to this herd would, during the period under review, have condemned every one of the 40 healthy quarters as diseased. With the cellular content as criterion only one quarter (7905 L.H.) would have escaped.

The results recorded in Tables 3 and 4 furnish a good illustration of the close relationship which exists between solids not fat, chloride and lactose, and confirm Richmond (1920) and Davies' (1936) view that the milk sugar in the factor chiefly involved in a deficiency in solids not fat. It will be observed that quarters high in solids not fat also have a high lactose and accordingly a low chloride content of the milk, and, conversely, deficient solids not fat milk is characterized by low lactose and high chloride percentage. Increase in chloride in the absence of physiological factors can no longer be regarded as proof of udder disease. In the secretion of abnormal milk, which involves a deficiency of lactose, an abnormally high chloride content must be accepted as a natural characteristic, since the inverse relationship between chloride and lactose necessitates, for osmotic considerations, a high chloride content in cases in which non-fatty solids and, therefore, lactose are low.

(IX). The Influence of Various Aetiological Factors.

Most of the available data on the effects of the various factors, besides disease of the udder, which are likely to have a detrimental influence on the composition of milk, give consideration only to the milk fat. In those cases in which the fat-free solids do receive some attention the information supplied is very often fragmentary and, therefore, not very reliable.

Cranfield, Griffiths and Ling (1927) rightly point out that one frequently observes articles and papers dealing with the quality of milk, in which no cognisance is taken of the fact that milk contains other solids besides fat. Yet the calorific value of non-fatty solids is nearly 15 per cent. greater than that of the fat. This fact, combined with the knowledge that the percentage of solids not fat in milk is subject to considerable variations, warrants more attention being paid to this portion of the constituents of milk than heretofore. From the review of the literature on the secretion of poor quality milk which has already been given it is also apparent that the deficiencies noted in solids not fat are more numerous and cause greater concern that those occurring in the fat. Moreover, it appears that the fat-free solids are more sensitive to adverse influences and therefore have a greater tendency to show deficiency than the fat. This investigation was therefore made as comprehensive as possible in an effort to determine the effect of the various aetiological agents on all the constituents included in the study.

The following sections are accordingly devoted to a detailed study of the rôle played by each of the undermentioned factors in the production of milk of inferior quality, namely: age, season and climate; stage of lactation, individuality, quarter differences, conformation and structure, non-specific mastitis and micro-organisms.

(i) *Age.*

According to all investigators the quality of milk declines with age, though all are not agreed as to the actual period when the decline commences. Many hold that there is an increase especially in the fat content in the second lactation as compared with the first, and that the deterioration starts after the second lactation. Others again maintain that a cow yields her best quality milk during the first lactation. Cooke (1892) appears to be the only one who concluded that there is no general tendency for the milk to become either richer or poorer as the cow grows older.

According to Mackintosh (1925) the quality of milk is at its best after the first and second calves, the percentage fat then decreasing slightly as the cow advances in age.

Tocher (1926) found a slight increase in the butter fat percentage as the cows increase in age between 2 and 5 years, and a gradual fall after 5 or 6 years. He also found the regression of solids not fat on age to be linear, the percentage continuously decreasing with increasing age. The conclusions of both Mackintosh and Tocher are based very largely on the analyses of milk of Ayrshire cows, and no figures are given for other breeds.

White and Drakeley (1927) analysing the results obtained at the shows held by the British Dairy Farmers Association during the previous 48 years, found that in British Friesian cows the fat percentage increased until the fifth year and declined after that, whereas the solids not fat content was at its highest point during the second and third year, and showed a gradual drop subsequently.

Bartlett (1934) noted that the first lactation showed a higher solid content throughout, and showed a more pronounced rise at the end of the lactation than later lactations of the same cow.

According to Turner (1936) the fat content of the milk of young animals is unusually high but then gradually declines with age, and the decline appears to be greatest in the breeds secreting milk with the highest fat content.

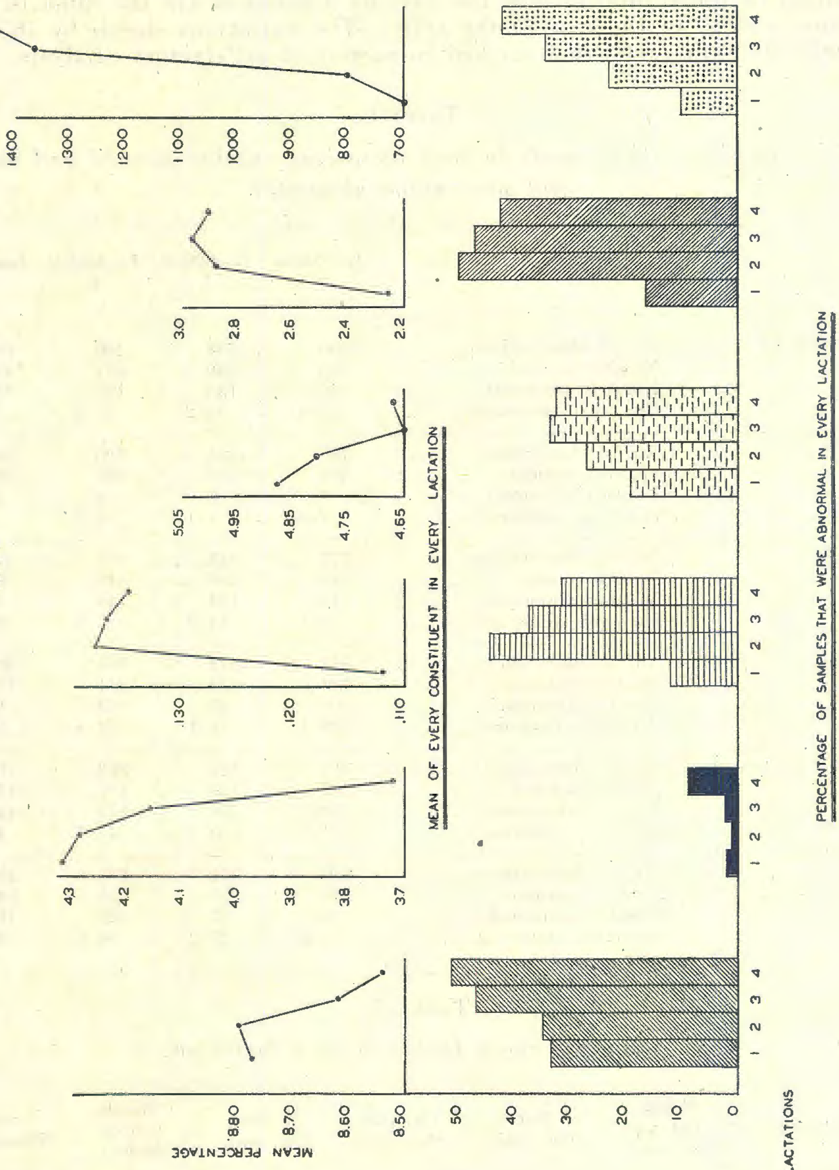
Very little information can be obtained from the available literature on the effect of advancing age on the chloride content of milk, but Davies (1938) considers that on the whole milk from successive lactations increases in chloride content. Little (1939) regarded it as significant that in succeeding lactations some cows produced milk of lower quality than that of their previous lactations (increase in pH and percentage chloride), and considered that this was due to some impairment of the udder which occurred during the previous lactations. (Table 6.)

For the purpose of obtaining accurate data to illustrate the variations which may occur in the composition of milk from one lactation to another the records used in this section have been calculated only from the results obtained in the analysis of milk from the seven cows which completed four lactations. The records of cows 7904, 7905 and 7909 are, therefore, not considered except in Table 9.

The total number of observations made for every constituent in each of the four lactations, and the number and percentage of samples which revealed abnormality in the milk in every lactation are detailed in Table 6. The percentage of samples which were found to be abnormal is further illustrated by means of blockgraphs (Fig. 4) each of which again is accompanied by a curve which indicates the variations in the mean for that constituent for the different lactations as presented in Table 7.

The data from which the mean of each factor for every lactation was determined were subjected to statistical examination, and the results of this are detailed in a Difference of Means table (Table 8).

FIG. 4


MEAN PERCENTAGE
MEAN OF EVERY CONSTITUENT IN EVERY LACTATION
PERCENTAGE OF SAMPLES THAT WERE ABNORMAL IN EVERY LACTATION
LACTATIONS

By an analysis of variance the necessary differences for each factor indicated in the table were found at two probability levels, namely P = ·05 and P = ·01. It will be observed in Table 8 that the results obtained by the application of the necessary differences for both values of P for the determination of the significance of the various differences are the same in every instance except in the case of the cells. The variations shown by the individual cell counts were too marked to permit of satisfactory analysis.

TABLE 6.

Number of observations made in each lactation, number normal and number and percentage abnormal.

		Lactation 1.	Lactation 2.	Lactation 3.	Lactation 4.
Solids not fat.......	No. of observations........	400	384	400	292
	Number normal...........	265	249	211	141
	Number abnormal.........	135	135	189	151
	Per cent. abnormal........	33·8	35·2	47·3	51·7
Fat................	No. of observations........	400	384	400	292
	Number normal...........	392	380	391	268
	Number abnormal.........	8	4	9	24
	Per cent. abnormal........	2·0	1·1	2·3	9·0
Chloride............	No. of observations........	373	343	393	279
	Number normal...........	328	189	245	190
	Number abnormal.........	45	154	148	89
	Per cent. abnormal........	12·1	44·9	37·6	31·9
Lactose............	No. of observations........	314	314	364	266
	Number normal...........	254	229	241	179
	Number abnormal.........	60	85	123	87
	Per cent. abnormal........	19·1	27·1	33·8	32·7
Chloride Lactose Index	No. of observations........	314	314	363	266
	Number normal...........	262	156	191	152
	Number abnormal.........	52	158	172	114
	Per cent. abnormal........	16·6	50·3	47·4	42·9
Cells................	No. of observations........	226	332	353	257
	Number normal...........	203	255	231	148
	Number abnormal.........	23	77	122	109
	Per cent. abnormal........	10·2	23·2	34·6	42·4

TABLE 7.

