SUPPLEMENTARY FEEDING FOR DAIRY PRODUCTION IN THE TROPICAL REGIONS OF AUSTRALIA

1. REVIEW OF THE LITERATURE

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INTRODUCTION

A review of the use of supplementary feeding with particular reference to the temperate regions was conducted by Leaver, Campling and Holmes (1968). Lamond (1968) outlined the important aspects which should be considered when supplementing dairy cows grazing tropical pastures. The aspects considered by Lamond as well as several others are reviewed in this paper.

In the absence of a satisfactory definition of "energy" and "protein" supplements, feeds of greater than 20% crude protein (CP) have been regarded as protein supplements and feeds of less than 20% CP regarded as energy supplements. Whilst the inadequacies of this definition are recognised, it is believed that it is a useful definition inasmuch as most experimentation to date has been of an empirical nature with the roughage source rarely defined either quantitatively or qualitatively.

PROTEIN SUPPLEMENTS

Vegetable protein

It is perhaps trite to separate the responses obtained following supplementation into those caused by "energy" supplements and those caused by "protein" supplements when the roughage source is rarely defined, and that consumed by the grazing animals has never been defined. However, under the above definition of "protein supplements" the CP level of a protein supplement will exceed that of the pasture under almost all conditions. In this sense they can validly be regarded as protein supplements.

Neither Joblin (1966) nor Muffrih (1968) could detect any differences in production following the feeding of a protein supplement to cows grazing on tropical pastures. Silva, Barbosa and Tavares (1966) provided cows grazing *Hyparrhenia rufa/Panicum purpurascens* pastures with maize and cottonseed meal either singly or in combination. The cottonseed meal supplement produced more milk than the other supplements, although the difference was not significant. A recommendation against the use of high protein supplements emanated from Hunkar and Smit (1968), although they suggested that low cow numbers may reduce the applicability of their work. However, the analysis of results used in their paper was based on observations that are not independent; thus whilst the trends they found may be important, the tests of significance used involved a conservative estimate of error and therefore placed more significance on differences than is actually the case.

In Australia two grazing experiments have been conducted on the subtropical eastern coast, comparing the value of protein supplements. Hamilton *et al.* (1970) fed cottonseed meal and sorghum singly and in combination. They found no response specifically attributable to protein and a linear correlation ($r=0.96$, $P < 0.01$) between 4% fat corrected milk (FCM) production and digestible dry matter intake. A similar conclusion was reached by Royal and Jeffery (unpublished data) when maize and soybean meal were fed either singly or in combination to cows grazing nitrogen fertilized kikuyu dominant pastures in winter. The response obtained was described by the equation:

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$$Y = 7.67 + 0.464\ X\ (r = 0.964,\ P < 0.001)$$

where Y = milk production (kg/cow/day) and X = amount of dry matter supplement fed (kg/cow/day).

There was no significant curvature associated with this response.

Thus in none of the experiments conducted with grazing cows in tropical or subtropical environments was a response specifically to protein supplementation demonstrated. This is a reflection of the conditions under which the experiments were conducted rather than an indication that protein supplements have no place in tropical dairying. The results of studies by Milford (1960), Glover and Dougall (1961), Hardison (1966) and Jeffery and Holder (1971) indicate that under many conditions a response specifically to protein could be anticipated.

Non-protein nitrogen

The testing of non-protein nitrogen (NPN) as a component of diets for dairy cattle is being studied increasingly, reviews of which have recently been published (Loosli and McDonald 1968; Helmer and Bartley 1971). As there is little experimental evidence that can be added to these reviews, there would be little point in further reviewing this subject. The major conclusions reached appeared to be:—

(i) NPN can replace part of the protein in rations—a palatability problem generally occurs if more than 1 or 2% of the supplement contains urea.

(ii) The use of NPN may result in equal milk production to that obtained from a vegetable protein supplement, but it is unlikely to exceed it; in most cases a lowered production occurred.

(iii) When fed with a high quality roughage source there will be little response to NPN supplementation.

