A STUDY OF ASPECTS OF THE UTILIZATION OF TALLOW BY YOUNG MILK-FED CALVES

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ABSTRACT

1. Three groups of 4 Friesian bull calves were individually fed from 7 days of age on one of the following diets; (L) - Buttermilk powder (B.M.P.) to promote 0.45 kg liveweight gain (LWG)/day; (H) - B.M.P. to promote 0.67 kg LWG/day; (HT) - B.M.P. supplemented with beef tallow to promote 0.67 kg LWG/day. The diets, reconstituted to 15% dry matter (d.m.), were fed in direct proportion to the animal's liveweight at the beginning of each of the 3 consecutive 10-day experimental periods.

   N.B. Skim milk powder (S.M.P.), initially used as the basal diet, was subsequently replaced by B.M.P. and the trial was restarted.

2. Daily faecal d.m. consistency was subjectively scored on a 0 - 5 scale. Quantitative measurements were made in conjunction with the faecal collections for the nitrogen balance.

3. Nitrogen balance data were collected from 3 of the 4 calves in each group during the last 5 days, and energy balance data during the last 2 days of each period.

4. The addition of 4% tallow (d.m. basis) significantly reduced the incidence of scours ($p < 0.01$) in calves fed a basal diet of either S.M.P. or B.M.P.

5. Mean LWG's of calves on treatments L, H and HT were respectively 0.57, 0.73 and 0.62 kg/day; these differences were not statistically significant ($p > 0.1$).

6. The calves on treatment H, although having the highest urinary nitrogen excretion ($p < 0.05$), retained the most nitrogen ($g/kg^{0.75}/day$) ($p < 0.05$). The ratio of digested nitrogen retained : M.E. intake was highest for the calves fed the tallow supplement. This suggests that energy rather than protein is the factor most limiting protein deposition in calves fed solely on B.M.P.

7. During the second and third periods diets H and HT promoted a significantly greater retention of energy than did diet L ($p < 0.01$). The percentage of energy retained as fat tended to be higher in calves on treatment H.

8. The maintenance energy requirement for a 50 kg calf was estimated to be 53.5 kcals D.E./kg liveweight. The efficiency of utilisation of M.E. for growth was found to be 78%.

INTRODUCTION

Cows whole milk, which is generally considered to be the ideal diet to promote rapid growth in the very young calf, is also the main source of the dairy farmers income. Consequently there has been a move from whole milk feeding of calves towards the use of low-fat milk diets or, of synthetic milk diets containing fats of non-milk origin to maintain an equivalent energy concentration to that of whole milk. Whereas the pasture-reared calf consumes grass from about one week of age, it is not until it reaches an age of three to four weeks that the capacity of the rumen is such that a significantly large proportion of the calf's energy requirement can be derived from this source.

Successful rearing of young calves can be achieved by the feeding of low-fat milk diets such as buttermilk powder. But to attain high rates of liveweight gain with such diets animals, must consume a greater quantity of dry matter than if they were fed a high-fat milk diet, if they are to maintain an equivalent energy intake. Unfortunately such dietary systems have frequently been shown to predispose the calf to scours which on all too many occasions result in death. Dietary fat supplements, of both plant and animal origin, have been shown to reduce the incidence of scouring in low-fat milk-fed calves, if certain conditions of feed preparation are observed, while at the same time promoting satisfactory rates of liveweight gain. However there has arisen a controversy as to whether such energy supplements bring about desirable muscle development or only an increased fat deposition in the adipose tissue.

This trial was designed to look at the efficacy of beef tallow, a cheap animal by-product, to act as an anti-laxative and as a concentrated energy source for calves fed a low-fat basal milk diet.

CHAPTER ONE

REVIEW OF LITERATURE

GENERAL

At birth the 'physiological capacity' of the reticulo-rumen of the calf is 0.5 - 1.6 litres (Warner, Flatt and Loosli, 1965 ; Tamate, McGilliard, Jacobson and Getty, 1962); this being equivalent to 35-40% of the total stomach capacity. This tissue was found, however, to hold 86% of the total wet stomach contents of fully fed mature cattle - the omasum 11%, and abomasum 3% (Makela, 1956).*

It is not until the animal consumes significant quantities of roughage that the size and anatomy of the forestomachs begin to approach those found in the adult (Savage and McCoy, 1942; Warner et al. 1956; Tamate et al. 1962). Therefore during the first few weeks of its life, the calf must to a large extent remain dependent on foods which it is able to digest in the abomasum. Although Stewart (1962) has detected significant levels of volatile fatty acids in the rumen fluid of fifteen-day old calves, resulting from the microbial digestion of cellulose, because of the bulk limitation imposed by the rumen, and the calf's inability to digest complex polysaccharides (e.g., starch) in the small intestine at this age (Porter, 1969). it is obvious that the very young calf would be unable to maintain itself satisfactorily on a forage or concentrate diet.

There would therefore appear to be an obligatory requirement for a milk, or milk substitute, diet during at least the first three weeks of life; and because of its excellent nutritional value (Roy, 1970) there would also be an apparent advantage in the extended feeding of such a diet for a period of several weeks, particularly if a rapid rate of growth is desired.

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* No data on physiological capacity of these tissues in adult cattle was found.

Young pre-ruminant animals fed a milk diet have a digestive system similar to, but not identical with, that found in monogastric animals (Porter, 1969) owing to the suckling-stimulated reflex closure of the oesophagal groove described by Comline and Titchen (1951). The imbided milk by-passes the reticulo-rumen and passes through the omasum into the abomasum. Here it very rapidly forms a firm curd or "clot" which then slowly breaks down during the following few hours (Mylrea, 1966a). This milk clot is formed as a result of the specific coagulating action of rennin on the dietary casein (Fell, 1962) in the presence of ionisable milk calcium (Mylrea, 1966a).

Although emptying of the abomasum occurs at an approximately exponential rate, during the first 4-6 hours after feeding a clear watery fluid, containing whey and the soluble carbohydrate lactose, flows into the intestine. This is subsequently followed by a thick white opaque fluid, comprising the fat and casein components of the diet (Mylrea, loc. cit.). Whereas the percentage flow of dietary nitrogen is relatively constant between meals, the carbohydrate supplies an immediate source of energy to the calf, while the more slowly released butterfat would appear to ensure a continued supply of energy during the feeding interval; this is associated with the fall in abomasal pH from the feeding to pre-feeding levels of 6 and 2 respectively, resulting in the clot disintegration (Mylrea, 1966a, b).

The absorption of these nutrients from the small intestine then follows a pattern similar to that described for both ruminants and non-ruminants, with the exception that the milk-fed calf is not able to utilise some complex non-milk polysaccharides (Porter, 1969), since at birth pancreatic amylase and the mucosal cell disaccharidases are either absent or inactive (Dollar and Porter, 1957; Velu, Gardiner and Kendall, 1969). There does not appear to be any reported enzymatic limitation to the utilisation by the young pre-ruminant calf of non-milk fats or proteins.

Colostrum and Whole Milk Substitutes

During the first twenty-four hours post-partum, it is essential that the calf is fed colostral milk, as it contains a much greater concentration of minerals and vitamins than is found in normal whole milk; and more particularly, contains γ-globulins which provide the calf with an immunity against endemic diseases during its first few weeks of life (Kaiser, Lysaught and Tulloh, 1969).

Following the feeding of colostrum, Flux and Patchell (1956) have shown that the calf reared on pasture can do equally as well when fed either a whole milk or buttermilk diet from three days of age. This early work has since been substantiated by Fraser (1961) using housed calves, and by Davey (1962a) with pasture-reared calves; both writers reported no significant difference in liveweight gain when feeding either wholemilk or buttermilk diets - the difference being a 30-40% lower butterfat content in the latter milk diet. Interpretation of the work by Davey is however confounded by the fact that the calves on either diet may have compensated any nutrient imbalance or deficiency by eating more grass, the intake of which was not measured.

Nonetheless, the findings of Flux and Patchell, of Davey, and of Fraser do show that satisfactory health and growth rates can be maintained with a milk diet containing on average only 9% butterfat (dry matter basis) as opposed to a whole milk diet containing 25-30% butterfat.

Reconstitution of Milk Replacers

The dry matter (d.m.) content of the reconstituted milk can have a marked effect on food intake, on the incidence of souring, and on food conversion efficiency (F.C.E.). Pettyjohn, Everett and Mochrie (1963) have shown with ad lib. feeding of calves a milk diet containing 5 or 10% d.m. that the physical capacity of the stomach limited the quantity of food consumed. These calves were unable to consume a volume of milk sufficient to equal the d.m. intake of calves fed milk reconstituted at a rate of 20% and 25%

d.m., even though the volume of imbibed milk in the latter treatments was significantly less. Similarly, Large (1965) found, when feeding lambs 10% and 25% reconstituted full-cream milk diets ad lib., that the group receiving the dilute milk diet, although consuming 100% more milk, was unable to consume as much milk solid as the other lambs. Although in this work there was no apparent correlation between faecal d.m. and the dilution factor, Preston (1957), Davey (1962b), and Pettyjohn et al. (1963) all reported a positive correlation within the bounds of their work.

Davey (loc.cit.) noted a faster rate of growth by calves fed a diet containing 22.4% d.m. compared with 12.4% and 6.6%; F.C.E. was maximised at 12.4% d.m. Pettyjohn et al. (1963) found that a diet containing 15% d.m. gave a maximum F.C.E., and that these calves grew only slightly slower than calves fed milk diets reconstituted at 20% and 25% d.m. Thus, whereas on the one hand the d.m. content of the milk diet should be kept low to avoid scouring, on the other it is desirable to feed milk of a higher d.m. content (ca. 15%), to prevent a bulk limitation to the quantity of milk consumed and to promote rapid growth and maximal food conversion efficiency.

Calf Diarrhoea

Diarrhoea in calves, more commonly known as scours, is unequivocally the most common disease associated with the rearing of milk-fed calves. For example, a British survey, cited by Roy (1969), showed that of 350 post mortem examinations, 44.9% of deaths were due to gastro-intestinal disorders, and a further 24.8% to septicaemia.

Scouring is attributed to several predisposing factors: a sudden change in diet, overfeeding, the feeding of a fat-free or over-heated milk powder diet, the feeding of unhomogenised and/or unemulsified non-milk-fat fat substitutes, and to substandard hygiene. Although scouring has a nutritional origin, the digestive dysfunction is amplified by the proliferation of micro-organisms in the lower digestive tract, thriving

on undigested feed residues which escape absorption in the duodenal region (Blaxter and Wood, 1953). Roy (1969) classifies diarrhoea into two categories, similar to those used for humans, depending on the end-products of micro-organism digestion.

1. Fermentative diarrhoea is associated with the feeding of an excess of lactose or indigestible non-milk carbohydrate to the pre-ruminant calf. Typical symptoms are an increased faecal level of low molecular organic acids, lactic acid and a low faecal pH.

2. A more serious putrefactive diarrhoea may develop following a very rapid outflow of digesta from the abomasum; this raises the intestinal pH, thereby permitting the growth of E.coli. and clostridial organisms. Toxins produced by the diarrhoetic organisms are thought to induce hyperperistalsis of, and hypersecretion from, the intestinal tract, accompanied by diminished water absorption.

Blaxter and Wood (1953) also suggest that some of the fermentation end-products - the volatile fatty acids - raise the osmotic pressure within the intestine, thereby resulting in a loss of body water.

The result of diarrhoea in severe cases is often death due to dehydration.

Shillam, Dawson and Roy, 1960; Shillam, Roy and Ingram, 1962 a and b; Shillam and Roy, 1963 a and b; have done exhaustive studies on the effect of overheating during the drying of milk powders, and the subsequent effect on calf scours. They have found that pre-heating (ca. 70-80°C) for up to 30 minutes prior to spray-drying, or roller drying at 110°C, results in a marked denaturation of whey proteins and the complexing of soluble calcium ions. Lister (1971) reported that severe heating of milk reduced by 50% the whey protein (albumin and globulin) content in the resultant milk powder. The clotting times for low and mildly heat-treated milks deter-

mined *in vitro* were 5.7 and 6.7 minutes respectively, whereas severely heated milk only formed a clot in the presence of added soluble calcium. Shillam *et al.* (1963b) suggest that scouring caused by overheated milk powders may be due to the passage into the small intestine of polypeptides (a substrate for intestinal pathogens) which have not undergone complete proteclysis in the stomach because of poor curd formation hence causing a more rapid pyloric outflow.

Mylrea (1966c) has shown that as the abomasum has a great propensity to expand, overfeeding with whole milk will result in scouring only if 'infection' conditions within the calf are high. This, it must be assumed, is due to the increased rate of flow associated with the exponential rate of abomasal emptying and consequent incomplete gastric proteclysis.