Mean for every factor in each lactation.

Lactation.	Solids not fat Per cent.	Fat Per cent.	Chloride Per cent.	Lactose Per cent.	Chloride-lactose Index.	Cells Thousands.
1............	8·7575	4·3178	·1123	4·8850	2·3560	699
2............	8·8032	4·2904	·1378	4·8118	2·8775	803
3............	8·6164	4·1629	·1367	4·6464	2·9743	1368
4............	8·5421	3·7221	·1354	4·6667	2·9125	1459

TABLE 8.

Difference of Means table.

Difference between.	Solids not fat.		Fat.		Chloride.		Lactose.		Chloride-lactose Index.		Cells.	
	P=·05 ND=·0968	P=·01 ND=·1281	P=·05 ND=·1782	P=·01 ND=·2358	P=·05 ND=·0087	P=·01 ND=·0153	P=·05 ND=·0396	P=·01 ND=·0524	P=·05 ND=·2869	P=·01 ND=·2869	P=·05 ND=640	P=·01 ND=847
1st and 2nd lactation..........	NS	NS	NS	NS	S	S	S	S	S	S	NS	NS
1st and 3rd lactation..........	S	S	NS	NS	S	S	S	S	S	S	S	NS
2nd and 3rd lactation..........	S	S	S	S	S	S	S	S	S	S	S	NS
2nd and 3rd lactation..........	S	S	NS	NS	NS	NS	S	S	NS	NS	NS	NS
2nd and 4th lactation..........	S	S	S	S	NS	NS	S	S	NS	NS	S	NS
3rd and 4th lactation..........	NS	NS	S	S	NS	NS	NS	NS	NS	NS	NS	NS

Solids not fat.—Table 6 and the relative block graph show that the percentage of samples that were abnormal rose progressively from the first to the fourth lactation, there being a consistent increase from 33·8 per cent. in the first lactation to 51·7 per cent. in the fourth. These figures suggest that the mean solids not fat percentage should show a linear regression from the first lactation onwards as found by Tocher. This, however, was not confirmed and as will be seen from the relative curve and in Table 7 the mean solids not fat percentage actually increased from 8·76 in the first to 8·80 in second lactation. Examination of the records of the individual quarters supplied in the appendix reveals that increase in the non-fatty solids percentage was shown by 18 of the 28 quarters, namely all quarters of 7910 and 7914 and 7912 L.H., 7913 R.F., R.H. and L.F., 7919 R.F., L.F., L.H., 7921 L.H., 7922 R.F. and L.H. One (7912 R.H.) was the same and a decrease was shown by the other nine, namely, 7912 R.F., L.F., 7913 L.H., 7919 R.H., 7921 R.F., R.H., L.F., 7922 R.H. and L.F. As will be revealed in the section on non-specific mastitis practically every one of the latter nine quarters suffered some degree of secretory disturbance during the second lactation, which undoubtedly was largely responsible for the depression in their solids not fat percentage. It would thus appear that in udders not exposed to infection or any other type of inflammatory condition the tendency in solids not fat percentage would be to increase during the second lactation. The peak is reached at this stage and then the decline sets in.

According to the Difference of Means table the increase noted between the first and second calvings was not significant, but the subsequent decline was significant in all cases, excepting that between the third and fourth lactations.

Fat.—In contrast with the fat-free solids the mean fat percentage obtained its highest point after the first calving and this showed a decline in each succeeding lactation. The percentage samples with abnormally low fat content was, however, higher in the first than in the second lactation.

The decrease noted in fat percentage from the first to the third lactation was not significant, but this was followed by a significant drop from 4·1629 per cent. in the third to 3·7221 per cent. in the fourth lactation. At the same time the number of abnormal samples increased from 2·3 per cent. to 9·0 per cent.

As far as the fat is concerned these results are not in agreement with those of most of the European workers though they conform with the views expressed by Turner in America, namely that the fat content of the milk of young animals is usually high, and declines with advancing age.

Chloride.—The most striking feature to be noted in the figures for chloride is the very marked rise both in the mean chloride content and in the number of samples that were found to contain abnormally high chloride in the second lactation, which again was followed by a slight decline in the third and fourth lactations.

According to the statistical analysis the increase in the second, third and fourth lactation period over the first is significant in every case, while the slight decline which followed in the third and fourth lactations is insignificant.

It cannot be concluded that the results obtained in this case offer a true reflection of the variations which occur in the chloride content of milk during successive lactation periods. The increase in the mean from ·113 per cent.

in the first lactation to ·1378 per cent. in the second is exceptionally high, whereas the decline which followed is contrary to the findings of Davies and Little. Attention has already been drawn to the fact that several quarters suffered secretory disturbances during the second lactation which caused a depression in their solid not fat content. The increase, however, which was shown in the milk of the other quarters was sufficient to off-set the decline in a few and to raise the mean solids not fat percentage to a higher level than it was in the first lactation.

The same does not apply to the chloride content. Only two quarters 7919 R.F. and L.F.) had a lower average in the second lactation than in the first. In one (7910 L.H.) it was the same, and in the remaining 25 the chloride content was increased. While in the majority of them the increases were apparently such as could be expected under normal conditions, the records show that it was very marked in the milk of those quarters which suffered a disturbance in secretion during the second lactation and also in all four quarters of 7921 in which a state of " microbism " was found to be present after her second calving.

Confirmation of the view previously expressed that the chloride is more responsive to adverse conditions in the udder than any other constituents of milk, is furnished by the records of some of these quarters in the second lactation. The fact that the solids are not affected quite to the same extent as chloride and lactose by inflammatory conditions of the udder is probably due to the increased permeability of the alveolar membrane in such cases, permitting an excessive amount of serum globulin and serum albumin to pass through into the milk.

As will be indicated later the effects of such adverse conditions are frequently prolonged, and in some cases were still obvious in the third lactation. A more correct evaluation of the effects of advancing age on the chloride content of the milk can therefore be made by disregarding the means obtained for the second and third lactations, and considering only the rise from ·1123 per cent. in the first lactation to ·1354 per cent. in the fourth as being more representative of the increase in chloride percentage of the milk from normal quarters during successive lactations.

Lactose.—The mean percentage for lactose showed a consistent decline from the first to the third lactation periods. The difference between the means for these three lactations was significant in every instance. This was followed by an insignificant rise from 4·6464 per cent. in the third to 4·6667 per cent. in the fourth lactation, this coinciding with the slight decline which was noted in the chloride content during the same period. The percentage of samples which were deficient in lactose increased correspondingly from 19·1 in the first to 33·8 in the third lactation, and dropped slightly to 32·7 in the fourth lactation.

The fact that the percentage of lactose did not show a considerable decline consistent with the increase in chloride in the second lactation is due to the omission of a number of samples on account of the difficulty experienced in the analysis for sugar of milk samples with a high degree of abnormality. Consequently the lactose content of samples which had exceptionally high chloride was frequently not determined.

Chloride-Lactose Index.—In samples in which the milk-sugar content was not determined it was naturally also not possible to ascertain the chloride-lactose index. Like the lactose, therefore, this index also does not reflect the variations to the same degree as the chloride. The curve indicating the mean of the index is thus very similar, though inverse to that of the lactose. There is a rise from 2·2560 in the first lactation to 2·9743 in the third followed by an insignificant decline to 2·9125 in the fourth.

The percentage of samples that were found to be abnormal to the chloride-lactose index also showed a very marked increase from 16·6 in the first to 50·3 in the second lactation. The reason for this has already been given in the section on chloride. This percentage dropped slightly to 47.4 and 42·9 in the third and fourth lactations respectively.

Cells.—The mean cellular content in every lactation showed an increase over that of the previous period, and the percentage of samples that yielded a cell count of over a million per ml. of milk increased similarly from 10·2 in the first to 42·4 in the fourth lactation.

Owing to the very marked indivadual variations which occur from time to time cell counts do not lend themselves readily to the usual statistical methods of examination, and it will be observed in Table 8 that with $P = \cdot 01$ the increase in any one lactation over that of the preceding period was not significant. With $P = \cdot 05$, however, the difference between the 1st and 3rd, 1st and 4th and the 2nd and 4th periods was significant.

It is obvious from the data in Tables 6 and 7 that many, if not all, of the quarters which commenced their lactation life by secreting milk of a certain standard underwent a gradual process of degeneration or deterioration after the first calving, which resulted in a reduction in the quality of the milk sereted in successive lactations. Consequently quarters which start by yielding milk of normal composition ultimately reach a stage when their milk is of such poor quality that the quarter as well as the milk must be regarded as abnormal.

This progressive deterioration of the udder with increasing age is illustrated in Table 9 in which the classification of the quarters into normal and abnormal is based on the means obtained for each of the six factors studied in every lactation. In the table N indicates that the means for all six constituents of the milk of the relative quarter in that lactation were equal to the standard adopted for normality. Failure on the part of the milk to attain the standard in one or more constituents is denoted by ABN with the deficient factor or factors in parenthesis.

Five quarters, namely, 7910 L.F., L.H., 7912 L.H., 7919 L.H. and 7922 L.H. remained normal in every respect throughout the first four lactations. Twelve quarters, namely, all of 7914, 7913 R.F., R.H., L.F., 7919 R.F., R.H., L.F., 7922 R.F. and R.H. gave milk with normal solids not fat percentage in all four lactations but was abnormal at various periods in one or more of the other factors—mostly cells and chloride-lactose index.

On the other hand 9 quarters, namely, all of 7905 and 7909 and 7921 L.F. yielded milk with a low solids not fat average in the first and all subsequent lactations, not one of these quarters succeeding in any lactation in obtaining a mean of 8·50 per cent. or over. They also showed an increasing number of abnormalities in the other factors after the first lactation period.

