32.8	9	2
119	34.0	116.5	13.3	64.2	93.9	30.6	9	3
120	30.0	125.2	5.6	14.3	109.6	8.2	6	2
121	29.5	128.7	11.8	72.8	93.9	29.8	9	2
122	32.0	129.6	8.7	71.2	90.4	28.7	9	3
123	27.0	114.8	6.7	76.7	95.7	25.6	9	2
124	32.0	130.4	8.2	83.2	88.7	32.2	9	2
125	32.5	114.8	22.0	47.5	99.1	30.3	9	2
126	41.0	113.1	22.3	22.3	111.3	12.8	6	1
1								
127	35.0	118.3	9.7	71.1	93.9	31.2	9	2
128	30.5	118.3	8.7	70.7	97.4	27.6	9	2
129	29.0	130.4	8.7	66.9	90.4	25.6	9	2
130	39.5	121.7	5.6	18.6	92.2	10.8	6	2