THE EFFECT ON FOOD INTAKE AND MILK PRODUCTION OF ADDING CONCENTRATE TO THE RATION OF COWS FED PASTURE

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INTRODUCTION

It has long been appreciated that well managed leafy pasture will provide sufficient energy and protein for high milk production. However, because of seasonality of pasture production there are periods in the year when the supply of pasture is deficient. Hay and silage are used to supplement pasture during these periods of shortages on New Zealand dairy farms, but are limited in their ability to maintain high levels of milk production, particularly early in lactation. Thus recourse may have to be made to the use of concentrates to maintain milk production during periods of pasture shortage. The limited amount of experimental work conducted in New Zealand on the use of concentrates (Hancock, 1953; Wallace, 1957) indicates that their use may be worthwhile. However, information on the effects of supplementing pasture with concentrates under controlled (indoor) experimental conditions is non-existent under New Zealand conditions.

Results obtained by overseas workers on the effect of concentrate feeding on milk production suggest that responses have been most erratic, especially when concentrates have been fed with pasture. In general these responses were less than would have been expected on the basis of feeding standards.

Reports on supplementary feeding of dairy cows by Corbett and Boyne (1958), MacLusky (1955) and Seath et.al. (1962) suggest that the concentrates fed acted as a substitute for pasture. In all of these experiments, however, the intake of pasture was measured by indirect methods.

Taking the above points into consideration two experiments were conducted. The first one was a small grazing experiment with the object of studying the effects of concentrates on milk yield and composition and to obtain experience in the problems of experimentation in a simple continuous trial using 16 Friesian cows. The other experiment involved nine Jersey cows and was mainly designed to study the effect of feeding concentrates on voluntary intake of pasture. This experiment consisted of a 3 x 3 Latin square replicated three times, with squares being run concurrently. Measurements of milk yield and milk composition were also carried out. Additional information was obtained on the rate of passage of feedstuffs with some of the cows, on digestibility of feeds with six wethers, and rumen fermentation studies with four (extra) fistulated cows.

CHAPTER I

REVIEW OF LITERATURE

The influence of concentrates feeding on food intake and the yield and composition of milk is reviewed.

1. THE EFFECTS OF CONCENTRATE FEEDING ON FOOD INTAKE.

The productive response to concentrates is likely to be greater if the effect of adding concentrates to a basal ration increases the total D.M. intake. If it results merely in substitution of concentrate D.M. for basal ration D.M., responses are likely to be less.

Studies on this question are reviewed below.

1.1. PASTURE INTAKE.

A limited number of experiments have been carried out to examine the effect of concentrate feeding on pasture consumption.

MacLusky (1955) investigated the effect of concentrate feeding on the pasture intake of four pairs of cows over four periods, each of one week duration. In each of the periods one or other cow of each pair was fed eight lb of "dairy cake" in addition to pasture. No description of the "dairy cake" was given. Table 1 shows the results of his experiment.

TABLE 1. The effect of a concentrate supplement on herbage intake.
(Adapted from MacLusky, 1955)
(Pasture intake - lb DM/cow/day)

	Period 1	Period 2	Period 3	Period 4	Mean
With 7.2 lb supplement DM	23.3	26.2	13.5	19.5	20.5
No supplement	24.1	26.8	17.6	24.5	23.3
Difference	0.8	0.6	4.1	5.4	2.8
Pasture substitution (lb/lb conc.)	0.11	0.08	0.57	0.75	0.39

On an average the substitution of pasture DM of 0.39 lb (0.1 - 0.75)/lb concentrate DM consumed was noted. The total DM intake increased and was of the order of 18.9 % (1.3 - 26.5%). The quality of pasture in the first two periods was better because of leafy growth than the last two periods when mature pasture was grazed, but digestibility was not determined. The herbage intake was estimated by sampling small plots before and after the grazing periods of 24 hours duration by hand clipping to ground level. This method of measuring intake is likely to be associated with large sampling errors.

Using the same technique described to estimate pasture intake, Corbett and Boyne (1958) fed dry molassed sugarbeet pulp to cows grazing pasture. Twenty-four cows were used in an eight-week changeover design over two seasons (Autumn and Spring). The experiment was divided into four periods of

14-days each. In both experiments the total intake of DM increased with supplementation. A substitution of 0.59 lb of pasture DM in Spring and 0.41 lb in Autumn per lb of concentrates fed was noted. The amounts of supplement consumed were 6.8 lb and 8.6 lb in Spring and Autumn, respectively, with the smaller amounts of concentrates in Spring giving a rather greater degree of substitution. The preciseness of intake measurements is questionable because large sampling errors are likely to be associated with the method used.

Further evidence on the extent to which pasture is replaced by concentrates is provided by Seath et.al. (1959). Three treatments compared were as follows:
(A) No grain, (B) 5 - 6 lb grain and (C) 10 - 12 lb grain. The grain fed consisted of corn and cob-meal, wheat bran and ground oats. Eighteen lactating cows were divided into three groups and the experiment was carried out over two years (1956 and 1957). The liberal rate (Treatment C) of grain feeding was accompanied by a decrease in DM intake of pasture averaging 24% or 0.84 lb/lb concentrates in 1956 and 10% or 0.36 lb/lb concentrates in 1957. In 1956, the reduction in pasture intake at both levels of grain feeding was quite pronounced, and the differences were statistically significant. For 1957, however, according to the authors, "the trend lacked statistical significance". It was suggested that the inconsistency of results was because of differences in pasture digestibility and availability between experiments. The

digestibility of pasture was 69.2% and 65.5% in 1956 and 1957, respectively. These differences, however, appear to be small. In 1957 the pasture growth was short because of a lack of rainfall and the cows were possibly restricted in the amount of pasture they were able to eat. Under such conditions it is quite probable that cows ate their ration of grain without greatly decreasing their intake of pasture. The gain in total DM consumption over that of pasture DM eaten was 4% and 13% in 1956 and 1957, respectively. The intake of herbage was estimated by the faecal chromogen and chromic-oxide method. This technique is not entirely satisfactory and may involve considerable errors (Minson and Kemp, 1961; Raymond, 1954; Stevenson, 1962; Greenhalgh et.al., 1960).

The substitution of pasture by concentrates has also been noted with sheep (Holder, 1962). In three experiments conducted with Merino sheep grazing Australian native pasture, feeding a grain (oats) supplement significantly depressed pasture intake. Calculation from original figures revealed that on an average pasture substitution of 0.75 Kg/Kg concentrates fed occurred. The intake of individual sheep was estimated by indirect methods, using the faecal-nitrogen and chromic-oxide technique.

Holder (1960) and (1962) also noted that the supplemented sheep spent less time grazing compared with the unsupplemented sheep, reflecting less intake of pasture by the former than the latter.

As far as I am aware no experiments have been conducted where the effect of concentrate feeding on pasture intake has been carried out under controlled indoor feeding conditions.

1.2. INTAKE OF HAY AND SILAGE.

A number of experiments appear in the literature demonstrating the effect of concentrate feeding on the intake of hay and silage. The effect of concentrate feeding on hay and silage may be affected by several factors, such as the physiological state of animal, the quality of the roughage, the type of roughage (hay or silage) and the type of concentrates used.

1.2.1. Physiological State of Animal.

(i) Lactating cows.

Jensen et.al. (1942) observed that if lactating cows are fed roughage ad.lib. a substitution of the roughage DM of 0.5 to 0.7 lb/lb concentrates DM may take place.

Using a changeover type of experimental design Autrey et.al. (1942) also noted a depression in the intake of roughage by grain feeding. The treatments compared in two experiments conducted separately were: (A) No grain, (B) Limited (6 lb) grain and (C) Full grain (12 lb). The grain mixture consisted of corn, cob-meal, rolled oats and crushed soya bean and the cows were fed all the hay and silage they could clean up. The extent of roughage substitution was 0.32 and 0.27 lb/lb concentrate DM in experiment I and 0.31

and 0.50 lb/lb concentrate DM consumed in experiment II with treatments B and C, respectively. The total intake of DM increased as the amount of concentrate fed increased, the differences being significant ($P < 0.05$) for treatments B (Exp.I) and C (Exp.II) and highly significant ($P < 0.01$) in favour of treatment C (Exp.I) compared with the control groups.

Reid and Holmes (1956) noted a decrease of 0.68 lb roughage D.M./lb concentrate DM eaten in a small scale changeover experiment. The basal ration consisted of good quality dried grass and medium quality hay. The concentrate mixture consisted of oats, barley, dried grass, fish meal, beans and earthnut cake. In a further experiment, Holmes et.al. (1957); concentrates (oats, barley, beans, beet pulp, soya bean, dairy cubes, grass cubes, and fish meal) were fed at 0, 2, 4 and 6 lb/gal of milk yield in addition to 6 lb dried grass, 6 lb hay and grass silage ad.lib. The extent of substitution of roughage DM was 0.67, 0.67 and 0.61 lb/lb concentrate DM intake on the above concentrates fed levels. However, the depression in roughage intake was low in another experiment by Holmes et.al. (1960), the amount substituted being 0.18 - 0.30 lb for every lb increase in concentrate DM eaten. The concentrate mixture used included the following constituents: barley meal, dried sugar-beet pulp, flaked maize, decorticated earthnut cake, soya bean meal and molassin meal. Hay and silage were fed ad.lib. The reasons for low substitution in this experiment compared with earlier experiments by the same authors is not known.

Two levels of concentrates feeding after calving were compared in a feeding experiment extending over a complete lactation using 16 cows in each of two years by Castle and Watson (1961). On the high and low levels of concentrate feeding the amounts fed were 4.1 and 2.2 lb/gal of milk, respectively. A substitution of roughage DM occurred by concentrate feeding at high level compared with low level and was of the order of 0.38 lb and 0.18 lb/lb concentrate DM in the first and the second year, respectively. The ingredients of concentrate mixture fed were - oats, barley, flaked maize, soya bean meal, locust bean meal, tic bean meal, ground nut cake and grass meal. The values for pasture replacement by concentrates were similar to those obtained by Holmes et.al. (1960).

(ii) Dry cows.

Schmidt and Shultz (1959) demonstrated a depression in roughage intake when two levels of concentrate were fed during later stages of pregnancy. Sixty-three cows were assigned to trios - one member of the trio did not receive any grain, a second member received 6lb grain and a third member received 15 lb grain/day. The basal ration consisted of hay fed ad.lib. and limited amounts of silage. The grain mixture included ground oats, ground corn, wheat bran, corn gluten feed, soya bean meal and cane molasses. Though there was no appreciable effect of 6 lb of grain feeding on the roughage intake, the high level of concentrates feeding (12.8 lb consumption) depressed intake of hay by 5.4 lb in comparison with no grain fed group. There is no indication as to whether intake figures are based on DM or green weight. Assuming that figures were expressed in D.M., then a substitution of 0.42 lb roughage DM/lb concentrates DM occurred in this experiment on high level of grain feeding.

More recently Campling and Murdoch (1966) conducted a series of changeover experiments to examine the effect of giving restricted amounts of concentrates on voluntary intake of roughages by dry cows. The results showed that feeding of up to 4 Kg concentrates to cows receiving hay ad.lib. caused little change in the intake of hay and a small increase in the intake of barley straw. Larger amounts of concentrates (6 - 14 Kg daily) reduced hay intake by 0.2 - 0.4 Kg DM/Kg concentrate DM given. The substitution of hay at the highest concentrate level was 50% compared with 18.30% substitution at 6 Kg concentrate feeding.

1.2.2. Quality of Basal Ration.

The quality of the basal ration used has been shown to affect the extent of substitution (although the word 'quality' may be used to describe various aspects of food, generally it implies concentration of nutrients such as energy and protein and/or digestibility of food). Reid (1956) reviewing American experiments concluded that the reduction in the intake of roughage with the consumption of concentrates seems to be less marked for high quality roughage than for low quality roughage. Holmes and MacLusky (cited by Corbett, 1961) noted that with high quality herbage, concentrates up to at least eight lb daily may be consumed in addition to normal intake of grass, but that with poor quality herbage there may be almost a weight for weight substitution for grass by concentrates.

The results obtained by Blaxter et.al. (1961), however, are at variance with the conclusion of Reid (1956). Blaxter et.al. (1961) working with sheep found that substitution of roughage was greater with better quality than with poor quality hay. Thus with hay of 74.2% digestibility, 100 g hay DM was replaced by 100 g concentrate DM, whereas only 47 g of hay DM was substituted by 100 g concentrates DM when the digestibility of the former was 44.7%. In a further experiment Blaxter and Wilson (1963) found that the voluntary intake of hay increased with increasing digestibility, although when concentrates were given in restricted amounts the depression in intake of hay was related inversely to the digestibility of the hay - the more digestible the hay the greater the depression of hay intake with concentrate feeding. It was suggested by the authors that the increase in hay intake of low digestibility with the concentrates was due to protein contained in the concentrates. It is well known that supplements containing nitrogen often increase the voluntary intake of low digestibility roughage by ruminants (Balch and Campling, 1962; Campling, 1964; and 1966). Recently Campling and Murdoch (1966) also observed that the decline in intake of hay when restricted amounts of concentrates were fed was greater with high quality hay than with low quality hay. However, the depression in intake of good quality hay was much smaller than that obtained by Blaxter et.al. (1961).

The effects of concentrate feeding on hay of varying quality are hard to reconcile with the statement of Reid (loc. cit.). Reid's conclusions were based on experiments with lactating cows whereas Blaxter et.al. (loc.cit.) and Campling and Murdoch (loc.cit.) obtained their results with sheep and dry cows, respectively. No specific experiments appear to have been conducted on the influence of the physiological state of animal or of species differences on the extent of substitution of concentrates for basal ration.

1.2.3. Type of Roughage.

It appears that the magnitude of substitution of roughage by concentrates fed is affected by the type of roughage, i.e. hay or silage. For instance Clifton et.al. (1963) noted a greater replacement of hay than silage DM/unit concentrates fed. This can be substantiated from the experiment of Campling and Murdoch (1966) who also noted higher depression of hay (0.2 - 0.4 Kg/Kg concentrate DM) than that of silage (0.13 - 0.23 Kg/Kg concentrate DM). Mather et.al. (1960) reported a decline of silage DM up to 0.26 Kg/Kg grain fed when rate of grain feeding was increased from a grain-milk yield ratio of 1:6 to 1:3 and cows were fed limited hay and grass silage ad.lib. The high producing cows decreased less than the low producers in forage DM intake when grain was fed at higher rate according to milk production. More recently Murdoch and Hodgson (1967)demonstrated a small decrease in silage intake when concentrates (7.3 Kg) were fed to lactating cows. The values of silage substitution were of the order of 0.11 - 0.20 Kg/Kg concentrates consumed. Exception exists in literature, for Danasobury (cited by Campling and Murdoch, 1966) obtained a considerable amount of replacement (0.6 Kg/Kg concentrates) of silage by concentrates.

1.2.4. Type of Concentrate.

Little is known about the effect of type of concentrates on the extent of substitution of roughage. Campling and Murdoch (loc.cit.) in one of the seven experiments on substitution specifically studied the effect of giving different kinds of concentrates on hay intake. No significant difference in the degree of substitution of hay was noted when fed with one of the following concentrate mixtures:

(A) Rolled oats and ground nut meal

(B) Flaked maize and ground nut meal

(C) Standard concentrate mixture - Barley, maize, wheat bran, decorticated ground nut cake, copra cake, palm kernal, molassin and minerals.

Similarly no appreciable differences were found in the extent of substitution by high or low-protein concentrates fed with hay and silage ad.lib. (Reid and Holmes, 1956). In contrast Murdoch (1964) using sheep reported a greater degree of hay substitution with low protein concentrate than with high protein concentrate. Thus the total intake was higher with high protein concentrate compared with low protein one.

1.2.5. Stage of Lactation.

In none of the experiments reviewed above was there any mention of the effect of stage of lactation on the degree of substitution of roughage by concentrates.

1.3. WHY SUBSTITUTION?

The reasons for depressions in intake of roughages by concentrate feeding are not clearly understood. The possibility of a change in the type of microbial fermentation in the rumen has been put forward by Donefer et.al. (1963). This suggestion implicates both physical and physiological factors as affecting voluntary intake. Physical in that the rate of digestion of crude fibre of the ration may be affected and so alter the rate of passage of food from the digestive tract. Physiological, in that there may be substantial changes in the physio-chemical environment of the rumen, i.e. change in pH and/or volatile-fatty-acid (VFA) production. Balch and Campling (1962) suggested that chemostatic or thermostatic mechanisms could operate with diets containing substantial amounts of concentrates. Reid et.al. (1957) have noted an accumulation of lactic acid in the rumen causing a depression in the pH as a result of feeding rations containing high levels of soluble carbohydrates. That the intake of concentrates when fed ad.lib. can be increased by adding buffers was shown by Nicholson and Cunningham (1961) and it would suggest that a fall in rumen pH limited the voluntary intake of concentrates by steers. However, Freer and Campling (1963) maintain that acidity alone is unlikely to be the limiting factor.

Depression of crude fibre digestion has been demonstrated by Head (1953), Hamilton (1942), Watson (1949), Montgomery and Baumgradt (1965), Conrad et.al. (1966), as a consequence of adding high carbohydrate concentrates. The lowered digestibility of crude fibre could be due to a reduction in the cellulytic activity of the micro-organisms, probably caused by a competition between the cellulytic and amylolytic groups of bacteria for nutrients (Elshazly et.al., 1961). It seems likely that this depressing effect on digestibility by concentrates is related to a depression in the rate of passage from reticulo-rumen (Crampton et.al., 1960). That mean retention of roughage in the digestive tract is increased when concentrates are added to a roughage ration has been shown by Balch et.al. (1955a), Eng et.al. (1964) and Campling (1966). Campling (1966) also noted an increased rumination time in cows receiving concentrates in addition to hay. At the end of meal the amount of digesta in the reticulo-rumen of the cows offered hay ad.lib. with restricted amounts of concentrates was about the same as that found when offered hay *ad.lib.* as the only food. This suggests a physical control on the voluntary intake of hay. However, the amount of digesta was low with the highest level of concentrates (7.5 Kg) than with any of the other diets, indicating a possible physiological limitation on intake.

1.4 SUMMARY

Table 2 summarises the effect of concentrates feeding on the voluntary intake of basal rations. When concentrates were added to basal rations of hay, silage or pasture, there occurred an increase in total intake of dry matter. This increase occurs depsite a degree of substitution of such rations by the concentrates. Among many other factors digestibility and the type of basal ration appeared to be important factors affecting the extent of substitution.

TABLE 2. Summary of Experiments Showing Effect of Concentrate Feeding on Voluntary Intake of Basal Ration.

Name Author	Year	Basal Ration	Amount of Concentrates DM consumed (Kg)		Kg basal ration substituted/Kg concentrates	% DM basal ration substituted	% Increase in total DM intake over that of basal ration when fed alone	Remarks
1. MacLusky	1955	Pasture	Periods - 1	3.3	0.11	3.3	26.5	Estimation of intake by hand clipping the herbage (i.e. indirect)
			2	3.3	0.10	2.3	24.8	
			3	3.3	0.57	23.3	17.6	
			4	3.3	0.75	22.0	7.3	
2. Corbett & Boyne	1958	Pasture	Spring	3.1	0.59	11.0	8.0	Estimation of intake indirect-cutting and sampling herbage.
			Autumn	3.9	0.42	11.8	16.0	
3. Seath *et.al.*	1959	Pasture	Exp I	2.3	0.74	11.9	4.1	Estimation of intake indirect-faecal chromogen chromic-oxide method
				4.0	0.84	23.6	4.4	
			Exp II	1.9	0.43	6.1	8.1	
				3.8	0.36	10.1	17.9	
4. Autrey *et.al.*	1942	Hay + Silage	Exp I	2.5	0.32	7.5	15.4	
				4.6	0.27	11.4	29.0	
			Exp II	2.2	0.37	6.6	11.0	
				5.0	0.50	20.4	20.4	
5. Jensen *et.al.*	1942	Hay + Silage	-	-	0.50 - 0.70	-	-	
6. Reid	1956	Hay or Silage	-	-	0.40 - 0.50	-	-	Conclusions from several American experiments

TABLE 2 continued

Name Author	Year	Basal Ration	Amount of Concentrates DM consumed (Kg)		Kg basal ration substituted/Kg concentrates	% DM basal ration substituted	% Increase in total DM intake over that of basal ration when fed alone	Remarks
7. Reid & Holmes	1956	Dried Grass + Hay		5.8	0.68	19.0	6.4	Comparison made with group fed 2.8 Kg concentrate
8. Holmes <u>et.al</u>.	1957	Grass silage <u>ad.lib</u>. + dried grass + hay		2.1 4.2 6.2	0.67 0.67 0.62	13.1 26.1 35.4	6.3 12.6 21.9	Considerable depression of silage intake, hay slightly and grass was little affected
9. Schmidt & Shultz	1959	Hay		2.7 5.8	0.13 0.43	-	-	Dry cows used
10. Holmes <u>et.al</u>.	1960	Hay + Silage + 1.8 Kg concentrates		3.6 5.4 7.2	0.30 0.14 0.18	4.8 6.7 8.7	10.7 24.6 38.1	Comparisons with group fed roughage + concentrates
11. Castle & Watson	1961	Hay + Silage 3.4 Kg conc.	I II	7.2 7.2	0.38 0.18	-	-	Comparison with group fed roughage + concentrate
12. Blaxter <u>et.al</u>.	1961	Hay digestibility 74%	-	-	1.0	-	-	Experiment with sheep
		Hay dig. 45%	-	-	0.47	-	-	

TABLE 2 continued

Name Author	Year	Basal Ration	Amount of Concentrates DM consumed (Kg)		Kg basal ration substituted/Kg concentrates	% DM basal ration substituted	% Increase in total DM intake over that of basal ration when fed alone	Remarks
13. Campling & Murdoch	1966		Concentrate mixtures	8.0 11.0 14.0	0.21 0.34 0.33	22.8 49.9 60.0	103.1 118.6 154.2	Dry cows used
			1. Standard conc.	6.0	0.29	18.1	54.2	
			2. Oats + GNC	6.0	0.37	22.3	50.0	
			3. Flaked maize + GNC	6.0	0.45	27.1	45.2	
14. Murdoch & Hodgson	1967	1. Grass silage + 1.0 Hay ad. lib./100 Kg b.wt.		7.3	0.20	-	-	Comparison was made with low (3.3 Kg) level of concentrate + basal ration
		2. Grass silage ad. lib. + 0.5 Kg hay/100 Kg b.wt.		7.3	0.11	-	-	

THE EFFECTS OF CONCENTRATE FEEDING ON MILK PRODUCTION

As noted in the previous section the total intake of cows fed concentrates in addition to basal diets is usually higher when compared with those fed roughage only. This higher intake may result in additional milk yield and a change in milk composition. The purpose of this section is to briefly review the effects of concentrate feeding on milk yield and milk composition of dairy cattle.