Helmer and Bartley (1971) discussed the difficulty of interpreting results because of their variability. They suggested that, in part, this may have been due to the use of low producing cows in early studies. A further factor which may increase the variability is the large variation between cows in their consumption of NPN containing rations. The factors discussed above would indicate that where high quality pastures are being fed a positive response to NPN supplementation could not be anticipated. If the pastures are of low CP content, the use of supplements containing more than 2% urea may result in palatability problems. Various other NPN compounds, including biuret and ammonium compounds can be used. Loosli and McDonald (1968) concluded that the only advantage of biuret over urea was lower toxicity. Ammonium salts have proved satisfactory NPN sources in a number of studies, but Loosli and McDonald (1968) concluded that whilst relatively satisfactory results may have occurred in feeding tests, none of the other NPN sources they examined were better than urea.

ENERGY SUPPLEMENTS

Level of fibre

French and Bodisco (1963) and Payne (1966) suggested that a negative relationship may exist between fibre level in a supplement and milk production response. Tsai *et al.* (1967) found a 6% increase ($P < 0.01$) in production from cows fed a low fibre supplement (8.8%) when compared with a "control" supplement (15.2%). More recently Stanley *et al.* (1969) have suggested that high fibre-high energy supplements may be the optimum combination for feeding in the tropics In three experiments they reported significant increases in butterfat production from cows given high fibre diets in Hawaii, but in one of these experiments the milk production from the high-fibre group was less than that from the low-fibre group. The effects of level of fibre in the supplement on response to supplementation are at this stage unclear.

Type of energy supplement

Few studies compared different types of energy supplements in tropical or subtropical areas. Thus a number of experiments conducted in the temperate areas have been included in Table 1 for comparison. The table lists the type of energy supplement and the response obtained. This table has been divided into results obtained in tropical and temperate regions.

TABLE 1

Response to Different Energy Supplements

Types of Supplement	Response	Reference
Tropical		
Simple and complex concentrate	Simple mix produced 4% more milk, equal FCM	Randel (1965)
Maize and molasses replaced maize in concentrate mix	No differences detected	Gilani and Sial (1968)
Mix varied from 15-30% molasses, 20-5% Maize		
Maize and molasses	Maize produced 24% more milk	Rodriguez and Preston (1969)
Wheat, oats, sorghum, maize and barley	No differences detected in milk or FCM production. Differences in butterfat and protein content observed	Jeffery and Buesnel (1971) (unpublished data)
Wheat, sorghum and dried molasses	No differences in milk or FCM production between the grains. Molasses supplement produced less milk, however, incomplete consumption of this feed, especially with Jerseys occurred	Jeffery and Buesnel (1971) (unpublished data)
Temperate		
Barley, maize and sorghum	No differences detected	Malossini (1963)
Mixed grain, maize	No differences detected	Pratt and Conrad (1965)
Milo and barley	No differences detected in milk production. Milo gave higher butterfat %	Brown *et al.* (1966)
Wheat, corn, barley, milo, oats and mixed concentrate	No differences in milk or FCM production	Tommervik and Waldern (1969)
Barley, wheat, mixed feed and mixed concentrate	No differences in milk or FCM production	Waldern and Cedeno (1970)

No differences in response have been found when different grains were compared in either subtropical or temperate areas. The only differences reported have been between either simple and complex mixes or molasses and grain. The small difference recorded between the simple and complex mixes (Randel 1965) may have been attributable to a greater intake of the simple mix. As the net energy of molasses is likely to be lower than that of maize (Nehring, Schiemann and Hoffman 1967), the response obtained by Rodriguez and Preston (1969) is not surprising. Also, if protein content of the roughage was low, molasses could not have provided any extra protein, whereas maize would have. Either or both of these factors could have contributed to the greater response from maize. The failure to detect differences in the studies conducted in temperate zones would allow the conclusion that with the exception of molasses, energy source is unlikely to have an influence on response to supplementation.

Influence of roughage source

Little work has been conducted under tropical or subtropical conditions investigating the influence of providing supplementary roughage. A number of comparisons of summer growing species, fed as hay or silage, exist. Some of this work has been conducted in tropical areas. Stanley and Morita (1966) found no differences in production when pineapple silage was used to replace pineapple bran in a ratio of 5:1. The amounts of silage fed were 0, 6.8, 13.6, 20.4 and 27.2 kg. Stanley, Morita and Ueyama (1964) examined diets of (a) pineapple bran (4.5 kg) plus concentrate; (b) diet (a) plus 2.91% sodium acetate; and (c) pineapple bran (5.4 kg), concentrate and napier grass (*Pennisetum purpureum*). No differences in milk production were observed. Daniel, Bhosrekar and Mullick (1969) compared production from cows fed concentrate (1 kg/3 kg milk) with the roughages *Medicago sativa, Avena sativa* silage, napier grass and maize. No differences were reported. A comparison of the silages of napier grass, maize and sorghum fed in conjunction with concentrates, resulted in significantly more milk (11%) being produced from the maize silage/concentrate feed (Soussa Lucci *et al.* 1968).