Fat-free Diets and Added Fats

Milk diets containing very little or no fat have been reported by many authors to induce calf scours (Cunningham and Loosli, 1953; Owen, Jacobson, Allen and Homeyer, 1958; Olsen and Williams, 1959; Bush, Schuh, Tennille and Walker, 1963; Mathieu and Barre, 1964). Secondly, as butterfat is a carrier of vitamins A, D and E (Ling, Kon and Porter, 1961), its removal from the milk is likely to result in a vitamin deficiency within the animal, unless corrected by the feeding of a vitamin supplement; particularly when feeding a fat-free diet from birth (Blaxter and Brown, 1952). The feeding of fat-free diets, either from birth or subsequent to colostrum feeding, will also initiate a fat deficiency syndrome described by Lambert, Jacobson, Allen and Zaletel (1954), since at birth blood lipid levels are low (Noble, Steele and Moore, 1971). But as the response to the feeding of any of several different types of fat was rapid, and the deficiency symptoms quickly disappeared (Cunningham and Loosli, *loc.cit.*) it would appear that these symptoms are not due either to an essential fatty acid deficiency (linoleic, linolenic and arachi-

donic acids - Tayler, 1969), or to a vitamin deficiency.

The addition of small amounts of fat to a low-fat milk diet increases the faecal d.m. content (Olsen and Williams, 1959; Bush et al., 1963; Mathieu and Barre, 1964), albeit too much fat will in some instances lower the faecal d.m. content (Grimes and Gardiner, 1959; Roy, Shillam, Thompson and Dawson, 1961). Furthermore, per unit of weight, fat provides more than twice the gross energy supplied by either protein or lactose, and consequently its inclusion in a low-fat milk diet reduces the d.m. intake requirement of the calf and, of particular significance, the intake of protein and lactose. Trials reported by Owen et al. (1958) and Bush et al. (1963) have both shown that the addition of 'whey-type' minerals significantly decreased the faecal d.m. content of calves fed a basal skim milk diet. Owen et al. (loc.cit.) further found that the addition of a 5% lactose supplement similarly resulted in a marked loosening of faeces. These authors propounded the thesis that whey minerals stimulate hypersecretion of bile salts which, in the absence of sufficient dietary fat, act as a laxative. The high lactose levels, they suggest, may induce scouring due to saturation of lactase, thereby providing a substrate for fermentative-type micro-organisms in the large intestine.

Cheng, Morehouse and Deuel (1949), using rats, reported that high dietary levels of Mg^{++} and Ca^{++} ions markedly increased the excretion of faecal soaps and decreased the excretion of neutral lipids. This, they suggested, would indicate that the addition of lipids to a fat-free basal diet would be commensurate with an increased soap formation and consequent removal of the laxative stimulus of the whey minerals. An alternative hypothesis suggested by Owen et al. (1958) is that laxative bile acids are removed by forming a complex with the dietary free fatty acids, which is then absorbed in the small intestine. On the other hand, excessive levels of fat, particularly if poorly incorporated, may form a protective coating over the milk protein, thereby preventing adequate curd formation and gastric proteclysis.

The Use of Milk-fat Substitutes

Initial attempts to use milk fat substitutes met with little success as, at that time, there was not a full appreciation either of the importance of the role played by vitamin E in preventing muscular dystrophy (Blaxter, 1952), or of the necessity to reduce the fat globule, by emulsification or homogenisation, to a size similar to that found in whole milk (Raven and Robinson, 1964a). Diets containing unhydrogenated fats such as soybean oil, palm oil, cod-liver oil, or non-ruminant fats, e.g., lard, have a great propensity to induce Vit E deficiency; Blaxter and Brown (1952) have reported that these fats rapidly deteriorate due to oxidation, resulting in the breakdown of the tocopherol compounds. These authors state that the requirement for Vit E is proportional to the iodine number of the fat. Whereas ruminant fats are comprised predominantly of palmitic, stearic and oleic acids, vegetable oils and non-ruminant animal fats contain, as well, a high proportion of C_{14} acids; the majority of these fatty acids are polyunsaturated (Hilditch, 1956). The composition of butterfat is notable for the high proportion of short chain ($< C_{12}$) and polyunsaturated fatty acids relative to the composition of ruminant adipose tissue (Garton 1967). These differences in composition of the various fats are of particular importance, in that it has been shown by Raven and Robinson (1958), and Gali (1965) cited Radostits and Bell (1970), that the co-efficient of digestibility is greater for fats of short chain length and a high degree of unsaturation. With calves, for example, butterfat, lard and tallow have co-efficients of digestibility at four weeks of age, of 97%, 93% and 85% respectively (Roy, 1964).

Some works reviewed by Radostits and Bell (1970) have shown that the feeding of polyunsaturated vegetable fats to young calves will induce ill-thrift, although the results of other workers is conflicting in some aspects of this work. Jarvis and Waugh (1949) attempted to overcome the problems of ill-thrift by supplementing a basal skim milk diet with cotton-seed oil artificially hydrogenated immediately prior to feeding. Although these calves had a growth rate of only 50% that of the control whole-milk-

fed calves, the calves fed an unhydrogenated cottonseed oil were emaciated, mortality was high and the survivors barely maintained their weight. On the contrary, Raven and Robinson (1958, 1959, 1960) showed a marked decrease in growth of calves fed artificially-hydrogenated palm and palm-kernel oils. Aaes-Jorgensen (1966) with rats similarly reported impaired growth when feeding artificially hydrogenated fats, but on the addition to these diets of linoleic acid an improvement in liveweight gain was noted. He suggested however that this phenomenon may not have been due solely to an essential fatty acid deficiency, but also to a toxic effect produced by biologically inert isomers formed during hydrogenation of the fat. Earlier evidence supporting this theory of toxin formation was reported by Adams, Gander, Gullickson and Sautter (1959). They found that a corn-oil preparation prepared daily raised the d.m. digestibility above that found when using an oil preparation prepared weekly which, they suggested, may have been due to an upsetting of the calf's metabolic system by toxins formed through spontaneous oxidation of the fat.

Tallow, although of a relatively lower digestibility (probably because of the high degree of saturation), is frequently used as a replacer of butterfat in artificial milk diets, as it is readily available in large quantities and at low cost, and it appears to cause fewer metabolic disorders than do the more highly digested vegetable oils.

Homogenization and Emulsification

> ".....there is general agreement that for efficient utilisation some form of treatment is necessary to reduce the size of fat globules".
>
> - Roy, Shillam, Thompson and Dawson (1961)

Kastelic, Bentley and Phillips (1950) were among the first to show that smaller fat globules formed by homogenization are more easily digested than the larger globules which are found in emulsified fats, a conclusion later borne out by Warner, Loosli and Ley (1962):

TABLE 1:

Apparent digestibility of fat plus a lecithin incorporated either by homogenization or melting and blending into skim milk diets fed to young dairy calves - after Warner, Loosli and Ley (1962).

Fat Type + Lecithin	Fat Content (% d.m.)	Homogenised in liquid form	Melted and Blended in liquid form
Butter	25	93	84
Tallow	25	90	73
Coconut Oil	25	89	89

Further, Raven and Robinson (1964a) in a series of experiments have reaffirmed the above findings and, as well, have shown the importance of an added lecithin for improving fat digestibility in diets where the fat has not been homogenised.

TABLE 2:

Mean digestibility of ether extractable material in different diets - after Raven and Robinson, (1964a).

Diet (All prepared as milk powders)	Ether Extractable Material (%)
Whole milk	95.2
Blended butterfat + skim milk	71.8
Blended butterfat + lecithin + skim milk	88.3
Homogenised palm-kernel oil + skim milk	94.1
Homogenised palm-kernel + lecithin + skim milk	96.3
Blended tallow + lecithin + skim milk	70.7
Homogenised tallow + lecithin + skim milk	86.8

It is abundantly clear that homogenization, except in the case of coconut oil (table 1), markedly improves the digestibility of dietary fat. This is probably due to a greater surface area of fat being exposed to the enzyme action of pancreatic lipase (Ling, Kon and Porter, 1961). It is also apparent that a lecithin improves the digestibility of lipids, whether or not the fat is homogenised, particularly when the fat is only blended into the diet. Although natural cows' milk contains high levels of lecithin, this is destroyed during the manufacture of milk powders (Hopkins, Warner and Loosli 1959), thus necessitating the addition of a supplementary lecithin or emulsifier, such as glycerol-mono-sterate, in artificial milk diets.

Fat globules in cows' milk range from 0.1 - 10 µm in diameter, although most are in the range 3-4 µm (Ling, et al. 1961). Raven and Robinson (1964a) found in their work that the globule size of blended tallow ranged from 5-10 µm with some being as large as 20 µm, whereas the globule size of tallow, if adequately homogenised, was of a similar size to that of the fat in whole milk. These same authors (1964b) have shown that the greatest need for small fat globules by the calf is during its first few weeks of life since - "In the case of vegetable fats and tallow there was a definite tendency for an improvement in fat digestibility to take place with increasing age of the calves, e.g., the mean digestibility of the tallow was 83.0 $\pm$ 1.2% at 1-2 weeks of age, and 88.9 $\pm$ 1.4% at 4-5 weeks of age ....." They attributed this observation to an increasing pancreatic lipase activity found in young calves between the age of one to seven days, (Huber, Jacobson, Allen and Hartman, 1961). They do not attempt to explain, however, why this increase occurred from seven to thirty-five days of age when, according to Huber et al. (loc.cit.), the activity of the enzyme does not significantly change, irrespective of the dietary composition.

A limited amount of research has shown that the conditions under which the fat is prepared have been shown to affect the subsequent effectiveness of the fat supplement. Vleig (1964) has pointed to the need for care when

making up a fat emulsion, as it is imperative not to overheat the tallow (m.p. 45°C) prior to adding the emulsifier, if the emulsion is to remain stable. And Liebholz (1966), in extensive feeding trials with calves, found that when high levels of tallow were homogenised into the diet, better weight gains were obtained when the diet was homogenised at 30°C than at 18.8°C, as at the lower temperature the incorporation of tallow into the milk was poor and settling on standing was observed.

Energy Requirements for Pre-ruminant Calves

Blaxter and Wood (1951) determined the energy requirements for young milk-fed calves confined to metabolism crates, by regressing the liveweight changes on digestible energy intake. They estimated a maintenance requirement of 52.4 kcals digestible energy (DE)/kg liveweight, and 307 kcals DE/100g liveweight gain. Van Es, Nijkamp, van Weerden and van Hellemond (1969), using an indirect calorimetric approach, estimated the maintenance energy requirement for calves up to the age of 10-14 weeks to be 42 kcals DE/kg liveweight, which is in close agreement with the requirement of 45 kcals DE reported by Brisson, Cunningham and Haskell (1957). Bryant, Foreman, Jacobson and McGilliard (1967) found a higher requirement of 48 kcals DE/kg liveweight for maintenance. Brisson et al. and Bryant et al. estimated the requirements for 100g liveweight gain to be respectively 268 and 370 kcals DE.

These differences in the estimated requirements for energy are not surprising in view of the age differences of the calves used, the errors associated with the measurement of liveweight, and the different techniques used to determine the requirements.

Protein Requirements for Pre-ruminant Calves

In reviewing the protein requirement for calves, Jacobson (1969) points out the ".....marked variations in the estimated protein (and energy) requirements of calves particularly in the ruminant stage", which, he continues ".....are influenced by the rate of gain, body size, age, diet and other

factors." For the 50 kg non-ruminating calf; the respective requirements of digestible crude protein for maintenance (g/day) and for 100g liveweight gain (g) were: Blaxter and Wood (1951) 32 and 16.2; Brisson et al. (1957) 20 and 22.2; Bryant et al. (1967) 35 and 15.8. Using the average of the energy and crude protein estimates, Jacobson has shown that the ratio of digestible crude protein (in grams) to digestible energy (in kilocalories) declines sharply as the rate of gain increases. For maintenance, and maintenance + 0.5 kg gain, the ratios are respectively 1:75 and 1:35. Milk containing 3.7% fat has a ratio of approximately 1:23, which indicates that for normal rates of growth, energy will be the growth limiting factor when milk is fed as the sole calf diet (Jacobson, 1969).

Level of Fat in Milk Replacers

Milk fat supplies as much as 50% of the total energy in whole milk, protein 26%, and lactose 24% (Roy, 1970) - the proportions being dependent on numerous animal and animal nutrition factors; whereas only 15-20% of the gross energy of buttermilk is derived from fat, if a 9% fat content is assumed. Many workers have attempted, with varying degrees of success, to improve the rate of liveweight gain, and more particularly nitrogen retention, by feeding different levels of milk fat substitutes in low fat milk diets (Blaxter and Wood, 1951; Olson and Williams, 1959; Stone Rennie and Ingram, 1963; Mathieu and Barre, 1964; Raven and Robinson, 1964; Leibholz, 1966; Roy, Stobo, Gaston and Greatorex, 1970a; Roy Stobo and Gaston, 1970b). Blaxter and Wood (1951) were among the first to show that when the digestible nitrogen intake was held constant, the amount of retained nitrogen could be increased by raising the energy content of the diet with a supplementary fat. This they attributed to a decline in the extent of deamination of dietary amino-acids for the supply of energy for protein synthesis. Olson and Williams (1959) fed a milk replacer diet containing 0%, 5%, 10%, 20% and 30% d.m. as lard, at a rate of feeding restricted to 10% of the calf's liveweight. They found that the rate of liveweight gain increased with each increase in the level of supplementary fat.