1.5 MILK YIELD

Variable responses in milk yield have been obtained by the addition of concentrates to basal rations. The basal diets used have been pasture, hay or silage.

1.5.1. Concentrates with Pasture Diet.

Hancock (1953) obtained large responses in milk yield by feeding concentrates throughout lactation at 1 lb/5 lb milk produced. The increase in milk yield was of the order of 15% during the course of three lactations in comparison with non-concentrate fed group. This conclusion is based on a comparison of the milk yield of five pairs of identical twins divided into two groups. Both groups received the same area of pasture for grazing, but one of the twin mates (one group) received concentrates in addition. Hay and silage were fed occasionally to all cows.

Edey (1956), in two changeover experiments, compared the response in milk yield with - (A) pasture alone and (B) pasture + 10 lb concentrates (crushed oats 8 lb + meat and bone meal 2 lb). The number of cows used were 12 and 20 in Exp. I and Exp. II, respectively. An increase in milk yield of 4 lb/cow/day was obtained in Exp. I ($P < 0.01$). In Exp. II, the differences in response in milk yield between periods were noted because of changes in pasture quality. In the first period of the experiment when the leafy pasture was grazed, a 2.9 lb ($P < 0.01$) increase in milk yield over that of control group was observed. In the second period of the experiment with relatively poor quality pasture the treatment differences rose to 4.7 lb ($P < 0.01$) in favour of concentrate fed group.

Two concentrate feeding trials, using 22 sets of identical twins, were carried out by Wallace (1957), Variable responses in milk yield were obtained in both experiments from feeding 6 lb of concentrates/cow/day. The concentrate mixture included crushed oats, barley meal, coconut meal and bran. In Exp. I, an increase of 40 gal of milk for first eight weeks of lactation was recorded, whereas in Exp. II the additional yield in favour of the concentrate fed group was only 15 gal. Carryover effects throughout the lactation were observed as a result of concentrate feeding. The pasture available during Exp. I was limited and therefore concentrate feeding alleviated the effect of under-feeding. Ample pasture was available in Exp. II and the replacement of pasture by concentrates may have occurred resulting in a relatively lower response.

Results of two experiments on supplementary feeding to pasture grazing cows have been reported by Corbett and Boyne (1958). Twenty-four cows were used in a changeover design in each experiment. In the Spring Exp. feeding of 8 lb dry molassed sugar-beet pulp resulted in an increase of 1.3 lb milk/cow/day ($P<0.05$). In the Autumn Exp. 10 lb of this supplement gave an additional response of 2.9 lb milk/cow/day ($P<0.01$). The results showed a greater degree of replacement of pasture by concentrates in the Spring compared with Autumn. Furthermore the amounts of supplement fed was higher in Autumn than in Spring. Both these factors could have led to a relatively higher total intake in Autumn than in Spring and possibly resulted in the greater response in the Autumn. Differences in pasture quality between two seasons may also have influenced the results obtained.

A series of experiments have been conducted by Castle and his colleagues in the U.K. at Hannah Dairy Research Institute. In Exp. I (Castle et.al., 1960), 6 lb of a mixture of three parts bruised oats and one part flaked maize was fed daily to three groups of five cows. One group received the supplement from 1 July until 30 October, and the other two groups from 1 August and 1 September, respectively. A control group received no supplement. In no period was there any significant difference in daily milk yield between supplemented and unsupplemented groups of cows. In Exp. II, three groups of four cows on a nine-week changeover trial grazed herbage and three treatments compared were as under:

(A) Pasture

(B) Pasture + 1.6 lb hay/day

(C) Pasture + 5.7 lb meal/day (meal = undecorticated cotton cake, bruised oats, locust bean)

Feeding of meal resulted in a small but significant ($P < 0.05$) increase in milk yield from 41.8 on the all pasture ration to 43.2 lb/day on the meal treatment. No effect of hay supplementation on milk yield was noted. In a further experiment Castle et.al. (1964) did not find any difference in milk yield between concentrate and non-concentrate groups. The experiment was a continuous one using 28 Spring calving Ayrshire cows in 1960 and 12 in 1961 for 23 and 22 weeks, respectively. The amount of supplement (compound dairy cube) consumed averaged 8.7 lb and 8.0 lb, respectively. Ample leafy pasture was available in both experiments.

Appreciable response in milk yield was obtained by Laird and Walker (1962) in two experiments when they fed concentrates to cows grazing pasture. The experiments were carried out in 1959 and 1960 using six pairs of cows each year with one member of the pair receiving supplement and the other acting as control. The concentrate mixture used consisted of eight cereals or cereal by-products, two vegetable protein sources and small proportion of fish meal. Initially 4 lb of supplement was fed per gallon of milk yield above 4 gal. but this was reduced progressively to 3.5, 3.0 lb and so on as the season progressed. The additional responses to concentrate feeding obtained during the first 11 weeks were 4.4 lb and 3.5 lb in each experiment. The cows used in these experiments were producing 4.5 or more gal. of milk/day and had been in milk for 45 days at the beginning of the experiment. The authors noted that the response was low initially, possibly because there was an ample supply of good leafy pasture. It rose to a peak about the fifth week of the experimental period and then showed a gradual decline to the end of the experiment. The responses to concentrate feeding decreased as the experiment advanced and the time since calving became progressively longer. The results indicated that stage of lactation may affect the degree of responses obtained with concentrate feeding.

Shepherd (1962) reported the results of a 4-year trial in which supplementary feeding of concentrates during Spring (average 70 days) was contrasted with no supplement using Ayrshire cows grazing pasture. The treatments were 7 lb/head daily of barley meal; 7 lb/head daily of balanced dairy meal (barley meal, decorticated ground nut cake, fish meal and minerals) and a control group receiving no supplement. Variable results in different years were obtained and mainly depended upon the availability and quality of the pasture. For instance, in 1956 and 1959 there was no response from either form of concentrate feeding. In 1957, barley meal gave an additional 13 gal of milk/cow and the dairy mixture 45 gal/cow over 77 days of supplementation. A carry-over effect occurred persisting through the late Summer and was of the order of 45 gal for barley meal and 48 gal/cow for dairy mixture over a period of 91 days after concentrate feeding.

Likewise in 1958, the supplement of barley gave a significant increase of 27 gal/cow and dairy meal gave a smaller increase of 18 gal/cow over 63 days. The carry-over effect measured over following 87 days for the barley group was 29 gal/cow but found to be non-significant because of several animals failing to maintain their lactation.

Two field experiments on meal feeding were carried out at Massey (Davey, Unpublished) with cows grazing pasture. In Exp. I, eight pairs of identical twins were used. The twin pairs were divided into a control group receiving no concentrate and an experimental group receiving 10 lb of meal (barley + bran) which resulted in an increase of 1.5 lb milk/cow/day. In Exp. II, 20 cows were used divided into two equal groups. Both groups were pastured together with small amounts of hay and silage also being offered. One of the groups received 10 lb of concentrate (barley + bran) per cow/day, which resulted in a small increase in milk yield (1.1 lb cow/day).

Similar observations were recently reported by Wood (1966), who conducted a series of three experiments on supplementary feeding to Spring calving Ayrshire cows grazing herbage. The treatments contrasted were feeding balanced concentrates at 3.75 lb/gal for production over and above 4.5, 3.0 and 1.5 gal milk/day. The average production of cows was about 4 gal at the beginning, dropping to 3 gal at the end of 12-week experiment. The responses to supplementary feeding although generally positive were quite small and in no trial yield differences significant.

1.5.2 Concentrates with Hay and Silage.

The degree of response in milk yield obtained by supplementary feeding to cows receiving hay and silage has been shown to be affected by the following factors:

(i) Current level of feeding

(ii) Previous level of feeding

(iii) Quality of concentrates

(iv) Genetic ability of the cow

(i) Current level of feeding -

Appreciable responses have been obtained in milk yield with concentrate feeding by Autrey et.al.(1942). The mean daily milk yields (FCM) were 30.3, 34.3 and 37.2 lb/cow/day for the following three levels of feeding:

(A) Hay + silage ad.lib.

(B) As in A + 1 lb concentrate/7 lb milk

(C) As in A + 1 lb concentrate/3.5 lb milk

The differences in milk yield between treatments were highly significant ($P < 0.01$).

The results of the two series of long term experiments have been reported by Jensen et.al. (1942). In the series I, cows were fed alfalfa hay in proportion to their maintenance requirements and one of the six levels of feeding ranging from 85 - 143% of Hacker Standard for production. In the series II experiment, roughage ad.lib. was fed throughout lactation with grain at 1.0 lb/6, 4, 3 or 2 lb of milk produced. The responses of 0.6 lb fcm/lb additional TDN at the highest level and 1.7 lb

TDN at the lowest level of concentrate feeding were obtained. The authors concluded that milk output does not increase in proportion to the additional input of the concentrates fed but increase at declining rate.

Burt (1957a) arrived at a similar conclusion on the basis of a series of five short term experiments. In all but two of these experiments additional milk yield was recorded when concentrates were fed above Woodman standards. The average response to an increase in 1.0 lb SE intake amounted to 0.7 - 1.0 lb milk/cow/day on basal ration of hay and silage. The response in milk yield/unit SE was lower at high level than at low level of intake of concentrates.

Castle et.al. (1961) contrasted two levels of concentrate feeding in addition to hay and silage. On an average the milk yield of high concentrate fed group was higher than the low group for the first 140 days period and also for the whole lactation. The differences between treatments, however, were small and non-significant. In a further experiment Castle et.al. (1963) found similar small responses in milk yield when concentrates were fed in addition to hay and silage diet.

A small but statistically non-significant increase of about 1.5 lb milk was obtained due to supplementary feeding by Fairbairn and Rickaby (1966). Thirty-five Autumn calving Friesian cows grazing pasture were used. All cows were fed 7 lb hay, 25 lb silage, 5 lb dried sugar beet pulp and concentrate at 3.5 lb/gal milk. Half of the cows received 4 lb rolled barley in addition to the basal ration fed.

(ii) Previous level of feeding -

The effect of previous level of feeding can be seen in the experiment reported by Broster *et.al*. (1958). Two levels of steaming up and two levels of concentrate feeding during the first 84 days of lactation have been contrasted in a 2 x 2 factorial experiment over three Winter seasons, using 52 Shorthorn and 36 Friesian heifers. The levels of steaming up were 4 lb rising to 14 and 4 lb of concentrates fed over the last 21 and 14 days of pregnancy, respectively. The levels of concentrates during lactation were 5 and 3 lb/gal milk/day. Roughage was fed for maintenance. Over the 84-day period groups HH, HL and LH gave, respectively, 4.0, 3.5 and 3.5 lb more milk/cow/day than group LL. (Differences significant at 5% level). The group HH showed little advantage over HL and LH. The treatments had a marked residual carry-over effect over the whole lactation and Groups HH, LH and HL continued to out-yield group LL throughout the lactation.

(iii) Quality of Concentrates -

That quality of concentrate fed may affect the degree of response obtained has been demonstrated by Holmes *et.al*. (1956). The authors used three concentrate mixtures, each containing 16% DCP but variable energy (SE) levels. The daily milk yields for the three treatments were 38.9, 40.6 and 40.9 lb from cows receiving concentrates having 59, 67 and 75 SE, respectively. The two rations of higher SE contents gave significantly more milk than the low SE ration. In a further experiment the feeding of three levels of DCP (10, 15 and 17%) gave non-significant differences in milk yield. The SE was held constant at 63.5% for each ration. In contrast Reid and Holmes (1956) found a slight but statistically significant ($P < 0.05$) difference in milk yield of cows fed a low protein (11.4% DCP) and a high protein (18.4% DCP) concentrate mixture with the energy content being held constant at 63.2 SE.

(iv) Genetic ability of cows -

A possibility that high producing cows may give a different response to concentrate feeding compared with low producers was indicated by Holmes et.al. (1957). Four treatments compared were - 0, 2, 4 and 6.0 lb concentrates gal milk produced in addition to silage fed ad.lib. and limited amount of hay. An average increase of 5.4 lb milk was noted in favour of group fed 6.0 lb concentrate/gal milk. The additional response was 0.9 lb milk/lb increase in SE. A significant difference was found between higher and lower yielding groups. Thus the higher producing cows gave an increase of 1.1 lb and lower yielding groups only 0.6 lb milk/lb additional SE. Similarly Burt (1957b) found a positive correlation with milk yield and concentrate feeding - with higher producing cows responding better than lower producers to concentrate feeding. Likewise there was an indication that heifers responded less than older cows, giving similar yield.

1.6 MILK COMPOSITION

The effects of level and type of feeding on milk composition are well established, and some of the effects have been related to changes in the amounts and relative proportions of the VFA produced by the bacterial fermentation of food-stuffs in the rumen. Since concentrate feeding alters the level of intake and fermentation products in the rumen, this section reviews the effects of concentrate feeding on milk composition.

1.6.1. Milk Fat.

(i) Concentrates with restricted roughage diets -

It has been known for many years that restriction of the roughage part of the ration may markedly reduce the percentage of fat in milk. The degree of restriction necessary to produce this effect, however, still remains somewhat in question. While 6 - 8 lb or less of long hay or other roughage has often been considered as the critical level (Powell, 1941; Loosli et.al. 1945; Stoddard, 1949; Tyznic and Allen, 1951; Balch et.al. 1952 and 1954 and Storry and Rook, 1965), moderate depressions in fat have occurred on diets containing large quantities of long hay (more than 10 lb) (Brown et.al., 1962; Loosli et.al., 1961) as well as on certain pastures (Hemken et.al., 1962; McClymont, 1950).

(ii) Physical nature of roughage -

Grinding and pelleting of roughage has been shown to cause a decrease in fat content of milk. In a study in which the hay was ground through 1/16" screen before pelleting (Ronning, 1960), a marked depression in fat test was observed, particularly with diets containing 30 and 45% concentrates. In earlier studies (Ronning et.al., 1959) hay ground through a 3/16" screen before pelleting was without effect. The critical nature of fineness of grind in effecting changes in milk fat content has also been demonstrated in a number of other studies (Palmquist and Ronning, 1961; Porter et.al., 1953, Rodrigue and Allen, 1960).

(iii) Type, treatment and level of concentrates -

The type, treatment and level of concentrates fed with ground or restricted roughage are important factors in determining the degree of fat depression. Concentrates containing flaked corn or heated starch appear to be especially effective in reducing fat production (Balch et.al., 1955b; Shaw et.al., 1959; Storry and Rook, 1965). Increasing the proportion of concentrates in the ration seems to further depress an already low test (Ronning, 1960). There is some indication that less depression in milk fat may be caused by high-protein concentrates than with low-protein concentrates on low roughage diets (Balch et.al., 1954).

Generally, rations which depress milk fat percentage result in a rather characteristic change in the rumen fermentation. An unusually low fat content is associated with an unusually high molar proportion of propionic acid and a corresponding low proportion of acetic acid in the rumen-liquor (Balch and Rowland, 1957;

Elliot and Loosli, 1959; Balch, 1960; Shaw, 1961; Bath and Rook, 1963). Further evidence for the association of VFA with milk fat content is provided by experiments involving intra-ruminal infusion or addition of salts of VFA to the diet (Stoddard, et.al., 1949; Tyznic and Allen, 1951; Balch and Rowland, 1957; Rook and Balch, 1961; Storry and Rook, 1962; Rook et.al., 1965; Wilson et.al., 1967).

(iv) Plane of nutrition -

The plane of energy nutrition of the cow has been shown to have some effect on milk fat. The under-feeding of cows early in lactation may result in an increase of milk fat (Flux and Patchell, 1954). There may be a slight decrease in milk fat per cent. with increased plane of nutrition (Rook, 1961). Feeding restricted amounts of concentrates to cows grazing pasture has been shown to decrease up to 0.2 percentage units of fat (Edey, 1956; Corbett and Boyne, 1958; Castle et.al., 1964). Rook (1961) stated that any effect due to plane of nutrition on milk fat content reflects simply a change in milk yield without a corresponding change in fat yield.

1.6.2. Solids not Fat (SNF)

Concentrate feeding may have its effect on SNF content in the following way:

(i) by increasing plane of energy nutrition

(ii) by increasing plane of protein nutrition

(iii) a specific effect.

(i) Effect of plane of energy nutrition -

It appears well established on the basis of many experiments that feeding at levels considerably above standards results in a small increase in the SNF content of milk (Holmes et.al., 1957; Castle et.al., 1958; Castle et.al., 1959; Holmes et.al., 1960; Castle and Watson, 1961; Rook, 1961; Rook and Line, 1961; Castle et. al., 1961a; Hooven et.al., 1963; Huber and Boman, 1966). On the other hand underfeeding results in a drop in SNF content (Riddet et.al., 1941; Rowland, 1946 and Flux and Patchell, 1954).

It has frequently been observed that a change from Winter feeding to early pasture may result in a substantial rise in the SNF content of milk (Rook, 1961). On the basis of work by Waite et.al., (1959) and Rook et.al., (1960), the pasture effect appears to be explained in terms of an increased level of energy intake.

(ii) Effect of protein intake -

Severe underfeeding of protein has been shown to reduce the SNF content while moderate underfeeding apparently has little effect on SNF (Rook, 1961). The bulk of evidence to date indicates that feeding protein at levels above feeding standards does not increase SNF content, although it may increase the non-protein-nitrogen (NPN) content (Rook and Line, 1962).

(iii) Specific effect of concentrates (or energy concentration) -

In most studies, the effect of energy concentration is difficult to separate from those of energy level, because concentrates were fed to achieve higher planes of nutrition. However, some experiments do indicate a specific effect of concentrates - for instance, Balch et.al. (1955b) noted greater increases in SNF (0.4 - 0.5%) - than could be attributed to energy level, when cows were changed from a normal ration to one low in hay and high in flaked maize. Likewise Balch et.al. (1954); Balch and Rowland (1959) and Rook and Balch (1961) have noted an increase in SNF percentage on fat-depressing rations or treatments. As noted earlier such rations reduce acetic acid and increase propionic acid proportion in the rumen liquor. A relationship has been sought between propionic acid and SNF content by intra-ruminal infusion of propionic acid. Thus Rook and Balch (1961), Storry and Rook (1962), Rook et.al. (1965) and Wilson et.al. (1967) have shown that intra-ruminal infusion of dilute propionic acid resulted in an increase in protein content of milk. It appears from available evidence that changes in SNF occur only in response to large changes in rumen propionate.

1.7. SUMMARY

The effect of concentrate feeding on milk yield is summarised in Table 3. Variable responses have been noted by different workers depending mainly upon the level and type of basal ration, quantity and type of concentrates and genetic potential of the animals used.

Changes in milk composition due to concentrate feeding have also been reviewed. A decrease in fat and increase in SNF contents of milk may take place on addition of concentrates to basal diets. The factors affecting these changes have been briefly noted.

TABLE 3 Summary of Responses in Milk Yield to Concentrates in Some Experiments

Author	Year	Basal Ration	Amount of Concentrates (Kg)	Increase in milk yield (Kg/day)		Average response in milk yield in Kg/unit additional food	Remarks
1. Hancock	1953	Pasture, occasionally Hay + Silage	2.6		2.0	0.77/Kg conc.	Figures calculated from original data - Table IV, Hancock, 1953.
2. Edey	1956	Pasture	4.5	Exp I	1.8	0.40 "	Good quality pasture
				Exp II	1.3	0.29 "	Good quality pasture
					2.1	0.47 "	Moderate quality pasture
2. Wallace	1957	Pasture	2.7	Exp I	3.2	1.18 "	Hard grazing
				Exp II	1.3	0.48 "	Liberal grazing
4. Corbett & Boyne	1958	Pasture	3.6	Spring	0.6	0.17 "	
			4.5	Autumn	1.3	0.29 "	
5. Castle *et.al.*	1960	Pasture	2.5 - 2.7	"	0.63	0.25 "	
6. Shepherd	1962	Pasture + 1.0lb/cow tying-up ration + 3lb hay/day	Barley meal 3.2	Exp I	0.8	0.25 "	
			Dairy cake 3.2		2.6	0.81 "	
			Barley meal 3.2	Exp II	1.8	0.56 "	
			Dairy cake 3.2		1.2	0.37 "	
7. Castle *et.al.*	1964	Pasture	3.6	-	-	-	No response

Table 3 continued

Author	Year	Basal Ration	Amount of Concentrates (Kg)	Increase in milk yield (Kg/day)		Average response in milk yield in Kg/unit additional food	Remarks
8. Davey	Unpublished	Pasture	3.7		0.7	0.19/Kg conc.	
9. Davey	"	Pasture + 6lb hay + 30 lb silage	4.0		0.5	0.12 "	
10. Laird & Walker	1962	Pasture	2.0 2.0	I II	2.0 1.6	1.0 " 0.8 "	
11. Jensen <u>et.al</u>.	1942	Hay				0.6 - 1.6 Kg/Kg TDN	
12. Autrey <u>et.al</u>.	1942	Hay + silage	1 Kg/7 Kg milk 1 Kg/3.5 Kg milk		1.8 3.3	0.80/Kg conc. 0.65/Kg "	
13. Burt	1957a	Hay + silage	-		-	1.0 Kg/Kg SE	
14. Castle <u>et.al</u>.	1961	Hay + silage	-		-	0.7 - 1.0 -/Kg SE	
15. Castle <u>et.al</u>.	1963	Hay + silage				1.0 Kg/Kg SE	
16. Holmes	1957	Hay + dried grass + silage				0.6 - 1.1Kg/Kg SE	

CHAPTER II

FIELD EXPERIMENT

A field experiment was carried out to observe the effect of concentrate feeding on milk production. The objects were to gain an insight into the nature of problems involved in such an experiment and to obtain a lead for further investigation.

2.1. MATERIALS AND METHODS

2.1.1. Animals

Sixteen, Autumn-calved, Friesian cows from No. 1 Unit of Massey University were used. The animals were in moderate to good condition. All but three of the cows had previously been used in an experiment involving a comparison of milk production between two pasture species. The general description of the animals used is given in Table 4.

