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# NUTRITION OF THE PRE-RUMINANT CALF

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## SUMMARY

The characteristics of milk and milk substitutes as feeds for the pre-ruminant calf are discussed. Particular reference is made to the effects of high heat treatment of milk powders on their value to the young calf.

Estimates of the energy and protein requirements of the pre-ruminant calf are discussed. There is considerable variation in the estimates of energy requirements between workers, but it is considered that the existing standards provide a more satisfactory basis from which to derive requirements for milk and milk substitutes than do "rule of thumb" methods.

The method of rearing calves where milk is restricted and calves are weaned early on to a concentrate and pasture diet, is discussed in relation to the amounts of milk fed.

## INTRODUCTION

The young calf like the adult ruminant has a stomach of four compartments, although the rumen in the calf at birth is largely non-functional. In the adult, the volume of the rumen accounts for about 80% of the total stomach volume, whereas, in the non-ruminant calf, the rumen accounts for only about 30%.

Liquid feed does not enter the rumen in the young calf but is diverted via the oesophageal groove to the abomasum. Enzyme digestion begins in the mouth and the abomasum and continues in the intestines.

The non-ruminant calf can only satisfactorily utilize milk proteins, lactose, glucose and milk, vegetable or animal fats, when these are given in liquid form. However, if calves are allowed access to dry feeds such as concentrates, hay or pasture, the rumen develops rapidly; the walls thicken, the epithelium becomes highly papillated, and the rumen increases in capacity. This development is hastened if whole milk or milk substitutes are fed at restricted levels but is delayed if the calf is fed large quantities of milk or milk substitutes. Provided development has been encouraged, the rumen is able to carry out much of the digestive functions of the adult rumen by the time the calf is 5 weeks old, although at this stage the rumen will not have reached its full capacity relative to the size of the animal. Thus although the feeding of milk may be discontinued at this stage, the calf must be offered feeds of high density and high digestible energy concentration, such as concentrates and leafy pasture although leafy pasture alone is unsatisfactory at this stage (Byford, 1974). Reviews on calf nutrition have been published by Preston (1963), Radostits and Bell (1970), Roy (1970a, b), Ralston (1971), and Gorrill (1972).

The purpose of this review is to consider the energy and protein requirements of the pre-ruminant calf, and the value of whole milk and milk substitutes in supplying these requirements.

## CALF DIETS

### Colostrum

Colostrum contains a high concentration of immunoglobulins and the calf receives antibodies from this source. The gut of the calf is permeable to large molecules for a period of 24 to 36 h following birth (Simpson-Morgan and Smeaton, 1972). Evidence provided by Kruse (1970) indicates that the absorption of macromolecules diminishes steadily following birth. Thus for maximum disease protection, calves must receive colostrum as soon after birth as possible. The importance of this cannot be over emphasized.

### Milk and Milk Substitutes

Milk substitutes have, as their base, buttermilk powder or skim milk powder with added fat (generally tallow in New Zealand) together with vitamins and minerals. Buttermilk powder is also often used alone, but skim milk powder because of its low fat content needs to be fortified with fat. The use of emulsifiers and adequate homogenization is necessary to ensure that the globule size of the incorporated fat is kept to a minimum. The use of antioxidants to prevent oxidation of fats is also desirable. The subject of the use of fats in milk substitutes has been reviewed in detail by Radostits and Bell (1970) and Raven (1970).

Some proprietary substitutes also contain antibiotics. There is a divergence of opinion as to whether they are necessary, and whether or not they contribute to the development of drug resistance.

Work carried out in the United Kingdom has shown that milk powders that have been subjected to high heat treatment during manufacture can have detrimental effects on calf health and liveweight gains (Shillam *et al.*, 1960; Shillam and Roy, 1963a, b; Shillam *et al.*, 1962a, b). Excessive heat treatment of milk powder denatures the whey protein fraction and results in a decrease in the concentration of ionizable Ca and a binding of the Ca.

Coagulation of milk by rennin, produced in the abomasum, ensures that the major protein fraction of the milk, casein, remains as a curd long enough to enable gastric digestion to proceed. This curd occurs in the presence of Ca ions and the firmness of the curd depends on the presence of these ions. Thus denaturation of whey proteins with a change in Ca is associated with poor clotting as well as a decrease in the rate of clotting. Thus proteins pass rapidly from the abomasum without sufficient gastric digestion occurring and the passage of abnormal quantities of undigested protein (Tagari and Roy, 1969) provides conditions which allow for the multiplication of colibacteria in the intestine.