Temperate species have also shown differences in their ability to support production from cows supplemented with an energy concentrate (Clifton, Miller and Cameron 1963; Rollins, Hoveland and Autrey 1963; Stoddart and Anderson 1965) whilst Murdock and Hodgson (1969) could not detect any differences in production that could be attributable to source of roughage.

Level of feeding

The response obtainable from cows grazing under temperate conditions has been reviewed by Leaver, Campling and Holmes (1968). Other than the publications they reviewed I am aware of only three others which included grazing dairy cows supplemented at more than one level of feeding. In Brazil, Aronovich *et al.* (1966) reported the results of an experiment which involved feeding cows on *Digitaria decumbens* (Pangola) pasture, Pangola plus 1 kg concentrate/3 kg milk produced in excess of 3 kg milk and Pangola plus 1 kg concentrate/3 kg milk. Respective FCM productions were 9.9, 10.6 and 11.6 kg/day. Monti and Tellechea (1966) found that grazing cows in Argentina not supplemented or supplemented with 1 kg grain (millet + sorghum, 1:1)/4 kg FCM or with 1 kg grain/8 kg FCM exhibited no difference in their milk production.

Vohnout *et al.* (1968) fed cows five levels of molasses ranging from 0 to 3 kg/head/day. The cows were grazing Pangola, guinea (*Panicum maximum*) and molasses (*Melinis minutiflora*) grasses. A linear correlation ($r^2 = 0.97$) related the amount of molasses fed to digestible energy intake. In a second experiment cows were fed either 0.47, 0.74 or 1.01 kg of TDN per 4 kg of FCM. It was estimated that the amount of supplement provided to the 1.01 group may have been excessive and that to the 0.47 group inadequate. Maximum economic return was obtained from the 0.74 group. Both the 0.74 and 1.01 groups produced more milk than the 0.47 group.

The determination of the response curve of milk production to varying forage: grain ratios in temperate areas has been reviewed by Miller and O'Dell (1969). These authors regarded the response as consisting of a family of curves; the elevation of the curves being dependent on the quality of the forage. As the quality of tropical forage is in general lower than that of temperate forage, it could be anticipated that varying these ratios will have a greater influence on production in the tropics. The wide variation in results obtained in the above experiment and those reported by Leaver, Campling and Holmes (1968) support this contention.

Further implications from the response curves suggested by Miller and O'Dell (1969) are that a model which includes definition of pasture, forage: grain ratios and cow effects should fairly accurately predict responses.

Stage of lactation and level of production

It is commonly recommended that cows should be fed early in their lactation in order to obtain the maximum response from supplementary feeding. Also, it is generally claimed that the highest yielding cows will give the greatest response to supplementary feeding. Stage of lactation (S) and level of production (L) are highly correlated; L has been expressed in terms of S by Gaines (1927) and Wood (1967). As these two factors are confounded with each other it is not clear whether the response will be affected by S or L, or S and L.

Blaxter (1959) and Broster (1963) concluded that the response of a cow to supplementation was directly proportional to initial yield. These conclusions are supported by a number of experiments reported in the literature, but there are some results which do not agree.

Regression analysis of the data of Jensen *et al.* (1942) and Jawetz (1955) reveals partial correlations of 0.551 (NS) and −0.943 ($P < 0.05$) relating milk yield/day with the response/lb additional starch equivalent (SE) if the amount of SE fed per 4.5 kg of milk is held constant. That is, a positive and a negative relation between L and response was obtained. These results are not conclusive but suggest that factors other than L may be operational in determining the response obtained. If the response is proportional to L then an interaction between L and plane of nutrition could be anticipated. Bloom *et al.* (1957) could find no evidence of such an interaction. McCullough and Neville (1960) stated that S had no effect on response when initial milk production was considered. Moberly (1965, 1966) reported a greater response to supplementation with high producers than low producers. However, examination of the figure presented in Moberly (1965) suggests that much of this difference may have been attributable to different milk productions between the groups at the commencement of the experiment. Visual estimation of the mean response to maize meal after 10 weeks, if initial production is considered is 1.9 kg and 1.4 for the low and high groups respectively. Mather *et al.* (1960) reported a greater response to the first increments of grain from cows with high production potential. These results were somewhat confounded with the amount of grain fed, though when corrections were made for this the same conclusion was reached.