2.1.2. Experimental Design

A preliminary period of 15 days (3 - 18 July) preceded the comparison period (19 July - 5 August) during which milk yield and milk composition were measured. The 16 cows were divided into eight blocks of two cows each on the basis of their milk production in the preliminary period. One of the cows within each block was randomly assigned to the concentrate feeding treatment and the other cow served

TABLE 4: Characteristics of Animals Used

Cow No.	Age (Years)	Day of Calving (Date)	No. of days in milk	Milk Production during an experiment prior to the present experiment (Kg/day)
7	3	24/4/66	85	21.2
10	2	17/4/66	92	16.4
13	2	2/5/66	77	17.3
33	3	28/4/66	81	15.3
58	4	4/5/66	75	19.7
62	4	14/4/66	95	14.5
84	2	1/4/66	108	17.9
100	7	17/4/66	92	20.3
4	5	19/5/66	60	21.9 *
11	3	26/5/66	52	15.4 *
41	3	29/4/66	80	18.0
68	2	5/5/66	74	14.3
75	4	13/5/66	66	15.8
77	9	11/5/66	68	22.7
87	4	24/4/66	85	19.9
96	7	15/4/66	64	15.0 *

* Figures from herd test.

as a control. Thus there were eight cows in the experimental group (A) and eight in the control group (B). All the cows received approximately 3.0 Kg hay and 12.0 Kg silage/cow/day in addition to pasture. The cows on treatment A were also fed 4.7 Kg concentrates/cow/day.

2.1.3. Feeding and Management.

The experimental animals were grazed with the No. 1 Dairy Herd. The herd grazed each morning a fresh paddock which had been spelled on an average for four weeks. The amount of pasture varied widely from sparse to moderate in different paddocks with the height varying from 2-12". Rye grass varieties predominated in all paddocks. The hay and silage offered appeared to be of moderate quality and contained mixed pasture species, chiefly rye grass varieties.

Concentrates were fed individually to treatment cows in a yard adjacent to milking shed after p.m. milking. The concentrate mixture consisted of coarsely ground barley and wheat bran in the proportion of 4:1.

2.1.4. Feed Availability.

Estimates of pasture availability were made as follows. Ten plots each of 20 sq. ft. were randomly selected and were cut on three randomly selected days during the comparison period. An effort was made to simulate the grazing by cows in the height of cutting. The samples were weighed, bulked and sub-samples were taken for DM determinations. DM yield was calculated for the paddocks. The total yield divided by the number of animals in the herd gave an estimate of the amount of pasture DM available/cow.

The mean weight/bale of hay was obtained by weighing 20 bales and from this the amount of hay available/cow/day was estimated. The silage offered was also weighed twice during the comparison period in a trailer over a weigh-bridge. An approximation was made of the amount of silage offered. The amounts of concentrates offered and refused were weighed every day.

Duplicate samples for each feed were used for DM determinations once a week. About 250 g. samples were kept for 24 hrs. at $75^{\circ}C$ in a forced-draught oven.

2.1.5. Sampling and Recording of Milk.

The cows were milked twice daily at 5.0 a.m. and 3.0 p.m. In preliminary period milk yield was measured for six milkings. Proportionate samples of two consecutive milkings were taken and bulked for SNF and fat determinations, making three composite samples in all.

During the comparison period milk weights for individual cows were recorded for five days a week at both the a.m. and p.m. milkings. Determinations of milk fat and SNF contents were carried out twice weekly on composite samples of four consecutive milkings.

The milk fat content was determined by the Standard Gerber Procedure (British Standard Specification, 1955) and Total Solids (T.S.) were determined gravimetrically, SNF being obtained by difference. The T.S. determinations were standardized by weighing 2 ml milk samples in clean and dry milk caps. The samples were dried to a constant weight for 6 hr at 85°C. Preliminary investigations showed that keeping samples at 85°C ± 2°C for six hr was satisfactory for T.S. determinations. Duplicate samples were used to determine both milk-fat and SNF contents. The determinations were repeated in cases where differences greater than 1% occurred.

2.1.6. Statistical Analysis.

There were some differences in milk yield, milk-fat and SNF contents and yields between two groups during the preliminary period. Therefore, the milk production data of comparison period were adjusted using Covariance Analysis technique (Snedecor, 1961). The treatment mean square was also tested against the "effective" residual error mean square (Cochran and Cox, 1957), but no difference in the test of significance was found from that obtained by testing adjusted treatment mean square against adjusted error mean square. (Snedecor, 1961).

For the first half of the comparison period the responses in milk production to concentrate feeding were different from those in the second half of this period. The results, therefore, are calculated both for complete comparison period and for the first half of this period.

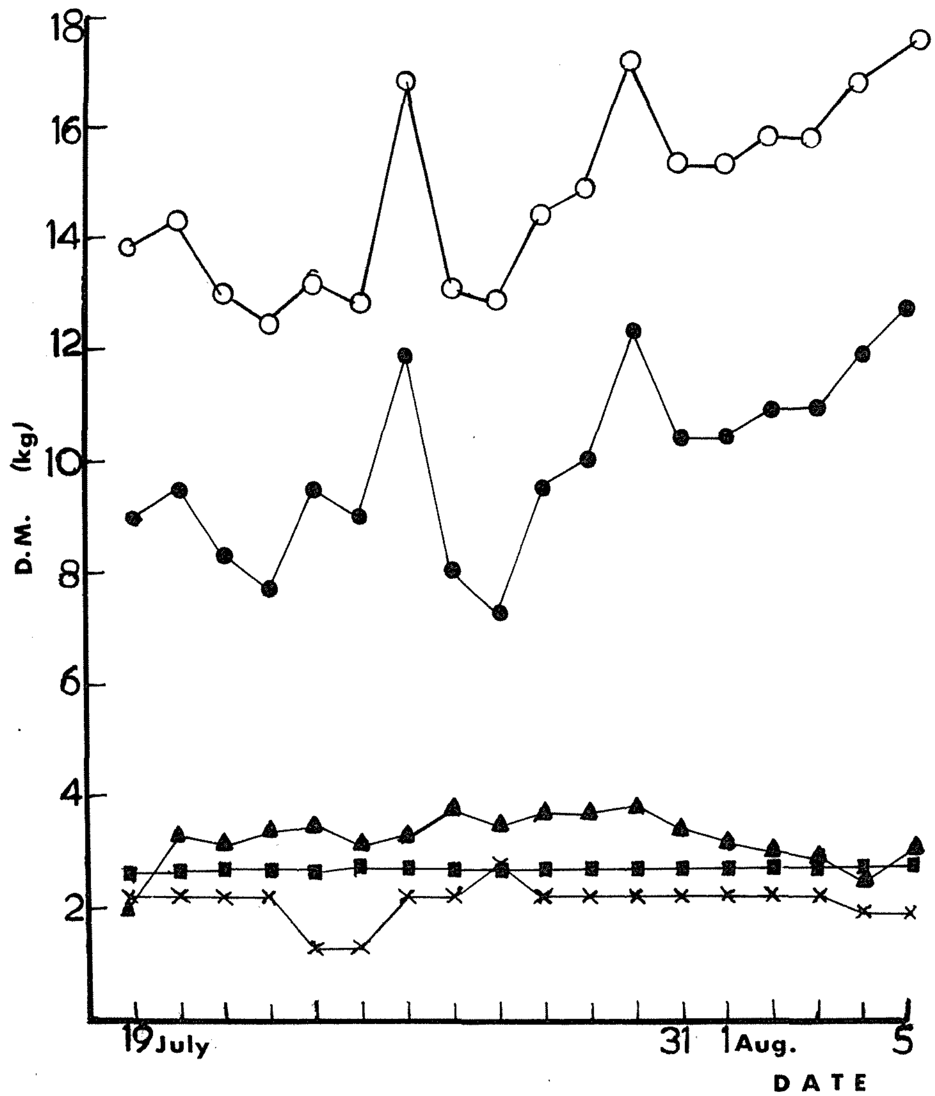


Fig.1: An estimation of feed availability, Hay ×——×; Silage ■——■; Concentrates▲——▲; Pasture ●——●; Total roughage○——○.

2.2. RESULTS

2.2.1. Feed Availability.

The pasture yield was variable and was estimated, by clipping and weighing (see section 2.1.4), to range from 200 - 320 Kg DM/acre. Approximately 7 - 12.5 Kg pasture DM was available/cow/day (Fig. 1). The DM of hay and silage offered was estimated to be approximately 2.2 and 2.5 Kg/cow/day, respectively. The cows did not clean up all the hay and silage offered. Figure 1 illustrates that the availability of all feeds ranged from 12.0 - 17.4 Kg DM/cow/day. Whilst the cows were offered 4.2 Kg DM concentrate, the actual consumption was below this (see figure 1), the consumption of concentrate declining particularly from 31 July onwards. This decline was mainly due to one cow 58 which ate 0.6 Kg/day and to a lesser extent to 33, 84 and 13 which ate approximately 2.5 Kg concentrates DM in the last week of the comparison period.

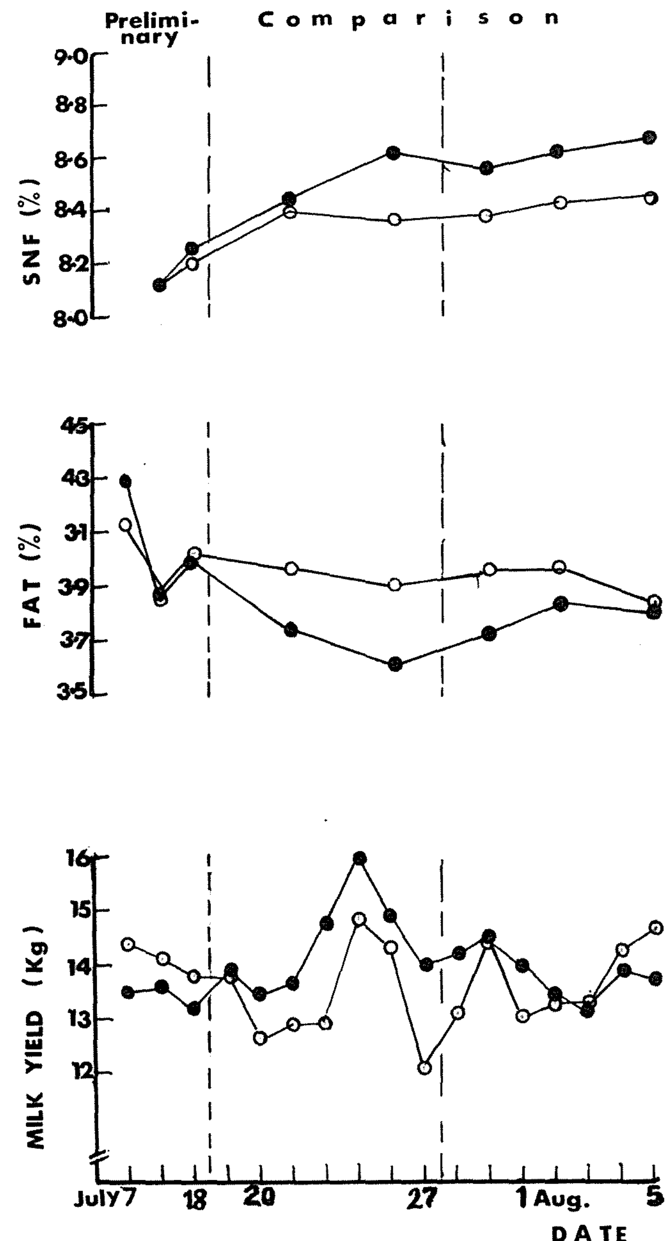


Fig.2: Changes in milk Production,
(A) Concentrates ●—● & (B) Control ○—○.

TABLE 5: Effect of Treatments on Milk Production in First-Half of the Comparison Period.

(Per/cow/day)

	Preliminary Period	Comparison Period (Actual)	Comparison Period (Adjusted)	SE	CV (%)	Significance of difference
Milk yield (Kg)						
A	13.4	14.4	14.4	±0.21	4.296	A>B **
B	14.1	13.2	13.0	±0.21	"	
Milk fat (%)						
A	4.08	3.63	3.62	±.077	5.718	
B	4.95	3.99	4.00	±.077	"	B>A *
Milk fat yield (g)						
A	546.0	516.0	525.0	±14.0	7.662	
B	574.0	529.0	520.0	±14.0	7.662	
SNF (%)						
A	8.21	8.55	8.54	±0.08	2.822	
B	8.18	8.46	8.47	±0.08	2.822	
SNF yield (g)						
A	1102.0	1234.0	1253.0	±24.0	5.947	A>B **
B	1160.0	1121.0	1102.0	±24.0	"	

A = Meal

B = Control

SE = Standard error of mean

CV = Coefficient of variation

* = $P<0.05$

** = $P<0.01$

TABLE 6: Effect of Treatments on Milk Production in Whole of the Comparison Period.

(Per/cow/day)

	Pre-Experimental	Experimental (Actual)	Experimental (Adjusted)	SE	CV (%)	Significance of difference
Milk yield (Kg)						
A	13.4	14.0	14.3	±0.24	4.963	A > B *
B	14.1	13.6	13.3	"	"	
Milk fat (%)						
A	4.08	3.75	3.74	±0.08	5.804	
B	4.05	3.93	3.94	±0.08	5.804	
Milk fat yield (g)						
A	546.0	522.0	532.0	± 25.0	13.662	
B	574.0	535.0	525.0	± 25.0	"	
SNF %						
A	8.21	8.60	8.58	±0.05	1.715	
B	8.18	8.42	8.43	±0.05	1.715	
SNF yield (g)						
A	1102.0	1208.0	1231.0	± 31.0	7.646	A > B **
B	1160.0	1146.0	1123.0	± 31.0	"	

A = Meal

B = Control

SE = Standard error of mean

CV = Coefficient of variation

* = $P < 0.05$

** = $P < 0.01$

2.2.2. Milk Production.

(i) Milk yield -

The mean daily milk yield of both groups is illustrated in figure 2. The milk yield of group A for the first-half of the experiment was significantly higher ($P < 0.01$) than group B, concentrate feeding resulting in an increase of 1.4 Kg milk/cow/day (Table 5) (Appendix 1). The differences were significant at the 5% level when the data were analysed for whole comparison period (Table 6)(Appendix 1).

(ii) Milk-fat content and yield -

The results of milk-fat contents for both groups are shown in figure 2 and tables 5 and 6. There was a significant ($P < 0.05$) difference between group A and B for the first-half of the experiment, the milk-fat of group B being higher by 0.38 percentage units than group A. However, analysis for the whole period showed a small but non-significant ($P > 0.05$) difference between the two groups (Appendix 2). Little difference was obtained in milk-fat yield between the two groups, both for the first-half and the whole comparison period (Appendix 3).

(iii) Solids-not-fat (SNF) content and yield -

The SNF content of the milk is included in Table 5 and 6, and in figure 2. The differences in SNF contents between the treatments, both for the first-half and the whole of the comparison period, were non-significant ($P > 0.05$) (Appendix 4). The SNF yields are included in tables 5 and 6, respectively for the first-half and whole of the comparison period. The results showed highly significant ($P < 0.01$) differences in SNF yields between the two groups (Appendix 5). The average increase due to concentrate feeding being 151 g and 108 g/cow/day for the first-half and the whole of comparison period, respectively.

2.3. DISCUSSION

The methods used to estimate the availability of the pasture, hay and silage were approximations only of the amount available to the cows. Cutting pasture by clippers from three paddocks for sampling and yield estimations may not be a true representation of actual availability of pasture. Similarly, weighing and sampling of hay bales and silage once a week and calculating the amount offered for the whole experimental period are likely to be associated with large errors. The actual consumption of feeds by animals is also a matter of speculation, particularly as some hay and silage were wasted. Despite these limitations it was felt that an approximation of the availability of the basal ration was required and would help in interpreting the results.

Appreciable increases in milk yield with the feeding of restricted amounts of concentrates in addition to pasture and/or hay and silage have been reported by many workers, e.g., Hancock (1953), Edey (1956), Wallace (1957), Corbett and Boyne

(1958), Shepherd (1962), Autrey et.al.(1942), Holmes et.al. (1957) and Laird and Walker (1962). Concentrate feeding in the present experiment resulted in an increase of 1.4 Kg in milk yield in the first-half of the experiment. It is likely that meal feeding perhaps alleviated the effect of shortage of feeds and possibly resulted in increased total intake causing an increase in milk yield. There were almost no differences in milk yield between the two groups during the second-half of the comparison period. This may be because the milk yield of meal fed group dropped and was coupled with an improvement in the milk yield of the control group (see figure 2). The examination of the original milk yield data of individual cows showed that the decline in milk yield of meal fed group was mainly due to cows 58, 33, 13 and 84 which partially went off meal during some of the days of last week of the experiment. The increase in milk yield of control group may have been due to increased availability of pasture during the last week of the experiment (see figure 1). A considerable increase in the milk yield of the herd was also noted reflecting an increase in pasture availability.

Two points on the graph (figure 2) are of interest. Firstly, a considerable rise in milk yield of both groups on 25 July. This coincided with an increased availability of pasture on that day. Secondly, a sudden drop in milk yield on 27 July which was probably due to the shortage of pasture noted on that day and perhaps also to the severe weather conditions for two days possibly affecting grazing behaviour of cows.

A small drop in milk-fat content has been noted by several workers when cows were fed restricted amounts of concentrates (e.g. Edey, 1958; Corbett and Boyne, 1959). In the present experiment a significant drop of 0.34 percentage units in milk fat content of cows fed meal occurred during the first half of the comparison period. The differences in milk-fat contents between meal fed and control groups gradually became smaller over the second-half of the comparison period. Because the milk yield of the meal fed group during the first-half of the comparison period increased, it is likely that drop in fat content was related to the increase in milk yield. Likewise the milk yield of the control group was improved during the second half of the experiment and the fat content of the same gradually declined. This suggests that concentrate feeding had its effect on milk-fat content through plane of nutrition (Rook, 1961). As expected, little or no differences in milk fat yield between the two groups were noted.

Small increases in SNF content of milk have been obtained where the energy intake has been increased well above accepted feeding standards (Rook, 1961; Elliot, 1962; Huber and Boman, 1966). Although in present experiment the differences in SNF content of milk between the two groups were non-significant, there was a small increase in SNF content in favour of the meal fed group. The SNF yield of the meal fed group was significantly higher than the control group ($P < 0.01$). This was due to the high milk yield during the first-half of the comparison period and a small change in SNF content obtained in favour of the meal fed group.

Despite an increase in milk yield of cows fed concentrate during the first-half of the comparison period the response was not good. One of the reasons for this, and particularly for no response in milk yield during second-half of the comparison period, may be that availability of basal ration was reasonably good and possibly concentrate feeding resulted in a substitution for the basal ration. It is, therefore, suggested that effect on intake of concentrate feeding may be best studied under controlled experimental conditions.

2.4. SUMMARY

1. Sixteen, autumn-calved, Friesian cows divided into two groups were used to determine the effect of meal feeding on milk yield and milk composition.

2. An increase in milk yield as a result of meal feeding was obtained, the mean response being 1.4 Kg ($P < 0.01$) and 1.0 Kg ($P < 0.05$) for the first-half and whole of the comparison period, respectively.

3. The milk-fat content of meal fed group decreased by 0.38 ($P < 0.05$) and 0.20 percentage units, respectively for the first-half and whole of the experiment. No differences in milk-fat yield between the two treatments were noted.

4. There was a small but non-significant increase in SNF content of milk in favour of the meal fed group. The SNF yield of the meal fed group, both for the first-half and the complete comparison period, was significantly higher ($P < 0.01$) than the control group.

CHAPTER III

INDOOR FEEDING EXPERIMENT

The main object of this experiment was to investigate the effect of two levels of concentrate feeding on the voluntary intake of pasture by lactating cows. To this end, the cows were arranged in three 3 x 3 Latin square and were fed freshly cut pasture indoors. Information was also sought on the influence of concentrate feeding on milk yield and milk composition of dairy cows. Supplementary information was obtained on rumen volatile-fatty-acids (VFA) from four rumen fistulated lactating cows and on the rate of passage of feeds from six of the experimental cows. Digestibility studies on the feedstuffs used were carried out with six Romney wethers fed pasture and concentrates in metabolism crates.

3.1. MATERIALS AND METHODS

3.1.1. Animals

Sixteen Spring calving Jersey cows from No. 3 Dairy Unit of the Massey University were selected initially but were reduced to 10 cows chosen on their ability to settle down to indoor feeding conditions. One cow was kept in reserve but dropped after completion of the two experimental periods. In addition four rumen fistulated Jersey cows were used from time to time to obtain supplementary information on VFAs. All cows had previously been rotationally grazed on pasture in the reserve herd at No. 3 Dairy Unit. Silage and occasionally hay was used to supplement pasture grazing. The general description of the cows used is given in Table 7.

TABLE 7: Characteristics of Cows Used

No.	Age	Day of Calving	Previous Season's Butterfat Production		Body weight 14 Sept.,1966
	(Years)	(1966)	(Kg)	(Days in Milk)	(Kg)
35	8	15 Aug.	173	316	335
36	7	1 Aug.	197	275	379
45	4	8 Aug.	145	244	267
77	4	18 Aug.	127	257	310
78	3	8 Aug.	134	270	303
82	5	27 Aug.	189	305	305
87	7	18 Aug.	232	305	336
95	4	5 Aug.	164	265	345
111	6	28 Aug.	203	262	309

3.1.2 General Outline of the Experiment

The general outline of the experiment is given as under:-

(i) Training period - 5 - 29 September

(ii) Preliminary period - 29 September - 11 October

(iii) Experimental - three 3 x 3 Latin squares running concurrently and divided into three periods which in turn were sub-divided as follows:-

(a) Period 1 -
   (i) Adjustment : 11 October - 19 October
   (ii) Comparison : 19 October - 31 October

(b) Period 2 -
   (i) Adjustment : 31 October - 6 November
   (ii) Comparison : 6 November - 18 November

(c) Period 3 -
   (i) Adjustment : 18 November - 24 November
   (ii) Comparison : 24 November - 7 December.

(i) Training period -

The object of the training period was to accustom the cows to indoor feeding and to the use of concentrates. Fresh cut pasture, hay and concentrates were fed to all cows during this period.

Initially some trouble was experienced with getting cows to eat and some cows became lame. Considerable attention was given to gradually introducing the cows to barn feeding. The cows were finally selected on the basis of their ability to adapt to indoor feeding.

(ii) Preliminary period -

The main object of this period was to establish the level of voluntary intake of pasture with the cows. Fresh cut pasture was offered *ad.lib.* twice daily. The daily intake of pasture was recorded for each cow. Daily milk yield was also recorded and samples of milk were taken for fat and SNF determinations.

(iii) Experimental period -

The cows were divided on the basis of their intake in the preliminary period into three groups, hereafter called squares (three with greatest intakes in square 3, next greatest in 2, and least in 3), of three cows each. Cows within a square were allocated at random to one of the following treatments:-

(A) Pasture *ad.lib.*

(B) Pasture *ad.lib.* + 2.7 Kg concentrates/cow/day.

(C) Pasture *ad.lib.* + 4.0 Kg concentrates/cow/day.

At the beginning of the experiment the animals on treatment C were fed 5.5 Kg of concentrates/cow/day but they went off feed as this level of concentrate feeding was approached. Therefore the amount was reduced to 4.0 Kg/cow/day.