The effects of excessive heat treatment of milk powders are summarized as follows (Roy, 1970c; Roy and Ternouth, 1972):

(1) The degree of denaturation of the whey proteins depends upon the severity and duration of the heat treatment.

(2) The feeding of milk replacers containing denatured whey proteins has caused a 30% reduction in liveweight gains of calves over the first three weeks of life.

(3) The rate of build-up of enteric infections when large numbers of calves are passed through a calf house is greater.

(4) The addition of Ca or chlortetracyclines to severely heat-treated skim milk powder does not counteract the deleterious effect on calves.

(5) Only low temperature pre-heating (77°C for 15 sec) before spray drying gave a product similar to that of whole milk.

Evidence of high heat treatment of New Zealand milk powders has been provided by Dr D. F. Newstead (pers. comm.) of the New Zealand Dairy Research Institute. He obtained six separate samples of a proprietary milk substitute based on buttermilk powder and found that two had been subjected to a high heat treatment, two to a medium-to-high heat treatment and two to a medium heat treatment. These results were based on a N.Z. Department of Agriculture (1971) test which estimates the degree of denaturation of whey proteins in the milk powders. It seems obvious that this area of calf nutrition requires investigation in New Zealand with the objective of controlling the quality of milk substitutes for calf feeding.

The composition of whole milk and two milk substitutes is given in Table 1.

TABLE 1: COMPOSITION OF MILK AND MILK SUBSTITUTES USED FOR FEEDING CALVES

| *Diet* | *Fat* | *Protein* | *Lactose* | *Ash* | *Dry Matter* |
|---|---|---|---|---|---|
| Whole milk | 4.5 | 3.3 | 4.5 | 0.7 | 13.0 |
| Buttermilk powder | 9.0 | 36.0 | 44.0 | 7.0 | 96.0 |
| Fat fortified milk substitute | 18.0 | 30.0 | 41.0 | 7.0 | 96.0 |
| Gross energy (MJ/kg) | 38.14 | 24.54 | 16.54 | | |

Obviously whole milk in particular varies in composition, and the values given in Table 1 are for purposes of illustration, and to provide a basis for determining the energy requirements of calves. A fat content of 9% has been assumed for buttermilk powder but the fat content varies around this value with different batches. The fat content of 18%, for the fat-fortified milk substitute, is similar to that for two well-known proprietary brands used for calf feeding. Other proprietary brands vary from as low as about 7% fat to 15% fat. Even a fat content of 18% is low compared with that for whole milk, and reconstitution of such a milk substitute to produce a mixture with a dry matter (DM) content similar to whole milk, would contain approximately 2.4% of fat.

Digestible energy (DE) values for milk and milk substitutes were calculated and are presented in Table 2.

The gross energy value of milk was calculated using the factors for the various constituents given in Table 1. These were the factors adopted by Blaxter (1952) from work by Andersen (1926). In calculating the DE content of the diets, a digestibility coefficient of 95% was assumed. While this was the value obtained for whole milk in experiments at Massey, it may be an overestimation for milk substitutes. Tallow

TABLE 2: DIGESTIBLE ENERGY VALUES OF WHOLE MILK AND MILK SUBSTITUTES AND THE ENERGY EQUIVALENCE OF MILK SUBSTITUTES TO WHOLE MILK

| *Diet* | *Digestible Energy (MJ)* | | *Energy Equivalence (ratio df DE in 1kg of powder to DE in 1kg milk)* |
|---|---|---|---|
| Whole milk (4.5% fat) | 23.9/kgDM | 31.0/kg milk | — |
| Buttermilk powder (9% fat) | 18.8/kgDM | 18.0/kg powder | 1.72 |
| Fat-fortified milk substitute (18% fat) | 20.5/kgDM | 19.7/kg powder | 1.57 |

has a lower digestibility than butterfat (Raven, 1970) and where heat treatment has denatured proteins the absorbed nutrients available would probably be reduced.

The data in Table 1, together with information on prices, enable a comparison to be made between whole milk and various milk substitutes on the basis of cost/MJ DE, *i.e.*, (Cost/kg)/(MJ DE/kg). The energy equivalence value in Table 1 also enables a comparison to be made between the cost of whole milk and the cost of milk substitutes.

At present (1974) it is cheaper to use whole milk than milk substitutes. However, there are many situations where only milk substitutes can be used. They are expensive feeds and the aim should be to use the cheapest substitute at the minimum rate, compatible with reasonable growth rates and good health of the calves.