The results of Stanley *et al.* (1969) are more difficult to interpret. Cows were grouped according to level of production during a standardization period and results are presented in Table 2.

TABLE 2

Effect of level of production on milk production response to Cottonseed Meal. Data from Stanley et al. (1969)

Level of Milk Production in Standardization Period (kg milk/cow/day)	Cottonseed-Control (kg milk/cow/day)
> 24.9	—3.3
20.4 — 24.5	—1.2
15.9 — 20.0	—0.1
< 15.9	1.7

The milk production of cows producing in excess of 15.9 kg milk/day was depressed by the cottonseed meal supplement, however, cows producing at a low level received a stimulus from the cottonseed meal supplement. If the relation between response and L is assumed to be linear than it would appear that the regression would have an intercept different from zero. This does not support the theory of proportional response-although it does indicate a possible relationship between L and response.

McCullough and Neville (1960) stated that neither L nor S were significant factors affecting percentage response of cows on similar qualities of pasture or silage. The cows in this experiment had their roughage diet supplemented with grain at a constant ratio (generally 1:4); thus if cows producing more milk consumed greater quantities of feed, then they would have consumed more supplement. For this reason the results are difficult to interpret, the only conclusion that can be reached, if it is assumed that consumption increased with milk production, is that the results tend not to support the proportional response theory.

An experiment reported by Jeffery (1970) and two further reversal experiments conducted by Jeffery and Buesnel (unpublished data) have been analysed in an attempt to separate the effects of L and S on response. Response was measured as the difference between production when a cow received a supplement and when she did not, with a correction for period effect. In the analysis of these experiments no significant relationships between response and L or S either singly or in combination could be demonstrated ($P > 0.22$).

The response of a cow to supplementary feeding is not always proportional to production. This relationship may be stronger under temperate conditions though several exceptions to the rule have been cited especially from experiments conducted in the tropics and subtropics. For elucidation of the animal factors affecting the response more experimentation is required.*

Breed

The response of Jersey and Holstein cows to low fibre supplements, when provided with fresh forage *ad lib.* were compared by Clark *et al.* (1968). The treatment reduced the butterfat percentage of the Jerseys by 12% and the Holsteins by 23%. This difference was ascribed to genetic differences between the breeds.

Time of feeding

A comparison of feeding a supplement before, during and after milking resulted in no differences in milk production between the groups (Suzuki 1964).

MINERALS

Several comprehensive reviews covering the use of mineral supplements with lactating dairy cows have been recently published. The following is a list of reviews and papers on a range of minerals: calcium, phosphorus and vitamin D (Smith, Holck and Spalford 1966; Hibbs and Conrad 1966), copper and cobalt (Ammerman 1970), iodine (Hemken 1970), iron and manganese (Thomas 1970), nickel (O'Dell *et al.* 1970), potassium (Pradhan and Hemken 1968), selenium (Hogue 1970) and zinc (Miller 1970). It would be tedious to attempt to review even part of the literature covered in these papers and the reader is referred to them for further details.

*In a recent experiment at Grafton (Jeffery, Buesnell and O'Neill, unpublished data) cows at four levels of production (7 to 14.1 kg milk/day) were fed one of five levels of concentrates (3 to 8.3 kg/cow/day). Low producing cows did not respond to increased feeding of concentrates, but high producing cows increased in production up to 6 kg concentrate per cow per day.

McDonald (1968) reviewed the mineral requirements of the grazing animal and as well as reviewing most of the above minerals he also considered magnesium, sodium, chlorine, molybdenum and fluorine. McDonald could find no evidence of primary calcium deficiencies in grazing ruminants and no evidence of responses specifically to chlorine, fluorine or iron. Diseases occur which respond to manganese, but if it exists, manganese deficiency is rare. Apart from primary or simple mineral deficiencies or toxicities, this group of nutrients have the ability to either ameliorate or exacerbate conditions caused by other minerals. For this reason requirements of the milking animal are ill defined (Agricultural Research Council 1965). This is caused by difficulty in:—

(i) measuring the utilization of absorbed minerals.
(ii) determining the availability of ingested minerals.
(iii) interactions between many of the minerals.
(iv) the chelation which occurs.