The 3 x 3 squares were replicated three times and the squares ran concurrently for three periods. The calendar dates for each period have been given earlier. (Page 54). Randomization of treatments in each square was carried out using the tables of Fisher and Yates (1957). The layout of the design is given in Table 8.

TABLE 8: The Experimental Layout

Square	I			II			III		
Cows / Periods	87	78	77	95	36	45	35	82	111
1	B	A	C	B	C	A	A	C	B
2	C	B	A	A	B	C	B	A	C
3	A	C	B	C	A	B	C	B	A

Treatment A = Pasture ad.lib.; B = Pasture ad.lib. + 2.7 Kg concentrates and C = Pasture ad.lib. + 4.0 Kg concentrates.

The Latin square changeover design permitted the removal of variation due to cows and periods, as both cows and periods were anticipated to be important sources of variation in intake and milk production with changing pasture quality and stage of lactation.

3.1.3 Feeds and Feeding

(i) Feeds -

Five paddocks, three at No. 3 Dairy unit and two at No. 1 Dairy unit, were reserved well in advance of the commencement of the experiment. Particular care was taken to avoid contamination with dung. Cutting of pasture was done daily and completed by 9.0 a.m. Sufficient pasture was cut every morning for a.m. and p.m. feedings. The pasture was kept in the feed preparation room adjacent to the feeding barn and was covered with a tarpaulin after the a.m. feeding in an attempt to prevent wilting, and to keep the dry matter content as even as possible through the mass.

The pasture was cut with a Flail Forage Harvester. This machine was satisfactory in that it chopped the pasture into 2 - 4" lengths with very little bruising. Pasture height varied from 4 - 14" and it was possible to cut the pasture at a height of 2 - 3" from the ground.

Care was taken not to cut too low, thus avoiding contamination of the feed with soil. The concentrates used consisted of the following ingredients in a pelleted form:

1. Barley meal - 80 parts by weight.
2. Wheat bran - 18 parts by weight.
3. Dried molasses powder - 2 parts by weight.

(ii) Feeding -

The pasture was fed twice daily at 9.0 a.m. and

5.0 p.m. "Topping up" of pasture was carried out during the day if felt necessary. The concentrates were fed to appropriate cows twice daily at 7.0 a.m. and 2.30 p.m. prior to the feeding of pasture.

(iii) Intake measurements -

The cows were fed individually. The pasture fed and refused was weighed and the weights were recorded to the nearest 0.5 Kg. To ensure ad.lib. feeding sufficient pasture was offered to each cow so that refusals were more than 10% of the amount fed. The refusals were weighed once daily at 3.0 p.m.

The concentrates were weighed to the nearest 50 g and fed in small removable bins placed on the side of feed bins. Refusals, if any, were weighed and weights were recorded to the nearest 50 g at each feeding.

(iv) Sampling of feeds offered and refused -

Three representative samples of the pasture offered to the cows were taken at each a.m. and p.m. feeding. One sample of refused pasture was taken each day if it exceeded 2.5 Kg for DM determination. If the refusals were below this amount the mean DM % of all refusals were used. However, this situation rarely arose as the refusals in most cases were considerable. Duplicate DM determinations were made from 225 g sub-samples of pasture. Thus six DM determinations for each feeding were carried out and the mean DM was used to calculate the pasture fed. Single DM determinations were made on each cow's refusal sample which was taken after thorough mixing. Three representative samples of concentrates fed were also taken twice during each period and duplicate DM determinations carried out for each sample.

The DM determinations were carried out by keeping the feed samples in a forced-draught oven at 75°C for 24 hrs.

3.1.4. General Management

The cows were kept in the feeding barn from 7.0 a.m. to 10.0 p.m. each day except during the p.m. milking, i.e. at 3.0 - 5.0 p.m., when they were kept in a loafing shed close to the feeding barn. A pad of sawdust was provided in the loafing shed. The animals had approximately 12 hr access to food every day. Water was available at all times both in the feeding barn and loafing shed. All the animals were groomed once a week.

Cows showing signs of oestrus were either mated or inseminated from October onwards and records kept.

3.1.5. Live-weight Measurements

The cows were weighed at the beginning and end of each period at 8.0 a.m. In an attempt to reduce the effect of gut-fill on live-weight the animals were starved for 14 hrs. Thus on the day prior to weighing the animals were allowed 1.0 hr access to their p.m. feed instead of the usual 5 hr. Live-weights were recorded to the nearest 1.0 Kg.

3.1.6. Milk Sampling and Recording

The cows were milked twice daily at 6.30 a.m. and 4.30 p.m.

in the milking shed adjacent to the feeding barn. Milk weights were recorded to the nearest 50 g at each milking for six days a week. Proportionate samples of milk for the determination of fat and SNF contents were taken at each milking. These were combined to give two determinations per week on the two composite samples of six consecutive milkings each. The samples were kept in a cold room at $4^{\circ}C$.

The milk fat determination was carried out by the standard Gerber Method (British Standard Specification, 1955) and the total-solids were determined gravimetrically by the technique standardized during the Field Experiment (See section 2.1.5). The SNF content was obtained by difference. Duplicate samples were used to determine both milk fat and SNF contents. The determinations were repeated in cases where differences greater than 1% occurred.

3.1.7. Botanical Composition of Pasture

Duplicate representative samples for botanical composition from pasture fed were taken twice weekly. The main components of pasture were separated out and dried from a 100 g sample so that the components could be expressed on a DM basis.

3.1.8. Chemical Composition of Feeds

Daily sub-samples of pasture were taken after DM determinations and bulked for each period of the experiment. Likewise concentrate samples after DM determinations were also preserved separately for each period. The bulked samples were ground in an "Apex" rotary grinder through a 1.0 mm. mesh.

Ground samples were stored at -12°C in screw top jars for chemical composition.

Ether extract, crude fibre and ash were determined by the A.O.A.C. (1960) methods. Crude protein was determined by a modified technique of A.O.A.C. (loc.cit) in which ammonia was collected in a saturated boric acid solution (Meeker and Wagner, 1933) and mercuric sulphate was used as a catalyst (Hiller et.al., 1941).

3.1.9. Digestibility of Feeds

The digestibility of pasture and concentrates was determined by total faecal collection from six wethers which were fed in metabolism crates.

(i) Animals -

Six 18 months old Romney wethers were used. Four of these had previously received sheep pellets fed indoors for a period of 6 months. Two of the wethers had been grazing pasture prior to the experiment.

(ii) Experimental procedure -

The general outline of the experiment is given as under:-

(a) Training period - 21 days.

(b) Preliminary period - 12 days.

(c) Collection period - continuous 10-day faecal collections from October to December.

(a) Training period - The object of the training period was to accustom the animals to the feeding conditions and to obtain an estimate of voluntary intake. Pasture and pelleted concentrates were fed to all sheep over the training period. Some difficulty was experienced in obtaining satisfactory and consistent intakes of pasture with the four wethers which had been fed indoors previously. The two sheep which had been grazing earlier consumed considerable more pasture over the training period.

(b) Preliminary period - The object of the preliminary period was to have the animals eating relatively constant amounts of pasture and concentrates for a period before beginning total collection as recommended by Blaxter et.al. (1961). The sheep were divided into two groups A and B. The wethers previously grazing were randomly allocated separately to each group with random allocation for the remaining animals. Group A received pasture only and group B pasture + 270 g concentrates. This amount of concentrates approximated the ratio of pasture to concentrates for the cows on treatment B of the main experiment.

(c) Collection period - The dates of the faecal collection periods are given below:

Period	Dates
1	24 October - 3 November
2	3 November - 13 November
3	13 November - 23 November
4	27 November - 7 December

As there were no clear differences in digestibility between groups A and B, it was decided to increase the level of concentrate fed to 360 g/day for the fourth collection period. An interval of four days at the high level of concentrate feeding preceded the last collection period.

DM determinations in fed and refused feed were carried out as outlined in section 3.1.3 (iv) and the ash content of the feed and faeces determination by igniting in a muffle furnace at 600°C for three hours to enable estimate of DOM intake to be made.

3.1.10. Rate of Passage

The technique employed was based on the method of Balch (1950) and involved the feeding of stained pasture and concentrates to the cows and counting coloured particles in the faeces.

(i) Animals and experimental procedure -

Two cows were randomly chosen from each of the three treatments A, B and C. These were as follows:-

Treatment	Cows
A. Pasture *ad.lib*.	82, 95
B. As in A + 2.7 Kg concentrates	35, 78
C. as in A + 4.0 Kg concentrates	45, 87

The pasture was dried and stained with 0.028% Crystal violet solution by boiling for 6 hours. The dried concentrates were stained by boiling in an

0.05% aqueous solution of Safranin. The stained feeds were washed in running water through a cheese bag and dried in an oven.

The amounts of stained pasture and concentrates offered were as follows:-

A - 700 g pasture

B - 700 g pasture + 225 g concentrates

C - 700 g pasture + 340 g concentrates

The amounts fed were approximately 5% of the cow's previous day's intake. The dyed feeds were offered at 6.30 p.m. and were eaten by 7.30 p.m. of 13 November in the second experimental period.

(ii) Sampling of faeces and counting of particles -

Faecal samples were taken *per rectum* for six days. The first sample was taken 11-hr after feeding, the next three at 4-hr intervals, followed by samples taken at six-hourly intervals increasing to 12-hr intervals on the last four days of the six-day sampling period. The samples were stored at -12°C until required for counting coloured particles.

Samples of faeces were sieved on weighed cotton gauzes under a jet of water and coloured particles counted under 10 X magnification. The gauzes were dried, weighed and stained particles were expressed as the number per 0.01 g DM. Six separate determinations were carried out with each faecal sample.

The recovery of stained particles was also expressed as a cumulative excretion for 6-day collection period. Cumulative per cents were plotted against time. From the resulting curves the 80 - 5% excretion times were determined which represent rumen retention time (Balch, 1950). A value 'R' (Castle, 1956) (calculated by adding together times of excretion from 5% - 95% at intervals of 10% taken from the cumulative curve and dividing the same by 10) was used as a measure of mean retention time (in hr) of the stained particles in the digestive tract.

3.1.11. Volatile-Fatty-Acids, Rumen pH and Rumen Ammonia

Four fistulated cows were used (No. 15, 16, 45 and 122). All cows received pasture ad.lib. Two of them were fed 2.7 Kg of concentrates/cow/day in addition to pasture.

The sampling for VFAs was carried out in the Period 1 on three days - 20, 26 and 31 October. Three samples were taken from each cow at 9.30 a.m., 12.0 noon and 2.30 p.m. on each sampling day. VFA determinations were carried out by steam distillation (Davey, 1964). pH of the rumen liquor and ammonia determinations (Conway and Malley, 1941) were also carried out on these samples.

3.1.12. Statistical Analysis

(i) Preliminary period -

Differences between cows and days in milk yield, milk fat and SNF contents and DM intake in preliminary period were examined by analyses of variance (Snedecor, 1961).

(ii) Latin square -

Analysis of variance for the Latin square as outlined by Snedecor (loc.cit.) and by Cochran et.al. (1941) for replications of squares was used to test for differences between squares, cows within squares, periods within squares, treatments, and the treatment x square interaction. The classifications of the components of variance is given in Table 9.

TABLE 9: Analysis of Variance
(Treatments fixed, squares, periods and cows random variables)

Source of Variation	d.f.	Mean Square	Components
Squares (S)	s-1	S	$\sigma^2 + a\sigma^2 P(S) + a\sigma^2 C(S) + a\sigma^2 S$
Cows within Squares (C)	s(a-1)	MC	$\sigma^2 + a\sigma^2 C(S)$
Periods within Squares (P)	s(a-1)	MP	$\sigma^2 + a\sigma^2 P(S)$
Treatments (A)	a-1	MA	$\sigma^2 + a\sigma^2 SA + sa\sigma^2 A$
Sq. x Tr. (SA)	(s-1)(a-1)	MSA	$\sigma^2 + a\sigma^2 SA$
Error (E)	s(a-1)(a-2)	ME	σ^2

The following procedure was used for testing significances - (M = Mean Square, n +no.)

Squares -
$$F = \frac{MS + ME}{MC + MP}$$

$$n_1 = \frac{(MS + ME)^2}{MS^2/(s-1) + ME^2/s(a-1)(a-2)}$$

$$n_2 = \frac{(MC + MP)^2}{MC^2 + MP^2/s(a-1)}$$

Cows within Square - $F = MC/ME$

$n_1 = s(a-1)$

$n_2 = s(a-1)(a-2)$

Periods within Square - $F = MP/ME$

$n_1 = s(a-1)$

$n_2 = s(a-1)(a-2)$

Treatments - $F = MA/MSA$

$n_1 = (a-1)$

$n_2 = (a-1)(s-1)$

Squares x treatment - $F = MSA/ME$

$n_1 = (a-1)(s-1)$

$n_2 = (a-1)(a-2)$

The statistical procedure outlined above enables the testing of overall differences between treatments to be made but not for treatment within square. Since the overall differences between treatments may be non-significant yet significant differences between treatment within some of the squares may exist, a separate analysis of variance for Latin square (Snedecor, loc.cit.) was carried out to examine the latter possibility.

The classification of components of variance is shown in Table 10.

TABLE 10: Analysis of Variance
(Treatments fixed, squares, periods and cows as random variables)

Sources of Variation	d.f.	Mean Square	Components
Squares	(s-1)	MS	$6^2 + a6^2P(S) + a6^2C(S) + a6^2A(S) + a6^2S$
Cows within Square	s(a-1)	MC	$6^2 + a6^2C(S)$
Periods within Square	s(a-1)	MP	$6^2 + a6^2P(S)$
Treatment within Square	s(a-1)	MA	$6^2 + a6^2A(S)$
Error	s(a-1)(a-2)	ME	6^2

The following procedure was used for testing the differences between treatments within square.

$$F = MA/ME$$

$$n_1 = s(a-1)$$

$$n_2 = S(a-1)(a-2)$$

This method was used for testing the differences between treatments within squares for milk yield, milk-fat content and yield, SNF content and yield. None of the treatment differences, except that for SNF contents of milk within square, were found to be significant, hence the analysis of variance for SNF only is given in Appendix 12(C).

An observation of the intake figures suggested an existence of difference between periods within treatments. To confirm this possibility statistically a separate analysis as outlined by Kempthorne (1952) for a hierarchal classification was carried out. Table 11 shows the components of variance.

TABLE 11: Analysis of Variance
(Treatment fixed, days, cows and periods as random variables)

Source of Variation	d.f.	Mean Square	Components
Treatments	(a-1)	MA	$\sigma^2 + \sigma^2 D + d\sigma^2 C + cd\sigma^2 B + bcd\sigma^2 A$
Period within treatment	a(b-1)	MB	$\sigma^2 + \sigma^2 D + d\sigma^2 C + cd\sigma^2 B$
Days within period	ab(c-1)	MC	$\sigma^2 + \sigma^2 D + d\sigma^2 C$
Cows within period	abc(d-1)	MD	$\sigma^2 + \sigma^2 D$

The testing was carried out as under:-

Treatment - $F = MA/MB$

$n_1 = (a-1)$

$n_2 = a(b-1)$

Period within treatment - $F = MB/MC$

$n_1 = a(b-1)$

$n_2 = ab(c-1)$

Days within period - $F = MC/MD$

$n_1 = ab(c-1)$

$n_2 = abc(d-1)$

(iii) Missing plots -

Using missing plot techniques of Snedecor (loc.cit.) values of intake and milk yield for following cows were calculated:-

Intake - Cow 111 - day 6 and 7 of Period 1.

Milk yield - Cow 111 - day 6 and 7 of Period 1, and day 5 of preliminary period.

Cow 35 - day 4 of period 2.

Cow 36 - day 10 of preliminary period.

Cow 77 - day 5 of preliminary period.

The error and total d.f. was reduced by one for each missing plot in analysing the differences in milk yield due to days in preliminary period and differences in intake due to periods within treatments.

(iv) Digestibility -

Differences in digestibility of OM between treatments and periods were examined by analyses of variance (Snedecor, loc.cit.).

(v) Relationship between feed intake and animal production -

The experiment was not designed to yield data for examination of the relationship between live-weight and intake or milk yield and intake, and the data available have limitations for this purpose. However, graphs were made and examined initially and the relationships which appeared clearest were examined one stage further by calculating multiple regression.

The relationship between initial live-weight (L.W.taken at the end of the preliminary period or beginning of the experimental period) together with the 4% FCM yield (mean of the three periods) and the total DOM intake (mean of the three periods) was measured by multiple regression technique of Snedecor (1961). Multiple correlation coefficient was also calculated to measure total relationship between live-weight, FCM yield, and food intake (Snedicor, 1945).

The use of total intake was satisfactory in that each cow had received each treatment, but less so in that they had the treatments at different times (periods), so that the response to a particular treatment could be affected by the period in which it was applied. In this simple examination of data, differences in milk yields of cows were ignored.

3.2. RESULTS

3.2.1. Feeds

(i) Botanical composition of pasture -

Table 12 shows that pasture consisted mainly of rye grass, white clover, cocksfoot, poa species and yorkshire fog. There was a noticeable increase in clover content from period 1 onwards at the expense of mainly yorkshire fog as the season advanced although the effects were confounded by the use of different areas from the two locations, i.e. No. 1 and 3 Dairy Units.

TABLE 12: Botanical Composition of Pasture
(Figures as % oven dried samples)

Species	Preliminary Period	Period 1	Period 2	Period 3
Ryegrass species (Lolium sp)	34.5	48.0	37.0	46.0
White clover (Trifolium repens)	22.5	12.0	15.4	29.6
Cocksfoot (Dactylis glomerata L.)	12.7	3.1	9.5	5.2
Poa species (Poa species)	8.2	14.0	10.5	3.5
Yorkshire fog (Holcus lanatus L.)	12.5	7.5	9.9	4.0
Others[a]	9.6	14.8	17.7	11.7

a + Include - Timothy (Phleum pratense); Sweet Vernal (Anthoxonthum odoratum); Goose Grass (Bromus mollis); Dogtail (Cynasurus cristatus); Brown top (Agrostis tenuis) and Weeds.

(ii) Chemical composition of feeds -

The chemical composition and DM content of pasture and concentrates are given in Table 13.

TABLE 13: Chemical Composition of Feeds
(Figures as % oven dried samples)

	Crude Protein	Crude Fibre	Ether Extract	Ash	Nitrogen-free Extract	DM of Feeds Fed
Pasture						
Preliminary Period	21.96	21.05	5.52	10.15	41.33	14.87
Period 1	20.33	22.44	5.02	10.36	42.05	14.97
Period 2	18.42	21.78	3.31	9.43	47.06	15.70
Period 3	17.89	23.27	2.79	9.20	46.75	17.60
Concentrates						
Period 1	13.35	7.15	3.07	3.73	72.70	88.30
Period 2	14.33	7.17	2.40	3.57	72.54	86.70
Period 3	14.27	7.21	2.73	4.29	70.55	89.10

The chemical composition of concentrates was similar in the three periods of the experiment. The DM content of pasture increased with the advance in season. Increases in crude fibre and decreases in crude protein and ether extract took place with the advance in time.

(iii) Apparent digestibility of feeds -

'Apparent digestibility', for sake of brevity, will hereafter be called digestibility.

Since there were three intake comparison periods for cows (section 3.1.2) and four collection periods (section 3.1.9) in digestibility study with sheep, the data of collection periods 2 and 3 were combined.

The results for digestibility of feeds for treatments and periods are summarised in Table 14.

TABLE 14: Apparant Digestibility of Feeds (Digestible Organic Matter %)

Treatments	A (Pasture)	B (Pasture + Concentrates)	S.E.	C.V. (%)	Significance of difference (Treatments)
Periods 1	79.6	79.4	±0.84	1.87	NS
2	76.7	76.5	±0.74	1.62	NS
3	74.7	75.1	±1.70	3.86	NS
(Periods)					
SE	±0.50	±0.50			
CV(%)	0.35	±0.35			
Significance of difference (Periods)	1 > 3 **	1 > 2 *	and 2 > 3 *		

SE = Standard Error of Mean
CV = Coefficient of Variation
* = P< 0.05
** = P<0.01

Little difference in OM digestibility between treatments was noted. Differences between animals within treatments were high, the mean variation for treatment A and B being 2.4 and 4.3 per cent. digestible OM units. The high variation in OM digestibility between sheep for treatment B was mainly due to sheep 6 which had consistently lower digestibility than the other two sheep of the same group in all the three periods. Likewise the high variation in pasture fed group (i.e. A) was due to sheep 3 which had consistently lower digestibility values than its two other mates of the same group. Sheep 3 and 6 were those which had previously grazed pasture.

3.2.2. Animals

(i) Health -

Most of the cows became lame in the first few days of their introduction to the stall feeding. Lameness disappeared within two weeks and no further foot troubles were noted thereafter, the routine of moving the animals to the sawdust loafing barn each night assisting the animals.

Bloat was a problem in the preliminary period, e.g. 3, 5, 6 and 7 October. A drench of 0.75 oz of a proprietary mixture of "Pluronic L64" diluted with 4 - 6 oz of water was found to be an effective remedy. As a precaution the pasture was sprayed with emulsified light mineral paraffin oil before feeding throughout the experiment. No case of bloat was noted during the experimental periods.

Despite the gradual introduction of cows to concentrate feeding some initial difficulty was experienced in maintaining intake during the change-over between periods. This was particularly noticeable with treatment C and occurred even when animals were changed from B to C treatment.

(ii) <u>Live-weights</u> -

The live-weights of the cows taken after a 14-hr fast at the beginning and/or end of each period of the Latin squares are summarised in Table 15.

TABLE 15: Live-Weights[1] (Kg)

Cow No.	Preliminary Period	Period 1	Period 2	Period 3	Gain in Weight
35	310.6	325.2	332.0	340.1	29.5
36	349.2	365.5	375.0	380.9	31.7
45	256.2	269.4	273.5	288.9	32.7
77	300.2	306.5	309.7	319.3	19.1
78	289.8	296.1	302.9	312.9	23.1
82	317.5	322.4	332.4	339.2	21.7
87	324.7	331.5	341.9	352.8	28.1
95	320.2	327.0	343.3	356.9	36.7
111	301.1	312.5	329.2	335.6	34.5

1. Taken at the end of each period.

All animals gained weight during the experiment with the total gain in weight from period 1 to 3 varying from 19.0 - 37.0 Kg (mean 28.5 Kg). The average gain/day was 0.5 Kg/cow. There was no consistent pattern in weight gains within periods, as some animals gained more weight during period 1 and others either during periods 2 or 3.

The effects of treatments on live-weight gains per period are summarised in Table 16. Differences in weight gain between treatments were non-significant (Appendix 6a). High coefficient of variation and standard errors are associated with treatment means.