## ENERGY REQUIREMENTS

### Liveweight Gains Required

Before describing the energy requirements of calves, various objectives in the rearing of calves need to be considered. The main purposes for which calves are reared are for beef and for herd replacements, although some calves may be reared for specialized veal production. Herd replacements need only gain about 0.5 to 0.6 kg/day, although this is an arbitrary level and is governed by such factors as the cost of feeds over the rearing period, and health of the animals.

The optimum rate of liveweight gain for calves intended for beef production has not been resolved but is probably greater than that for herd replacements because of the effects of the rate of early growth on subsequent liveweight. There is evidence (Everitt, 1972; Reardon and Everitt, 1972) for a close relationship between liveweight at weaning and liveweight at 400 days or more. In two of their experiments calves were fed restricted amounts of whole milk from birth to weaning so that liveweight gains were 0.38 and 0.44 kg/calf/day, or were fed whole milk so that liveweight gains were 0.75 and 0.67 kg/day. Differences in liveweights at weaning between the restricted and unrestricted calves were still present over 18 months later and there was little evidence for compensatory growth.

In a recent experiment at Massey, which is still in progress (Davey *et al.*, unpubl.), three groups of Friesian calves (8/group) were fed whole milk for the first 5 weeks of life so that they gained 0.2, 0.4 and 0.6 kg/day. The calves were all fed alike on concentrates and pasture for a further 7 weeks and then on pasture alone. The differences in mean liveweight/calf of 7 kg between each of the three groups at 5 weeks were still present when the calves were 18 weeks old. In earlier work (Davey, 1962) differences in liveweights between groups of calves at 9 weeks of age had largely disappeared by 18 weeks. The calves in this experiment were fed alike for the first 4 weeks of life and grew at a similar rate over this period. The period of differential growth, due to differences in the intake of a milk substitute, occurred over the period 4 to 9 weeks of age. The implication is that the period from birth to four weeks of age is critical, so that low liveweight gains over this period could have a permanent effect. What needs to be determined is the optimum growth rate of the calves over this early period in relation to subsequent growth rate, and the optimum rate of gain in relation to the economic use of feed and the health of the animal.

## ENERGY STANDARDS

Energy requirements for the maintenance and liveweight gain of the pre-ruminant calf have been reviewed by Preston (1963), Jacobson (1969), Roy (1969), Ralston (1971), Gorrill (1972) and Johnson (1972).

The Agricultural Research Council (A.R.C., 1965) presented mean values for the fasting heat production of cattle of 0.59 MJ/kg$^{0.73}$ at one month of age, decreasing to a value of 0.38 MJ for 3-year-old cattle.

The value for the one-month-old animal was based on work by Ritman and Colovos (1943) and Blaxter and Wood (1951a) who obtained mean fasting heat productions of 0.64 and 0.51 MJ/kg$^{0.73}$, respectively.

Assuming a fasting heat production of 0.59 MJ/kg$^{0.73}$, a net availability of ME of 85% (Blaxter, 1952) and 98% of the digestible energy metabolized (Roy *et al.*, 1964), then the maintenance requirement in terms of DE would be approximately 0.24 MJ/kg. From respiration experiments carried out with veal calves receiving a liquid milk replacer only, Van Es *et al.* (1969) obtained a value for maintenance of 0.45 MJ ME/kg$^{0.75}$, approximately equivalent to 0.16 MJ DE/kg. Van Es (1972) in summarizing his review on the maintenance requirements of young growing cattle stated that maintenance requirements were probably slightly higher than for older cattle. Van Es was of the opinion that lack of training for experimental conditions could result in high fasting heat productions with young cattle.

Estimated calorific values for liveweight gain in pre-ruminant calves (A.R.C., 1965) range from 8.67 to 10.89 MJ/kg. On the basis of an efficiency of utilization of ME for gain of 80% (77 to 81%, Gonzalez-Jimenez and Blaxter, 1962), requirements for gain in terms of DE would be approximately 10.89 to 14.24 /kg. Johnson (1972) reported an efficiency of 63% in Rhodesian work giving DE requirements of 14.03 to 17.59 MJ/kg, and Van Es *et al.* (1969), a value of 69%, giving requirements of 12.77 to 16.12 MJ DE/kg gain. The mean of these two latter values (14.45) appears in Table 3.

Requirements in terms of DE for calves receiving milk or milk-based diets as determined by various workers are summarized in Table 3.