Of the remaining 14 quarters which gave milk with a normal solid not fat content in the first lactation two (7921 R.F. and R.H.) became abnormal in the second lactation and remained abnormal subsequently. Seven, namely, all of 7904, 7912 R.F., 7921 L.H. and 7922 L.F. gave normal solid not fat percentage in the first two lactations but became abnormal after the third

TABLE 9.

Deterioration of quarters in successive lactations.

Cow and Quarter.		1st Lactation.	2nd Lactation.	3rd Lactation.	4th Lactation.
7904	RF	N	N	ABN (SNF, CLI and Cells)	—
	RH	N	N	ABN (SNF and Cells)	—
	LF	N	N	ABR (SNF)	—
	LH	N	N	ABN (SNF)	—
7905	RF	ABN (SNF)	ABN (SNF, CI, L & CLI)	ABN (SNF, CI, L & CLI)	ABN (SNF, CI, L & CLI).
	LF	ABN (SNF)	ABN (SNF, CI, L & CLI)	ABN (SNF, CI, L & CLI)	ABN (SNF, CI, L & CLI).
	LF	ABN (SNF & CLI)	ABN (SNF, CI, L & CLI)	ABN (SNF, CI, L & Cells)	ABN (SNF, CI, L & CLI).
	LH	ABN (SNF)	ABN (SNF, CI, L & CLI)	ABN (SNF, CI, L & Cells)	ABN (SNF, CI & CLI).
7909	RF	ABN (SNF & CLI)	ABN (SNF, CI, L, CLI & Cells)	ABN (SNF, CI, L, CLI & Cells)	—
	RH	ABN (SNF & CLI)	ABN (SNF, CI & CLI)	ABN (SNF, CI, CLI & Cells)	—
	LF	ABN (SNF)	ABN (SNF, CI, L, CLI & Cells)	ABN (SNF, CI, L & CLI)	—
	LH	ABN (SNF & CLI)	ABN (SNF, CI, L, CLI & Cells)	ABN (SNF, CI, L & CLI)	—
7910	RF	N	N	N	ABN (SNF & CLI).
	RH	ABN (Cells)	N	N	ABN (SNF).
	LF	N	N	N	N.
	LH	N	N	N	N.
7912	RF	N	ABN (CLI & Cells)	ABN (SNF, CI, L, CLI & Cells)	ABN (SNF, CI, L, CLI & Cells).
	RH	ABN (Cells)	N	N	ABN (SNF & Cells).
	LF	ABN (Cells)	ABN (CLI & Cells)	N	ABN (SNF & Cells).
	LH	N	N	N	N.
7913	RF	N	N	N	ABN (CLI).
	RH	B	N	ABN (Cells)	ABN (Cells).
	LF	ABN (Cells)	ABN (CLI)	N	N.
	LH	N	ABN (CI, L, CLI Cells)	ABN (Cells)	ABN (SNF, CI, L, CLI Cells).
7914	RF	N	N	ABN (CLI Cells)	ABN (Cells).
	RH	N	N	ABN (Cells)	ABN (Cells).
	LF	N	N	N	ABN (Dells).
	LH	N	N	N	ABN (Cells).
7919	RF	ABN (CI)	N	ABN (CI CLI)	N.
	RH	N	ABN (CI CLI)	N	N.
	LF	ABN (CI & CLI)	ABN (CI CLI)	ABN (CI, L CLI)	N.
	LH	N	N	N	N.
7921	RF	N	ABN (SNF, CI, CLI & Cells)	ABN (SNF, CI, CLI Cells)	ABN (SNF, L, CLI Cells).
	RH	ABN (Cells)	ABN (SNF, CI, CLI Cells)	ABN (SNF, CI, L, CLI & Cells)	ABN (SNF, L, CLI Cells).
	LF	ABN (SNF L)	ABN (SNF, CI, L, CLI & Cells)	ABN (SNF, CI, L, CLI... (Cells)	ABN (SNF, L, CLI Cells).
	LH	ABN (L)	ABN (CI, L, CLI Cells)	ABN (SNF, CI & Cells)	ABN (SNF, L, CLI Cells).
7922	RF	ABN (Cells)	N	ABN (CI, CLI)	ABN (Cells).
	RH	N	N	N	N.
	LF	N	ABN (CI, CLI & Cells) Cells)	ABN (SNF, CI, L, CLI & Cells)	ABN (SNF, CI, CLI Cells).
	LH	N	N	N	N.

SNF = Solids not fat. CI = Chloride. L = Lactose. CLI = Chloride-lactose index.

calving. Cow 7904 did not complete the fourth lactation, but the other three quarters remained abnormal in the fourth lactation. The milk from the remaining five quarters, namely, 7910 R.F., R.H., 7912, R.H. L.F. and 7913 L.H. had a normal solid not fat content in the first three lactations, but became abnormal in the fourth.

The progressive nature of the deterioration of the udder is shown by the increasing changes from normal to abnormal in the successive lactation periods. An apparent improvement is shown by a few quarters (e.g. 7912 R.H., L.F., 7913 L.F. and 7919 R.F., R.H. and L.F.) in that factors which were abnormal in one lactation again became normal in the next. The causal agents of the abnormality in these cases were usually of a transitory nature, and an improvement appeared to follow when the cause was removed. It is interesting to note that such recoveries were observed mainly in connection with cells, chloride and chloride-lactose index. When depression of solids not fat percentage to a point below the normal occurred complete recovery was never restored. It is sufficient that no quarter which has once failed to give an average of 8·50 per cent. or over in one lactation ever succeeded in regaining normality in solids not fat in a subsequent lactation.

Discussion.

Examination of the data presented in this section provides definite proof of a gradual deterioration of the mammary gland and in the quality of the milk secreted by it during successive lactations.

The important part played by advancing age in the production of milk of abnormal composition is demonstrated by the marked increase in the percentage of samples that were abnormal to the various tests from the first to the fourth lactations, and by the differences in the means of the various factors studied.

The increases in the percentage of abnormal samples from the first to the fourth lactation were as follows.—

Solids not fat, from	33·8 to 51·7 per cent.
Fat, from	2·0 to 9·0 per cent.
Chloride, from	12·1 to 31·9 per cent.
Lactose, from	19·1 to 32·7 per cent.
Chloride-Lactose index, from ...	16·6 to 42·9 per cent.
Cells, from	10·2 to 42·4 per cent.

The following changes in the means were observed during the same period:—

Solids not fat decreased from	8·7575 to 8·5421 per cent.
Fat decreased from	4·3178 to 3·7721 per cent.
Lactose decreased from	4·8850 to 4·6667 per cent.
Chloride increased from	0·1123 to 0·1354 per cent.
Chloride-lactose index increased from ...	2·2560 to 2·9125 per cent.
Cells increased from	699 to 1459 thousands per ml.

The important problem from the practical and economic aspect is to determine the causes responsible for the decline produced in the quality of milk by advancing age.

Physiological factors and notably hormonal control of the functional activity of the udder may be involved. It has been proved that hormones like oestrogen, thyroxine and prolactin may produce an increase in the milk-solids, but this is only a temporary increase, and no evidence has as yet been adduced to suggest that hormonal control over milk secretion tends to become relaxed as the animal gets older. With our present knowledge one is, therefore, not justified in incriminating hormones or other physiological factors.

Assuming that the animals are in good health and well nourished the search for the primary cause of the decline in the quality of milk secreted must be directed to the udder itself.

The available literature contains no records to indicate to what extent, if any, histological examination of normal udders has been carried out in an endeavour to observe what changes take place in the structure of the gland with advancing age. Biochemical analysis of the milk and clinical examination of the udder in this investigation suggest that there is a gradual increase in fibrous tissue at the expense of the glandular portion of the gland. The effect of this would be to reduce the capacity of the alveoli and tubules to synthesize milk, and probably also to increase the permeability of the alveolar epithelium, thus facilitating the passage from the blood to the milk of blood serum and its solutes. With advancing age therefore the normal selective absorption and sythetic powers of the epithelial cells would be reduced, and instead of the cells performing their function of selecting and synthesizing the constituents of normal milk, they may allow some of the constituents of blood to pass into the milk unchanged. Increase in fibrous tissue would also cause a certain loss of elasticity thus reducing the ability of the udder to expand and increase its storage capacity on filling, with the result that the intramammary pressure will be unduly increased.

With the udder as with any other part of the body it is not possible to completely prevent the ravages of increasing age. To a certain extent degeneration of the udder is therefore unavoidable, and must be regarded as the natural result of the " wear and tear " process continually going on in the gland. There are, however, conditions which, when permitted, will greatly intensify the normal deterioration of the udder and cause a more rapid decline in the quality of the milk secreted. Most of these conditions can be placed in one category under " bad management ". They are, for instance, prolonged lactation, insufficiently long dry or rest period, incomplete milking, slow milking, careless handling, injuries to udder, increased bacterial activity apart from pathogenic infection, etc.

In considering the causes of the decline of the udder and of the quality of the milk secreted one must remember the basic fact that an unnatural strain is placed on the mammary gland of the modern dairy cow by demanding that it should be maintained in an almost continuous state of high functional activity from the time the cow first calves until she dies. Nature originally designed the udder of the cow with a view to providing just sufficient milk for the nourishment of the calf during the first few months of its existence. This would imply a total of approximately 200 gallons over a period of about six months every year. Man in his greed stepped in and by means of careful selective breeding and feeding has now forced the production up five or six times on a conservative estimate and extended the lactation period to ten months or more. Nature provided that the udder should have a rest of six months every year for regenerative purposes. Man has reduced this recuperative period to two months or even less.

The prevailing impression appears to be that the cow must be maintained in milk as long as possible, and that the dry period must be as short as possible. No consideration is given to the fact that the secretion of milk involves a continuous and intense process of breaking down and building up of glandular tissue. The tendency, therefore, to reduce the dry period to a minimum and not to allow the udder tissues sufficient time for regeneration between the different lactations must inevitably lead to more rapid decline than would otherwise have been the case.