The stability of the complexes formed follows the Irving-Williams series, Mn < Fe < Co < Ni < Cu > Zn (Thomas 1970).

PREPARTUM FEEDING

Heifers have a large growth requirement and restriction of feed prior to the first calf may not only affect lactation performance, but also growth rate and size of the animal at calving. A cow's weight increases until she is six to nine years old, depending on breed, and at least 80% of the total mature weight will be normally reached by the time she has her second calf (Brody 1945). Thus cows which have already had one or more calves are considered separately from nullipara as it seems likely that an effect on their growth rate would be less important than one on nullipara.

No experiments have been conducted in the tropics or subtropics examining the effects of prepartum feeding, thus all examples in the following section have been obtained from temperate region studies.

Feeding nulliparous animals

The results of a number of experiments in which nullipara have been fed at different levels and milk production figures obtained are presented in Table 3. Broster (1963) concluded that within limits of ± 15% of "normal" standards of feeding for growth little effect is observed on subsequent yield. The results of experimentation have tended to support this, although with the relatively large errors involved in most of these experiments, treatment effects must be fairly large in order to detect differences, e.g. assuming a coefficient of variation of 20%, 29 replications are required for an 80% chance of detecting a 15% difference between the means (Cochran and Cox 1957).

TABLE 3

The effect of level of feeding on nulliparous animals

Precalving Treatment	Response	Reference
Experiment commenced 3 months before calving A. 6 heifers on low plane of nutrition B. 6 heifers on high plane of nutrition	FCM production B > A	Jarl (1940)
1st Experiment Heifers fed 1 month prior to calving	Milk production	Bonnier, Hansson and Skjervold (1948)
A. 65-70% Swedish standards	1st lactation B > A (288 kg)	
B. 120-135% Swedish standards	2nd lactation B > A (259 kg)	

TABLE 3 (continued)

Precalving Treatment	Response	Reference
2nd Experiment		
A. 75-90% Swedish standards B. 110% Swedish standards	No differences detected	
Heifers reared on the following A. Low plane of nutrition B. Normal plane of nutrition C. High plane of nutrition	Milk production 1st lactation A and C > B 2nd lactation A and C > B	Hansen and Steensburg (1950)*
Monozygous twins fed from 3 months A. Normal rations (no grain after 12 months) B. *Ad lib.* grain	Milk production 1st lactations A > B (by approximately 100%)	Swanson and Spann (1954)
From 4 to 24 months A. Restricted ration (66% TDN supplied to "B") B. Normal rations	Milk production 1st lactation B > A 2nd lactation B = A	Swanson and Hinton (1962a)
Experiment commenced 6 weeks precalving A. Restricted grazing of sparse sward B. Generous grazing + 3.6 kg/cow/day concentrates	Milk production 3-30 weeks from calving B > A	Foot, Line, and Rowland (1963)
102 heifers reared from birth to calving A. 62% Morrison's standards B. 100% Morrison's standards C. 146% Morrison's standards	Milk production No differences over the first 4 lactations	Reid *et al.* (1963)
From 7 weeks precalving Hay *ad lib.* to all groups Starch Equivalent Crude Protein A. 1.08 0.18 B. 1.18 0.64 C. 3.60 0.60 D. 3.58 1.90	FCM production (kg/animal/day) 1st 66 days A. 17.4 kg B. 17.6 kg C. 17.8 kg D. 17.7 kg	Broster, Tuck and Balch (1964)
From 8 weeks precalving A. Generous spring grazing B. 66% of allowance of A	Milk production No differences over first 8 weeks of lactation	Broster and Tuck (1967)
From birth to calving, 3 groups A. Normal rations B. 70% TDN of A to 91 weeks 12 weeks prepartum received concentrates	FCM production (kg), 1st lactation A B Identical twins 3403 3501 Holstein 4696 4796 Jersey 2837 3337	Swanson *et al.* (1967)
From 21 days prepartum to 5 days post partum A. No grain feeding prepartum B. Received additional 220 kg grain/animal overall	Milk production First 7 weeks of lactation B > A (1.2 kg/animal/day	Emery *et al.* (1969)

*Results may be subject to bias as not all animals completed the experiment (Burt 1956)

In the experiment of Swanson and Spann (1954), not only was production lowered from the overfed group, but also their productive life was shortened. Although some doubt was placed on the reliability of the experiments of Hansen and Steensburg (1950) by Burt (1956) it tends to demonstrate the variable responses that can occur. This variability is evident from the results of Bonnier, Hansson and Skjervold (1948) who detected differences in production between two levels of nutrition and repeated the experiment with slightly changed levels of feeding, but could detect no differences in the second experiment.