However, in extensive trials where Leibholz (1966) fed calves 0%, 10%, 20% and 30% of homogenised tallow at near ad.lib levels of intake, the maximum observed rate of gain, averaged over a four week period, was found to occur with calves fed the 20% tallow supplement. The rate of growth in declining order was: 10%, 30% and 0% tallow. During the last two weeks of this trial the rate of growth was similar for diets which contained both 20% and 30% of the supplementary fat. Leibholz concluded from this, and from a second experiment, that the addition of between 15%and 25% tallow to a skim milk diet resulted in the most satisfactory liveweight gains. Stone et al.(1963) observed that the addition of 15% tallow to a skim milk diet resulted in a better liveweight gain than the addition of 10% tallow, and Mathieu and Barre (1964) progressively improved the liveweight performance of veal calves by increasing the butterfat content of a reconstituted milk diet from 1% to 4.5% (wet matter basis). These latter workers noted an increasing retention of nitrogen per 100g of liveweight gain as the energy content of the milk decreased. However, the daily gain of nitrogen was improved by the addition of fat to the diet. Raven and Robinson (1964b) found that the energy supplied to skim milk by the addition of palm oil, refined palm kernel oil, and tallow, at a level simulating the energy content of whole milk, brought about a substantial improvement in the efficiency of nitrogen retention as compared with that on low-fat milk diets. However the per cent nitrogen retention with the filled milk diets was slightly lower than obtained with whole milk diets. The effect on the carcass composition was not reported. Roy, Gaston, Shillam, Thompson, Stobo and Greatorex (1964) presented evidence to show that after seven weeks of age either that energy was limiting the amount of nitrogen retained by calves fed whole milk, or that the maximum potential for nitrogen retention had been reached and surplus energy was being laid down as fat. In more recent work, Roy et al.(1970a) found that, by raising the fat content from 20% margarine to 30% margarine in a basal skim milk diet, there was no change in the protein content of the carcass, although the amount of adipose in the carcase of the 'high fat' calves

was markedly higher. Roy et al. (1970b) in a follow-up trial found that whereas the daily nitrogen retention was similar in high and low fat-fed calves, the percentage of digested nitrogen retained was greater in the 'high fat' calves, thus suggesting that in fact a more effective use was being made of the digested protein than was indicated by the absolute nitrogen retention. They, however, concluded from these two trials that margarine is not a readily available source of energy for calves when fed as a supplement to a low-fat milk diet.

The work to date has clearly shown that fat of non-milk origin can be beneficially used by calves to promote increased growth when fed in a milk diet, providing that adequate care is taken over incorporating the fat into the basal milk diet; vitamin deficiencies are corrected; toxic products from oxidation are prevented from forming; and that the level of fat used does not exceed 25-30% of the dry matter. However, there still remains some doubt as to whether this extra source of energy can be used to spare the unnecessary de-amination of dietary protein and hence increase the nitrogen retention in the carcass.

There appears to have been no work done in this field, incorporating the use of both energy and nitrogen balances, and so the present trial was therefore designed, using these two techniques, to see whether a low level of supplementary fat in the form of beef tallow would raise the nitrogen retention in calves above that attained by calves fed a basal low-fat milk diet. A further aspect studied was whether or not the low level of tallow was adequate to significantly increase the dry matter content of the faeces, and thereby reduce the risk of calf mortality due to diarrhoea.

Skim milk powder (S.M.P.) was used as the basal diet because of its low fat content, but for reasons to be discussed in Chapter III, this experiment was terminated prematurely, and a new experiment was commenced using B.M.P. as the basal diet. For this reason Chapters II and III have

been divided into sections: Section One deals with the main trial using B.M.P. and Section Two with the aborted trial using S.M.P.

Figure A:

Organisation of the experiment showing the average age in days of calves at the beginning and end of each period, and the number of calves used for collection of liveweight and balance data.

Collected Data	Number of Calves	Preliminary Period	Changeover Period	Experimental Period		
				Period 1	Period 2	Period 3
Liveweight	12	Up to 7	8-11	14-23	24-33	34-43
Intake and excreta for energy and nitrogen balances	9			19-23	29-33	39-43
Indirect estimation of heat production for energy balance.	9			22-23	32-33	42-43

CHAPTER TWO

MATERIALS AND METHODS

SECTION ONE

Buttermilk Powder Experiment

2.1. Animals

Twelve Friesian bull calves born in April and May were collected at 3 to 6 days of age from the Massey University dairy farm and a local town milk supplier.

2.2. General Outline of Experiment

The experiment consisted of a preliminary period, a change-over period and three consecutive ten-day experimental periods. Calves were fed indoors on a buttermilk or buttermilk plus tallow diet commencing at approximately fourteen days of age.

- Four calves L1, L2, L3 and L4 were fed on a low plane of energy intake in the form of reconstituted buttermilk powder (B.M.P.), hereafter referred to as treatment L.
- Four calves H1, H2, H3 and H4 were fed on a high plane of energy intake in the form of reconstituted B.M.P., hereafter referred to as treatment H.
- The remaining four animals HT1, HT2, HT3 and HT4, were fed an energy intake equivalent to that of the calves on treatment H; part of this being provided in the form of reconstituted B.M.P. and the remainder as beef tallow. This treatment is hereafter referred to as treatment HT.

The calves were randomly allocated to each treatment on arrival at the Massey University Animal Physiology Unit.

The level of energy intake, the source of energy and expected liveweight gains are shown in figure 1.

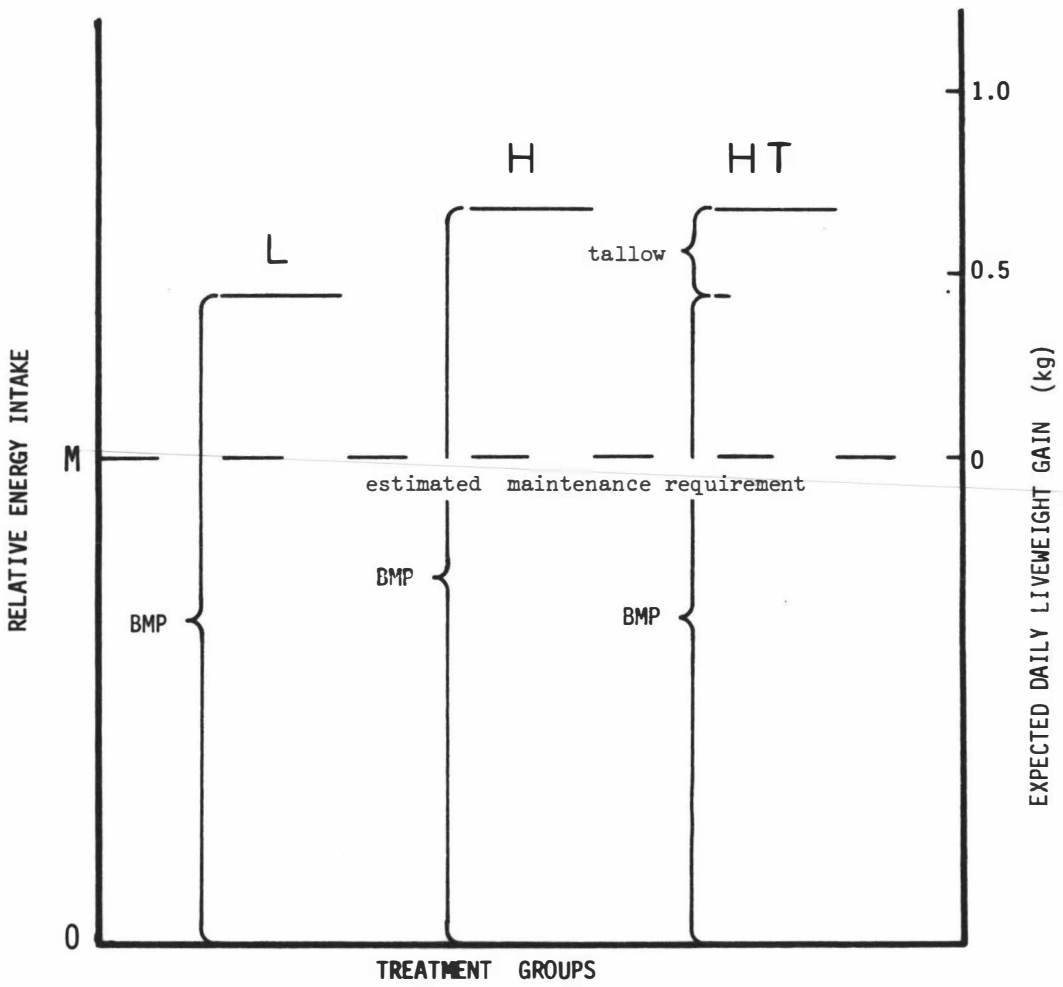


Fig.1 : Outline of the experiment showing the relative energy intakes, the source of energy and expected daily liveweight gains of the three groups of calves.

2.2. (cont'd)

Due to the limited resources available only calves 1, 2 and 3 on each of the three treatments were used for energy and nitrogen balance work. The fourth calf in each group was otherwise managed and fed identically; these three animals were used to provide additional liveweight data and to be available as replacements in the case of death of one of their respective group mates.

2.3. Experimental Design

2.3.1. Preliminary and changeover periods

The aim of the preliminary period was to allow the calves time to become accustomed to the confinement of their metabolism crates and to teach them to drink from a bucket. As well, each of the 'balance' calves spent some time in a calorimetry chamber.

A four-day changeover period, commencing at about eight days of age, was instituted when changing from whole milk feeding to the respective treatment diets, as it is well known that a sudden change in diet particularly with young animals, will often result in digestive upsets, e.g., Preston (1957).

2.3.2 Experimental Periods

During the experimental periods, each of which consisted of ten days, the food intake was held constant. Faeces and urine were quantitatively collected from each of the nine 'balance' calves during the last five days of each period. The faecal samples and urine sub-samples from each calf were bulked at the end of the respective periods and stored for subsequent chemical and dry matter analysis. The animals spent the final two days of each period in an indirect calorimeter. (See figure A)

2.4. Feeds and Feeding

2.4.1 Quality of feed

During the preliminary period all calves were fed a proprietary whole milk replacer in equal quantities at 9.00 a.m. and 4.30 p.m. This milk was reconstituted by adding one part of powder to eight parts of water and fed at a daily rate of 10% of calf liveweight.

The B.M.P. was manufactured by the spray-drying process and marketed as a finest quality product. However, this was subsequently found to be incorrectly labelled as the powder was only of 'stock food' quality due to overheating in the spray-drier (Ministry of Agriculture and Fisheries, pers. comm.): this being detected by the small lumps of burnt powder found floating on the surface of the reconstituted milk.

The beef tallow from the Longburn Freezing Company was classified as 'edible', and the glycerol-mono-stearate (G.M.S.) manufactured by Abel's, was similar to that used in the baking industry. Both were stored at 3°C while not in use. The mean chemical composition of the buttermilk powder and fats (with S.E.'s) are as follows:

Material	Protein (% d.m.)	Fat (% d.m.)	Ash (% d.m.)	Gross Energy (kcals/g)
Buttermilk powder	31.88±0.11	8.65±0.14	7.07±0.02	4.64±0.01
Tallow		0.54(F.F.A) 99.46(T.G.)		9.55±0.00
Glycerol-Mono-Stearate		100		8.47±0.00

2.4.2. Level of feeding

The experiment was designed so that the calves on treatment L were fed sufficient energy for maintenance plus 0.45 kg liveweight

2.4.2 (cont'd)

gain/day, while calves on treatments H and HT were fed sufficient energy to allow for maintenance plus 0.68 kg live-weight gain/day. The amount of powder fed was calculated from the energy requirements for milk-fed calves estimated by Blaxter and Wood (1951) to be 52.4 kcals digestible energy/kg liveweight/day for maintenance, and 307 kcals/digestible energy/0.1kg live-weight gain. In the present experiment the gross energy of a preliminary buttermilk powder sample was found to be 4.65 kcals/g and it's digestibility was assumed to be 92% (Roy, 1970).