Incomplete milking is considered merely from the economic aspect by the dairyman who is usually only concerned with the immediate loss of milk caused in this manner. The ultimate effects, however, are probably even more costly in so far as not only is a substantial portion of rich milk left in the udder at every milking but such retention of milk must contribute largely to udder deterioration. The continual presence of milk in the quarter implies that a certain pressure is always maintained on the secretory portion of the gland whereby the alveoli and secreting tubules are constantly labouring under pressure, the degree of which depends on the volume of milk present. It is logical to assume that degeneration will be more rapid in a gland subjected to continuous pressure than in one which is completely emptied and allowed "breathing space", even though only for a very brief period, after each milking. This contention is supported by the well-known fact that the persistency of lactation is much higher in the properly milked cow than in one that is not completely milked out.

Retention of milk in the duct system, in addition to predisposing to premature decline, will also tend to inhibit to a certain extent the normal synthesis of milk by maintaining pressure on the cells performing this function and will thus cause a depression in the milk solids. Turner (1936) has suggested that continued pressure on the alveolar cells will alter the method of secretion by preventing the rupture of the cells which secrete fat, casein and lactose and thus allowing only those constituents which can diffuse through the cell membrane to escape.

Slow milking would be conducive to incomplete milking. According to Petersen (1942) the effects of oxytocin, the pituitary hormone which is responsible for the "letting down" of milk, only lasts for 7 minutes. If milking is not completed within that period a certain volume of milk is retained in the alveoli and tubules with results similar to those described above. For the complete emptying of the udder it is essential that the act of milking be completed within 7 minutes after the stimulus to the cow to "let down" her milk is first applied.

The effects of invasion of the udder with non-pathogenic bacteria will be discussed in the relative section, and need not therefore be considered here.

(ii) *Season and Climate.*

Though seasonal variations in milk solids are known to occur, there is some difference of opinion as to the nature and extent of such changes and also with regard to their causal factors. It is, however, generally accepted that under European and American conditions the milk-solids are higher in winter than in summer. Hills (1892) found that fat varies inversely with temperature changes and that this was also true of the total solids and solids not fat.

A depression in solids not fat percentage during summer months but no significant seasonal influence on fat percentage was found independently by Ragsdale and Brody (1922), Hayes (1926), Weaver and Mathews (1928) and Houston and Hale (1932).

Lesser (1932) found that in a herd of 50 British Friesians the solids not fat percentage was below 8·50 standard in 80·1 per cent. samples during the winter months (October-March) but increased markedly immediately the animals were turned out to grass in May, and continued to be high while they were out at grass in May and June.

Mackintosh (1933) concluded that fat percentage follows a general curve being lowest in summer and highest in winter, and that cold weather tends to increase and warm weather to lower fat percentage.

Davies (1936) holds that drought conditions in summer may cause an appreciable lowering of milk composition, due possibly to the combined effects of (*a*) insufficient water supply, (*b*) irritation by insects, and (*c*) the physiological necessity of secreting a liquid lower in calorific value in lower quantity to suit the natural smaller need of a potential suckling during hot weather.

Turner (1936) found that under drought conditions fat and protein will be above normal with a deficiency in lactose and increase in chloride, though the high temperatures which generally accompany drought have the opposite effect on fat causing it to decline.

Kay (1937) states that drought conditions may seriously diminish milk quality and that in drought both high environmental temperature and nutritional difficulties are jointly responsible. Under certain conditions feeding of protein concentrates especially in summer appear to have a good effect on both quantity and quality of milk.

Trambicus (1938) examined bulk Hungarian milk twice per month for four years and noted that the average percentage solids not fat declines in summer months each year, the drop being more marked the higher the summer temperature. He concluded that this drop cannot be explained entirely on the basis of the change in the percentages protein and sugar, there being some other, at present, unexplained, factor.

From an investigation in variation in the composition of the milk of the Missouri station herd Herman (1938) deduced that season and temperature together account for the known lower solids not fat content in summer months.

Jacobsen and Willis (1939) in the United States found a pronounced lowering of fat and solids not fat percentage during summer months with the lowest values occurring in August and the highest in December and January.

Riddet *et al* (1941) in New Zealand fed three groups of cows over a 90-day period as follows: (*a*) continuously on a normal plane of nutrition, and (*b*) and (*c*) alternately fed on a normal ration and a half ration for 30-day periods under a double reversal plan. This changing of (*b*) and (*c*) from full to half caused a slight reduction in yield, but no consistent influence on fat content, but caused a consistent decrease in fat-free solids. This returned to normal when full feeding was resumed.

According to Smit (1929) in South Africa the milk solids generally rise above the average during winter, decline during spring and summer, reaching the lowest point in February or late January. A prolonged dry, hot season (for example in the Western Province) has a depressing effect on solids not fat. Very rough and bleak weather tends to reduce solids not fat, but where cows are well protected the effects are slight. Fine cold weather tends to raise the test while hot or muggy weather tends to lower it.

Not much information is available on the effect of season on the chloride and lactose. Davies (1937) states that drought in summer produces a slight increase in chloride and a slight decrease in lactose. Jorgenson and Oostergaard (1939) found no seasonal variations in lactose, while according to Cranfield and associates (1927) any deficiency in solids not fat in summer is due more to lactose than to protein. Trambicus (1938) found that a continuous period of intense cold was marked by a drop in the percentage protein and a rise in chloride.

The first essential in considering the influence of season on the composition of milk is to take the necessary precautions to ensure the exclusion as far as possible of the effect of other complicating factors which might lead to false deductions. The most important of these is stage of lactation which, according to Turner (1936), may cause variations of greater magnitude than the seasonal influence. If, for instance, all the lactations of the ten cows in this experiment were to have commenced in the first three months of the year the full effects of stage of lactation would completely have overshadowed the changes brought about by the various seasons.

In such an investigation it is desirable to have the calving dates dispersed more or less evenly throughout the year so that the data for any one period of the year would be derived from the records of cows in all stages of lactation.

In Table 10 are given the numbers of the different cows that calved in every month, and also the year of calving in parenthesis. It will be observed that the total of 38 calvings which form the basis of this work were scattered fairly evenly throughout the year, 22 falling in the first and 16 in the second sir months.

TABLE 10.

Dispersal of Calving Dates.

Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
7905 (1941)	7912 (1943)	7905 (1943)	7912 (1940)	7921 (1939)	7912 (1939)	7913 (1939)	7914 (1941)	7910 (1939)	7904 (1939)	7905 (1939)	7909 (1940)
7913 (1941)	7913 (1943)		7919 (1941)	7922 (1939)	7904 (1939)	7914 (1939)		7910 (1940)	7910 (1939)	7909 (1939)	7912 (1940)
7905 (1942)			7921 (1941)	7919 (1940)		7919 (1939)			7914 (1942)		7912 (1941)
7909 (1942)			7922 (1941)	7922 (1940)		7914 (1940)					7910 (1942)
7913 (1942)			7914 (1942)	7904 (1941)							
			7922 (1942)	7921 (1942)							

A further complicating factor, particularly when only a small number of animals are used, is the possibility of the lactation periods of certain cows coinciding, so that the records of none of them are included in determining the average for certain months. It will be noted, however, that the lactations of the three cows (7905, 7909 and 7921) yielding the poorest quality milk commenced in January (3), March (1), April (1), May (3), November (2) and December (1). One or more of them was thus included in every month of the year.

By this fortuitous dispersal of the calving dates the effects of stage of lactation and of individuality were reduced to insignificant proportions.

The total number of observations made every month throughout the whole period, the number and percentage of samples that were abnormal and the mean for every factor for the different months are presented in Table 11. The data in this table are further illustrated in Figure 5 by the curves representing the means and the block graphs giving the percentage of samples that failed to reach the prescribed standard in every month.

According to the records supplied in Table 11 no milk sample ever failed to reach the legal limit of 3 per cent. fat in the month of October throughout the four years. With this exception, however, a variable number of abnormal reactions to the tests for every factor were obtained in every month, and the data now have to be examined in order to ascertain in which month or months the highest percentage of abnormalities occurred.