It was concluded by Burt (1956) that as long as very early nutrition and nutrition in late pregnancy was adequate, then "underfeeding" was unlikely to have detrimental effects. The experiment of Swanson *et al.* (1967) supported this conclusion, and demonstrated how feed savings of 20-25% may be achieved without depressing production.

Feeding cows in late pregnancy

The effects of late pregnancy feeding tend to be less marked than those caused by altering the plane of nutrition in the growth phase of the animals (cf. results of Emery *et al.* (1969) in Table 4). Broster (1963) stated "underfeeding any animal prior to calving will reduce its milk yield". However, Greenhalgh and Gardner (1958) pointed out that true "steaming up" should be compared with normal feeding and not underfeeding, as it often has been. When compared with "normal" rations, the advantages of steaming-up are not always apparent. The results of a number of experiments comparing levels of nutrition in late pregnancy are listed in Table 4.

TABLE 4

The effect of varying levels of nutrition in late pregnancy

Precalving Treatment	Response	Reference
2 months prior to calving A. 1.8 kg grain/cow/day B. 5.4 kg grain/cow/day	Milk production A = B	Woodward, Shephard and Graves (1932)
6 weeks prior to calving A. Normal rations B. Feeding 0.9-2.7 kg concentrates/cow/day C. Equivalent roughage to "B"	Milk production B > A in weeks 3, 5 and 7 of lactation	Blaxter (1944)
3 year experiment 10-13 weeks precalving A. Sparse pasture + 1.4-3.6 kg hay/cow/day B. Generous pasture + hay and silage *ad lib.*	Butterfat yield kg/cow B > A Year 1 Year 2 Year 3 12 29 27	Lees, McMeekan and Wallace (1948)
3 year experiment 10 weeks precalving A. Sparse pasture + 3.2 kg hay/cow/day B. Generous pasture + hay and silage *ad lib.*	Butterfat yield kg/cow B > A Year 1 Year 2 Year 3 10 13 11	Campbell and Flux (1953)
6 weeks prepartum A. 171 kg grain B. 124 kg grain (control)	First 84 day FCM production (kg) A B 1655 1658	Greenhalgh and Gardner (1958)

TABLE 4 (continued)

Precalving Treatment	Response	Reference
3 year experiment 2 × 2 factorial 1st factor High and Low nutrition in last 3 weeks pregnancy 2nd factor High and Low nutrition for first 84 days of lactation	305 day milk yield HH HL LH LL 3728 3706 3668 3061	Broster (1958)
2 year experiment 8 weeks precalving A. Nil grain B. 2.7 kg/cow/day C. 6.8 kg/cow/day	Whole lactation FCM production (kg) A. 5501 B. 5498 C. 5507	Schmidt and Schultz (1959)
2 × 2 factorial 1st factor: High and Low nutrition in last 5 weeks (168 v 81 kg/cow) 2nd factor: High and Low feeding till spring grazing (0.41 v 0.22 kg concentrate/litre)	Whole lactation milk (kg) HH HL LH LL 4000 3388 3796 3596	Castle and Watson (1961)
136 kg grain in latter part of lactation 136 kg grain in 6 weeks precalving Roughage only in dry period Roughage and concentrate (137 kg) in dry period	3583 kg milk (1st 30 weeks of lactation) 3435 kg milk (1st 30 weeks of lactation) 3383 kg milk (1st 30 weeks of lactation) 3650 kg milk (1st 30 weeks of lactation)	Swanson and Hinton (1962b)
12 weeks precalving A. 2 kg hay/cow/day B. 2.3 kg concentrate/cow/day + hay *ad lib.* C. 12 kg concentrate/cow/day + hay *ad lib.*	12 weeks FCM production (kg) A. 1945 B. 1885 C. 2167	Davenport and Rakes (1969)
3 year experiment A. 2 months prepartum to 5 days post partum. Nil grain. After 5 days post partum *ad lib.* grain B. Grain offered *ad lib.* from 21 days prepartum	Milk production (kg/day) *Heifers* *Cows* A. 20.2 30.8 B. 21.4 31.1 P < 0.01 N.S.	Emery *et al.* (1969)
2 × 2 factorial 1st factor: 115 v 160% digestible energy requirements 6-8 weeks precalving 2nd factor: High v "normal" postpartum feeding	305 day milk production (kg) HH HL LH LL 6534 6223 7002 5600	Gardner (1969)
5-7 weeks precalving A. *Ad lib.* hay + concentrates 3 weeks precalving B. Complete feed 10-14 kg/day Increased to appetite after calving C. Diet "B" + vitamin B_{12}	Daily milk production (kg) 9 week mean A. 20.1 B. 19.6 C. 20.0	Walker and Elliot (1969)