Calves on treatments L and H were fed solely on B.M.P. reconstituted with water to contain 15% dry matter. The calves on treatment HT were fed sufficient B.M.P. to provide the maintenance energy requirements. A further batch of buttermilk was prepared (15% d.m.) to which an amount of emulsified tallow was added such that 2.2 kg of this fat-fortified buttermilk supplied sufficient energy to allow for 0.68 kg liveweight gain/day. The ratio of fat to B.M.P. was adjusted so that the tallow plus G.M.S. contributed to 0.23 kg of the total gain. The lipid additive had a gross energy content of 9.44 kcals/g and an assumed digestibility of 86% (Raver, 1970).

2.4.3. Feed preparation

Milk powder was added to luke-warm water in a fifteen gallon straight-sided milk can, and thoroughly mixed with a milk vat agitator. The milk was then passed through a 2 mm mesh sieve to remove any undissolved lumps of powder. The dry matter content of the reconstituted milk was determined in duplicate by oven drying approximately 5 g in an aluminium milk bottle cap at 103°C for twenty four hours. All reconstituted milk was stored at 3°C until required, but none was kept longer than thirty six hours.

2.4.3 (cont'd)

Tallow was heated to ca. 60°C in a small metal bucket to which was added 5% (w/w) of G.M.S. The mixture was then thoroughly blended with a wire wisk. The required weight of this lipid mixture was poured into the warm reconstituted milk, then vigorously agitated and passed twice through a gear pump and spray nozzle at 60-70 p.s.i. pressure. The weight of tallow incorporated into the milk was found by difference between the dry matter content before and after the addition of fat. This milk also was stored at 3°C until required.

Initially, and several times during the experiment, the fat globule size of the homogenized tallow-supplemented milk was measured using an optical microscope with a calibrated eyepiece. Milk samples were taken both immediately after passing through the homogenizer and after the milk had been stored in the cool room for several hours. Whole milk was used to provide a comparison of the fat globule size, but no statistical analysis of size distribution was carried out.

2.4.4. Feeding

At the beginning of each new ten-day period the calves were weighed and the feed requirement for the following ten days determined. The milk was weighed (± 5g) into tared calf buckets to which was added a 15g measure of a calf mineral supplement:

Composition of calf mineral supplement (active ingredient/454g of supplement)			
Vitamin A	585,000 i.u.	Fe	0.51g
Vitamin D_3	56,000 i.u.	Zn	1.25g
Vitamin E	348 i.u.	Mn	0.26g
Vitamin C	5.59 g	Cu	0.12g
		I	0.006g
		Co	0.003g
		Mg	5.04g

The buckets of milk were then placed in a large heated water bath

2.4.4 (cont'd)

When all the milk had been consumed the buckets were scrubbed in hot water containing a detergent and sanitiser and then rinsed. Between feedings the buckets were kept immersed in a dilute anti-bacterial waterbath. Refusals were weighed prior to the following feeding.

2.5. Weighing

The calves were weighed on arrival, and before feeding on the following two days with the average of these weights being used as the independent variable for the subsequent analysis of covariance. Calves were also weighed at the commencement of the experimental period, and on entering and leaving the calorimeter. The three calves not on 'balance' were weighed at ten-day intervals. All calves were weighed on two consecutive days at the end of the experiment. Weighings were done on a portable 'Avery' weighing platform accurate to 0.25 kg.

2.6. Calf Health

Calves were kept under constant surveillance for scouring and any other outward signs of poor health. Twice daily during the thirty-day experimental period a subjective observation of the consistency of the faeces was recorded for each calf using the following six point scale:

0 - firm, dry faeces
1 - moist faeces
2 - wet faeces
3 - very wet faeces
4 - scours
5 - severe scours

The higher of these two classifications (i.e., that describing the lower apparent faecal d.m. content) was used in the subsequent Chi-Square analysis.

2.6. (cont'd)

Treatment for scours involved the immediate halving of the daily milk ration followed by a gradual re-introduction over the following three days. Chronic scours were further treated with a 5g sulphamethazine tablet for two days and 2.5g on the third day. Severe scours were treated by feeding very dilute milk fortified with 0.3 kg glucose, 0.1 kg Kaolin clay and 0.30 kg of a proprietary electrolyte mix. With continued severe scouring oxytetracyline drugs were used.

2.7. Calf Housing and Calorimetry

All calves when not in the calorimeter were kept in metabolism crates in two controlled temperature rooms for the duration of the experiment. Ambient temperature was maintained at 15°C ($\pm$ 1°C).

During the preliminary period the animals spent at least two days in the indirect calorimeter during which time a close watch was kept and any necessary adjustments to the calorimeters were made.

Two calorimeters were used and the calves were alternated between them in order to randomise any uncorrected systematic errors.

2.7.1. Operation of the calorimeters

Each calorimeter consisted of a chamber of galvanised sheet metal on rigid steel framework. 1.7m x 0.7m x 1.5m high (internal measurements), with a front and back door sealed by rubber gaskets. Both chambers were insulated with 2.5 cm thick expanded polystyrene. The front doors of the chamber had built into them a feed and water trough which was accessible through a 0.3m x 0.3m rubber-sealed hatch. A perspex window protected by wire mesh in both back

2.7.1. (cont'd)

and front doors enabled the operator to inspect the animals within the chamber; however, the animals within each chamber could not see each other.

The calculated volume of each calorimeter was 2,200 litres. The air temperature within the calorimeter was controlled at 15°C (± 1°C) by means of a water cooled heat exchanger and a thermostatically controlled electric heater mounted above a false ceiling beneath the top of the chamber. A small electric fan forced air through the air-conditioning unit concomitantly mixing the incoming air with that air already in the chamber.

Air was exhausted from each chamber, by two rotary vacuum pumps mounted in parallel, through a 2.5 cm diameter P.V.C. pipe set in the top of the rear door of the chamber. Fresh air was drawn from outside the building and entered the chamber through a 2.5 cm opening above the water trough in the front door of the chamber. Each calorimeter was operated at a pressure of about 2 cm water guage below atmospheric pressure in a well ventilated, temperature controlled room.

The exhausted air was drawn through a device which cooled it to about 3°C, and then into a room thermostatically heated to 28°C. Thus the air was re-heated to a constant temperature before being drawn through two dry-gas meters connected in series. The air temperature was measured as it left the cooling device and again as it left the gas meters. As the air was assumed to be saturated on leaving the air cooler an estimation of the water vapour pressure could be made. Barometric pressure was also recorded. With this data it was possible to correct the metered volume of air to conditions of S.T.P.D.

2.7.1. (cont'd)

An automatic solenoid switching system enabled small samples of air (1 l/min) to be drawn by a small electric diaphragm pump from both the incoming fresh air before it entered the chambers, and the exhaust air on leaving the chambers. These air samples were dried in two separate 3m x 2.5 cm diameter silica gel columns. The system of solenoid values enabled exhaust air to be drawn alternately from each calorimeter for four-minute intervals, and fresh air for an eight minute interval every four hours. Thence, the small samples were pumped through an automatic infra-red carbon dioxide analyser (range 0-1.5% CO_2) and an automatic paramagnetic oxygen analyser (range 19-21% O_2) connected in series. The electrical output from each analyser was connected to a separate channel of a two-channel recorder (0.5 mV full range). The recorded traces for a twenty one to twenty three hour period were integrated manually with a travelling planimeter. Both gas analysers and the recorder were calibrated daily by pumping through them two different compressed-gas mixtures of known composition. The CO_2 and O_2 content of these mixtures, determined volumetrically with a Lloyd-Haldane gas analyser, were 0.988% and 20.339%, and 0.972% and 19.842% respectively.

The calculated respired gas volumes, corrected to S.T.P.D., were further adjusted for the change in the chamber air composition between the beginning and end of each measurement period.

Heat production was calculated using the formula of Brouwer (1965):

$$HP = O_2 \times 3.866 + CO_2 \times 1.200 - N \times 1.431$$

Where HP = heat produced, kcals/24 hr
O_2 = oxygen consumed, litres/24 hr
CO_2 = carbon dioxide produced, litres/24 hr
N = urinary nitrogen excreted, g/24 hr

An example of the calculation of heat production is shown in appendix 3.

2.7.2 Tests applied to the calorimetric equipment

The dry-gas meters were tested against a spirometer (150 l) at the Palmerston North Gas Department workshops, over the range of flow rates used in the experiment.

The whole apparatus was tested by the controlled burning of a weighed amount of absolute alcohol within the calorimeter for periods of up to twelve hours duration. A series of such tests produced a mean measured O_2 consumption of 97.1% ($\pm$ 0.7%) of the theoretical oxygen consumption.

The calorimetric chamber, tested for air leaks by metering simultaneously the incoming and outgoing air, revealed a leakage of about +3%; this representing a gain of air drawn into the system. No leaks were found between the chambers and the gas meters.

2.8 Collection of Faeces and Urine

Urine was funnelled from the metabolism crate into a plastic bucket containing approximately 2.5% (v/w) 0.1 N H_2SO_4 of the previous day's excreted urine. The urine was weighed each day and a thoroughly mixed 10% subsample was stored in a covered bucket at 3°C; acidity was maintained at approximately pH 2.

Faeces were collected on a flat metal tray with raised edges, placed under the wire mesh grate of the metabolism crate. Faeces were also collected daily, bulked into 'calf periods' and stored at - 12°C in a covered plastic container.

With healthy calves urine contamination by faeces was negligible, but with scouring calves contamination did occur in some instances as a result of overflow from the faece collection tray

2.8 (cont'd)

into the urine bucket. Urine contamination of faeces was not a significant problem.

At the end of the calf's balance period the bulked faeces were transferred to a plastic bag, weighed in the frozen state and again stored at - 12°C. The bulked urine subsample was thoroughly mixed and approximately 2 litres was transferred to a plastic bottle and stored at - 12°C. The specific gravity was determined gravimetrically.

2.9 Chemical Methods

Random samples (ca. 0.5kg) of tallow, glycerol-mono-stearate and of each batch of milk powder were taken and stored in a sealed plastic bag at - 12°C.

All chemical analyses were done in duplicate and where necessary blank determinations were also carried out.

2.9.1 Nitrogen determination

The nitrogen content of feeds and excreta was determined by the macro-kjeldahl method (A.O.A.C., 1965).

Bulked faecal samples were thawed, then mixed for two minutes in a large electric mixer. A 4-5 g subsample was put into a nitrogen-free plastic bag (0.5 g) and the bag plus contents digested in the usual way. A weighed sample was taken from the faecal slurry (ca. 150 g) and oven-dried in a flat-bottomed metal dish at 70°C for forty eight hours to determine the dry matter content. The dried faeces were then pulverised in a 'Waring Blender' and were stored in a screw-top glass bottle for further analyses.

2.9.2 Lipid determination

A chloroform-methanol fat extraction method (Folch, Lees and Stanley, 1957) was used to extract the total lipid from a 4-6 g sample of dried faeces. The weighed sample was diluted twenty times (w/v) with a 2:1 chloroform-methanol solution. After a thirty minute extraction period, the solids were removed by filtration through a scintered glass funnel (X-2) which was then rinsed with pure solvent. The lipid-containing filtrate was transferred to a separating funnel, diluted 20% with an electrolyte solution and left to stand overnight. The 'lower phase' containing the lipid was then transferred to a weighed oven-dried flask, the solvent removed, and flask plus lipid were oven-dried overnight before re-weighing.

Butterfat from the B.M.P. was extracted by the method of Pearson (1970).

2.9.3 Gross energy determination

The gross energy of feeds, faeces and urine were determined in an Adiabatic Bomb Calorimeter. Approximately 0.75 g of B.M.P. was weighed into a plastic bag of known calorific value and the total calorific value was measured. Faecal samples were similarly analysed. A 25.0 ml urine sample was pipetted into a petri-dish and then freeze-dried for twenty four hours. The polythene film containing the urine solids was folded tightly and combusted. Corrections were made for the calorific value of the polythene, the specific gravity and H_2SO_4 content of the urine sample when calculating the total urinary energy.

2.10 Statistical Analysis

2.10.1 Analysis of energy and nitrogen balance data

Analyses of variance for a randomized block design, as outlined by Snedecor (1961), was used to test for differences between calves,

2.10.1 (cont'd)

treatments and periods for all data obtained in the energy and nitrogen balances. The classification of the experimental observations showing expectations of the mean squares are shown as follows:

Source	d.f.	Expectation of M.S.
Treatment	(t-1)	$\sigma^2 + p\sigma_\alpha^2 + \frac{r.p}{t-1} \cdot \Sigma T_i^2$
Period	(p-1)	$\sigma^2 + \frac{r.t}{p-1} \cdot \Sigma P_j^2$
TxP	(p-1)(t-1)	$\sigma^2 + \frac{r}{(p-1)(t-1)} \sum_{ij} \lambda_{ij}^2$
Animal within treatments	t(r-1)	$\sigma^2 + p.\sigma_\alpha^2$
Error	t(r-1)(p-1)	σ^2
Total	(t.p.r.-1)	

σ^2 = experimental error
σ_α^2 = animal variance
T_i = treatment effect
P_j = Period effect
λ_{ij} = treatment x period interaction
r = number of animals per treatment

Testing was carried out as follows:

(a) Treatments - The 'animal within treatments' mean square was used to test for differences between treatment means.