TABLE 16: Effect of Treatments on Live-Weight Gain (Weights - Kg/cow/period)

Treatment	Weight gain (Kg)	S.E.	C.V. (%)	Significance of difference
A	9.6	±0.51	15.75	
B	8.9	±0.51	15.75	NS
C	10.1	±0.51	15.75	

A = Pasture *ad.lib.*
B = Pasture *ad.lib* + 2.7 Kg concentrates
C = Pasture *ad.lib.*+ 4.0 Kg concentrates
S.E. = Standard error of mean
C.V. = Coefficient of Variation

3.2.3. Preliminary Period

(i) DM intake -

The mean DM intake of pasture during this period was 10.1 Kg (8.5 - 11.5 Kg)/cow/day (Table 17). Difference in DM intake between cows and between days were highly significant ($P < 0.01$) (Appendix 6b). There was little increase in DM intake over the preliminary period suggesting that animals had become accustomed to indoor feeding conditions.

(ii) <u>Milk production</u> -

Table 17 shows the mean milk yield, milk-fat and SNF contents of individual cows. Differences between cows were highly significant ($P < 0.01$) but between days were non-significant (Appendix 7).

TABLE 17: Preliminary Period - Milk Production and Food Intake

Cow No.	Milk Yield	Milk Fat Content	SNF Content	DM Intake
	(Kg)	(%)	(%)	(Kg)
35	15.7	4.61	8.87	10.4
36	15.0	4.67	9.13	10.3
45	12.6	4.05	8.63	8.5
77	14.4	4.28	9.18	9.8
78	12.1	5.56	9.48	9.6
82	18.2	5.21	9.26	11.5
87	12.1	6.10	9.23	9.3
95	14.8	5.86	8.90	10.6
111	13.1	5.42	9.72	11.0
Mean	14.2	5.14	9.16	10.1
SE	±0.27	±0.14	±0.17	±0.27
CV(%)	5.91	4.66	3.27	8.0

SE = Standard Error of Mean

CV = Coefficient of Variation

3.2.4. Experimental Period

(i) Intake -

The refusals of pasture DM were 12.0, 17.7 and 19.3% of pasture DM consumed on treatments A, B and C, respectively. The amount being refused indicated that cows were fed to appetite.

The average quantities of both pasture and total (pasture + concentrate) DM intake/cow/day are shown in figures 3, 4 and 5 and Table 18 for each treatment. The total DM and DOM intake of cows fed concentrates was significantly higher ($P < 0.01$) than cows fed pasture alone. Differences in total DM and DOM intake between the two levels of concentrate were small and non-significant (Appendix 8). The mean per cent. increase in total DM intake was 6.8 and 9.2% for treatments B and C respectively, over that of treatment A (Table 19). Feeding of concentrate resulted in a depression of pasture DM and DOM intake ($P < 0.01$) (Appendix 9), the average decrease in DM being 0.63 and 0.66 Kg/Kg concentrate DM consumed in treatment B and C respectively. Expressed in terms of percentage, the pasture consumption was decreased on an average by 17% and 11%, respectively, in treatment C and B compared with A (Table 19). The range in coefficient of variation for intake was 3.0 - 4.0%.

Differences between periods within square both for pasture and total DM and DOM intake are summarised in

Table 20. It will be noted that these were small and significant at the 10% but not at the 5% level (Appendix 8), the range in coefficient of variance being 2.3 - 3.5%. Figures 3, 4 and 5 show that DM intake of cows fed pasture alone (Treatment A) increased from period 1 to period 3 and pasture DM intake of animals on treatment B and C remained fairly similar over the three periods. To detect difference, if any, between periods within treatment a separate analysis was carried out (section 3.1.12) which revealed highly significant ($P < 0.01$) differences between periods (Appendix 10). Further analysis showed that DM intake of pasture in periods 2 and 3 was significantly higher ($P < 0.01$) than period 1, but the difference between periods 2 and 3 were small and non-significant. No differences in pasture DM intake between periods within treatments B and C were found.

Because of the increase in the intake of the pasture DM (Treatment A) over the experiment, a variation in the extent of substitution between periods was noted, the amount of pasture DM substituted/Kg concentrate DM consumed increasing from about 0.4 Kg in period 1 to 0.9 Kg in period 3. Likewise the changing pattern of substitution between periods was reflected in the greater total (Pasture + concentrate) DM intake over that of pasture intake in period 1 compared with periods 2 and 3 (Table 19).

Figure 6 illustrates the daily DOM intake for each treatment over the three periods of Latin square. It will be noted that the DOM intake between periods within treatments is fairly similar, though differences between concentrate and non-concentrate fed groups were obvious.

Figures 3, 4 and 5 illustrate the DM intake/cow for each treatment in period 1, 2 and 3, respectively. Depressions in intake on introduction to concentrate feeding, particularly on treatment C, are noticeable during each adjustment period. The figures also demonstrate a variation in intake between days within each period. On 30/1 day of the comparison period 3 the DM intake of pasture was considerably low. This depression was associated with the pasture from a new paddock contaminated with dung and weeds and was more mature than the pasture normally available. The intake data of this day were omitted from calculations.

Differences in total daily DM and DOM intake between cows within squares were highly significant ($P<0.01$) (Appendix 8), the range being 12.4 - 14.9 Kg for DM and 9.1 - 10.5 Kg for DOM intake (Appendix 14). Differences between squares were small and non-significant.

TABLE 18: Effect of Treatments on Food Intake

(Kg/cow/day)

Treatments	A	B	C	SE	CV (%)	Significance of difference
Dry Matter						
Pasture	13.2	11.7	10.9	±0.15	3.8	(A Vs B & C ** (B Vs C *
Total (Pasture + Concentrates)	13.2	14.0	14.4	±0.15	3.2	(A Vs B & C ** (B Vs C NS
Digestible Organic Matter (DOM)						
Pasture	9.1	8.1	7.6	±0.11	4.0	(A Vs B & C ** (B Vs C *
Total (Pasture + Concentrates)	9.1	9.9	10.3	±0.11	3.5	(A Vs B & C ** (B Vs C NS
Total DM intake as per cent. live-weight	4.09	4.34	4.47			

A = Pasture *ad.lib.*
B = Pasture *ad.lib.* + 2.7 Kg concentrate
C = Pasture *ad.lib.* + 4.0 Kg concentrate
* = $P < 0.05$
** = $P < 0.01$
NS = Non-significant ($P > 0.05$)
SE = Standard error of mean
CV = Coefficient of variation

TABLE 19: Extent of Changes in Intake Due to Concentrate Feeding
(Kg/cow/day)

Periods Within Treatments		1	2	3	Mean
Pasture DM Intake	A	12.34	13.44	13.75	13.18
	B	11.46	11.98	11.62	11.69
	C	10.89	10.91	10.86	10.89
Concentrate DM Intake	A	-	-	-	-
	B	2.40	2.38	2.32	2.37
	C	3.45	3.54	3.41	3.45
Total DM Intake	A	12.34	13.44	13.75	13.18
	B	13.86	14.36	13.94	14.05
	C	14.34	14.45	14.27	14.35
Net Substitution of Pasture DM	B	0.88	1.46	2.13	1.49
	C	1.45	2.53	2.89	2.29
Kg Pasture DM substituted per Kg concentrates Intake	B	0.367	0.613	0.918	0.633
	C	0.420	0.715	0.847	0.661
Per cent. substitution of Pasture DM Intake	B	7.13	10.86	15.49	11.16
	C	11.75	18.82	21.02	17.19
Net Increase in Total DM Intake by using Concentrates	B	1.52	0.92	0.19	0.88
	C	2.00	1.01	0.52	1.18
Per cent. Increase in DM over Pasture DM Intake	B	12.32	6.84	1.38	6.85
	C	16.21	7.51	3.78	9.17

A = Pasture *ad.lib.*
B = Pasture *ad.lib.* + 2.7 Kg concentrate
C = Pasture *ad.lib.* + 4.0 Kg concentrate

TABLE 20: Effect of Periods on Food Intake

(Kg/cow/day)

Periods within Squares		1	2	3	SE	CV (%)	Significance of difference
Dry Matter	Square						
Pasture	I	11.3	11.1	11.4	±0.23	3.46	
	II	11.0	12.4	12.1	±0.23	3.30	3, 2>1 +
	III	12.4	12.9	12.8	±0.23	3.07	
	Mean	11.6	12.1	12.1			
Total	I	13.2	13.0	13.3	±0.23	2.96	
	II	13.0	14.3	14.0	±0.23	2.83	2, 3>1 +
	III	13.3	14.9	14.7	±0.23	2.66	
	Mean	13.5	14.0	14.0			
Digestible Organic Matter							
Pasture	I	8.0	7.7	7.8	±0.17	3.57	
	II	7.8	8.6	8.2	±0.17	3.41	
	III	8.8	9.0	8.7	±0.17	3.18	
	Mean	8.2	8.4	8.2			
Total	I	9.5	9.2	9.2	±0.14	2.58	1>2 +
	II	9.4	10.1	9.7	±0.14	2.47	2>1, 3 +
	III	10.3	10.5	10.1	±0.14	2.33	
	Mean	9.7	9.9	9.7			

SE = Standard error of mean
CV = Coefficient of variation
+ = $P < 0.10$

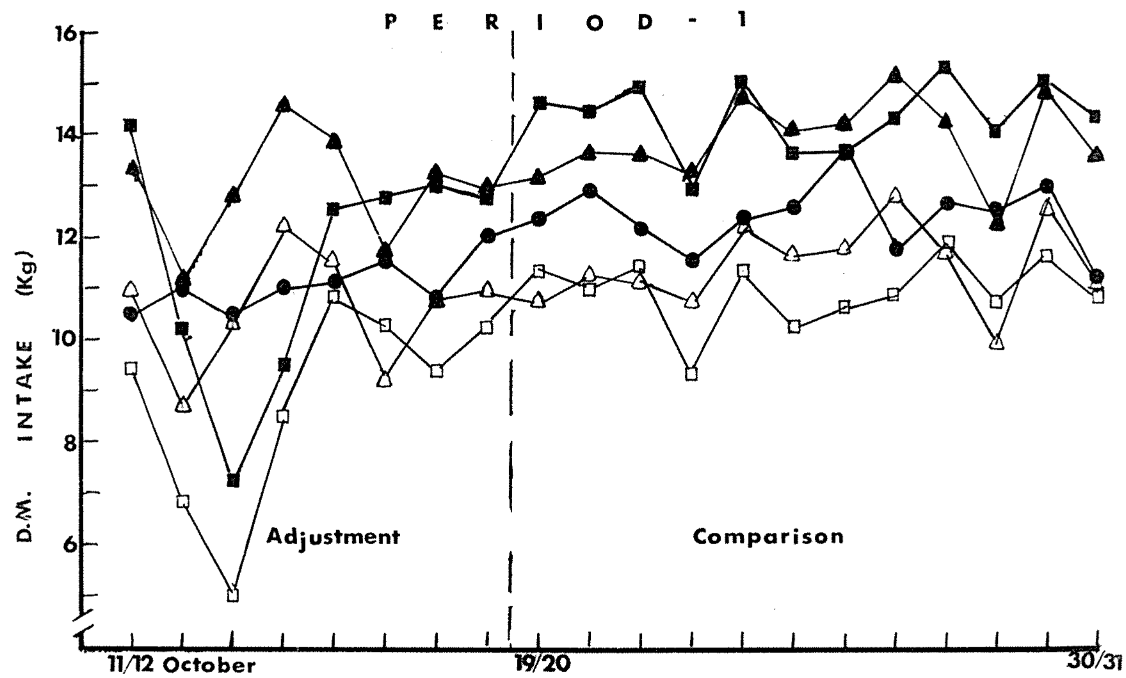


Fig. 3: D.M. intake/cow/day, Total (pasture + concentrate) ▲—▲ B; ■—■ C & Pasture ●—● A; △—△ B; □—□ C.

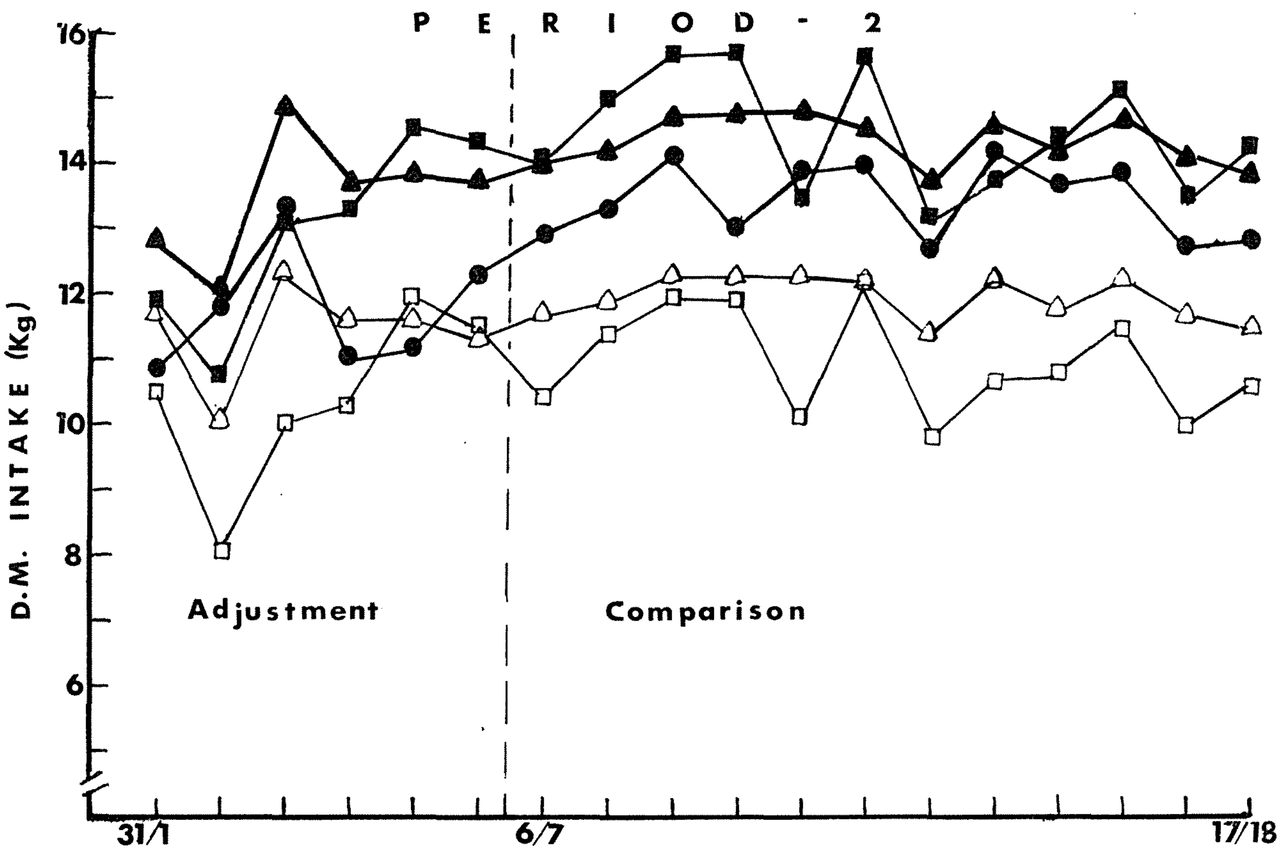


Fig. 4: D.M. intake/cow/day, Total (pasture+Concentrate) ▲—▲ B; ■—■ C & pasture ●—● A; △—△ B; □—□ C.

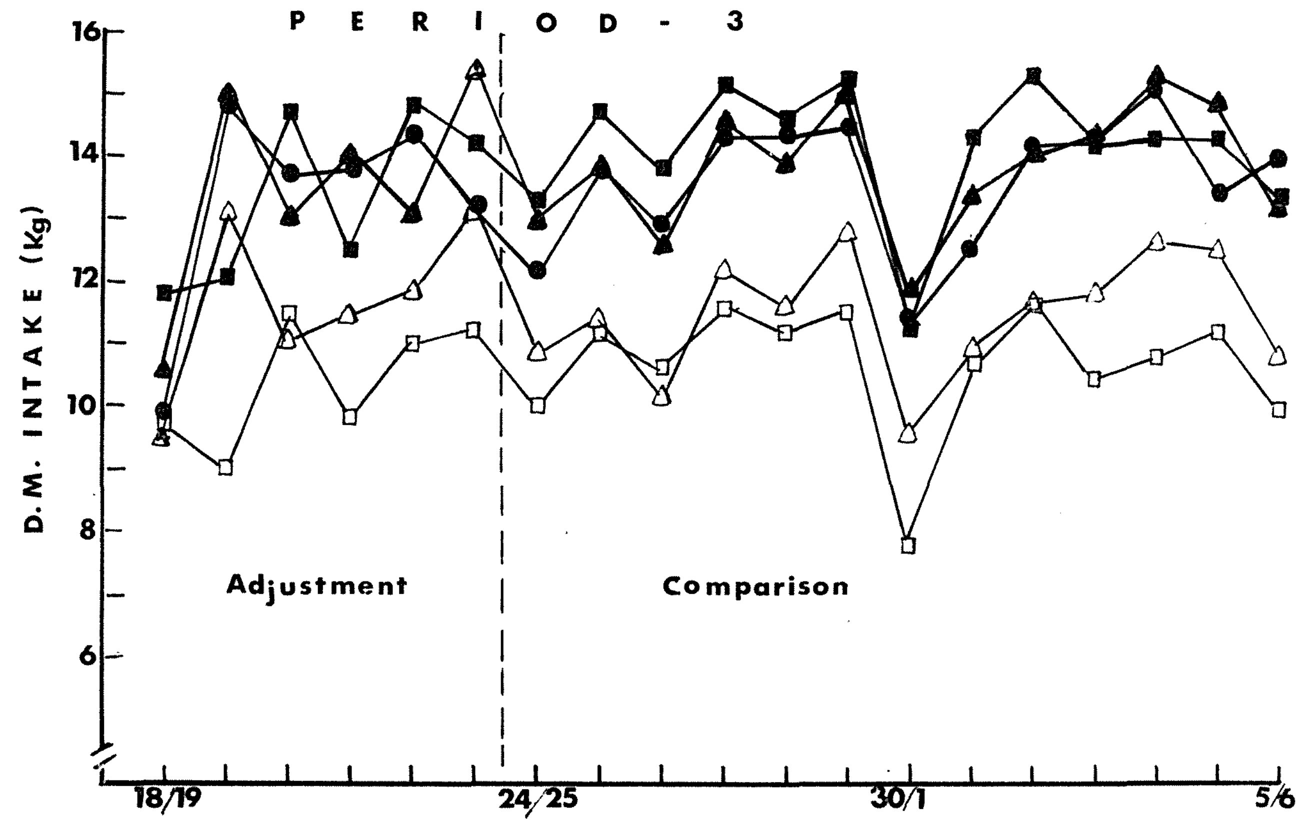


Fig.5: D.M. intake/cow/day, Total(pasture+concentrate) ▲—▲ B; ■—■ C & pasture ●—● A, △—△ B, □—□ C.

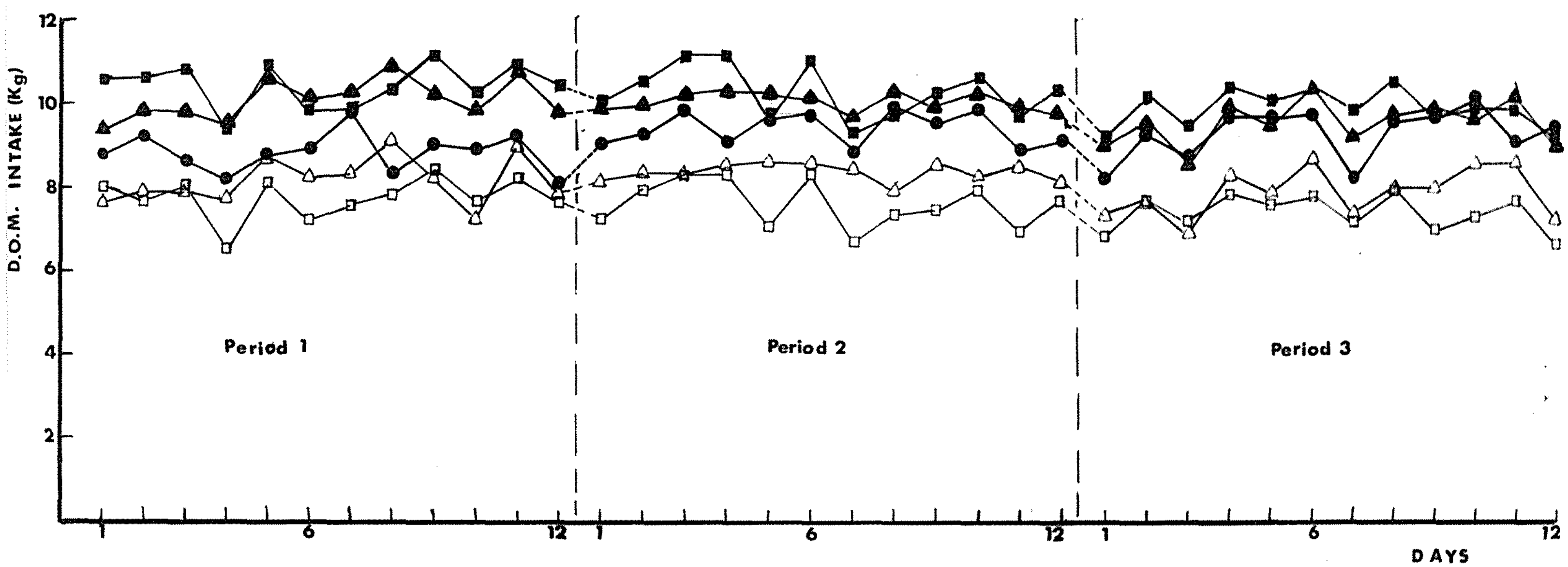


Fig.6: D.O.M. intake/cow/day, Total (pasture + concentrate) ▲—▲ B; ■—■ & pasture ●—● A; △—△ B; □—□ C.

(ii) Milk production -

(a) Milk yield and FCM yield - The mean daily milk and 4% FCM yields/cow for each treatment are given in Table 21. Differences in milk and FCM yields between treatments were small and non-significant (Appendix 11). The range in coefficient of variation was 3.9 - 5.2%.

The milk yield declined steadily from period 1 to period 3 (Table 22). The differences between periods within squares were highly significant ($P<0.01$) (Appendix 11). The significance of difference for individual periods within squares are shown in Table 22. The range for coefficient of variation was between 1.8 - 3.6%. Unlike milk yield, differences in FCM yield between periods within squares were non-significant (Appendix 11).