Interpretation of the results in Table 4 is difficult with so many factors being confounded. Attempts have been made to investigate the reasons for the response obtained. Blaxter (1944) obtained a correlation between the farmers assessment of condition at calving and production at the fifth week of lactation ($r = 0.612$, $P < 0.01$). Schmidt and Schultz (1959) obtained a correlation of 0.04 between condition rating at calving and 12 week FCM production. Davenport and Rakes (1969) reported a correlation between adjusted beginning weight (a measure of condition) and FCM production of 0.439 ($P < 0.01$). In both cases where the correlation between milk production and condition at calving was significant, differences in production occurred. These results are in agreement with the hypothesis that under conditions where a true weight gain during pregnancy is recorded little effect will be obtained from steaming-up and hence low correlations between milk production and condition would occur. However, if harsh treatments are imposed on one group resulting in underfeeding, differences in production and consequently higher correlations between condition and production will be obtained.

Burt (1956) suggested that a greater response per unit weight of supplement fed may be obtained to precalving than to post calving supplementation. These results were based on the results of three experiments, although the two with the greatest responses (Woodward, Shepherd and Graves 1933; Blaxter 1944) involved underfeeding (Greenhalgh and Gardner 1958).

To draw conclusions from these results is difficult, but the trends which appear to emerge are that under conditions when the "control" or normal diet is nutritionally a "reasonable diet" and hence true liveweight gains occur then virtually no response in milk production will follow precalving supplementation. If, the control diet causes liveweight losses prior to calving, the response to supplementation will be large. Thus the experimenter is under the obligation to use a reasonable control diet, in that if this diet is a biased selection the results will be meaningless to the area they are intended to help.

As no experiments involving prepartum feeding have been conducted in tropical or subtropical zones no conclusions can be drawn about the effects feeding may have on production. Until experiments are conducted a fairly safe recommendation for these areas would appear to be that precalving feeding should be used only if the cows are losing true body weight prior to calving.*

CARRYOVER EFFECTS

One of the most difficult features of experimentation with supplementary feeding is the evaluation of carryover effects from feeding a supplement. Broster (1958) suggested that carryover effects are important and their existence seriously limits the interpretation of short term experiments. Carryover effects have been recorded in some long term experiments with grazing animals (Moberly 1966; Broster, Broster and Smith 1969) although Mather *et al.* (1960) and Laird and Walker-Love (1962) could find no evidence of these effects in experiments lasting for complete lactations. Even though provision for detection of these effects can be incorporated into short term experiments (Patterson and Lucas 1962), they have been rarely recorded. Lucas (1960) reviewed the advantages and applications of long and short term experiments. The advantages of short term experiments for grazing experiments were pointed out by Brockman and Gwynn (1961).

In any experimentation consideration of the possibility of carryover effects and the effect they may have on the conclusions of the study and its economic evaluation should be borne in mind. However, the sensitivity of changeover designs (Lucas 1960) make them a useful weapon in the armoury of the experimenter.

*After this review was written Broster (1971) published a most comprehensive review on prepartum feeding.

SYSTEMS

Many investigations have involved comparisons of systems. Although it is difficult to dissect the factors responsible for differences in production, from these systems, some discussion on their results seems desirable. Publications discussed in the review of Leaver, Campling and Holmes (1968) are not discussed in this section.