(b) Differences between periods, animals and treatment x period interactions were tested against the error mean square.

2.10.2 Regression analysis

The relationships between energy retained and both gross energy and metabolizable energy intake; and log heat production and log liveweight, were measured by analysis of regression (Snedecor, 1961). As regressions based on the pooled data were confounded by animal, period and treatment effects, these were

2.10.2 (cont'd)

removed and a measure of the error regression obtained. Where variations between treatments in the relationship were suspected, individual regression analysis were made for each treatment.

2.10.3 Covariance analysis

The relationship between liveweights at the end of each period and the initial pre-treatment liveweight was analysed using covariance analysis (Snedecor, 1961).

2.10.4 Faecal observations

Analysis of Chi-Square (Snedecor, 1961) was used to detect for differences in faecal dry matter classifications between treatments.

2.10.5 Significance of differences

The method of least significant difference (Snedecor, 1961) was used to locate the difference between means which were statistically significant.

Note 1:

The following signs have been used throughout to describe the level of significance of differences between means:

***	Differences significant at the 1% level of probability.
**	Differences significant at the 5% level of prcbability.
*	Differences significant at the 10% level of probability.
N.S.	Differences not significant.

Note 2:

S.E. Standard Error of the mean.

SECTION TWO

SKIM MILK POWDER EXPERIMENT

This experiment was designed in a manner identical to that already described, with the exception that S.M.P. (1% milk fat on a dry matter basis) was used in place of B.M.P. which contained 9% milk fat.

This experiment was terminated after ten days of S.M.P. feeding and consequently no 'balance' data were obtained. However, faecal observations were recorded on thirty seven calf-days. Because of the short duration of this experiment the results and discussion of this section of the work have been given less emphasis that those of the B.M.P. experiment.

CHAPTER THREE

RESULTS

SECTION ONE

3.1 Animals

3.1.1 General

The calves quickly settled into their metabolism crates and readily drank their milk from buckets, with the exception of calf L4 which had frequently to be coaxed into drinking. This calf was the only one to refuse milk while in a state of good health. In the calorimeter the animals remained quiet at all times.

3.1.2 Health

The pooled subjective faecal consistency score of the four calves within each of the three treatments have been summarised in appendix 2. Those calves fed the tallow supplement had considerably firmer faeces than their mates fed solely on B.M.P.: only one case of scours being recorded against treatment HT, whereas eleven cases was recorded against treatment L and nine against treatment H. Chi-Squared analysis showed scouring (viz. classifications 4 and 5) to be dependent on the fat content of the diet ($p < 0.05$).

Many of the calves showed a tendency towards scouring when changed from a whole milk diet to the experimental diet. However this tendency was only of short duration and faecal observations during the change-over period were not included in the above analysis. The single case of scours recorded against treatment HT (calf HT1) occurred during the first period on the experimental diet.

A quantitative faecal dry matter analysis was also carried out using data from oven-dried faeces collected from the nine calves

TABLE 3

Percentage Dry Matter of Bulked Oven-Dried Faeces Collected During the Five-Day Balance Periods.

Treatment	Calf	Period 1	mean	Period 2	mean	Period 3	mean	Treatment Mean ± S.E.
L	L1 L2 L3	13.73 17.89 17.95	16.52	14.28 15.62 16.19	15.36	19.42 14.55 19.27	17.75	16.54±0.85
H	H1 H2 H3	17.23 18.65 11.81	15.89	15.60 13.76 15.52	14.96	18.73 14.49 17.22	16.81	15.89±0.85
HT	HT1 HT2 HT3	23.90 18.36 17.64	19.97	21.21 19.20 19.25	19.89	20.40 24.89 21.13	22.14	20.66±0.85
Period mean ± S.E.			17.49±0.85		16.73±0.85		18.90±0.85	

Significant Result HT > L = H***

TABLE 4

Type of Drug Administered as Determined by Faecal Consistency and Slowness of Recovery of Calves to Normal Health.

Calf	Period 1		Period 2		Period 3	
	S.M.*	O.T.C.†	S.M.	O.T.C.	S.M.	O.T.C.
L1		X	X		X	
L2		X	X		X	
L3		X	X		X	
H1	X				X	
H2		X		X		X
H3	X					
H4		X			X	
HT1	X				X	

* sulfa methazine

† oxytetracycline

3.1.2 (cont'd)

during their respective five-day balance periods. These data are summarised in table 3. Analyses show that calves on treatment HT voided firmer faeces than calves on the other two treatments ($p < 0.01$), but differences between periods were not significant. It is interesting to note the close agreement between the two faecal parameters used in view of the fact that the qualitative assessment was based on all twelve calves during the entire thirty-day experimental period, whereas the quantitative measures were based on the means of only three five-day balance periods of nine calves.

Calf L4 developed severe and chronic scouring at one week of age and subsequently required veterinary treatment. As sulphonamide drugs were ineffective in controlling scouring an oxytetracycline was used with this calf, and subsequently with other calves, when necessary. Table 4 summarises the periods during which individual calves were treated with drugs for digestive disorders.

Calf HT1, during its final balance period, developed a severe infection of the right hind hock which appeared to cause great discomfort. The calf's rectal temperature (39.8 - 40.6°C) was slightly above normal during this period and its respiratory rate was nearly double that of two other healthy calves viz. 50 - 55 as compared with 29 and 37.

3.1.3 Liveweight

The mean growth curves for each group of calves recorded during the experiment are shown in figure 2 and all data are summarised in table 5. The mean liveweight gains, adjusted by covariance analysis for differences in initial liveweight, over the thirty-three day period from the commencement of the change-over period were 0.57, 0.73 and 0.62 kg/day for treatments L, H and HT respectively. These

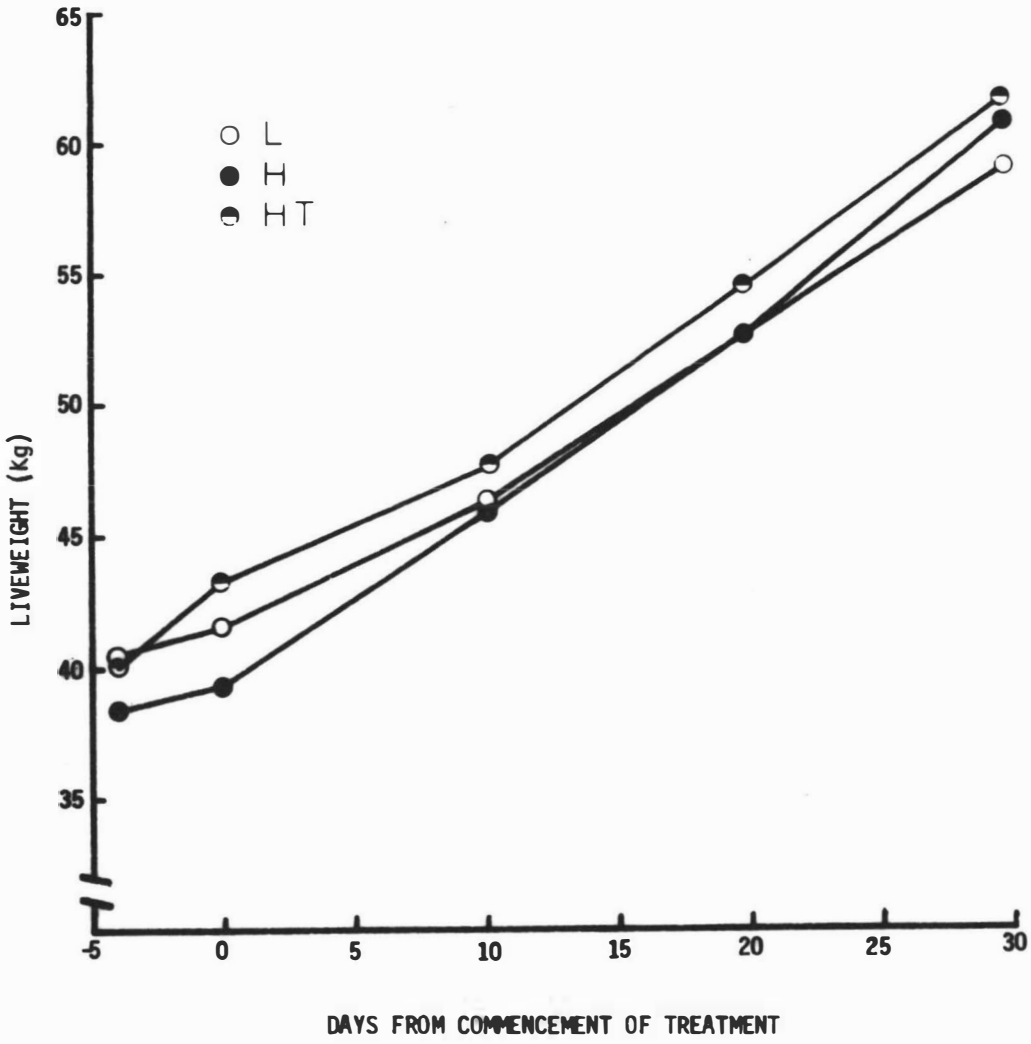


Fig.2 : The average growth curve for each of the 3 groups of calves.

TABLE 5

Liveweight Data from Calves Fed Buttermilk Powder

Calf	X_0	X_1	Y_2	Y_3	Y_4
L1	38.7	40.9	46.4	52.9	59.2
L2	41.1	43.4	48.9	55.4	61.6
L3	46.3	48.5	52.2	60.4	66.2
L4	32.6	33.6	37.9	42.0	49.3
Mean	39.7	41.6	46.3	52.7	59.1
H1	34.7	36.8	43.0	49.7	57.4
H2	35.4	38.8	45.2	51.2	58.9
H3	35.9	36.9	41.1	48.8	56.7
H4	45.6	47.2	54.0	61.0	69.4
Mean	37.9	39.9	45.8	52.7	60.6
HT1	44.4	47.6	50.0	56.1	61.5
HT2	35.4	39.3	45.7	50.6	61.3
HT3	37.7	40.9	44.8	51.4	57.4
HT4	43.4	44.5	49.9	59.0	65.6
Mean	40.2	43.1	47.6	54.3	61.4

X_0 = liveweight prior to commencement of change-over period.

Y_1 = liveweight at commencement of period 1.

Y_2 = liveweight at end of period 1.

Y_3 = liveweight at end of period 2.

Y_4 = liveweight at end of period 3.

Note: All weights are means of two consecutive daily weighings except Y_2 and Y_3 for the fourth calf in each group.

3.1.3 (cont'd)

differences were not statistically significant (see appendix 3).

Calves L3, L4, H3, HT1 and HT3 grew slowly during their first ten-day period; the growth rates being 0.17, 0.43, 0.42 and 0.40 kg/day respectively. Conversely calf L3 had a very rapid apparent gain during its second ten-day period, but calf L4, which often refused its milk, continued to grow slowly relative to its group mates. There was, however, little indication that calf HT1 suffered any set-back in growth during period 3, even though it was obviously under considerable stress as a result of its infected hind hock.

3.2 Derivation of the Exponent of Liveweight

All balance data have been expressed in terms of unit liveweight raised to the power 0.75 in accordance with Kleiber's recommendation to the European Association of Agriculture Production (1965). The actual exponent applicable to this group of calves was determined by regression of the pooled data of log heat production on log liveweight (figure 3, appendix 4) from which the following equation was derived:

$$Y = 0.852\ (\pm 0.08)\ X + 2.007$$

where Y = log heat production

and X = log liveweight

This exponent of liveweight (b = 0.85) is in reasonable agreement with Kleiber's value of 0.75, and thus justifies the use of the latter value in analysing the present results, particularly as this exponent is now the accepted 'standard' - the use of which allows comparisons to be made with the results of other workers.