TABLE 3: ESTIMATED DIGESTIBLE ENERGY REQUIREMENTS OF THE PRE-RUMINANT CALF RECEIVING WHOLE MILK OR MILK SUBSTITUTE, PER UNIT OF LIVEWEIGHT AND LIVEWEIGHT GAIN

| *Authority* | *Maintenance (MJ/kg liveweight)* | *Growth (MJ/kg liveweight gain)* |
|---|---|---|
| Blaxter and Wood, 1951b | 0.22 | 12.85 |
| Bryant *et al.*, 1967 | 0.20 | 15.49 |
| Brisson *et al.*, 1957 | 0.19 | 11.18 |
| Roy *et al.*, 1958 | 0.21 | |
| Roy *et al.*, 1964 | | 12.64 |
| McGilliard *et al.*, 1969 | 0.17 | 15.99 |
| Van Es *et al.*, 1969 | 0.16 | 14.45[1] |
| Johnson, 1972 | 0.17 | 17.46 |
| Davey *et al.*, 1974 (Massey data, unpubl.) | 0.16 | 16.12 |

[1] See text for derivation of this value.

The results obtained by various workers can be separated into those where requirements are high for maintenance and low for liveweight gain, and low for maintenance and high for liveweight gain.

In Fig. 1, DE requirements using either 0.17 or 0.21 MJ/kg for maintenance, and either 12.56 or 16.75 MJ/kg liveweight gain have been compared. At a liveweight gain of 0.5 kg/day there is close agreement between the two sets of estimates, and it is at maintenance and at low and high liveweight gains that the disagreement is greatest. Rates of gain of 1.0 kg/calf/day are too high for both replacement and beef calves. They represent the potential that might be attained by calves intended for veal production. The discrepancy at maintenance and at low liveweight gains is of chief concern, as this is the recommended level at which milk should be fed in the restricted milk plus dry feed system of rearing.

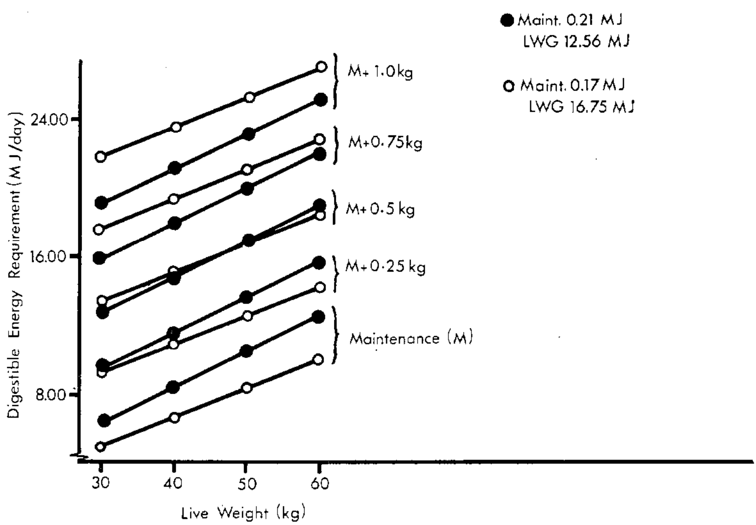


FIG. 1: *Comparison of two estimates of energy requirements for maintenance and liveweight gain by pre-ruminant calves receiving a milk or milk substitute diet.*

## QUANTITIES OF WHOLE MILK OR MILK SUBSTITUTES

Requirements of whole milk based on a maintenance requirement of 0.19 MJ DE/kg and 14.52 MJ DE/kg liveweight gain (means of values given in Table 3) are given in Table 4.

As shown in Table 4, requirements based on a commonly-accepted standard used in New Zealand of 1 kg whole milk/10 kg liveweight are misleading. Requirements based on this

TABLE 4: WHOLE MILK REQUIRED (kg/day) FOR MAINTENANCE AND MAINTENANCE PLUS LIVEWEIGHT GAIN FOR THE PRE-RUMINANT CALF

| *Liveweight (kg)* | *Liveweight Gain (kg/day)* | | | | *Whole Milk at 10% of Liveweight* |
|---|---|---|---|---|---|
| | *0.0* | *0.25* | *0.5* | *0.75* | |
| 30 | 1.8 | 2.9 | 4.1 | 5.2 | 3.0 |
| 40 | 2.4 | 3.6 | 4.7 | 5.8 | 4.0 |
| 50 | 3.0 | 4.2 | 5.3 | 6.5 | 5.0 |
| 60 | 3.7 | 4.8 | 5.9 | 7.0 | 6.0 |

Maintenance: 0.19 MJ DE/kg.
Growth: 14.52 MJ DE/kg liveweight gain.

standard appear to penalize the smaller calf and, according to Table 4, would provide the small calf (30 kg) with milk sufficient for about 0.25 kg liveweight gain per day, whereas for the large calf (60 kg) it would provide sufficient for approximately 0.5 kg liveweight gain/day.