The feeding value of tropical grasses and their milk producing capacity has generally been considered as being low (Glover and Dougall 1961; Hardison 1966; Payne 1966; Hamilton *et al.* 1970; Jeffery and Holder 1971). The lower production obtainable from these pastures has generally been ascribed to low digestible energy intakes. Few experiments have compared systems of allocating supplements to animals on tropical or subtropical pastures. The results reported by Taylor (1941) present very high yields of milk and butterfat per hectare. Friesian and Jersey cows each grazed 0.4 ha of kikuyu (*Pennisetum clandestinum*). Two and three cows, respectively, of the breeds were maintained on the pasture with the addition of a further cow to either group when the pasture was growing very quickly. Each group was supplemented with 0.68 and 0.45 kg, respectively, of maize meal at each milking. A summary of Taylor's results are presented below.

Average results over 7 years

	Friesians	*Jerseys*
Superphosphate (kg/ha)	321	321
Sulphate of ammonia (kg/ha)	640	609
Muriate of potash (kg/ha)	39	39
Maize meal fed per ha (kg)	1,917	2,057
Milk yield per ha (kg)	12,137	12,811

Colman (1970) reported increases in production of 92 and 45 kg butterfat/ha following the supplementation of cows grazing on kikuyu at a stocking rate of 4.94 cows/ha. Cows on this stocking rate and receiving supplementation (369 and 419 kg crushed oats/cow/lactation respectively) produced 540 and 406 kg butterfat per ha. Blydenstein *et al.* (1969) using a variable stocking rate technique recorded a production of 6014 kg milk/ha from cows grazing Pangola grass fertilized with urea (100 kg/ha), potassium chloride (150 kg/ha) and triple superphosphate (80 kg/ha). The cows (Criollo, Jerseys and Crosses) received 1 kg concentrates/4 kg milk produced. Thus, although the feeding value of tropical pastures has been generally regarded as being low, under some conditions and particularly with the use of supplements very high levels of production per hectare have been recorded.

Moberly (1966) used maize meal as a supplement for grazing dairy cows. The meal was supplied over a period of 10 weeks and the mean production of supplemented and unsupplemented cows (24 weeks average) was 9.3 and 6.3 kg milk/cow/day. Castro (1967) compared the production of cows receiving a supplement of ground maize ears and cottonseed meal plus *ad lib.* sugar cane, maize silage or a mixture of these two roughages. No differences in production were recorded.

In a two-year experiment conducted at Wollongbar involving the grazing of cows on a *Glycine wightii*/kikuyu pasture in which half the cows received a supplement (crushed oats) according to their production, the mean increase in butterfat/cow was 43% for the two years, (Jeffery *et al.* 1970). In the experiment reported by Jeffery (1970) a response of 1 kg FCM/cow/day was obtained from cows receiving 2.7 kg crushed oats a day and grazing mainly kikuyu pastures. This represented a 13% increase in production. At Grafton, on the North Coast of New

South Wales a response of 1.2 kg milk/cow/day was obtained from cows grazing a mixed sward comprised mostly of tropical species and receiving 3 kg concentrate mix/day (Jeffery and Buesnel, unpublished data). This represented an 8% increase in production.

CONCLUSIONS

High levels of production per hectare can be obtained from dairy cows grazing tropical and subtropical pastures. Relatively few experiments have been conducted with grazing cattle in the tropics and subtropics, hence, until results come from these regions, the results from temperate pastures must form the guide lines within which recommendations are made. The major conclusions from this review are:—

(i) Although it is recognised that at times the cow will be grazing pastures of low CP content, in general, energy supplementation will be the most economical form of supplementation.

(ii) The type of grain supplement used is relatively unimportant.

(iii) At low levels of supplementation ($\leqslant$ 3 kg/cow/day), there is little evidence available to suggest that the response to supplementation is proportional to production.

(iv) Experimentally it has been difficult to demonstrate that prepartum supplementary feeding of cows gaining true body weight (as distinct from live-weight which includes foetal growth) will yield increases in milk production.

Empirical methods of experimentation have been adopted by most experimenters. Results from these experiments are valuable in regional research but do not make large contributions to an understanding of the animal-supplement-pasture complex. Consideration should now be given to the future role and direction of experiments involving supplementary feeding. In this regard single factor and factorial approaches to experimentation may prove most efficient.

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