Differences in both milk and FCM yields between squares were non-significant but between cows within squares were highly significant ($P<0.01$) (Appendix 11). The range in milk and FCM yields were 13.0 - 17.7 and 15.0 - 20.0 Kg/cow/day, respectively (Appendix 15).

The milk yield on 2 December of period 3 was considerably lower because of drop in previous day's intake (section 3.2.4(i'). The data for milk yield was, therefore, omitted from calculations.

(b) Milk fat content and yield - The mean milk fat contents and yields for each treatment are included in Table 21. Though milk fat content of treatments B and

C were lower by 0.11 and 0.13 percentage units compared with A, the differences did not reach significant level ($P>0.05$) (Appendiz 12a). The coefficient of variation was 5.1% for the treatments. Differences in milk fat yield between treatments were also non-significant with the coefficient of variation being 6.7% (Appendix 13).

The milk fat contents rose with the advance in stage of lactation and on analysis significant differences ($P<0.05$) between periods within squares were noted (Appendix 12a). The milk fat contents in period 3 were higher than periods 2 and 1 and were also higher in period 2 than 1. The significance of differences is shown in Table 22. Unlike milk fat content, differences in fat yield between periods within square were small and non-significant.

Milk fat contents varied from 4.70 - 6.04% between cows resulting in highly significant ($P<0.01$) differences between cows within square. Likewise, differences in milk fat yield between cows were also highly significant ($P<0.01$) (Appendix 13), the range being 709.0 - 862.3 g/cow/day (Appendix 15). Differences in milk fat contents and yields between squares were non-significant.

(c) SNF content and yield - The results of SNF contents and yields for each treatment are included in Table 21. The milk of the cows receiving 4 Kg concentrates was slightly higher in SNF than those on pasture alone.

These differences between treatments, however, were small and non-significant (Appendix 12b). A separate analysis was carried out to detect if there were differences between treatments within square which revealed a significant difference ($P<0.05$) (Appendix 12c). Further analysis showed that this difference was wholly due to treatment C of Square III only (see Table 21). Examinations of original data further revealed that the difference was mainly due to an unusually high SNF value of the milk of one cow in the second period. No appreciable difference in SNF yield between treatments existed.

Differences in SNF content between periods within squares were significant ($P<0.05$) (Appendix 12b). The least significant difference (LSD) test showed that the significant difference was due to an unusually low SNF value in period 1 of square II (Table 22). Examination of original data showed that the low SNF value was related to the milk of cows No 45 and 35 in period 1. Differences in SNF yield between periods within square were significant ($P< 0.5$). The significance of differences for periods is included in Table 22.

Differences in SNF content and yields between squares were non-significant, but highly significant ($P< 0.01$) between cows within square (Appendix 12b, 13b). The ranges between cows in SNF yield and contents are included in Appendix 15.

TABLE 21: Effect of Treatments on Milk Production

(Per/cow/day)

Treatments	A	B	C	SE	CV (%)	Significance of difference
Milk Yield (Kg)	14.2	14.8	14.4	±0.19	3.92	
4% FCM yield (Kg)	16.8	17.3	16.7	±0.30	5.24	
Milk fat Content (%)	5.31	5.20	5.18	±0.08	5.11	
Milk fat yield (g)	746.1	762.1	733.8	±16.0	6.69	
SNF Content (%)	9.45	9.51	9.62	±0.05	1.75	
SNF yield (g)	1339.8	1401.0	1386.9	±19.0	3.85	
SNF Content (%) For treatment within square						
I	9.64	9.69	9.63	±0.05	0.922	
II	9.22	9.26	9.39	±0.05	0.988	
III	9.50	9.59	9.84	±0.05	0.908	C > A & B *

A = Pasture ad.lib.
B = Pasture ad.lib. + 2.7 Kg concentrate
C = Pasture ad.lib. + 4.0 Kg concentrate
SE = Standard error of mean
CV = Coefficient of variation
* = $P<0.05$

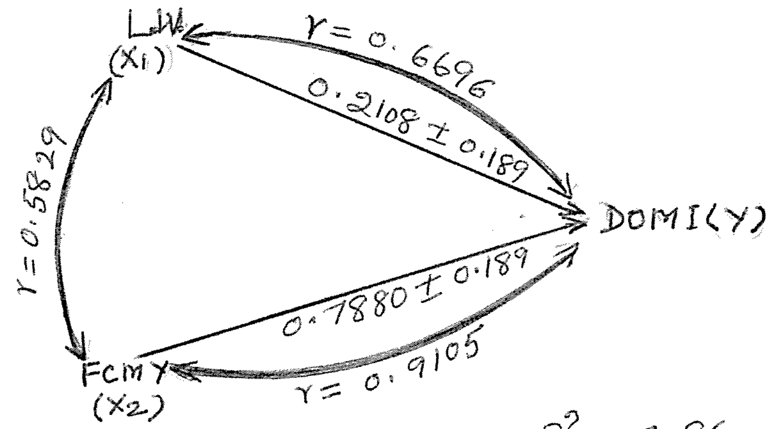
TABLE 22: Effects of Periods on Milk Production
(Per cow/day)

Period within Square		1	2	3	SE	CV (%)	Significance of difference
	Square						
Milk yield (Kg)	I	13.9	12.6	12.1	±0.27	3.57	1 > 2 *, 1 > 3 **
	II	14.9	14.4	13.6	±0.27	3.22	1 > 3 *
	III	17.3	16.0	15.4	±0.27	2.84	1 > 2 * 1 > 3 **
	Mean	15.3	14.3	13.7			
Milk-fat Content (%)	I	5.57	5.66	5.92	±0.08	2.45	3 > 1 *
	II	4.78	4.83	5.05	±0.08	2.45	
	III	4.79	5.26	5.18	±0.08	2.45	3 > 1 * 2 > 1 *
	Mean	5.05	5.25	5.38			
SNF Content (%)	I	9.59	9.75	9.61	±0.05	0.922	
	II	9.05	9.44	9.37	±0.05	0.958	2, 3 > 1 *
	III	9.60	9.62	9.65	±0.05	0.923	
	Mean	9.41	9.62	9.54			
SNF yield (g)	I	1215.3	1231.7	1165.3	±29.0	4.03	1 > 3 *
	II	1354.3	1366.0	1275.0	±29.0	3.75	
	III	1645.7	1535.0	1484.7	±29.0	3.21	1 > 3, 2 *
	Mean	1441.8	1377.6	1308.3			

* = $P < 0.05$
** = $P < 0.01$
SE = Standard error of mean
CV = Coefficient of Variation

(iii) <u>Relationship between feed intake and animal production</u> -

The relationships among the variables (DOM intake, live-weight and FCM yield) are shown in the following figure.



$R^2 = 0.86$

The calculation of multiple regression equation revealed that partial regression coefficient of DOM I on live-weight was not significant ($P > 0.05$) but that of FCM yield was ($P < 0.01$) (Appendix 16). The multiple regression equation obtained is given below:

DOM I = 2.743 + 0.0057 LW + 0.3108 FCM ±0.138

Further analyses of data showed that the independent variables, live-weight and milk yield were fairly strongly correlated ($r = 0.58$). Milk yield had a strong direct relationship with DOM intake (<u>partial</u> regression = 0.788) and a weak indirect one (0.5829 x 0.2108 = 0.123).

Live-weight showed a weaker direct relationship with DOM I (partial regression = 0.211) and an indirect relationship (0.5829 x 0.7880 = 0.459) which was greater than the direct one. When both independent variables were included, with a multiple regression equation (see above), the relationship between live-weight and DOM I was not significant, most of the variance in food intake being accounted for by the relationship with milk yield. Thus about 14% and 72% of the total variation in food intake was related to variation in live-weight and milk yield, respectively.

3.2.5. Rumen VFAs, pH and Ammonia

The proportion of VFAs, total VFA concentrations, rumen ammonia levels and rumen pH are summarised in Table 23. Differences in these values between pasture and pasture + concentrate fed animals were small and high coefficient of variation is associated with mean values.

TABLE 23: Effect of Treatments on Rumen VFAs, pH and Ammonia

Item	Pasture + Concentrates			Pasture		
	Mean	SE	CV	Mean	SE	CV
A. Proportions of VFAs						
Acetic Acid	69.1	±0.37	2.25	69.9	±0.28	1.70
Propionic Acid	17.4	±0.32	7.70	17.1	±0.24	5.91
Butyric Acid	13.5	±0.21	6.74	13.0	±0.23	7.54
B. VFA Concentration (mg/100 ml)						
Acetic Acid	9.40	±0.22	10.10	9.07	±0.24	11.47
Propionic Acid	2.36	±0.09	15.25	2.23	±0.06	11.21
Butyric Acid	1.84	±0.05	12.50	1.71	±0.05	13.45
Total	13.61					
C. Rumen Ammonia (mg/100 ml)	32.9	±1.67	21.49	35.4	±1.90	22.74
D. Rumen pH	6.0	±0.04	3.16	6.20	±0.06	3.87

3.2.6. Rate of Passage of Feeds

Figure 7 illustrates the excretion of stained pasture and concentrate particles for each treatment. There appeared to be no appreciable differences between treatments in the rate of disappearance of digesta of pasture from the digestive tract. However, the concentrates on treatment C passed faster than on treatment B through the gut.

The "R" values of pasture for animals were variable and no consistent differences between treatments occurred. Table 24 shows that differences in "R" values between the levels of concentrates fed were large. The values for rumen retention time are also included in Table 24. There is some indication that pasture digesta on treatment C passed faster from reticulo-rumen than on treatment B which in turn passed faster than treatment A. The differences between cows were large and appeared to be related with total intake. Like mean retention time, the rumen retention time of high level of concentrates was shorter than low level of concentrate fed. The results as a whole clearly demonstrate that the rate of passage of the concentrate was faster than that of pasture both from the rumen and the whole gut.

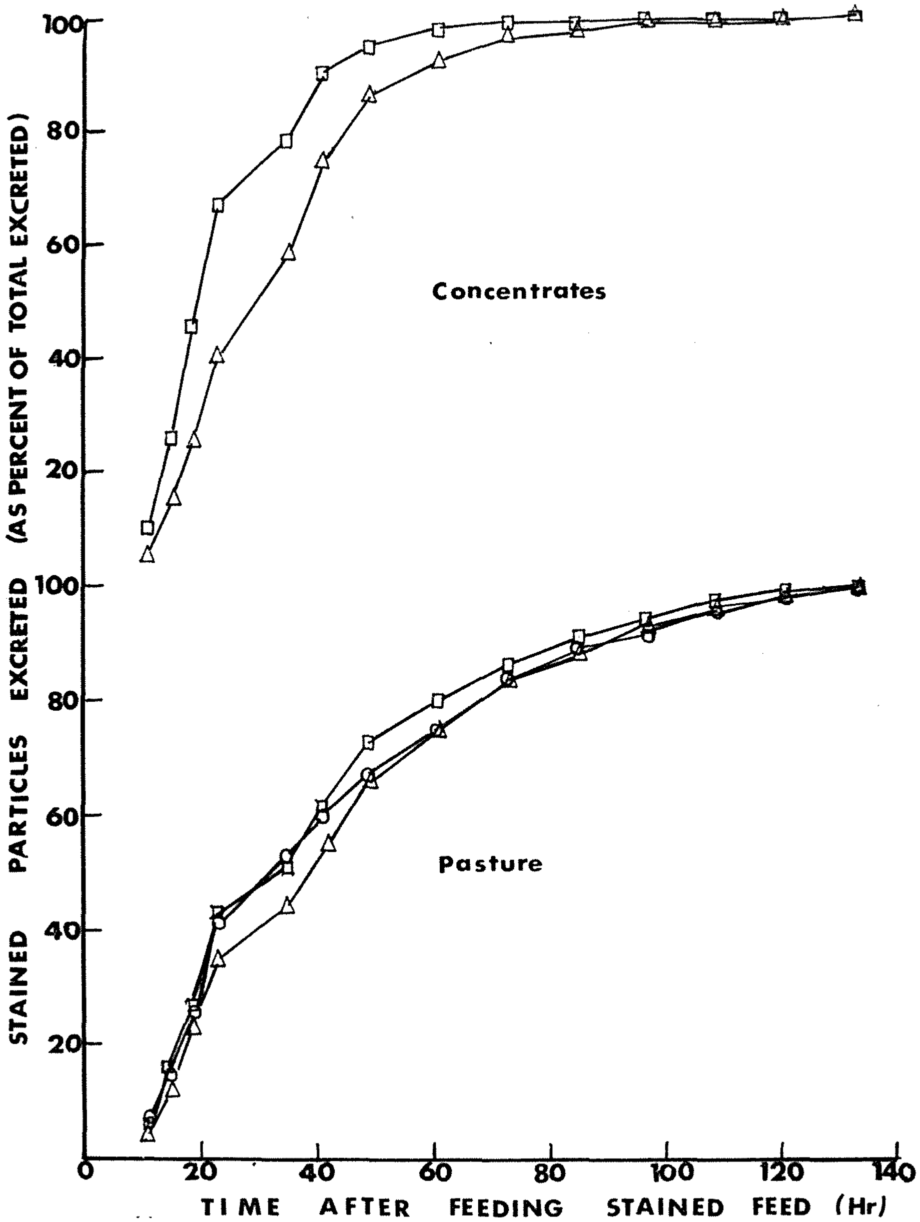


Fig. 7 Rate of excretion of stained feeds, treatment: ○—○ A; △—△ B & □—□ C.

TABLE 24: Rate of Passage of Feeds

Cow No.	Treatment	Body-Weight	Food Intake	Pasture		Concentrates	
		(Kg)	(Kg DM/ day)	Mean Retention time * "R" (hrs)	Rumen Retention time ** (hrs)	Mean Retention time * "R" (hrs)	Mean Retention time** (hrs)
82	A	327	14.6	44.5	64.0		
95	A	355	14.2	38.5	53.5		
	Mean		14.4	41.0	58.7		
35	B	328	14.9	42.4	52.0	33.8	35.5
78	B	302	12.5	45.7	59.5	31.7	34.0
	Mean			44.0	55.7	32.7	34.7
45	C	272	13.1	42.0	55.0	20.7	22.0
87	C	337	15.0	37.7	45.0	25.7	31.0
	Mean		14.0	39.8	50.0	23.7	26.5

* After Balch (1950)

** After Castle (1956)

3.3. DISCUSSION

3.3.1. Experimental Design

Latin square change-over designs provide a satisfactory technique in cattle experiments in that variation due to animals and time can be eliminated. In this experiment variation caused by differences in intake between cows and changes in stage of growth of pasture were removed. In addition it enabled the effects of a concentrate supplement on milk production to be studied without the confounding effects of stage of lactation. The main limitation of the design is the difficulty of eliminating the residual (carry-over) effects, although the use of extra period in the design of Lucas (1957) allows an estimate to be made of residual effects. However, this design was not possible under the circumstances of the present experiment. Several workers have used a change-over period varying from 4 - 7 days between two periods to lessen the carry-over effects, e.g. Corbett and Boyne (1958), Holmes et.al. (1960), Castle et.al. (1960), Sphar et. al. (1966) and Murdock and Hodgson (1967). A 6 - 8 day change-over (adjustment) period was used in the present experiment to keep carry-over effects to a minimum. Although supplementing pasture with concentrates had no appreciable effect on milk yield, the introduction of the concentrates was associated with a temporary loss in appetite during the change-over periods. This depression in intake resulted in lowering of milk yield, particularly in treatment C. Small depressions in milk yield were also associated with the restriction in food intake before weighing, at the beginning of each period. However, the milk yield practically recovered by the end of the change-over (adjustment) periods and it is unlikely that this temporary reduction in milk yield could have led to a significant carry-over effect. This assumption is supported by the results of Munford et.al. (1964) and Flux and Patchell (1957) who noted almost no carry-over effects following starvation for 14 hr, and underfeeding for 5 days, respectively.

3.3.2. Feeds

(i) Botanical composition of pasture -

Rye grass varieties and white clover formed the major components of the mixed pasture used in the three periods. The only consistent change in proportions of various pasture species present, as the season advanced, was that the percentage of white clover increased from period 1 to 3.

(ii) Chemical composition of feeds -

Changes in chemical composition though comparatively small were similar to the changes observed by Hutton (1961) in that the decline in crude protein was associated with an increase in crude fibre and decrease in ether extract. The ash content of the pasture decreased as the season advanced.

The values for ether extract and ash obtained in the present experiment were rather higher than those of Hutton (loc.cit.) but similar to those noted by Davey (1964). The values of crude protein obtained were similar to the values reported by Hutton (loc. cit.) in corresponding months, except that crude protein in the preliminary period of the experiment was relatively higher and may have been due to high percentage of clover in that period. Since the pasture was fairly leafy throughout the experiment the crude fibre contents were lower than those noted by Hutton (loc. cit.) and Davey (loc. cit.) during corresponding months, although Davey reported values as low as 18.4% for crude fibre for immature pasture. The values are similar to those reported for mixed pasture by Wilson (1966). The concentrates fed had a relatively constant composition during all the three periods.

(iii) Apparent digestibility of feeds -

Since it was not possible to conduct digestibility studies with cows it was felt with some reservations that digestibility data obtained with sheep would be satisfactory. The reservations were (1) the effect of animal species on digestibility and (2) differences in levels of intake between lactating cows and the wethers and its possible effect on digestibility. In connection with the first objection it is to be noted that Watson et.al. (1948) reviewing numerous experiments carried out during the period from 1890 - 1948, concluded that for all practical purposes any differences in ability of sheep and cattle to digest food were negligible. Similar observations were also made by other workers, e.g., Minson (1958) and Jang et.al. (1962). Regarding reservation (2), Hutton (1962a) did not find great differences in digestibility between two groups of cows receiving pasture ad.lib. and 60% of ad.lib.

Little difference in digestibility between supplemented and non-supplemented groups were noted, suggesting that the digestion coefficient of the concentrate might have been similar to that of pasture used.

The variation in digestibility between sheep in present experiment is difficult to explain. Blaxter (1962) noted that differences in ability of individuals to digest food is usually small and rarely exceed one unit of digestibility. The variation noted in the present study appeared to be due mainly to the two sheep which had been grazing outdoors prior to the commencement of the experiment, whereas the other four sheep had been fed a pelleted ration indoors for a considerable length of time.

3.3.3. Animals

(i) Health -

Apart from unavoidable temporary lameness that developed on introducing the cows to the barn feeding, all animals remained in good health throughout the experiment.

(ii) Live-weight -

One of the largest sources of error in estimation of live-weights in dairy cattle feeding experiments is digestive tract fill. In an attempt to reduce the influence of this fill on live-weight the cows were fasted for 14 hr before weighing. This method has been found to be more accurate than taking a mean of three daily weights by Koch et.al. (1958) and Bath et.al. (1966). The 14-hr fasting does not, however, ensure a measure of true weight of an animal, for food residues may remain longer than seven days in the digestive tract (Blaxter, loc.cit.).

All the cows gained weight during the experimental period, the average gain in weight being 0.5 Kg/cow/day. The rate of gain appears to be similar to the value obtained by Corbett and Boyne (1958) in a similar experiment. Small, but non-significant, differences in rate of weight gain between treatments were noted. This is perhaps not surprising because of the comparatively small differences in the total intake between treatments.

3.3.4. Intake

(i) Preliminary period -

Although considerable differences in DM intake between cows and days were noted, the cows appeared to be eating to a satisfactory level of intake, except for a few days in the preliminary period when some of the cows suffered from bloat. The "Pluronic L 64" detergent administered appeared to be quite effective in controlling bloat.

(ii) Experimental period -

(a) General - Several workers have used 10 - 15% feed refusals as a criterion to ensure ad.lib. intake in feeding experiments, e.g. Blaxter et.al. (1961) and Murdock and Hodgson (1967). In the present study the pasture DM refusals varied from 10 - 20% indicating that the cows were liberally fed.

A large decrease in the intake of both pasture and concentrates occurred when the cows were first introduced to concentrate feeding. The decrease was particularly severe in the first period when attempts were made to feed treatment C cows up to 5.5 Kg of concentrates. This problem was not as acute during change-over before comparison periods 2 and 3, possibly because some of the cows had received concentrates in the preceding period and also the amount on C treatment was reduced to 4.0 Kg. The decrease in intake occurred despite a gradual introduction of concentrates. A consistent feature was the reduction of total intake within two days following the start of concentrate feeding with a gradual improvement in intake over the next four to six days. The problems of temporary loss in appetite has also been noted by Sphar et.al. (1966) when concentrates were fed in addition to hay and silage. However, the levels of concentrates fed by these workers were 2 - 3.5 times higher than those of the present experiment. It is interesting that during the training period the cows were eating up to 7.0 Kg concentrates/cow/day with no effect on intake when hay was also being fed in addition to pasture. It was thought that low dietary fibre level in the ration may have affected intake. However, the crude fibre content of the pasture was comparatively high (21 - 23%) so that low dietary fibre levels were unlikely to be the reason. It is more likely that problems of adaptation were involved with the introduction of concentrates resulting in a sudden change in the rumen microbial environment (Hungate et.al., 1952). However, this still does not explain the partial loss in appetite that occurred even when cows were changed from the B to C treatment, where it might be expected that the cows had become adapted to concentrate feeding after 18 days on treatment B. Moreover there seemed to be a limit of about 4.0 Kg beyond which serious effects on food intake occurred. Originally it had been planned to feed 5.5 Kg concentrates/cow/day in the C treatment, but because of persistent intake problems this was reduced to 4.0 Kg/cow/day.

A further reason for the loss in appetite may be the production and accumulation of lactic acid in the rumen because of the high soluble carbohydrate contained in the concentrates (Reid et.al., 1957). The data obtained from the four fistulated cows did not indicate, from the limited evidence available, that conditions in the rumen were severely affected. There was only a small drop in pH with concentrate feeding compared with the severe reductions observed by other workers (Freer and Campling, 1963; Reid et.al., 1957 and Hungate et.al., 1952). However, fistulated cows had already been adapted to concentrate feeding and the lack of change in rumen pH and VFA proportions may not have reflected the situation in the rumens of cows experiencing intake depressions in the change-over period. Further work is indicated as this could also be a problem specific to the pasture and concentrate combination. Castle (Pers Comm.) stated that he had experienced feeding problems when barley-meal was fed with pasture, but these problems had disappeared when rolled barley was fed.

(b) Substitution - To the extent that concentrate feeding resulted in a depression in the voluntary intake of pasture the results are in general agreement with MacLusky (1955), Corbett and Boyne (1958), Seath et.al. (1959) and Holder (1962). Reduction in roughage (hay or silage) intake with concentrate feeding has also been noted by Autrey et.al. (1962), Jensen et.al. (1942), Reid and Holmes (1956), Holmes et.al. (1957), Schmidt and Schultz (1959), Holmes et.al.(1960), Blaxter et.al. (1961), Blaxter and Wilson (1963), Campling and Murdoch (1966) and Murdock and Hodgson (1967). As far as I am aware this is the only experiment where a precise estimate of substitution of pasture by concentrate has been obtained.