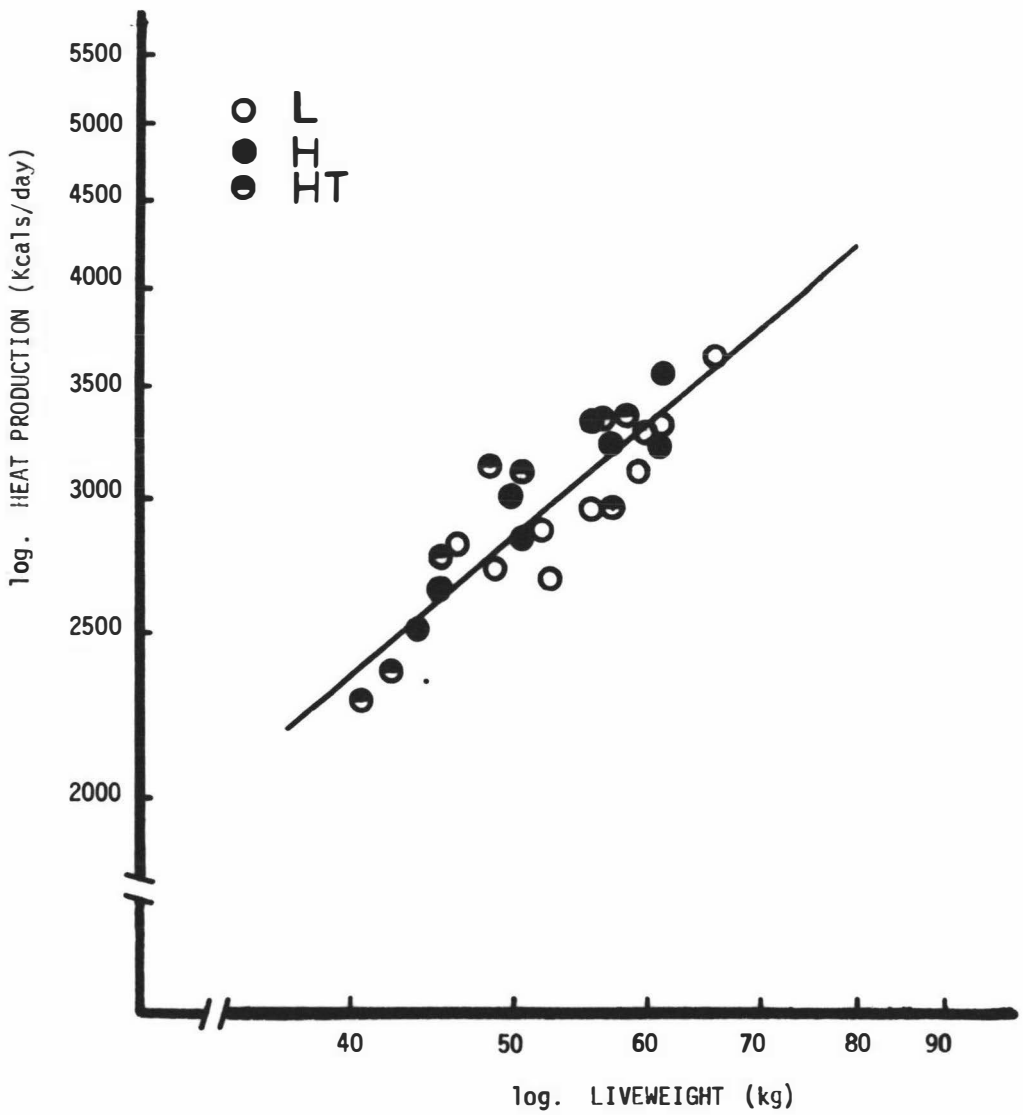


Fig. 3 : Logarithmic relationship between heat production and Liveweight.

3.3 Intake and Digestibility

3.3.1 Intake

The calves' energy requirements were formulated on the basis of their liveweight ($kg^{1.0}$) since all quoted requirements are based on this unit of liveweight. Mean daily intake of the major constituents of the respective diets(per $kg^{1.0}$) during each of the three ten-day periods have been summarised in table 6. Dry matter, crude protein and milkfat intakes were significantly greater in treatment H than in the other two treatments ($p < 0.01$), although the calves fed the tallow supplement had a greater intake of total dietary fat. Calf L1 was unaccountably fed above its B.M.P. allowance during period 1 and hence the mean intake of crude protein, butterfat and gross energy (of B.M.P. origin) was greater by this group, than by the tallow-fed group of calves. As a consequence analyses of variance have been carried out using data from periods 2 and 3 only, as well as from all three periods.

Mean G.E. intakes ($kcals/kg^{0.75}/day$) are summarised in the energy balance (table 9). Calves on treatment H and HT had a significantly greater G.E. intake ($p < 0.01$) than the calves on treatment L; the difference between treatments H and HT was significant at the 10% level. Considering only the last two periods, differences in G.E. intakes, significant at the 5% level, were in the order H > HT > L. The difference between diets H and HT can be attributed to a consistently lower-than-intended fat content in the tallow-supplemented milk diet. The low mean G.E. and N intakes on treatment H, period 1, resulted from calves H2 and H3 refusing their daily ration on one of their respective five-day balance periods - this coinciding with observed scouring by these calves.

Whereas the tallow-fed calves received 9% more energy from dietary fat than calves on treatments L and H, they received 3% less energy in the form of protein (table 6); lactose was assumed to contribute the

TABLE 6

Mean Daily Ration of B.M.P., Protein, Butterfat and Tallow/kg Liveweight, Fed According to the Calf's Weight at the Beginning of each Period: Percentage of Gross Energy Intake Derived from Protein and Fat; and Percentage of Total Dry Matter Intake as Fat.

Treatment	Period	Liveweight at Commencement of Period	Dry Matter Intake B.M.P.	Protein Intake	% G.E. Intake Derived from Protein *	Butterfat Intake	Tallow Intake	% Total d.m. Intake as Fat	% G.E. Intake Derived from Fat **
		(kg)	(g/kg/d)	(g/kg/d)	%	(g/kg/d)	(g/kg/d)	(%)	(%)
L	1	44.27	22.08	7.08	29.3	2.02	-	9.18	16.0
	2	49.29	20.34	6.36	28.5	1.80	-	8.83	16.6
	3	54.20	19.25	6.07	28.6	1.71	-	8.90	16.8
H	1	37.49	24.78	7.94	30.0	2.14	-	8.65	16.5
	2	42.90	24.75	7.78	28.6	2.15	-	8.69	16.3
	3	49.80	26.35	7.47	28.4	2.10	-	8.86	16.9
HT	1	41.90	20.15	6.46	25.6	1.76	1.37	12.80	25.9
	2	46.80	19.99	6.30	25.5	1.70	1.37	13.05	26.1
	3	50.00	19.77	6.27	26.2	1.76	1.10	12.01	24.5

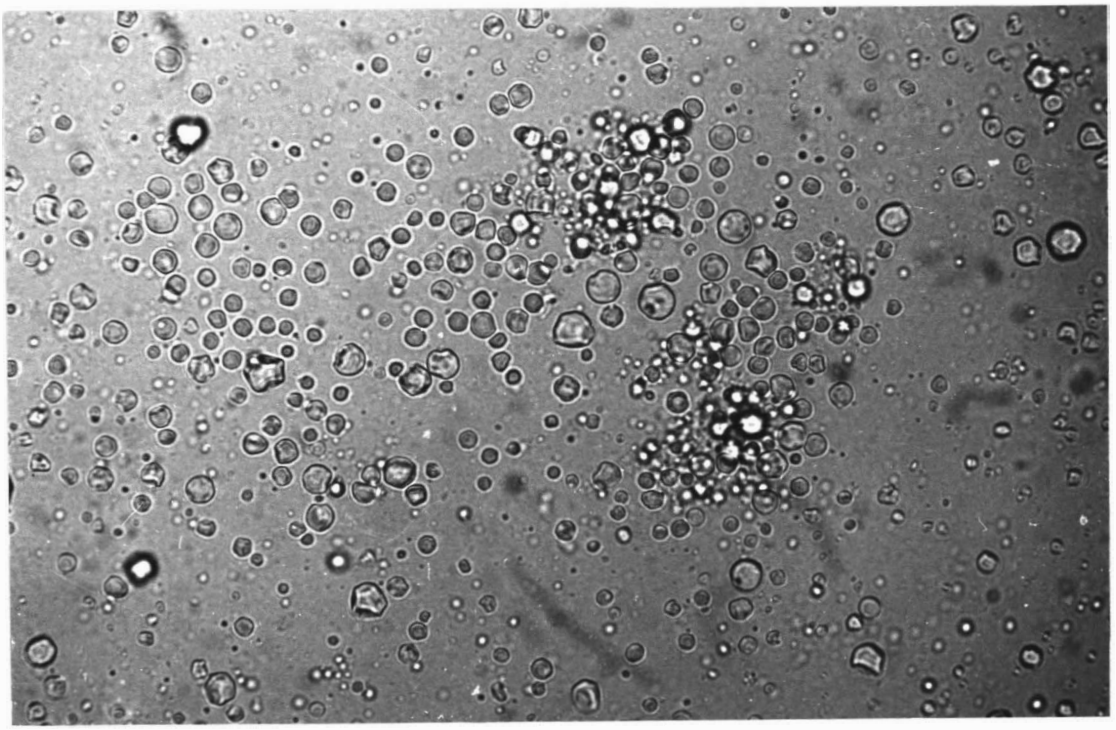
* 4.27 kcals/gm milk protein

** 8.79 kcals/gm butterfat
9.44 kcals/gm tallow

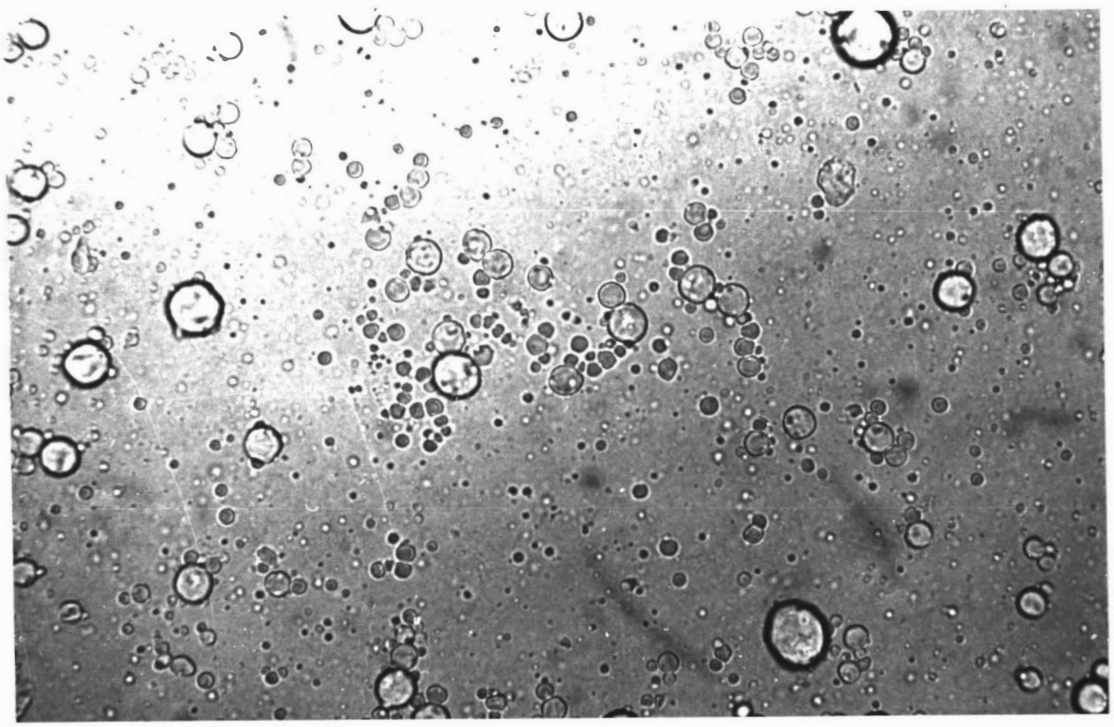
TABLE 7

Mean Coefficients of the Percentage Apparent Digestibility of Crude Protein, Ether Extract, Dry Matter and Gross Energy.

Period	Treatment			Period Mean	S.E. of Means
	L	H	HT		
CRUDE PROTEIN					
1	90.2	87.0	90.3	89.2	
2	89.2	93.6	90.9	90.9	
3	92.5	94.0	93.3	93.2	
Treatment Mean	90.6	91.5	91.2		±0.9
Significant Effect	Treatments N.S.			Periods - $1 <^{*} 3$	
ETHER EXTRACT					
1	92.8	89.1	93.2	91.7	
2	91.8	95.5	94.4	93.9	
3	95.0	94.9	95.0	95.0	
Treatment Mean	93.2	93.2	94.2		±0.6
Significant Effect	Treatments N.S.			Periods - $1 <^{***} 3$	
DRY MATTER					
1	95.0	93.3	95.0	94.0	
2	93.8	96.4	95.2	95.1	
3.	95.5	95.9	96.0	95.8	
Treatment Mean	94.8	95.2	95.4		±0.2
Significant Effect	Treatments N.S.			Periods - N.S.	
GROSS ENERGY					
1	94.5	92.7	94.1	93.8	
2	95.1	96.3	94.4	95.3	
3	95.5	96.2	95.4	95.7	
Treatment Mean	95.1	95.1	94.6		±0.6
Significant Effect	Treatments N.S.			Periods - $1 <^{*} 3$	



A. Wholemilk



B. B.M.P. plus Tallow

PLATE 1. Photomicrographs of Fat Globules in (A) Wholemilk and (B) Reconstituted B.M.P. plus Tallow.