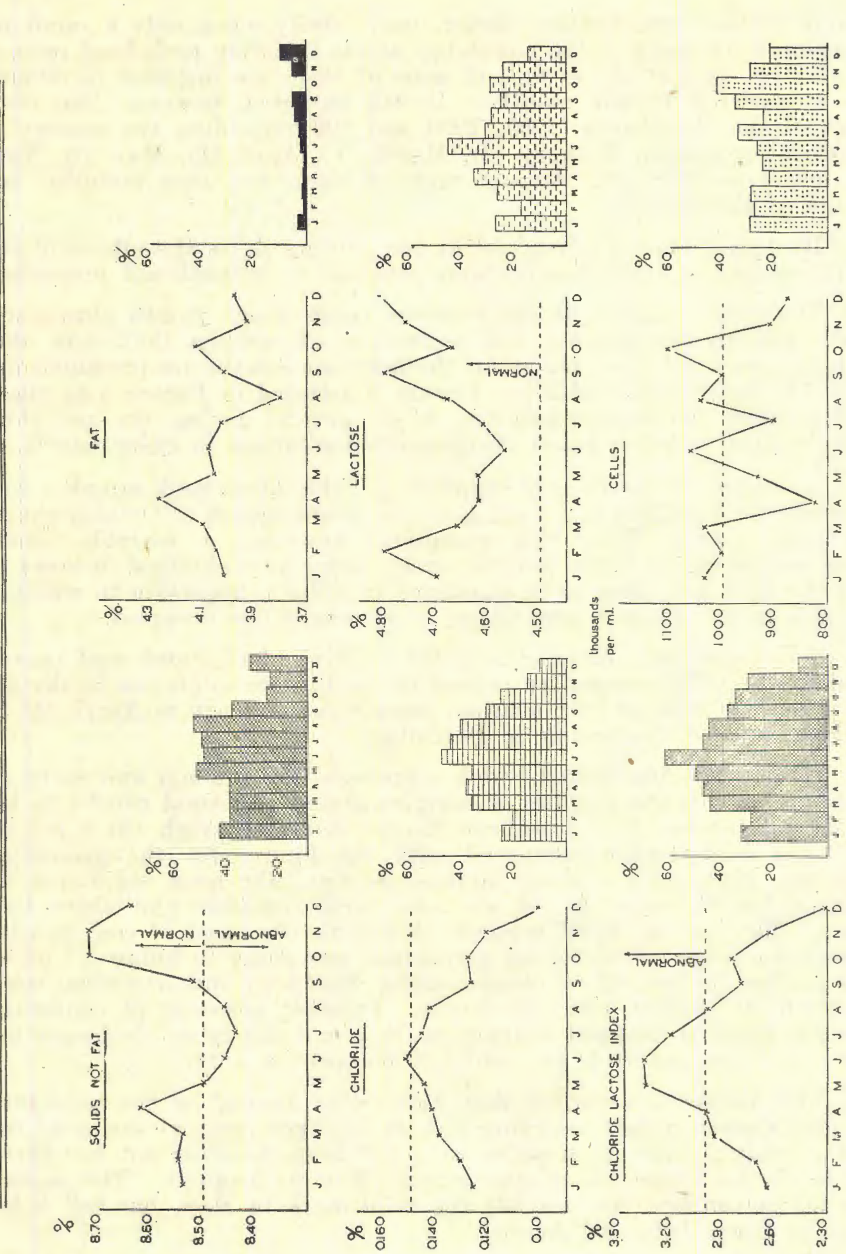
Solids not fat.—Reference to the relative block graph and curve (Fig. 5) shows that the seasonal variations in the fat-free solids can be divided into three periods each of four months, namely (*a*) January to April, (*b*) May to August, and (*c*) September to December.

During the first period which represents late summer and early autumn in South Africa the number of samples giving abnormal results to tests for solids not fat was fairly uniform though relatively high (39·8 per cent. to 43·9 per cent.) when compared with the figures for the preceding four months. Except for a sharp increase in April the mean solids not fat percentage for the same period was also fairly uniform and above the legal limit. The rise in April suggests that with the onset of cool weather and winter the mean solids not fat percentage was going to follow a line more or less similar to that which obtains under European and American conditions to reach its highest point in winter. Instead, however, of continuing the upward trend it dropped sharply in May and continued declining to reach the lowest average (8·44 per cent.) of the year in July.

The number of samples that were below normal in the tests for solids not fat showed a corresponding rise to 52.5 per cent. of the total in May, and a majority of the samples were deficient in solids not fat during the whole of the second or winter period (May to August). The mean solids not fat percentage just reached the 8·50 mark in May, but fell below this level in June, July and August.

With the advent of spring the mean percentage again passed the legal standard with 8·52 in September while the number of samples that were deficient dropped to 38·7 per cent. In October the fat-free solids showed a very steep rise to reach the highest level of 8·72 per cent. This was maintained in November but was followed by a drop to 8·64 per cent. in December. The percentage samples in which the milk was deficient in solids not fat accordingly also reached its lowest point of 24·1 per cent. during this period.

FIG 5: THE MEANS (CURVES) FOR EVERY FACTOR AND THE PERCENTAGE OF SAMPLES THAT WAS ABNORMAL (BLOCK GRAPHS) IN EVERY MONTH OF THE YEAR.



An analysis of variance showed that with $P = \cdot 05$ the mean solids not fat percentage for October and November was significantly higher than that for May, June, July and August.

Fat.—During the first ten months of the year the mean fat percentage revealed a similar trend to that of the fat-free solids, namely an increase from January to April followed by a marked decline in autumn and winter

TABLE 11.

Number of Observations made, Number and Percentage Abnormal, and M

Month.	Solids not Fat. Observations. Total.	Solids not Fat. Abnormal. No.	Solids not Fat. Abnormal. Percentage.	Solids not Fat. Mean Percentage.	Fat. Observations. Total.	Fat. Abnormal. No.	Fat. Abnormal. Percentage.	Fat. Mean Percentage.	Chloride. Observations. Total.	Chloride. Abnormal. No.	Chloride. Abnormal. Percentage.	Chloride. Mean Percentage.
January	132	58	43·9	8·54	132	4	3·0	4·02	122	28	24·6	·126
February	128	51	39·8	8·55	128	1	0·8	4·05	116	24	20·7	·131
March	108	43	39·8	8·54	108	2	1·9	4·10	107	39	36·4	·139
April	120	48	40·0	8·62	120	2	1·6	4·27	111	43	38·7	·142
May	120	63	52·5	8·50	120	1	0·8	4·06	115	42	36·5	·145
June	128	64	50·0	8·46	128	3	2·3	4·08	114	55	48·2	·152
July	132	67	50·8	8·44	132	4	3·0	4·03	112	50	44·6	·146
August	132	71	53·8	8·46	132	6	4·5	3·80	132	54	40·9	·143
September	132	51	38·7	8·52	132	7	5·3	4·02	131	43	32·8	·127
October	132	34	25·8	8·72	132	0	0	4·13	132	34	25·7	·128
November	112	27	24·1	8·72	112	6	5·4	3·93	104	16	15·4	·121
December	100	32	32·0	8·64	100	10	10·0	3·98	96	10	10·4	·101

137-138b →

TABLE 11 *(cont.)*

1.

ormal, and Mean for every Month of the Year

Lactose.				Chloride-Lactose Index.				Cells.			
Observations.			Mean Per-centage.	Observations.			Mean.	Observations.			Mean (Thousands).
Total.	Abnormal.			Total.	Abnormal.			Total.	Abnormal.		
	No.	Per-centage.			No.	Per-centage.			No.	Per-centage.	
106	29	27·4	4·70	105	34	32·4	2·64	87	26	29·9	1,035
113	20	17·7	4·80	113	33	29·2	2·72	110	31	28·2	1,004
97	26	26·8	4·66	96	43	44·8	2·97	105	31	29·5	1,035
95	34	35·8	4·62	95	45	47·4	3·09	89	20	22·5	823
98	31	31·6	4·62	97	49	50·5	3·34	105	26	24·8	933
103	47	45·6	4·57	103	64	62·1	3·36	111	30	27·0	1,061
105	33	31·4	4·61	105	50	47·6	3·20	120	35	34·3	904
121	35	28·9	4·68	121	55	45·5	3·07	107	26	24·3	1,043
126	32	25·4	4·80	126	48	38·1	2·79	98	35	35·7	1,093
123	36	29·3	4·67	123	43	35·0	2·84	92	39	42·4	1,106
91	22	24·2	4·76	91	23	25·3	2·63	67	20	29·9	910
81	12	14·8	4·81	81	9	11·1	2·31	86	19	22·1	877

← 137-138a

and a rise in spring. Though there was a substantial rise in September and October this was not maintained in November and December. Fat, however, did not reach its peak at the same time in spring and early summer as the other solids but in autumn (April). A marked depression was shown in August when the lowest mean (3·80 per cent.) was reached. This corresponds with the results obtained for European conditions by Tocher (1925), who found that fat content was at its lowest during the latter half of winter.

The average fat percentage was always well above the standard. A small and variable number of samples were found to be deficient every month, excepting October, with the highest percentage (10) of deficiencies in December.

The seasonal variations in the fat percentage were not statistically significant.

Chloride.—The mean for chloride showed a consistent increase from 0·126 per cent. in January to 0·152 per cent. in June. This was followed by a steady decline during the last six months of the year to the lowest average, namely 0·101 per cent. in December. Comparison with the relative curves shows that when milk was richest in solids not fat and lactose during the last four months of the year, the chloride content on the other hand was at its lowest, and that the marked decline in solids not fat in late autumn and winter was accompanied by a sharp rise in chloride which exceeded the normal limit when it reached its peak (0·152 per cent.) in June. Further, the mean chloride content of the milk during the period January to April like the solids not fat occupied an intermediate position between that of the other two periods.

Minor deviations from the normal solids not fat—chloride relationship can be discerned in a critical analysis. For instance, chloride did not show a decline in April when there was a rise in solids not fat, and the lowest mean for chloride was obtained in December whereas the highest solids not fat percentage was recorded in October and November. These and other insignificant anomalies revealed in the data for lactose can be accounted for by recalling the fact that the analyses for determining chloride and lactose were not carried out on the same samples as were used for solids not fat determinations, and also that the mean of the latter for any four-weekly period was calculated from a number of analyses made during that period, whereas the chloride and lactose contents were determined from only one sample.

The highest number of samples that were found to have an abnormal chloride content was obtained in June with 48·2 per cent. After that the percentage of abnormal samples, like the mean, declined steadily to 10·4 in December.

Lactose.—With slight exceptions, such as an unexpected rise in February and a drop in October both of which can be explained by the difficulty previously mentioned in connection with the examination for lactose of samples of abnormal milk, the curve for lactose is the inverse of that for chloride. Except for the rise in February the lactose content shows a consistent decrease from January to June when the lowest level (4·5 per cent.) was reached. After this there was a rising trend to its highest average of 4·81 per cent. in December when chloride was at its lowest. The monthly mean for lactose never dropped below the arbitrary standard of 4·50 per cent.

Like chloride the largest percentage of samples (45·6) that were deficient in milk sugar was detected in June and the lowest (14·8) in December.

Chloride-lactose index.—The curve showing the mean chloride-lactose index for every month is almost identical to that of chloride. Starting from 2·64 in January it showed a consistent increase, and also reached its highest point (3·36) in midwinter, namely in June. This was followed by a well-marked decline which, apart from a slight rise in October when lactose showed a drop, was maintained to reach the lowest mean (2·31) in December. By far the largest percentage (62·1) of samples that were detected as abnormal by this index occurred in June after which a regular drop was shown until the lowest percentage (11·1) was reached in December.