The extent of substitution for basal ration by concentrates reported in literature varied widely depending upon the type and quality of basal ration, the previous and current levels of feeding, the type and level of concentrates and the physiological state of the animals used (Section 1.1). The mean substitution of pasture DM by concentrates in the present study was 0.65 Kg/Kg concentrate DM consumed. This value is similar to that obtained in experiments by Reid and Holmes (1956), Holmes et.al. (1957) and Seath et.al. (1959).

The extent of substitution in period 1, when digestibility of pasture was higher was less than in period 2 or 3, when digestibility was lower. These results do not support the conclusion of Blaxter et. al. (1961) who noted greater substitution with higher quality roughage, although the substitution value in period 3 obtained in present experiment was only slightly lower than that noted for similar digestibility dried grass by Blaxter et.al. (loc.cit.), using wethers. The results are in line with Reid's (1956) general conclusion that substitution is inversely related to digestibility. However, Reid's observations were made with feeds of lower digestibility such as hay and silage. MacLusky (loc.cit.), using lactating cows grazing pasture, noted a greater substitution in period 3 and 4 of his experiment when pasture was mature compared with period 1 or 2, when relatively leafy growth was available for grazing. Headley (cited by Autrey et.al., 1942) reported that where cattle were accustomed to eating large quantities of roughage, grain added to the ration replaced by pound per pound, but only after the cattle had been on grain for some time. Complete one for one substitution did not occur in the present experiment. It is possible that if the experiment had been continued longer, then 1 : 1 substitution for pasture by concentrates might have occurred, as values close to the 0.9 Kg/Kg were obtained in the period 3. It is also possible that cows fed pasture alone (treatment A) increased their DM intake over the experiment because they were still adapting to indoor feeding conditions. However, in view of the results obtained by Hutton (1962b), Trimberger et.al. (1962) and Johnson et.al. (1966), the increased intake of pasture could have been associated with the stage of lactation rather than adaptation and the increase in intake may reflect increases in gut capacity as lactation advanced (Fell and Campbell, 1964). Change in the DM intake of cows receiving concentrates were small between periods, which is contrary to the argument of adaptation to indoor conditions mentioned for treatment A above. It is also unlikely that increasing intake of pasture on treatment A could have been because of changes in DM of pasture that occurred between periods as Campbell et.al. (unpublished) found no difference in intake with pasture ranging in DM content from about 15% - 20%.

Campling (1966) explained the depression in hay intake when concentrates were fed to cows in terms of decreased rate of disappearance of digesta from the gut. His results suggest that physical capacity of the gut was limiting the voluntary intake of hay. In the present experiment comparatively small difference in rate of passage of pasture digesta (fig.7) or mean retention time (R) between groups fed concentrate and non-concentrate were observed. This suggests that factors other than physical capacity of gut were limiting the intake of pasture when concentrates were fed. The technique used to carry out rate of passage studies of the pasture in the present experiment, however, may well be questioned, for it involved staining, boiling and drying of the pasture, resulting in material considerably different from the original fresh pasture. Whether this material passed through the digestive tract at the same rate as pasture did is a matter of speculation and requires further investigation.

If considered valid, the results show that the mean retention time of pasture in the gut was considerably shorter than that of diets such as hay or straws (Balch, 1965). Comparatively shorter mean retention times have been noted for high digestibility feeds by Blaxter (1962). The shorter mean retention time of concentrate may have been because of the small particle size which pass faster from the reticulo-rumen in comparison with larger particles (Balch loc.cit.), Eng et.al. (1964) also noted faster rate of passage of corn than hay when both were fed in various combinations.

(c) Total intake - Since substitution of concentrate for pasture was not complete the total DM intake of cows fed concentrates was significantly higher than those receiving pasture alone. Increases in total intake as a consequence of concentrate feeding has been noted by many workers (see table 2). The increase in total DM intake in the present experiment was, however, comparatively small. Non-significant differences in total DM intake between the groups fed two levels of concentrates were noted. The increase in total DM intake in favour of concentrate fed groups may have been because of the faster disappearance of concentrate digesta from the reticulo-rumen and the whole gut (Table 24). Thus faster rate of passage of the concentrate may allow the animal to eat more by decreasing rumen load.

The total intake of DM expressed as per cent. of live-weight obtained in the present experiment is considerably higher than results obtained by other workers. Hutton (1963) has observed a maximum level of 3.7 Kg pasture DM intake/100 Kg live-weight by lactating cows in contrast to a 4.0, 4.3 and 4.5 Kg D.M. intake/100 Kg live-weight on treatment A, B and C respectively in the present study. One of the main reasons for these higher values was the fact that the animals were fasted for 14-hr before weighing, leading to reduced gut fill and therefore low live-weights. Thus this weighing procedure resulted in increased estimation of intake when expressed as per cent. of live-weight. The absolute DM intake for pasture group (treatment A) appears to be similar to that obtained by Hutton et.al. (1964, fig. 1) in one of their trials.

Highly significant differences existed between cows with respect to forage intake as measured by DM, DOM and DM intake as per cent. of live-weight. These may be due to the influence of various factors such as milk yield, live-weight, live-weight changes, concentrate intake, age, body condition, stage of lactation, gut capacity and perhaps to inherent capacity to eat.

(d) DOM intake - Although significant differences in DOM intake between concentrate and non-concentrate fed groups took place, fig. 6 shows that changes in DOM intake between periods within treatments were small. Also the differences in DOM intake between treatment B and C were small and non-significant. It is possible that cows were eating to a constant DOM intake during the experimental period. Evidence appears in literature that amount of digesta in the reticulo-rumen does not limit the voluntary intake of animals receiving high concentrate : hay ratios (Conrad et.al., 1964; Montgomery and Baumgradt, 1965). It was suggested that factors such as gut capacity ceased to be limiting when the digestibility of ration was around 65% - 70% and that at this level physiological factors were assuming importance. The digestibility of feeds in the present experiment was higher than 70% and it is possible that physiological factors were limiting intake. This may be true for concentrate fed cows, but the fact that DM intake of cows fed pasture alone (Treatment A) increased with advance in stage of lactation suggests that gut capacity may have limited the voluntary intake of these cows (see page 108). That pasture DOM intake of cows on treatment A, however, was similar over the three periods, but again this was due to decrease in digestibility of pasture over the experiment. Thus the results obtained gave no clear insight into the mechanisms of appetite control under the present experimental conditions.

3.3.5. Milk Production

(i) Milk yield -

The supplementing of pasture with concentrates has been shown to have variable effects on milk yield. For e.g. Castle et.al. (1964) found that concentrate feeding made no difference in milk yield of cows grazing ample pasture. On the other hand, considerable increases in milk yield have been reported by Wallace (1957); Edey (1956); Hancock (1953) and Laird and Walker (1962) when up to 4.7 Kg of concentrates were fed to cows grazing outdoors. In some other experiments either small (Corbett and Boyne, 1958; Castle et.al, 1960; Fairbairn and Rickaby, 1966; Wood, 1966) or variable (Shepherd, 1962) increases in milk yield have been noted in response to concentrate feeding. In the present experiment concentrate feeding had little effect on milk yield. The results are in agreement with those of Castle et.al. (1964) and in general also confirm the results of two short-term experiments carried out by Davey (unpublished) in which only a small increase in milk yield was obtained with concentrate feeding. One reason for this lack of response was demonstrated in the present experiment in that under liberal pasture feeding conditions substitution of pasture by concentrates occurs. It is difficult to understand the results of Wallace's and Edey's experiments where under ample pasture feeding a comparatively large response to concentrates was obtained.

As expected, the milk yield declined with advance in stage of lactation. The 4% yield did not show any difference between periods because decline in milk yield was associated with increase in milk fat content.

(ii) Milk-fat content and yield -

Concentrate feeding may affect the fat content of milk in two ways. Firstly, a specific effect resulting in a decrease in milk-fat content associated usually with a relatively narrow acetate to propionate ratio in the rumen liquor of concentrate fed animals (Balch, 1955a; Rook, 1961; Rook and Balch, 1961; Shaw, 1961; Bath and Rook, 1963). Secondly, by increasing the plane of nutrition, thereby increasing the milk yield with a consequent small decrease in milk-fat content (Burt, 1957c; Rook, 1961 and Elliot, 1962). In the present experiment since there was neither any appreciable effect on VFA proportions in the rumen liquor nor on milk yield, the small effect on milk fat is not surprising. Similar results (Davey, unpublished) have been noted in Massey experiments and by Castle et.al. (1960) who found little or no change in milk-fat content of cows fed concentrates.

A gradual increase in milk-fat content occurred with advance in lactation, which was reflected in appreciable differences between periods. This is a normal consequence with advance in the stage of lactation (Rook, 1961).

Since the gradual increase in milk fat accompanied the decline in milk yield the milk fat yield did not vary significently between periods. No effect of concentrate feeding on milk-fat yield was observed.

(iii) <u>SNF content and yield</u> -

Small or no increases in SNF content as a result of feeding concentrate in addition to basal ration have been noted by many workers, e.g. Castle <u>et.al</u>. (1958, 1959, 1961), Holmes <u>et.al</u>. (1957, 1960), Huber and Boman (1966), Hooven <u>et.al</u>. (1963), Rook (1959, 1961). Although there was an increase of 0.17 per cent. units in SNF content of milk from cows fed high level of concentrate compared with cows fed pasture alone in this experiment, the differences between treatments were non-significant. Again, in view of the lack of change in rumen VFA proportions and milk yield the results are perhaps not surprising. There was a small, but non-significant ($P > 0.05$) increase in SNF yield of cows fed concentrates.

3.3.6. Relation between Food Intake and Animal Production

Calculation of multiple regression equation revealed that partial coefficient of live-weight was not significant but that of FCM yield was highly significant ($P < 0.01$), suggesting that milk yield was closely related to intake, the standardized partial regression coefficient being 0.79. This did not indicate, however, that food intake was determined by milk yield or vice versa, but merely suggested that differences in food intake might be predicted quite well, for approximately 72% of the total variation in intake was noted to be related to milk yield alone. The knowledge of differences in live-weight did not add much to the precision of the prediction. In this connection, Holmes et.al. (1965) and Jones et.al. (1965) noted a non-significant partial regression coefficient with $LW^{0.75}$ but that for milk yield was significant. More precise estimates of regression coefficient in the present study might have been obtained if variability in intake due to live-weight gain, level of concentrate fed, age and stage of lactation etc. were to be taken into consideration. However, the small number of cows used limited the usefulness of proceeding with very detailed analyses.

3.4. SUMMARY

1. An experiment was conducted with lactating cows to examine the nutritional effects of adding concentrates to a diet of pasture. Nine Jersey cows were used in a 3 x 3 Latin square repeated three times; the squares ran concurrently. The treatments compared were - (A) pasture *ad.lib.*, (B) pasture *ad.lib.* + 2.7 Kg concentrates/cow/day, (C) pasture *ad.lib.* + 4.2 Kg concentrates/cow/day. Each period of each square was of 18 day duration. The data of the last 12 days in each period were used for comparison of treatment effects.

2. The addition of concentrates to the diet of cows offered pasture *ad.lib.* decreased the voluntary intake of pasture DM by 0.63 Kg and 0.66 Kg concentrates DM fed, in treatment B and C, respectively. An increase of 6% and 10% in total DM intake in favour of treatments B and C respectively was noted.

3. The pasture DM consumption averaged 13.2, 11.7 and 10.9 Kg/cow/day for treatments A, B and C respectively. In addition concentrates DM consumed were 2.3 and 3.5 Kg respectively on treatments B and C. The total intake of supplemented cows was significantly greater ($P < 0.01$) than that of pasture fed cows.

4. No difference in digestibility between pasture and pasture + concentrate diets when fed to wethers was noted, though differences between periods were obvious.

5. The total DOM intake in treatments A, B and C respectively were 9.1, 9.9 and 10.3 Kg/cow/day; the differences between concentrate and non-concentrate groups were highly significant ($P < 0.01$). The differences in DOM intake between periods within treatment were small.
6. The rate of disappearance of pasture digesta from alimentary tract on all treatments was similar. The mean retention time for concentrates was considerably lower than pasture. The mean retention times for pasture on treatments A, B and C being 41.0., 44.0 and 40.0 hr and for concentrates were 34.7 and 26.5 hr on treatments B and C respectively.
7. The milk yields of cows on treatments A, B and C were 14.2, 14.8 and 14.4 Kg/cow/day respectively, the differences being non-significant ($P > 0.05$).
8. Concentrate feeding reduced milk fat content by 0.11 and 0.13 percentage units and increased SNF contents by 0.06 and 0.17 percentage units on treatments B and C, respectively. These differences, however, were non-significant ($P > 0.05$). The yields of milk fat and SNF were unaffected or slightly affected by concentrate feeding.
9. All cows remained in good health throughout the experiment, except for the temporary lameness which developed on introduction of cows to stall feeding.

10. The cows gained on an average of 0.5 Kg/cow/day in live-weight throughout the experiment. Differences in live-weight gain between treatments were non-significant.

CHAPTER IV

CONCLUSIONS

The results of the indoor feeding experiment showed that when concentrates were fed to cows receiving *ad.lib.* pasture, the former partially substituted for the latter. The extent of substitution may have varied with the stage of lactation or changes in pasture quality (see section 3.3.4). The experiment suggested that substitution may be one possible reason why responses to concentrates fed with pasture in the present and in other experiments have often been disappointing. Some additional information obtained indicated that when levels of the concentrate exceeded 3 Kg/cow/day, the cows lost their appetite for a time. This may be one of the reasons for the rather disappointing responses to concentrate feeding in the field trial. Microbiological and physio-chemical evidence is needed to help explain the depression in intake resulting from high levels of concentrate feeding.

The suggestion made in discussion, that factors other than gut capacity may limit intake when concentrates are fed, needs investigation. Different ratios of grass to concentrates could be fed and rumen fill, rate of passage and rumen digestion measured, to determine whether or not gut capacity is limiting intake. Investigations are also needed on the effect of change in size of the gut with regard to stage of lactation and its influence on intake.

Milk yield, milk composition and live-weight were not significantly affected by concentrate feeding in the indoor experiment. Apart from the substitution the effect may have been due to the relatively small increase in intake or the short duration of each experimental period. Further evidence is required on the effects of feeding concentrates along with pasture on intake, milk yield and milk composition. Longer term field experiments with different amounts and qualities of pasture and concentrates are needed. These should be supplemented with indoor feeding trials where precise measure of intake can be made.

The responses obtained in the field experiment were not as great as might have been expected in view of the apparent shortage of feeds. One of the reasons may have been that pasture was not really limiting despite its apparent sparseness.

While a better response would be expected when pasture is definitely limiting, as in the grazing experiment at Ruakura (Wallace, 1957, Exp. I) it is clear from the field trial that it is a difficult problem to assess pasture availability and hence to judge the likely response to concentrate feeding in a particular situation. If a liberal supply of pasture is available concentrate feeding may result in substitution of the former and consequently poor responses in milk yield. The extent of substitution and hence the response to concentrates may also depend on the following factors: stage of lactation (section 1.5), type of basal ration (Campling and Murdoch, 1966; Clifton et.al., 1963), type of concentrates (Murdoch, 1964), amount of concentrates (Campling and Murdoch, 1966), quality of basal ration (Blaxter et.al., 1961, Reid, 1956). In addition some other factors such as previous level of feeding (Broster et.al., 1958), the genetic potential of milk production and age of cows (Burt, 1957b) may also play an important part in affecting the responses obtained (Also see section 1.5).

The substitution of concentrates for pasture under practical farming conditions may be important in that pasture may be saved for later use or concentrates may be used during periods of severe deficiency of pasture.

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APPENDIX 1

(A) Covariance Analysis, using Preliminary Period Milk Yield as X and Comparison Period Milk Yield as Y for <u>whole</u> of the Comparison Period (Table 6)

Source	d.f.	SSX	SPXY	SSY	SSY'	df'	MS	F	Result
Total	15	72.539	61.189	64.448					
Blocks	7	44.695	43.058	45.730					
Treatment	1	2.835	-1.252	0.853					
Error	7	25.009	19.383	17.865	2.842	6	0.474		
Tr + Error	8	27.844	18.131	18.718	6.912	7			
For testing TR difference						1	4.070	8.586	*

(B) Covariance Analysis, using Preliminary Period Milk Yield as X and Comparison Period Milk Yield as Y for <u>First-Half</u> of the Comparison Period (Table 5)

Source	d.f.	SSX	SPXY	SSY	SSY'	df'	MS	F	Result
Total	15	72.539	54.532	60.520					
Blocks	7	44.695	41.640	42.372					
Treatment	1	2.835	-3.226	5.672					
Error	7	25.009	16.118	12.476	2.088	6	0.348		
Tr + Error	8	27.844	12.892	18.148	12.179	7			
For testing TR difference					10.091	1	10.091	28.997	**

APPENDIX 2

(A) Covariance Analysis, using Preliminary Period Milk Fat Content as X and Whole of the Comparison Period Milk Fat Content as Y (Table 6)

Source	d.f	SSX	SPXY	SSY	SSY'	df'	MS	f	Re-sult
Total	15	2.104	1.819	2.318					
Blocks	7	0.929	0.734	0.852					
Treat-ments	1	0.003	-0.019	0.129					
Error	7	1.173	1.104	1.337	0.298	6	0.0497		
Tr + Error	8	1.176	1.085	1.466	0.465	7			
For testing TR diff-erence					0.167	1	0.1670	3.360	NS

(B) Covariance Analysis, using Preliminary Period Milk Fat Content as X and First-Half of the Comparison Period Milk Fat Content as Y (Table 5)

Source	d.f.	SSX	SPXY	SSY	SSY'	df'	MS	f	Re-sult
Total	15	2.104	1.416	2.469					
Blocks	7	0.929	0.353	0.625					
Treat-ments	1	0.003	-0.039	0.518					
Error	7	1.173	1.104	1.326	0.287	6	0.0478		
Tr + Error	8	1.176	1.065	1.844	0.880	7			
For testing TR diff-erence					0.593	1	0.5930	12.406	*

APPENDIX 3

(A) Covariance Analysis, using Preliminary Period Milk Fat Yield as X and <u>Whole</u> of the Comparison Period Milk Fat as Y (Table 6)

Source	d.f.	SSX	SPXY	SSY	SSY'	df'	MS	F	Result
Total	15	0.1447	0.1158	0.1079					
Blocks	7	0.0912	0.0761	0.0722					
Treatment	1	0.0031	0.0016	0.0008					
Error	7	0.0504	0.0380	0.0349	0.0320	6	0.0053		
Tr + Error	8	0.0535	0.0396	0.0357	0.0328	7			
For testing TR difference					0.0008	1	0.0008	<1	NS

(B) Covariance Analysis, using Preliminary Period Milk Fat Yield as X and <u>First-Half</u> of the Comparison Period Milk Fat Yield as Y (Table 5)

Source	d.f.	SSX	SPXY	SSY	SSY'	df'	MS	F	Result
Total	15	0.1447	0.0855	0.0734					
Blocks	7	0.0912	0.0530	0.0435					
Treatment	1	0.0031	0.0014	0.0007	0.0100	6	0.0016		
Error	7	0.0504	0.0311	0.0292	0.0102	7			
Tr + Error	8	0.0535	0.0325	0.0299	0.0002	1	0.0002	<1	NS
For testing TR difference									

APPENDIX 4

(A) Covariance Analysis, using Preliminary Period SNF Content as X and Whole of the Comparison Period SNF Content as Y (Table 6)

Source	d.f.	SSX	SPXY	SSY	SSY'	df'	MS	F	Result
Total	15	0.969	0.729	0.920					
Block	7	0.496	0.368	0.429					
Treatment	1	0.006	0.024	0.121					
Error	7	0.467	0.337	0.370	0.127	6	0.021		
Tr + Error	8	0.473	0.361	0.491	0.216	7			
For testing TR difference					0.089	1	0.089	4.238	NS

(B) Covariance Analysis using Preliminary Period SNF Content as X and First Half of the Comparison Period SNF Content as Y (Table 5)

Source	d.f.	SSX	SPXY	SSY	SSY'	df'	MS	F	Result
Total	15	0.969	0.578	0.906					
Block	7	0.496	0.210	0.262					
Treatment	1	0.006	0.013	0.033					
Error	7	0.467	0.355	0.611	0.341	6	0.057		
Tr + Error	8	0.473	0.368	0.644	0.358	7			
For testing TR difference					0.017	1	0.017	<1	NS

APPENDIX 5

(A) Covariance Analysis, using Preliminary Period SNF Yield as X and <u>Whole</u> of the Comparison Period SNF Yield as Y (Table 6)

Source	d.f.	SSX	SPXY	SSY	SSY'	d.f.	MS	F	Result
Total	15	0.5897	0.5105	0.1683					
Block	7	0.3817	0.3707	0.4109					
Treatment	1	0.0134	-0.0145	0.0054					
Error	7	0.1946	0.1538	0.1683	0.0488	6	0.0081		
Tr + Error	8	0.2080	0.1393	0.1737	0.1644	7			
For testing TR difference					0.1156	1	0.1156	14.171	**

(B) Covariance Analysis, using Preliminary Period SNF Yield as X and <u>First-Half</u> of the Comparison Period SNF Yield as Y (Table 5)

Source	d.f.	SSX	SPXY	SSY	SSY'	df'	MS	F	Result
Total	15	0.5897	0.4569	0.5382					
Block	7	0.3817	0.3521	0.3715					
Treatment	1	0.0134	-0.0260	0.0506					
Error	7	0.1946	0.1308	0.1161	0.0282	6	0.0047		
Tr + Error	8	0.2080	0.1048	0.1667	0.1139	7			
For testing TR difference					0.0857	1	0.0857	18.234	**

APPENDIX 6

(a) Live-weight Change (Table 16)

Analysis of Variance

Source	d.f	S.S	M.S.	f	Result
Total	26	412.792			
Square	2	52.760	26.380	1.5047	NS
Periods within Square	6	59.420	9.903	<1	NS
Cows within Square	6	45.744	7.629	<1	NS
Treatment	2	6.739	3.369	1.493	NS
Treatment x Square	4	9.027	2.257	<1	NS
Error	6	240.102	40.017		

(b) Dry Matter Intake - Preliminary Period (Table 17)

Source	d.f.	S.S.	M.S.	f	Result
Total	107	309.857			
Days	11	169.719	15.4290	23.3454	**
Cows	8	81.978	10.2472	15.5049	**
Error	88	58.160	0.6609		