3.3.2 Fat globule size

Microscopic measurements of the fat globules in the homogenised tallow diet showed that they were mainly in the range 1 to 7 μ diameter, with very few being greater than 10 μ. Although it was not possible to distinguish between tallow and milk fat it is probable that the larger fat globules were of tallow origin as prepared slides of B.M.P. showed that the milk-fat globules ranged in size from 0.5 to 4.0 μ diameter. Photographs of the prepared tallow diet and of fat in whole milk are shown in plate 1, a and b. Whole milk was used in this comparison since it is widely accepted that this is probably the ideal diet for young calves.

3.3.3 Digestibility

The coefficients of apparently digested crude protein, ether extract, dry matter and gross energy presented in table 7 show no significant differences between treatments ($p > 0.05$), although the digestibility of the fat, the protein and the energy increased significantly with increasing age (viz. as liveweight and plane of nutrition increased) ($p < 0.05$).

3.4 Nitrogen Balance

Table 8 summarises the mean values of nitrogen intake, faecal and urinary nitrogen losses, and the apparent daily nitrogen retention, all of which are illustrated in figure 4. Expressed as $g/kg^{0.75}/day$, the calves fed the high level of B.M.P. had a significantly greater intake of nitrogen (N) than those fed the low level of B.M.P., which in turn had a greater intake ($p < 0.01$) than the tallow-fed calves. However, analysis of the last two periods showed that the N intakes on treatments L and HT were similar, but statistically less than on treatment H ($p < 0.01$). Although the

NITROGEN BALANCE: Mean Data of Three Observations/Treatment (g/kg$^{0.75}$/day); Mean Percentage of Digested Nitrogen Retained; Nitrogen Retained/kcal M.E. Intake; and Ratio of Digested Nitrogen Retained/kcal M.E. Intake.

Measurement	Period 1			Period 2			Period 3			Mean			S.E. Treatment Mean	Significance of Result		
	L	H	HT	L	H	HT	L	H	HT	L	H	HT		Diet	Period	Interaction
Nitrogen Intake	2.70	2.83	2.45	2.44	2.86	2.39	2.46	2.85	2.45	2.53	2.84	2.43	±0.04	H > HT=L ***	N.S.	N.S.
									*	2.45	2.85	2.42	±0.04	HH > HT=L ***	N.S.	N.S.
Faecal Nitrogen	0.26	0.36	0.24	0.26	0.19	0.24	0.18	0.17	0.16	0.24	0.24	0.21	±0.04	N.S.	1>3 **	N.S.
Urinary Nitrogen	0.96	1.24	1.06	1.24	1.49	1.11	1.34	1.56	1.24	1.18	1.43	1.14	±0.08	H>HT=L *	3>1 ***	N.S.
										1.29	1.52	1.18	±0.07	H>HT=L **	N.S.	N.S.
Retained Nitrogen	1.48	1.23	1.14	0.93	1.18	1.03	0.93	1.12	1.04	1.12	1.18	1.07	±0.05	H>HT=L **	1>2=3 ***	*
										0.93	1.15	1.04	±0.04	H>HT>L **	N.S.	N.S.
% Digested Nitrogen Intake Retained	60.9	49.6	51.6	42.9	44.3	48.2	41.1	41.9	46.0	48.3	45.2	48.6	±3.10	N.S.	1>2=3 *	N.S.
										42.0	43.1	47.1	±2.24	N.S.	N.S.	N.S.
Nitrogen Retained/kcal M.E Intake ($\times 10^{-3}$)	6.61	5.47	5.05	4.56	5.05	4.53	4.50	4.68	4.62	5.22	5.07	4.74	±0.22	N.S.	N.S.	N.S.
% Digested Nitrogen Retained/kcal M.E. Intake	0.27	0.22	0.23	0.21	0.18	0.21	0.19	0.17	0.24	0.22	0.19	0.23	±0.01	HT L>H *	1>2=3 **	N.S.
										0.20	0.18	0.23	±0.01	HT>L>H ***	N.S.	N.S.

* Analysis of Variance for Periods 2 and 3

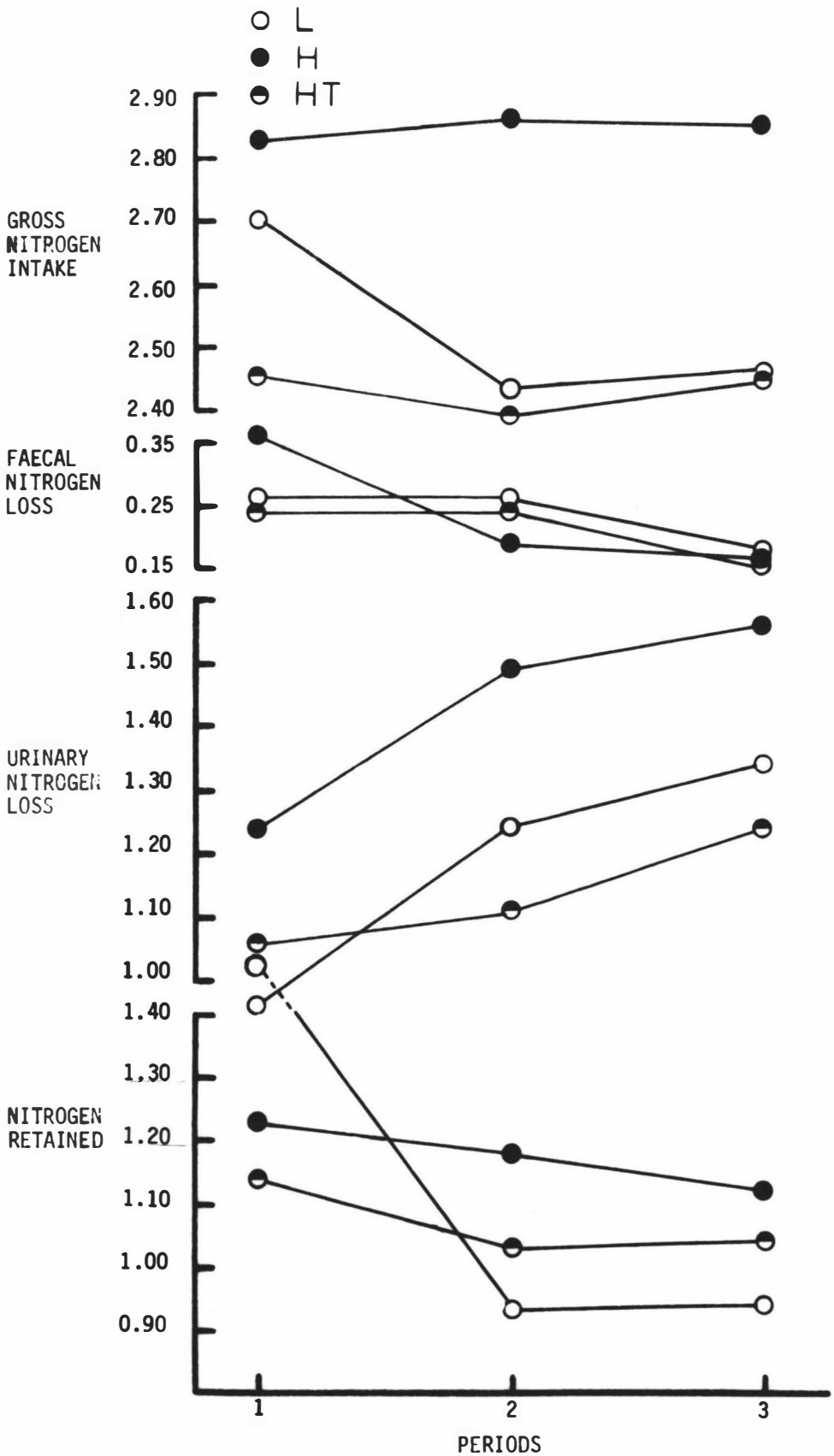


Fig.4 : Mean daily nitrogen balance data ($g/kg^{0.75}/day$)

3.4 (cont'd)

daily faecal N excretion of all calves decreased with increasing age ($p < 0.05$), there was no apparent difference between treatments. Animals receiving the higher N intake, viz. treatment H, had a greater urinary N excretion than those on the lower N intake ($p < 0.1$), and in all three treatments urinary N was greater in period 3 than in period 1 ($p < 0.01$). With respect to nitrogen retention, there were treatment differences in the order H HT = L ($p < 0.05$), and significantly more N was retained in period 1 than in the other two periods ($p < 0.01$). Analysis of the final two periods showed significant differences in retained N of the order H > HT > L ($p < 0.05$).

Because the N intake differed between treatments, an analysis was carried out to test for a difference in the percentage of digested nitrogen retained. Although the percentage retained was greatest by the tallow-fed calves during the latter two periods, this difference did not reach significant proportions ($p > 0.1$).

The very high apparent mean nitrogen retention in period 1 by the calves on treatment L is attributable to the low nitrogen content in the excreted urine of the calf L3. Since the percentage of nitrogen in this urine sample was about half that of all other urinary samples, the author has some doubt about the validity of this mean value, and the subsequent analysis of retained nitrogen based on all three periods.

There was no difference between treatments in the ratio of N retained : M.E. intake ($p > 0.1$), but there was a highly significant decline in the ratio from period 1 to period 2 ($p < 0.01$). Of greater interest though is the significantly greater ratio of apparently digested nitrogen retained : M.E. intake in periods 2 and 3 of the order HT > L > H ($p < 0.01$).

3.5 Energy Balance

The means of G.E. intake, faecal and urinary energy losses, heat production, and estimated energy retention are presented in table 9 and shown graphically in figure 5. The G.E. intake data have been discussed in section 3.3.1. There were no significant differences in faecal energy or heat losses between treatments ($p > 0.10$), but calves on treatment H lost significantly more energy via their urine than did the other animals ($p < 0.05$) - this being associated with the greater urinary nitrogen excretion by these animals. The coefficient of correlation between the pooled urinary energy and urinary nitrogen data was found to be +0.77, and the prediction equation from regression analysis to be:

$$U_E = 9.45\ U_N + 0.24$$

where: U_E = urinary energy (kcals)

U_N = urinary nitrogen (g)

There were no significant trends in the amount of energy retained based on the analysis of variance of all three periods ($p > 0.1$), but analysis of the last two periods showed that calves fed the two high energy diets retained more energy than did those on the low energy diet ($p < 0.01$). Similarly, only in the analysis of the last two periods was there any significant difference in the ratio of energy retained : M.E. intake where the ratio was significantly greater for groups H and HT than for group L ($p < 0.05$). This ratio did not change with increasing age.

The total energy retained was partitioned into that retained as protein and that retained as fat using a value of 5.7 kcals/g of protein (N x 6.25) stored (Brouwer, 1965); energy retained as fat was estimated by difference from total energy retained. These data, and the ratios of energy retained as fat : energy retained as protein , are summarised in table 10. Calves on treatment H deposited a greater per-

TABLE 9

ENERGY BALANCE: Mean Data of Three Observations/Treatment (kcals/$kg^{0.75}$/day); Mean Percentages of Apparently Digested and Apparently Metabolised Energy Retained.

MEASUREMENT	PERIOD 1			PERIOD 2			PERIOD 3			MEAN			S.E. Treatment Mean	SIGNIFICANCE OF RESULT		
	L	H	HT	L	H	HT	L	H	HT	L	H	HT		Diet	Period	Interaction
Gross Energy Intake	246.2	255.1	251.8	228.5	266.6	252.8	229.1	264.1	250.4	234.6	261.9	251.7	±4.0	H=HT$>^{***}$L	N.S.	N.S.
									≠	228.8	265.3	251.6	±2.3	H=HT$>^{***}$L	N.S.	N.S.
Faecel Energy Loss	12.7	18.4	15.2	12.9	9.8	14.2	9.2	9.9	11.6	11.9	12.7	13.5	±2.2	N.S.	1$>^{**}$3	N.S.
										11.0	9.9	12.9	±2.1	N.S.	N.S.	N.S.
Urinary Energy Loss	8.7	12.5	11.0	11.6	15.9	10.7	12.2	14.6	11.2	10.9	14.3	11.0	±0.6	H$>^{**}$HT=L	N.S.	N.S.
										11.9	15.2	11.0	±0.6	N.S.	N.S.	N.S.
Metabolisable Energy Intake	224.7	224.2	225.7	204.0	240.8	227.9	207.6	239.6	227.6	212.1	234.9	227.0	±3.2	H=HT$>^{***}$L	N.S.	N.S.
										205.8	240.2	227.7	±1.45	H$>^{***}$HT$>^{***}$L	N.S.	N.S.
Heat Produced	152.9	147.0	153.4	145.6	160.3	154.7	151.7	154.1	155.4	150.0	153.8	154.5	±3.6	N.S.	N.S.	N.S.
										148.6	157.2	156.0	±4.5	N.S.	N.S.	*
Energy Retained	71.8	77.3	72.3	58.5	80.5	73.2	55.9	85.5	72.2	62.1	81.1	72.6	±5.7	N.S.	N.S.	N.S.
										57.2	83.0	72.7	±3.9	H=HT$>^{***}$L	N.S.	N.S.
% Apparently Digested Energy Retained	30.7	32.1	30.5	27.1	32.1	30.6	25.3	33.3	30.2	27.7	32.3	30.4	±1.8	N.S.	N.S.	N.S.
										26.2	32.4	30.8	±1.7	H=HT$>^{*}$L	N.S.	N.S.
% Apparently Metabolised Energy Retained	32.0	33.9	31.9	27.4	31.8	32.1	26.9	35.7	31.6	28.8	33.8	31.9	±1.9	N.S.	N.S.	N.S.
										27.2	33.7	31.9	±3.4	H=HT$>^{**}$L	N.S.	N.S.