Corroboration of the view previously expressed, namely, that the chloride-lactose index is more reliable and reveals a higher number of abnormal milk samples than either chloride or lactose alone, is provided by both the mean of the index for every month and the percentage of samples that were revealed as being abnormal (Table 11 and Fig. 5). It will be observed that the curve for the index closely resembles the inverse of the curve for solids not fat, and it supplies more convincing confirmation of the abnormal state of the milk in winter as revealed by the solids not fat test than either chloride or lactose.

Statistically ($P = \cdot 05$) the chloride-lactose index for May and June was significantly higher than that for November, December, January and February. With $P = \cdot 01$ the index for December was also significantly lower than for April, May, June and July.

The great similarity between the two sets of curves, namely, those for solids not fat and lactose on the one hand and for chloride and chloride-lactose index on the other offers a good illustration of the direct relationship between the former two and also between the latter two. It also lends support to the view that lactose is the factor mainly involved in a depression of solids not fat, since the chloride content and the chloride-lactose index are both determined by the lactose content of the milk.

Cells.—The cellular content of the milk is the only constituent in which no seasonal variation could be detected. It will be noted in Table 11 and in the relative curve (Fig. 5) that the mean cell count fluctuated considerably throughout the year. It exceeded a million cells per ml. in the first three months and also in June, August, September and October, thus being within normal limits for only five months out of twelve.

Environmental Temperature.

The inclination of European and American investigators to incriminate high environmental temperature for the depression in milk solids in summer naturally stimulated a desire to ascertain to what extent a rise in temperature was responsible for lowering milk solids under South African conditions. For this purpose the mean maximum and minimum temperatures for every month during the four years were determined and are recorded in Table 12 and Fig. 6.

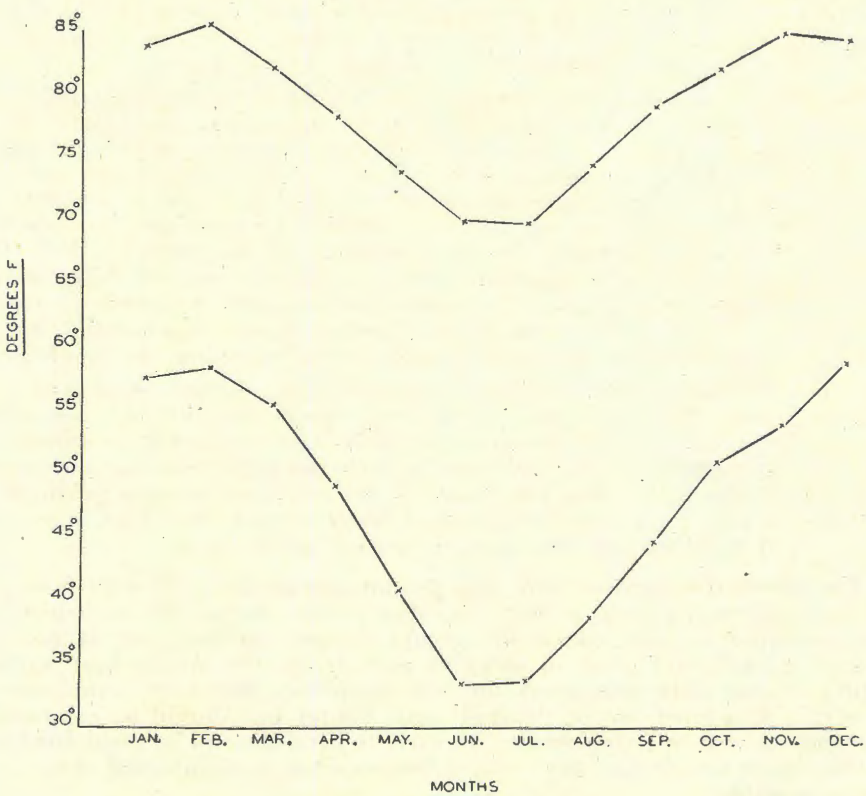
A comparison of the data given along with that contained in Table 11 and Fig. 5 will immediately reveal that in this investigation high temperature did not produce a decline in milk solids. On the contrary, the best quality milk was obtained during some of the hottest months like November and December, while milk was at its poorest in June and July when the lowest maximum and minimum temperatures were reached.

TABLE 12.

Maximum and Minimum Temperature for Every Month.

	Mean Temperature.	
	Maximum.	Minimum.
January	83·8	57·5
February	85·5	58·4
March	82·2	55·5
April	78·3	49·0
May	74·0	40·9
June	70·1	33·5
July	70·0	33·8
August	74·6	38·8
September	79·3	44·9
October	82·3	51·4
November	85·1	54·2
December	84·7	59·1

FIG 6: MEAN MAXIMUM AND MINIMUM TEMPRATURE FOR EVERY MONTH



Discussion.

The most significant feature revealed by the data in this section is that contrary to the findings of the great majority of investigators in the Northern Hemisphere and of the only one (Smit) who has studied this aspect of inferior quality milk in South Africa, the poorest quality milk and the largest percentage of abnormal results were obtained in mid-winter (June and July). This was confirmed by five of the six criteria employed to determine the normality of milk, the cellular constituent being the only one which yielded inconclusive results. With the coming of spring and summer a very marked and persistent improvement in the quality of milk was observed and this reached its peak during the hottest months. This was followed by an intermediate period from January to April when milk quality was not maintained at the same high standard as in the preceding four months though it did not drop to the abnormal level which prevailed during the winter months.

In view of these findings no support can be given to the opinion of the majority of European and American workers that high environmental temperature is mainly responsible for the depression in milk solids observed by them. In this connection it is important to point out that none of them has as yet attempted an explanation as to the exact manner in which high environmental temperatures can decrease milk solids. There is no physiological basis for such a hypothesis.

On the contrary a physiological explanation can be given for the view that, all other factors being constant, cold wintry weather would depress rather than increase milk solids. According to Quin (1943) an animal adapts itself to changes in environmental temperatures in two ways:—

(i) *Physiological.*—For instance by changes in its external body covering, such as growing a thick, hairy coat in winter, and by vaso-constriction of the superficial blood vessels, thereby decreasing the loss of bodily heat. These changes are sufficient to protect the animals against a drop in external temperature until what is known as the "critical temperature" is reached. The latter depends on the condition of the animal. For those that are well nourished and in good condition the critical temperature is low. For others that are poor and undernourished it is high. When the critical temperature is reached the changes mentioned are no longer capable of maintaining the bodily heat.

(ii) *Biochemical factors* then come into play. In the absence of sufficient digestible and nourishing food the animal then starts utilizing its own reserves for itself. In the lactating animal the first effects of this are seen in both the yield and the composition of the milk. The precursors of the milk constituents in the blood are diverted from their normal destination in the udder to increase metabolism for the maintenance of bodily heat.

The obvious deduction from this is that during the cold winter months it is not sufficient merely to keep the diet of the dairy cow on a plane of nutrition equal to that which she enjoys during summer, but it must be increased to a higher level in order to provide for the bodily heat without drawing on the milk precursors for that purpose. Moreover, supplementation of the diet must not be delayed until winter but should be commenced in autumn or even in late summer in order to keep the cow in good condition and thereby to ensure that her critical temperature is maintained at as low a level as possible.

It is significant that some of the workers in other countries do not appear to be altogether satisfied that high temperatures alone can be responsible for the drop in milk solids, and some like Davies and Kay have suggested that nutritional factors may be contributory causes. According to the available literature Lesser is the only British worker who found a depression in solids not fat percentage in winter. It is unfortunate that his study did not include an investigation into the feeding of the herd on which his conclusions were based. This might have disclosed that the winter diet was not of the same standard as that usually supplied in Britain.

All the evidence points to the fact that nutrition is the principal aetiological factor in the seasonal variations shown by milk solids. With the severe winter conditions obtaining in Europe and North America the proper feeding and nutrition of dairy cows have been brought to a much finer art than in South Africa, and a far better supply of nourishing and digestible winter food is available. Thorough investigation might reveal that the British and American cow receives a much more nutritive ration in winter than in summer. In view of the findings of Roux *et al* (1935) that heavy feeding on succulents depresses solids not fat it is probable that the decline observed in summer in those countries is brought about by excessive feeding of succulents, and that the effects of this may be accentuated by conditions of drought especially in late summer before the commencement of the winter feeding programme.

In South Africa many still believe that dairy cows can survive and produce milk throughout the year mainly on whatever nourishment they can obtain from the pastures and veld, and that very little supplementary feeding is required in winter. This fact and all the other available evidence suggest that malnutrition is responsible for the very marked deterioration in the quality of milk during winter. Strong support is lent to this view by the following significant statement by Bonsma (1943: " On the whole farmers overestimate the feeding value of their pastures which over the greater part of the country have a much lower nutritive value than European pastures. The period of high protein values and digestibility of pastures in South Africa is limited to a short period of 6 to 8 weeks during the period of rapid spring growth. During the summer months and early autumn the feeding value of the natural vegetation is inadequate for the maintenance of high producing cows ".

The short six to eight weeks period of high protein values and digestibility of pastures coincides exactly with the period (October and November) in which the quality of milk obtained from the cows in this experiment was far higher than at any other time of the year (Fig. 5). The good quality of the milk produced by these animals during the summer months and notably the high standard obtained in the two months when nutritional conditions were at the optimum level suggest that the ordinary South African grade Fries is inherently not inferior to her prototype in other countries and that she has great potentialities as a producer of high quality milk provided she is maintained under conditions of good health and nourishment. Under present conditions, however, she too frequently labours under a very great disadvantage in that she is expected to yield good quality milk on a plane of nutrition which is subnormal for 9 months out of every 12.