Despite the variation in requirements between workers (Table 3) it is maintained that feeding standards are of value as a base from which to examine existing practical recommendations. Further work is required on the subject, particularly as concerns possible differences in energy requirements between breeds.

## PROTEIN REQUIREMENTS

Less emphasis is placed on the protein requirements of the young calf, as there is likely to be a surplus of protein where milk or milk substitutes are fed. Protein requirements for the young calf have also been summarized recently by Joyce (1971). The main concern will be to consider the ratio of protein to DE in the diet of the young calf.

The minimum available protein requirements (A.R.C., 1965) and ratio of available protein requirements to DE requirements are given in Table 5.

The ratios given in Table 5 illustrate the sharp decline in the proportion of available protein to DE as the rate of liveweight gain increases. The ratio of available protein (g) to DE (kJ) in whole milk (4.5% milk fat) is approximately 1:92, with a corresponding value for a fat fortified milk substitute (18% fat) of 1:67 and a value of 1:50 for buttermilk powder (9% fat).

The obvious conclusion to be drawn is that energy rather than protein is limiting and that with buttermilk powder particularly, and even with the fat-fortified substitute, there is a large surplus of protein to the animal's requirements. This is a wasteful use of protein, and consideration needs to

TABLE 5: MINIMUM AVAILABLE PROTEIN REQUIREMENTS[1] AND RATIO OF AVAILABLE PROTEIN REQUIREMENTS TO DIGESTIBLE ENERGY REQUIREMENTS FOR A 50kg CALF RECEIVING A MILK OR MILK SUBSTITUTE DIET

| | *Liveweight Gain (kg/day)* | | | |
|---|---|---|---|---|
| | *0.0* | *0.25* | *0.5* | *1.0* |
| Requirement of available protein (AP) (g/day)[1] | 30 | 80 | 125 | 220 |
| DE (kJ/day)/AP (g/day)[2] | 1:316 | 1:164 | 1:134 | 1:109 |

[1] A.R.C., 1965.
[2] Based on—maintenance 0.19 MJ/kg and 14.52 MJ/kg gain.

be given towards providing milk substitutes with a lower protein content.

Roy (1970c) calculated the minimum crude protein content, on a DM basis, required in milk substitutes for various liveweights and a liveweight gain of 0.5 kg/day. For a liveweight gain of 0.5 kg/day, the values were 20.0% for a 40 kg calf and 16.5% for a 60 kg calf.

## EARLY WEANING

A system of restricted milk feeding and early weaning on to concentrates, generally when the calves are 5 weeks old, has been developed overseas (see review by Preston, 1963; Roy, 1970a; Gorrill, 1972) and in New Zealand by Khouri *et al.* (1967) and Khouri (1969). The main advantage of the early weaning system lies in the reduced labour needed when dry feeding, and the reduced cost of the dry feed, particularly where milk substitutes are being used. There is also evidence, from work in the United Kingdom, of a lower incidence of diarrhoea in the early-weaned ruminant calf (Roy, 1970a), particularly where milk substitutes are being fed. Consumption of solid feed is encouraged by restricting milk or milk substitutes to well below the potential appetite of the calf and by providing a solid feed of low density, high digestible energy concentration and as palatable as possible. The system is essentially one of compromise between a reduction in the performance of the calves prior to weaning and the need to obtain high intakes of solid feed at an early age.

Preston (1963) stated that by restricting the amount of milk given, usually to a level which will support maintenance and approximately 200 g daily liveweight gain, calves can be induced to eat 0.5 kg of dry feed daily at 3 weeks old. In the initial stages, before the calves were eating appreciable amounts of concentrates, this level of milk would be too low, particularly for beef production, in view of the discussion earlier concerned with the possible effects of rate of gain over the first month on subsequent liveweight. Thus although the aim of the restricted-milk, early-weaning system is to encourage calves to eat concentrates, it could be argued that calves should be receiving sufficient milk to gain 0.5 kg/day or more during the first three weeks of life, particularly if they are intended for beef production. Hodgson (1965) citing the work of Quayle (1958) stated that the consumption of solid feed increases rapidly after liquid feeding ceases, and the relationship between dry feed intake before and after weaning is not close. Evidence obtained recently at Massey supports this observation.

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