APPENDIX 7

(a) Milk Yield - Preliminary Period (Table 17)

Analysis of Variance

Source	d.f.	S.S.	M.S.	f	Result
Total	87	376.91			
Cows	8	319.19	39.8987	53.9682	**
Days	9	5.97	0.6633	<1	
Error	70	51.75	0.7393		

(b) Milk-fat Content - Preliminary Period (Table 17)

Analysis of Variance

Source	d.f.	S.S.	M.S.	f	Result
Total	26	11.4701			
Cows	8	10.4805	1.3100	23.1858	**
Days	2	0.0947	0.0473	<1	NS
Error	16	0.9049	0.0565		

(c) SNF Content - Preliminary Period (Table 17)

Analysis of Variance

Source	d.f.	S.S.	M.S.	f	Result
Total	26	4.051			
Cows	8	2.516	0.3145	3.456	*
Days	2	0.078	0.0390	<1	NS
Error	16	1.457	0.0910		

APPENDIX 8

(a) Total DOM Intake (Table 18)

Analysis of Variance

Source	d.f.	S.S.	M.S.	f	Result
Total	26	18.936			
Square	2	4.689	2.3445	1.8711	NS
Cows within Square	6	6.657	1.1095	20.0344	**
Period within Square	6	1.038	0.1730	3.1340	+
Treatment	2	5.753	2.8765	24.5854	**
(i) A Vs B & C	1	5.3248	5.3248	45.5111	**
(ii) B Vs C	1	0.4290	0.4290	3.6667	NS
Treatment x Square	4	0.468	0.1170	2.1196	NS
Error	6	0:331	0.0552		

(b) Total DM Intake (Table 18)

Analysis of Variance

Source	d.f.	S.S.	M.S.	f	Result
Total	26	35.460			
Square	2	9.897	4.9485	1.8031	NS
Cows within Square	6	13.642	2.2737	14.2731	**
Period within Square	6	3.354	0.5590	3.5091	+
Treatment	2	6.818	3.4090	17.1998	*
(i) A Vs B & C	1	6.2764	6.2764	31.6670	**
(ii) B Vs C	1	0.5415	0.5415	2.7320	NS
Treatment x Square	4	0.793	0.1982	1.2442	NS
Error	6	0.956	0.1593		

APPENDIX 9

(a) Pasture D.O.M. Intake (Table 18)

Analysis of Variance

Source	d.f.	S.S.	M.S.	f	Result
Total	26	24.130			
Square	2	4.613	2.3065	1.9948	NS
Cows within Square	6	6.012	1.0020	12.6356	**
Periods within Square	6	1.164	0.1940	2.4464	NS
Treatment	2	11.431	5.7155	52.6744	**
(i) A Vs B & C	1	10.1417	10.1417	93.4719	**
(ii) B Vs C	1	1.2896	1.2896	11.8857	*
Treatment x Square	4	0.434	0.1085	1.3682	NS
Error	6	0.476	0.0793		

(b) Pasture DM Intake (Table 18)

Analysis of Variance

Source	d.f.	S.S.	M.S.	f	Result
Total	26	51.599			
Square	2	9.582	4.7910	1.8205	NS
Cows within Square	6	12.634	2.1057	13.7807	**
Periods within Square	6	3.662	0.6103	3.9943	+
Treatment	2	23.957	11.9785	56.5824	**
(i) A Vs B & C	1	21.2766	21.2766	100.5035	**
(ii) B Vs C	1	2.6803	2.6803	12.6608	*
Treatment x Square	4	0.847	0.2117	1.3854	NS
Error	6	0.917	0.1528		

APPENDIX 10

Pasture DM Intake : Period within Treatment

Analysis of Variance

Source	d.f.	S.S.	M.S.	f	Result
Total	321	923.008			
Treatment	2	290.694	145.347		
Periods within Treatment	6	45.124	7.5207	19.33	**
Days within Period	99	166.610	1.6829		
Cows within Days	214	420.580	1.9653		

APPENDIX 11

(a) Milk Yield (Table 21)

Analysis of Variance

Source	d.f.	S.S.	M.S.	f	Result
Total	26	118.316			
Square	2	50.026	25.0130	2.3993	NS
Cows within Square	6	51.186	8.3376	39.2357	**
Periods within Square	6	13.056	2.1760	10.240	**
Treatment	2	1.480	0.7400	2.2896	NS
Treatment x Square	4	1.293	0.3232	1.5209	NS
Error	6	1.275	0.2125		

(b) 4% FCM Yield (Table 21)

Analysis of Variance

Source	d.f.	S.S.	M.S.	f	Result
Total	26	91.688			
Square	2	37.607	18.8035	2.5025	NS
Cows within Square	6	38.154	6.3590	12.9696	**
Periods within Square	6	8.105	1.3508	2.7550	NS
Treatment	2	1.690	0.8450	1.0596	NS
Treatment x Square	4	3.190	0.7975	1.6957	NS
Error	6	2.942	0.4903		

APPENDIX 12

(a) Milk Fat Content (Table 21)
Analysis of Variance

Source	d.f.	S.S.	M.S.	f	Result
Total	26	10.287			
Square	2	3.426	1.7130	1.6339	NS
Cows within Square	6	5.660	0.9433	46.4679	**
Periods within Square	6	0.705	0.1175	5.7882	*
Treatment	2	0.090	0.0450	<1	NS
Treatment x Square	4	0.284	0.0710	3.4975	+
Error	6	0.122	0.0203		

(b) SNF Content (Table 21)
Analysis of Variance

Source	d.f.	S.S.	M.S.	f	Result
Total	26	2.964			
Square	2	0.769	0.3645	1.1295	NS
Cows within Square	6	1.598	0.2663	33.2870	**
Periods within Square	6	0.312	0.0520	6.5000	*
Treatment	2	0.127	0.0635	2.3091	NS
Treatment x Square	4	0.110	0.0275	3.4375	+
Error	6	0.048	0.0080		

(c) SNF Content : (Treatment within Square) (Table 21)
Analysis of Variance

Source	d.f.	S.S.	M.S.	f	Result
Total	26	2.964			
Square	2	0.769			
Cows within Square	6	1.598			
Period within Square	6	0.312			
Treatment within Square	6	0.237	0.0395	4.937	*
Error	6	0.048	0.0080		

APPENDIX 13

(a) Milk Fat Yield (Table 21)
Analysis of Variance

Source	d.f.	S.S.	M.S.	f	Result
Total	26	0.1780			
Squares	2	0.0609	0.0304	1.9812	NS
Cows within Squares	6	0.0858	0.0143	11.000	**
Periods within Squares	6	0.0105	0.0017	1.3076	NS
Treatment	2	0.0036	0.0018	<1	NS
Treatment x Square	4	0.0096	0.0024	1.8461	NS
Error	6	0.0076	0.0013		

(b) SNF Yield (Table 21)
Analysis of Variance

Source	d.f.	S.S.	M.S.	f	Result
Total	26	1.033			
Squares	2	0.471	0.2355	2.7256	NS
Cows within Squares	6	0.424	0.0707	28.280	**
Periods within Squares	6	0.094	0.0157	6.280	*
Treatment	2	0.018	0.0090	3.214	NS
Treatment x Square	4	0.011	0.0028	1.120	NS
Error	6	0.015	0.0025		

APPENDIX 14

Food Consumption - Variation due to Cows Intake
(Kg/Cow/Day)

Cows Within Square		1	2	3	SE	CV (%)	Significance of difference
Dry Matter	Sq.						
A. Pasture	I	12.5	10.5	10.8	±0.23	3.46	1 > 2, 3 **
	II	11.9	12.7	10.9	±0.23	3.30	2 > 1*, 2 > 3**
	III	12.9	13.0	12.2	±0.23	3.07	NS
	mean	12.4	12.1	11.3			
B. Total (Pasture + Concentrates)	I	14.5	12.4	12.7	±0.23	2.96	1 > 2, 3**
	II	13.5	14.7	12.9	±0.23	2.83	2 > 3 ** 2 > 1*, 1 > 3*
	III	14.8	14.9	14.2	±0.23	2.66	NS
	mean	14.4	14.0	13.3			
DOM							
A. Pasture	I	8.7	7.3	7.5	±0.17	3.57	1 > 2, 3 **
	II	8.2	8.8	7.6	±0.17	3.41	1 > 3* 2,· 3**
	III	8.9	9.0	8.5	±0.17	3.18	NS
	mean	8.6	8.4	7.9			
B. Total	I	10.2	8.7	9.0	±0.14	2.58	1 > 2, 3 **
	II	9.7	10.3	9.1	±0.14	2.47	2 > 1 *, 1 > 3* 2 > 3 **
	III	10.5	10.5	10.0	±0.14	2.33	1 > 3, 2 > 3 *
	mean	10.1	9.8	9.4			

APPENDIX 15

Variability in Milk Production due to Cows
(Kg/Cow/Day)

Cows within Square		1	2	3	SE	CV (%)	Significance of difference
	Sq.						
Milk Yield (Kg)	I	13.8	12.0	12.9	±0.27	3.57	1 > 2 **
	II	13.0	16.1	13.8	±0.27	3.22	2 > 1, 3 **
	III	17.2	17.7	13.6	±0.27	2.83	1, 2 > 3 **
	mean	14.7	15.3	13.4			
Milk-Fat Content (%)	I	6.04	5.93	5.18	±0.08	2.45	1 > 3 ** 2 > 3 **
	II	5.48	4.70	4.49	±0.08	2.86	1 > 2, 3 **
	III	4.52	4.88	5.82	±0.08	2.76	3 > 1, 2 ** 2 > 1 *
	mean	5.34	5.17	5.16			
Milk-Fat Yield (gm)	I	831.7	709.7	663.7	±20.0	4.898	1 > 2, 3 **
	II	709.0	758.0	622.0	±20.0	5.170	2 > 3 ** 1 > 3 *
	III	781.0	862.3	788.7	±20.0	4.441	2 > 1, 3 *
	mean	773.9	778.7	691.5			
SNF Content (%)	I	9.59	9.91	9.45	±0.052	0.922	2 > 1, 3 **
	II	9.30	9.58	8.98	±0.052	0.958	2 > 1, 3 ** 1 > 3 **
	III	9.36	9.54	10.02	±0.052	0.923	3 > 1, 2 **
	mean	9.42	9.68	9.48			
SNF Yield (Gm)	I	1323.3	1187.7	1211.3	±29.0	4.029	1 > 2, 3 *
	II	1204.0	1548.0	1243.3	±29.0	3.754	2 > 1, 3 **
	III	1613.3	1691.7	1360.3	±29.0	3.215	1, 2 > 3 **
	mean	1380.2	1475.8	1271.6			

APPENDIX 16

Multiple Regression Analyses

$\overline{X}_1$	= 307.778	$\overline{X}_2$	= 16.955	$\overline{Y}$	= 9.767
$x^2{}_1$	= 5363.6	Σx_2^2	= 25.2	$\Sigma \overline{Y}$	= 3.94
$x_1 \; x_2$	= 214.3	$\Sigma x_2 \; Y$	= 9.05	$\Sigma x_1 y$	= 97.1
by 1.2	= 0.0057	by 2.1	= 0.3108		
by 1.2	= 0.60;	$Sy.12^2$	= 0.60/6 = 0.10;	$\Sigma \hat{Y}.12^2$	
			= (3.94 - 0.60)	= 3.34	

Analyses of Variance

Source	df	SS	MS	f	Result
Total	8	3.94			
Regression	2	3.34	1.67	16.7	**
Residual	6	0.60	0.10		

Test of Each of X After the Effect of the Other has been Removed

Source	df	SS	MS	f	Result
X_1 & X_2	2	3.34			
X_1 alone	1	1.76			
X_2 after X_1	1	1.58	1.58	15.8	**
X_1 & X_2	2	3.34			
X_1 alone	1	3.25			
X_1 after X_2	1	0.09	0.09	0.9	NS
Error	6	0.60	0.10		

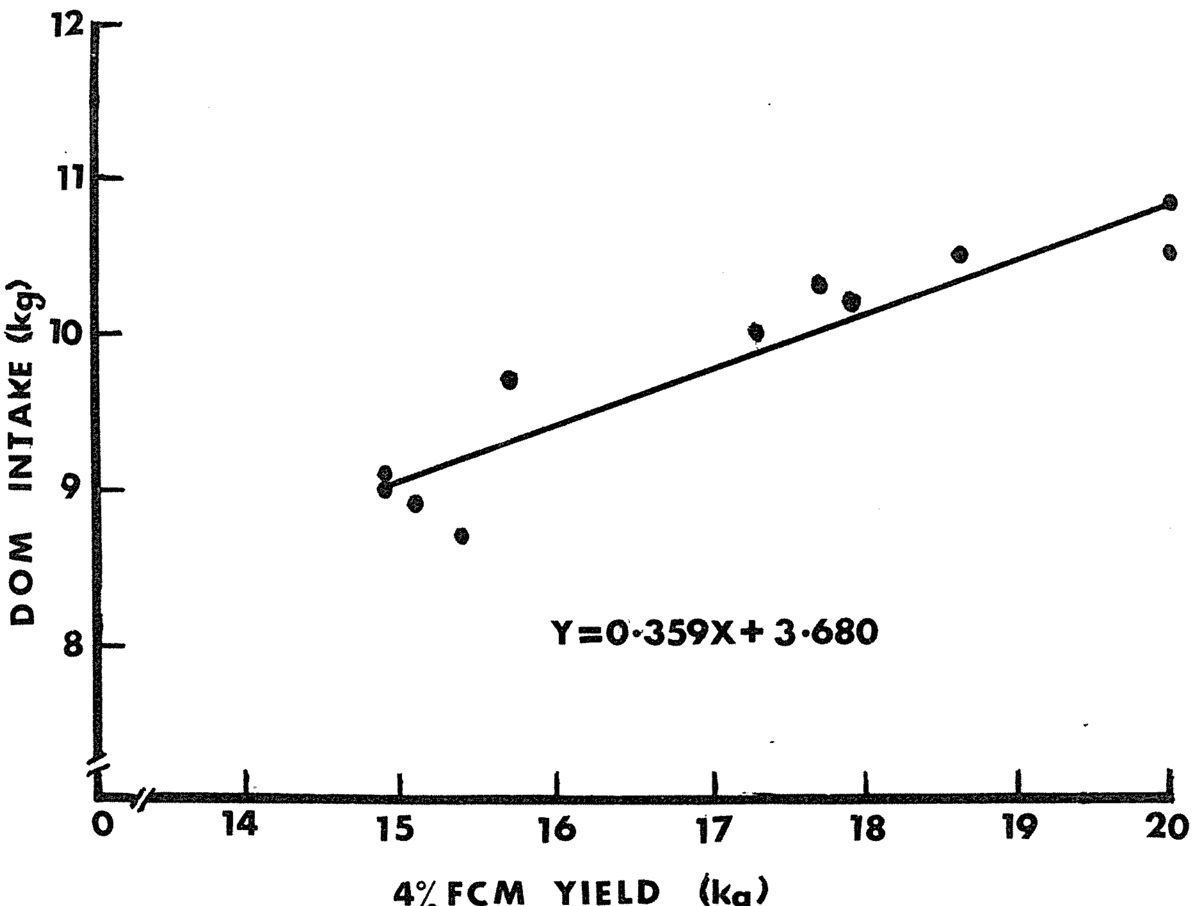


Fig.8: Relation between the DOM intake and 4% FCM yield.

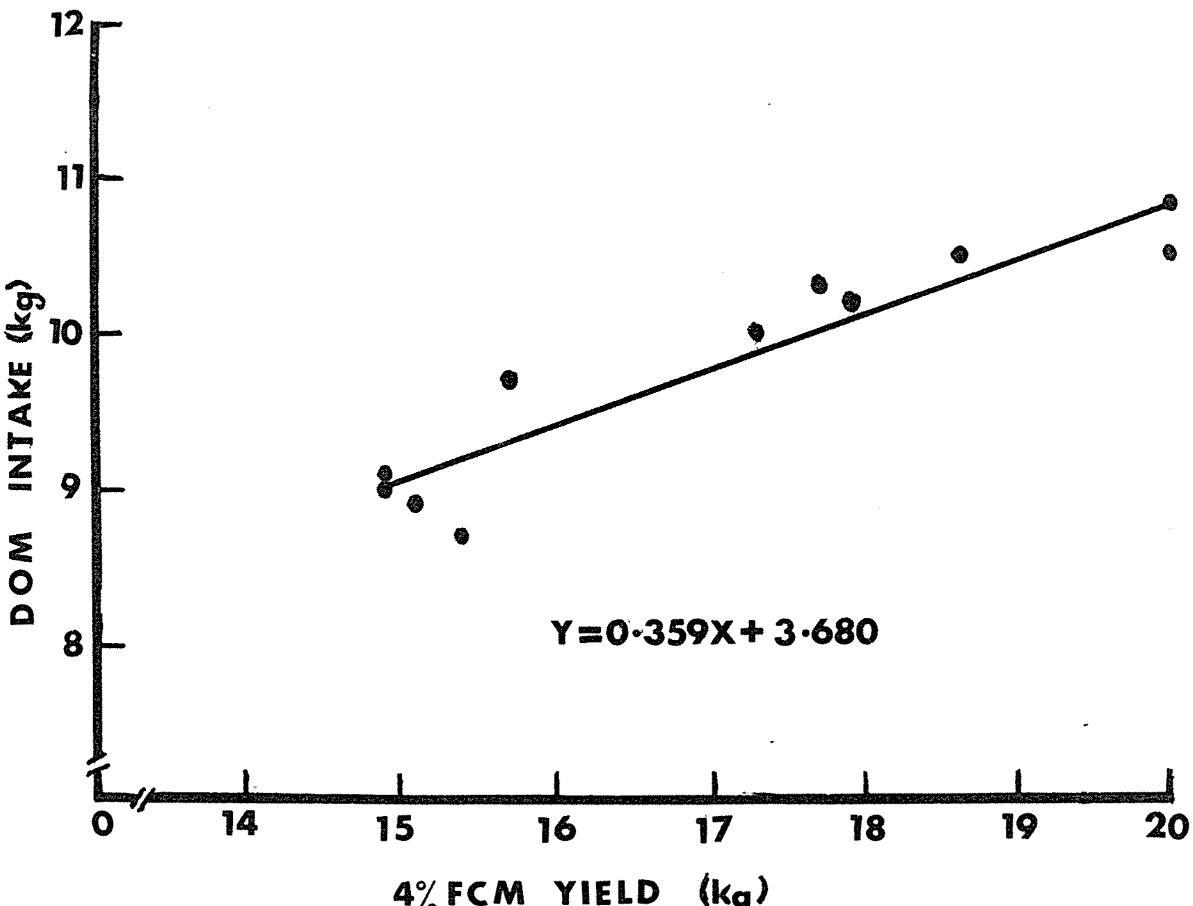
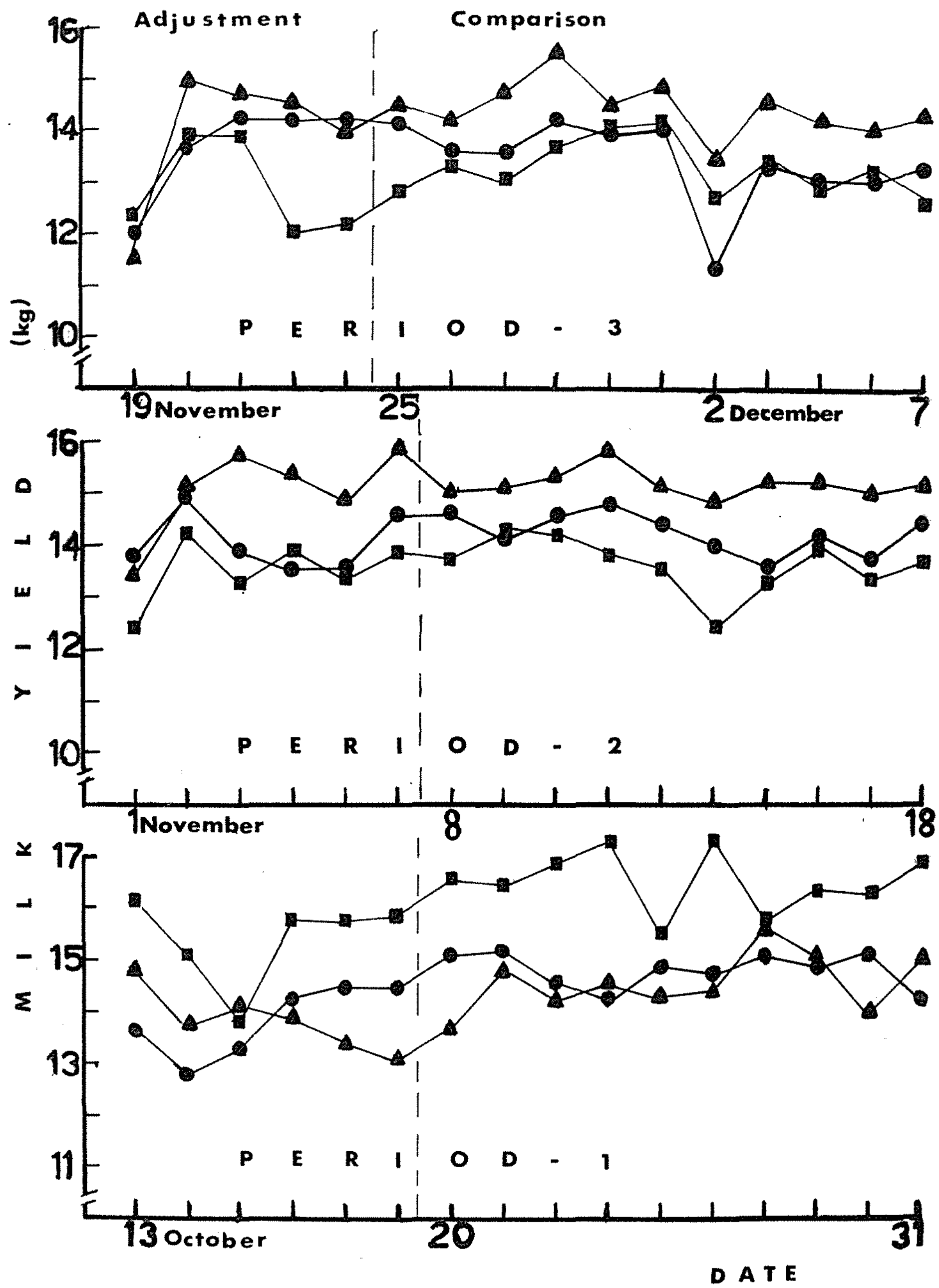


Fig.8: Relation between the DOM intake and 4% FCM yield.



Change in milk yield/cow/day, ●—● A, ▲—▲ B & ■—■ C.