In a big country like South Africa with varying conditions of climate, soil and vegetation it would obviously be inadvisable to attempt generalisations on the results obtained from only a small number of animals in one area. Wider investigation will probably reveal discrepancies. Smit's results for instance show closer agreement with those obtained in Europe and America. It should, however, be pointed out that his investigations were carried out in the Western Province of the Cape, a thousand miles from Onderstepoort, where climatic and pastoral conditions are vastly different from those obtaining in the Transvaal. The Western Province is in the winter rainfall area whereas the rest of the country has a summer rainfall. In discussing the regional variations in yield Bonsma (1943) pointed out that farmers in the Western Province enjoy a local advantage in that they have available a larger variety of concentrates than those of the grassveld areas of the Transvaal where, in addition, the veld may be low in protein and many areas are deficient in phosphates.

The view that the depression in milk quality observed during the winter months is mainly due to undernourishment does not appear to be in agreement with the findings of Groenewald (1935) who concluded that rations definitely had no influence on the composition of milk. The objects of his investigation, however, were (i) to study the influence of a very low intake of certain minerals on the mineral content of the blood of dairy cows; (ii) to determine the influence which these low mineral intakes exercise on milk production, as well as on milk composition.

His experimental animals were accordingly maintained under unnatural conditions and received a very poor diet. They were housed in separate boxes at night and in a concrete floored paddock during the day. They, therefore, had no natural grazing and received a ration with very low roughage content. Moreover, they were kept under these conditions for nine months before the first calving and were, therefore, probably in low condition when they came into milk. This may account for the poor quality of their milk, namely, 8·2 per cent. solids not fat. Further his observations were only made over the first three months of each of two lactations.

(iii) *Stage of Lactation.*

Crowther (1905) was probably the first to draw attention to the fact that the composition of milk is influenced by the period of lactation. He found that the percentages for fat and fat-free solids tend to fall for the first three months of lactation and to increase thereafter.

According to Tocher (1925) the minimum amount of fat occurs at the 14th to the 16th week, while the minimum solids not fat occurs at 17 to 21 weeks.

Drakely (1927) observed an initial decrease in fat percentage followed by an increase till near the end of the lactation period, the time required for the minimum to be reached varying with the different breeds, 35 to 105 days after calving. He found similar variations but of lesser magnitude for the solids not fat content.

Smit (1929) states that the milk of newly calved cows, provided they are in good condition and healthy at calving time, is generally rich in solids not fat, but the percentage falls until about the 30th to the 100th day after calving when the lowest point is generally reached. From this point on the milk may gradually increase in solids not fat content or remain fairly constant until the end of the lactation period. During the last few weeks the test for solids is generally the highest for the whole lactation period.

Turner (1936) also points out that the variations produced by period of lactation are to some extent influenced by the condition of the animal, and he found that when cows are fat at the time of calving the milk fat will decline for a month or more and then increase gradually with the advance of the stage of lactation. In thin animals the percentage fat is usually low shortly after parturition and does not decline further, but a slow, gradual rise begins instead.

According to Bartlett (1934-35) milk is rich in solids not fat immediately after calving, but the concentration falls rapidly and a fairly constant level is reached about 40 days after calving. This level is maintained for most of the lactation period, but a continuous rise becomes evident over the last three months of lactation. Somewhat similar results are obtained in the case of the fat.

Jacobsen and Wallis (1939) noted a general decrease in total solids during the first three months of lactation followed by a general upward trend. The lowest total solids percentage was noted in the third or fourth month.

Eckles (1939) states that the influence of the stage of lactation upon fat content of milk is often overestimated and concludes that in general it may be said that under the conditions typical of good farm practice there is little if any increase in fat content until the point is reached when the decline in milk production is rapid.

Very little work appears to have been done on the variations in chloride and lactose content with advancing lactation. According to Caulfield and Riddell (1935) chloride is highest at the onset of lactation but declines rapidly the first 10 to 20 days, and after that there is a general upward trend throughout the remainder of the lactation period.

The examination of foremilk from 112 quarters of 24 uninfected cows by Little (1939) revealed a marked increase in alkalinity, percentage of chloride, number of leucocytes and, occassionally, bacterial counts. This change in the reaction of the milk during prolonged milking was not common to all the cows in the three herds, and it was more noticeable in the milk from the older cows. (Table 13.)

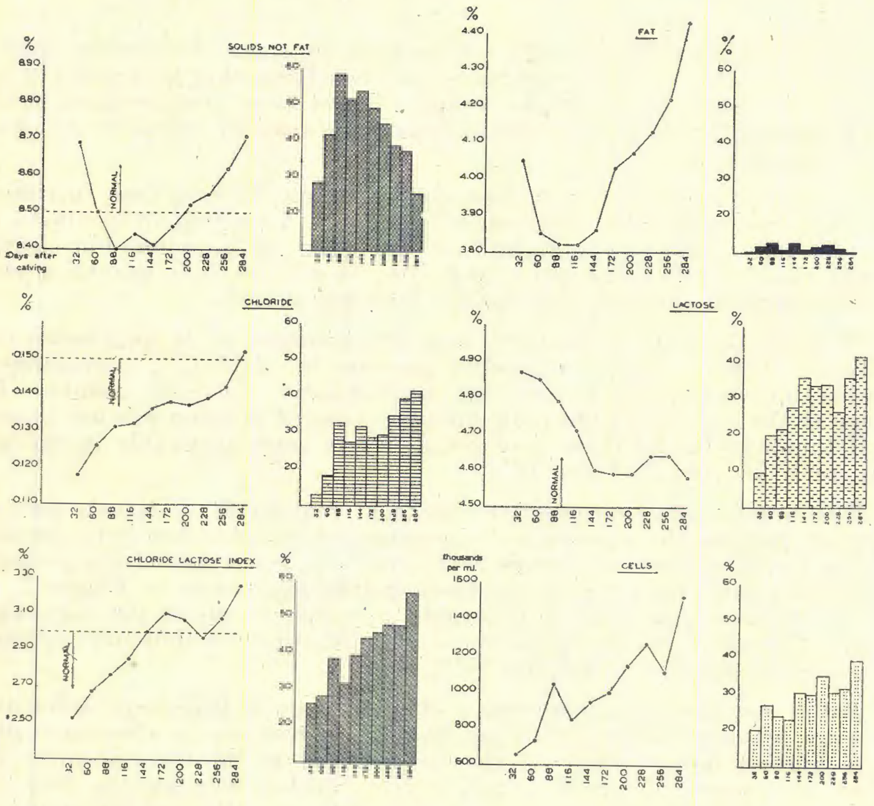
The number of determinations made at four-weekly intervals for each of the six factors, the number and percentage of samples that were abnormal and the mean obtained for every constituent for every period are presented in Table 13 and illustrated by the block graphs and curves in Figure 7. In the calculation of the data in this table only the records of the cows which completed the 284 day lactation were included, the two thus omitted being the second lactations of 7914 and 7919.

Solids not fat.—The percentage of milk samples that were deficient in solids not fat increased rapidly from 28·8 in the first month after parturition to the highest figure (58·3) which was obtained in the third month. The largest percentage abnormal samples were yielded between the 88th and 144th days after the commencement of lactation, during which period the majority of results showed the milk to be deficient in non-fatty solids. After that there was a general drop in the proportion of abnormal results, and the lowest figure of the whole lactation period (25·8 per cent.) was reached in the last month.

The highest mean solids not fat percentage (8·71) was also obtained in the final month, but this percentage was only slightly higher than that (8·69) for the first month. After the first four weeks, however, the decline was very rapid until the lowest percentage (8·40) was reached in the third month. For the next two or three months the mean percentage fluctuated just above this point, and it will be observed in the curve that it was below the normal limit for about four months between the 60th and 200th day after calving. After that a consistent improvement was maintained until the end of the period.

An analysis of variance showed that with P = ·01 the mean solids not fat percentage for the first and tenth months was significantly higher than that obtained in the second to the seventh months, and that in the ninth month it was significantly higher than in the third to the sixth months after parturition.

FIG. 7: THE MEANS (CURVES) FOR EVERY FACTOR AND THE PERCENTAGE OF SAMPLES THAT WERE ABNORMAL (BLOCK GRAPHS) AT FOUR WEEKLY INTERVALS AFTER PARTURITION.



Fat.—Though the highest number (5·3 per cent.) of samples that were deficient in fat was obtained in the third and fifth month when milk quality was at its lowest, it is evident that stage of lactation was not an important factor in producing milk with abnormally low fat content. While there was an appreciable depression of fat between the 60th and 144th day, the mean was always well within the margin allowed for normality. The curve for fat (Fig. 7) is very similar to that for the fat-free solids, except that fat started the upward trend at an earlier stage than the other solids, and when compared with the mean for the first month fat showed a more pronounced rise in the final stages of lactation than fat-free solids.

TABLE 13.

Number of Observations made at Different Intervals after Parturition, Number

TABLE 13 *(cont.)*

er and Percentage Abnormal, and the Means for Each Factor.

Days after Calving.	Solids not Fat. Observations. Total.	Solids not Fat. Abnormal. No.	Solids not Fat. Abnormal. Per-centage.	Solids not Fat. Mean Per-centage.	Fat. Observations. Total.	Fat. Abnormal. No.	Fat. Abnormal. Per-centage.	Fat. Mean Per-centage.	Chloride. Observations. Total.	Chloride. Abnormal. No.	Chloride. Abnormal. Per-centage.	Chloride. Mean Per-centage.	Lactose. Observations. Total.	Lactose. Abnormal. No.	Lactose. Abnormal. Per-centage.	Lactose. Mean Per-centage.	Chloride-Lactose Index. Observations. Total.	Chloride-Lactose Index. Abnormal. No.	Chloride-Lactose Index. Abnormal. Per-centage.	Chloride-Lactose Index. Mean.	Cells. Observations. Total.	Cells. Abnormal. No.	Cells. Abnormal. Per-centage.	Cells. Mean (Thousands).
32	132	38	28·8	8·69	132	1	0·8	4·05	114	17	12·9	·118	94	9	9·6	4·87	92	24	26·1	2·52	83	17	20·0	657
60	132	55	41·7	8·50	132	5	3·8	3·85	128	24	18·2	·126	125	25	20·0	4·85	125	35	28·0	2·67	100	27	27·0	735
88	132	77	58·3	8·40	132	7	5·3	3·82	124	43	32·6	·131	115	25	21·7	4·79	115	44	38·3	2·76	104	25	24·0	1,043
116	132	68	51·5	8·44	132	2	1·6	3·82	132	36	27·3	·132	127	33	27·6	4·71	126	40	31·7	2·85	113	26	23·0	849
144	132	71	53·8	8·41	132	7	5·3	3·86	132	42	31·8	·136	114	41	35·9	4·60	114	45	39·5	3·00	112	34	30·4	945
172	132	65	49·2	8·46	132	2	1·6	4·03	126	38	28·8	·138	113	38	33·6	4·59	113	50	44·2	3·10	110	33	30·0	999
200	132	59	44·7	8·52	132	5	3·8	4·07	127	39	29·5	·137	121	41	33·9	4·59	120	55	45·8	3·07	114	40	35·1	1,144
228	132	51	38·6	8·55	132	6	4·5	4·13	131	46	34·8	·139	114	30	26·3	4·64	121	58	47·9	2·97	107	33	30·8	1,270
256	132	49	37·1	8·62	132	3	2·3	4·22	124	52	39·4	·142	114	41	35·9	4·64	115	55	47·8	3·08	94	30	31·9	1,107
284	132	34	25·8	8·71	132	1	0·8	4·43	111	55	41·7	·153	89	37	41·6	4·58	90	51	56·7	3·26	84	33	39·3	1,524

(1) 3½ Lactations only. (2) 3 Lactations onl

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Table 14

Total yield of milk, solids not fat and fat, and average solids not fat, fat chloride, lactose, chloride-lactose index and cells for each cow, and the total number and percentage of abnormal reactions given by each.

Cow.	Milk Yield in lb.	Solids not Fat.				Fat.				Chloride.			Lactose.			Chloride-Lactose Index.			Cells.		
		Yield in lb.	Mean.	Abnormal.		Yield in lb.	Mean.	Abnormal.		Mean Percentage.	Abnormal.		Mean Percentage.	Abnormal.		Mean	Abnormal.		Mean (1000 per ml.).	Abnormal.	
				No.	Percentage.			No.	Percentage.		No.	Percentage.		No.	Percentage.		No.	Percentage of total.		No.	Percentage.
7905	27057·9[1]	2173·850	8·03	139	96·5	960·612	3·55	8	5·6	0·160	90	65·7	4·44	73	57·0	3·64	99	77·9	302	7	5·3
7909	19812·4[2]	1602·330	8·09	114	95·0	687·455	3·47	5	4·3	0·158	75	63·0	4·45	58	56·3	3·57	82	78·1	1,241	42	37·8
7921	30156·4	2521·287	8·36	109	68·1	1080·415	3·58	19	11·9	0·145	59	39·8	4·38	76	59·4	3·39	80	62·5	2,053	82	70·7
7904	17891·9[2]	1528·592	8·54	46	38·3	687·140	3·84	4	3·3	0·120	14	12·2	4·78	12	10·8	2·50	19	17·1	425	13	8·7
7910	27717·0	2408·015	8·69	41	25·6	1254·055	4·52	2	1·3	0·122	19	12·6	4·88	17	11·6	2·53	29	19·8	532	21	15·6
7912	26425·7	2270·125	8·59	55	34·4	1108·339	4·19	3	1·9	0·128	36	23·7	4·74	38	26·4	2·78	44	30·6	1,906	57	47·9
7913	19647·3	1705·987	8·68	33	20·6	784·140	3·99	1	0·6	0·133	38	25·2	4·68	35	25·4	2·86	45	32·6	1,129	37	29·8
7914	23219·1	2089·965	9·00	4	2·6	1023·893	4·41	1	0·7	0·119	28	18·2	4·99	12	9·7	2·27	20	16·1	824	30	26·5
7919	19473·3	1701·819	8·74	34	24·3	805·786	4·14	0	0	0·137	36	31·7	4·81	15	14·6	2·84	36	34·9	324	7	7·2
7922	25112·9	2199·944	8·76	35	21·9	1052·790	4·19	2	1·3	0·130	40	26·3	4·81	17	13·1	2·74	44	33·8	833	35	30 7

[1] 3½ Lactations only.

[2] 3 Lactations only.

The variations in the percentage butterfat due to stage of lactation were not statistically significant.

Chloride.—During the first ten days after parturition the chloride content of milk is high and liable to show many variations. The results of such chloride determinations as were made during the first ten days were, therefore, deliberately omitted from these records. Consequently the abnormalities and the high level of chloride which is characteristic of milk at the onset of lactation are not reflected in these results. With the passing of the initial period of fluctuation chloride content becomes more stabilised during the next two or three weeks, and the lowest number (12·9 per cent.) of samples with abnormal chloride content were recorded in the first month. After this the number of abnormal samples increased gradually, showing a marked rise in the last three months to reach the maximum (41·7 per cent.) in the last month.

The lowest mean chloride content (0·118 per cent.) was also recorded in the first month. This was followed by a consistent rise which was maintained throughout the lactation, a marked rise being shown in the last four weeks to the highest point (·153 per cent.).

Lactose.—The block graphs for lactose and chloride are very similar, both showing that only a small percentage of samples examined for these two constituents in the first month was abnormal, but that the percentage rose rapidly to reach its peak in the last month of lactation in both cases. The number of abnormal results for lactose thus increased from 9·6 per cent. to 41·6 per cent. at the end of lactation.

The curve for the mean lactose percentage follows a course opposite to that of chloride and shows that lactose percentage declined as chloride increased. The decline was quite marked in the first 144 days, the lactose content dropping from 4·87 per cent. in the first to 4·60 per cent. in the fifth month. After that it was more or less stationary, but showed a slight rise in the 8th and 9th months followed by a drop to the lowest level (4·58 per cent.) in the 10th month. At no time throughout the period did the mean lactose percentage drop below the standard of 4·50.

Chloride-Lactose Index.—The block graph for the index shows a more consistent increase in the percentage of abnormal samples detected during the whole of the lactation period than does either the chloride or the lactose graphs and that the majority of samples were abnormal to the index in the last month.

The mean chloride-lactose index increased from 2·52 in the first month to 3·26 in the last month af lactation, and, with the exception of a drop to 2·97 coincident with a rise in lactose in the 8th month, the index was abnormally high continuously from the 6th month till the end.

The mean chloride-lactose index for the first month was significantly lower ($P = \cdot 05$) than that for the sixth, seventh, ninth and tenth months.

Cells.—The mean cell content also revealed a consistent increase with the advance in lactation and the average cell count increased from 657,000 in the first month to 1,524,000 per ml. in the tenth month of lactation. With two exceptions, in the 4th and 9th months, the mean count for every period showed a substantial increase over that for the preceding period.

Though no detailed differential counts were made it was observed that the increase in cells with advancing lactation was due to both leucocytes and epithelials. A difference noted between the increase in cells due to advancing lactation and that which characterizes invasion of the quarter with pathogenic bacteria is that the increase in leucocytes in the former case was mainly confined to lymphocytes and mononuclears, whereas in a pathogenic state there is a marked increase in the percentage of neutrophiles in the milk.

Discussion.

The effect of stage of lactation on the composition of milk may be greatly influenced by complicating factors like season, individuality, age, disease of the udder and pregnancy. In this investigation most of the factors were eliminated by using animals known to be free from disease, by confining the study to the same animals and by extending it over several lactations. In the previous section it was indicated that the mutual effects of season and period of lactation were almost completely obviated by a reasonably even distribution of the calving dates throughout the year.

The very marked influence exercised on the composition of milk by both season and period of lactation as revealed in the last two sections is of great practical importance in that its application to dairy husbandry is essential to dairymen who have to ensure that their bulk milk-supply maintains a standard equal to or above that prescribed by the regulations. Breeding will have to be arranged in such a manner that the depressing effects of these two factors do not coincide. Thus, if all cows had to come into milk during the months February to April, the combined effect of both season and stage of lactation will cause a very marked deterioration in the quality of milk during the winter months. Unless the winter depression in South Africa is overcome by more judicious and more generous feeding, the only manner in which the dairyman will be able to maintain his milk supply at the required standard will be by arranging his breeding programme so that cows either come into milk or are in advanced lactation during the winter months.

Accurate evaluations of the effect of stage of lactation is not possible unless cognisance is taken of the fact whether the cows were pregnant or not when the observations were made. According to Bartlett (1934-35) the solid not fat content of non-pregnant cows is not maintained at such a high level as that of pregnant animals. In fact the solid not fat content of non-pregnant cows shows a decrease instead of an increase towards the end of lactation, except in the case of cows in their first lactation. Barlett found that for four months after effective service the trend of the curve is level or falls slightly. By the fifth month there is a slight rise which continues till drying off. Non-pregnant cows on the other hand show a definite decrease which continues throughout lactation.

Of the ten animals in this investigation cow 7904 was not pregnant when she completed her first lactation, but with this exception all the cows conceived and were pregnant during the second half of every lactation. In the absence of controls it was thus not possible to determine the effect of pregnancy. In view of Bartlett's findings, however, it is obvious that pregnancy was principally responsible for the pronounced rise in total solids in the milk of these cows during the last few months of lactation.

The effect of pregnancy in raising milk solids draws attention to the rôle played in the production of poor quality milk by disease of the genitalia, such as sterility and contagious abortion, and by the wilful prolongation of lactation practised by some dairymen who intentionally withhold service