≠ Analysis of variance based on periods 2 and 3

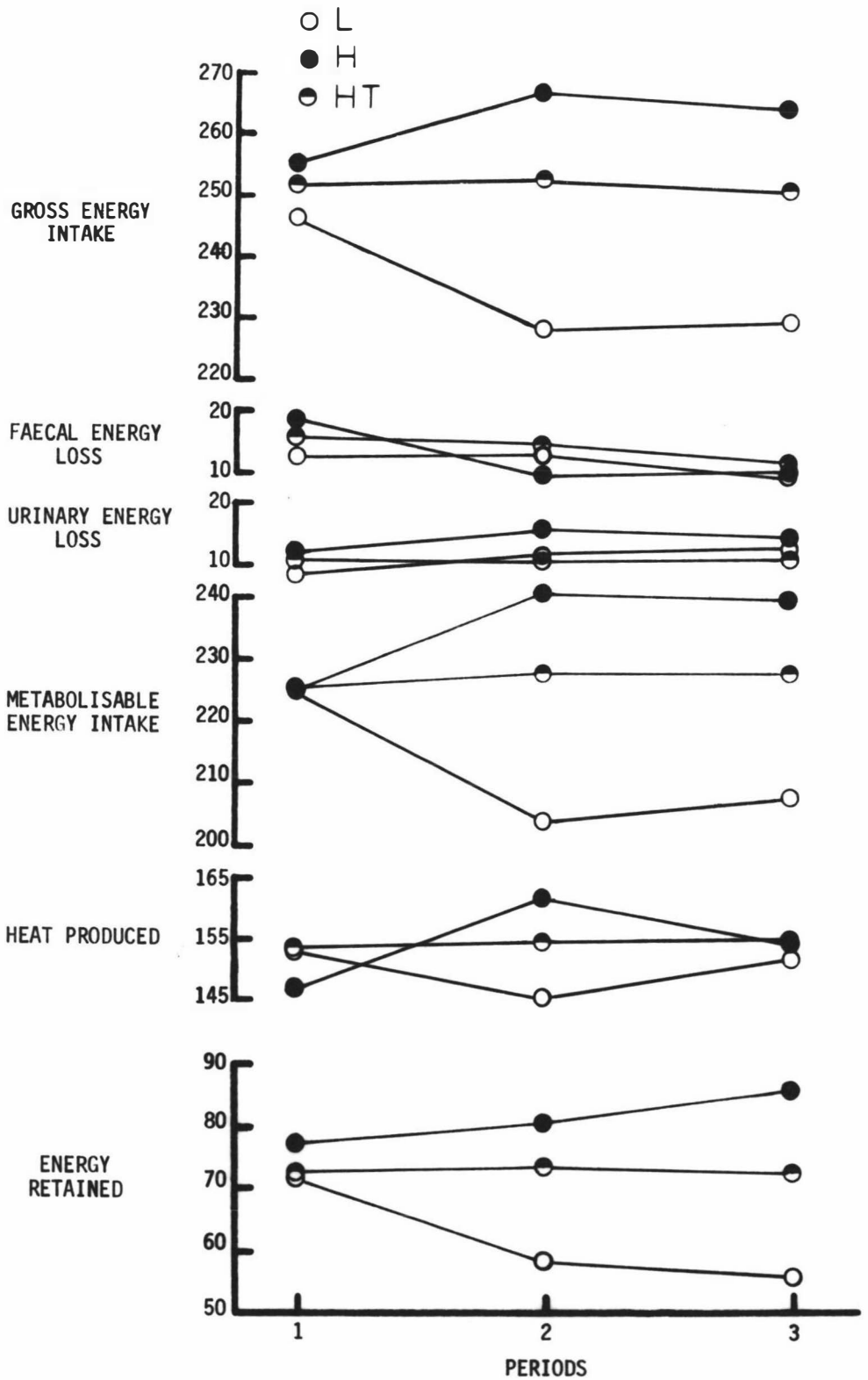


Fig.5 : Mean daily energy balance data (kcals/kg$^{0.75}$/day)

TABLE 10

The Partition of Retained Energy as Protein and Fat (kcals/$kg^{0.75}$/day); the Ratio of Energy Retained as Fat: Energy Retained as Protein; and Percentage of the Total Energy Retained which was Retained as Protein.

Measurement	Period 1			Period 2			Period 3			Mean			S.E. Treatment Mean	Significance of Result		
	L	H	HT	L	H	HT	L	H	HT	L	H	HT		Diets	Periods	Interaction
Protein Energy Retained/$kg^{0.75}$	52.72	43.81	40.61	33.13	42.03	36.69	33.13	39.89	37.04	39.66	41.91	38.11	±1.78	H > HT=L**	1>2=3***	N.S.
									*	33.13	40.96	37.04	±1.42	H > HT>L**	N.S	N.S.
Fat Energy Retained/$kg^{0.75}$	20.67	37.14	29.91	23.14	37.36	35.30	24.78	45.63	35.14	22.86	40.04	33.23	±5.21	N.S.	N.S.	N.S.
										23.96	41.69	35.22	±3.85	H=HT > L*	N.S.	N.S.
Fat Energy: Protein Energy	0.39	0.86	0.74	0.70	0.89	0.96	0.75	1.14	0.95	0.61	0.99	0.88	±0.14	N.S.	N.S.	N.S.
										0.74	1.00	0.96	±0.12	N.S.	N.S.	N.S.
% Energy Retained as Protein	72.01	51.10	64.90	59.07	53.53	52.43	57.29	46.65	51.33	62.79	50.43	56.22	±4.35	N.S.	N.S.	N.S.

* Analysis of Variance for Periods 2 and 3

3.5 (cont'd)

centage of the retained energy as fat (per $kg^{0.75}$ liveweight) than the calves on treatment L($p < 0.05$): the percentage retained as fat by the tallow-fed calves being between these two levels. There was an apparent but non significant trend for the percentage of fat deposited per day to increase with increasing age.

However, these results may be greatly exaggerated by the very high apparent nitrogen retention in period 1, treatment L, and consequently the age effect in particular, may have little biological significance.

The relationships between energy retention and M.E. intake (appendix 8), and energy retention and G.E. intake (appendix 9 - pooled data only) were analysed by linear regression. As the difference between regressions of energy retention on M.E. intake for each treatment was non significant, the data was pooled and used to estimate, by extrapolation to zero energy retention, the maintenance energy requirement (figure 6). The following equations were derived from the pooled data of all twenty-seven energy balance experiments:

$$Y = 0.708\ (\pm\ 0.09)\ X_1 - 104.8$$

$$Y = 0.782\ (\pm\ 0.09)\ X_2 - 103.7$$

where Y = energy retained (kcals/$kg^{0.75}$/day)

X_1 = G.E. intake (kcals/$kg^{0.75}$/day)

X_2 = M.E. intake (kcals/$kg^{0.75}$/day)

The estimated maintenance requirements being:

148.0 kcals G.E./$kg^{0.75}$/day

132.6 kcals M.E./$kg^{0.75}$/day

which is equivalent to 53.5 kcals D.E./kg liveweight/day for a 50 kg calf; a mean loss of the D.E. intake in the urine, found in this experiment to be 5.1%, was used to derive the D.E. requirement from the estimated M.E. value above.

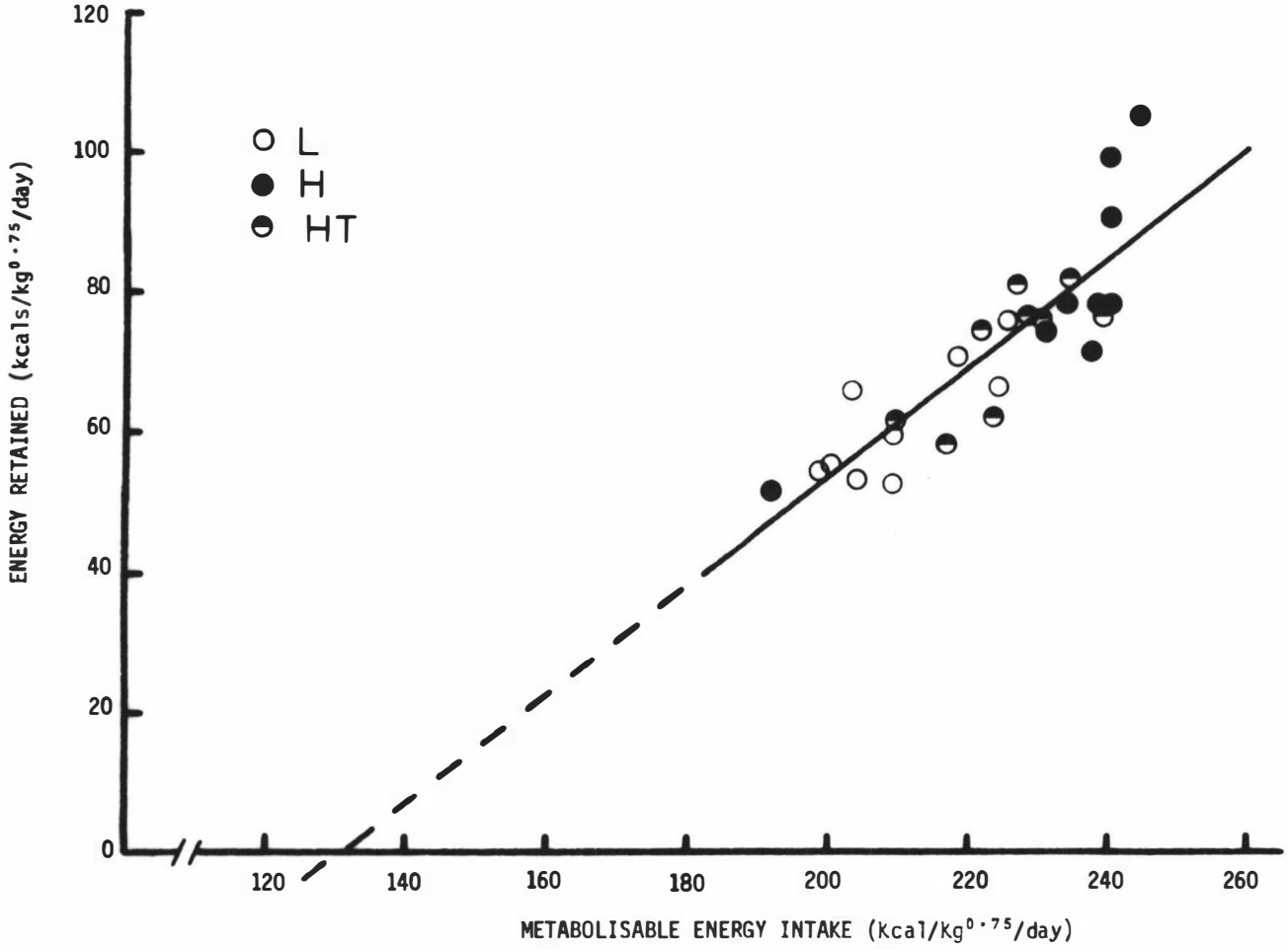


Fig. 6 : Relationship between Energy Retained and Metabolisable Energy Intake

SECTION TWO

Skim Milk Powder Experiment

Several of the calves in this experiment became emaciated and very lethargic when fed the S.M.P. diets. Observations on faecal characteristics obtained during the short duration of this experiment, which reflect to a large extent the poor health of these calves, are summarised in appendix 2. Analysis of Chi-Square confirmed the observation that the calves fed the basal S.M.P. diet suffered from very severe scouring, whereas those fed the tallow supplement only had a faecal classification in the 'moist' to 'very wet' range.

As shown in table 5, the liveweight changes of the calves were very erratic and, in the main, independent of the level of energy intake although the tallow-fed calves did show a greater consistency in their growth rate - this reflected the better health of these animals.

After ten days of feeding S.M.P., the health of four of the nine calves was such that it was thought prudent to terminate the experiment in order to prevent calf mortalities. This decision was made on two counts: firstly, it was found that roller-dried milk powder had been inadvertantly used instead of spray-dried powder - the former having been reported to induce scouring in young calves (Shillam et al., 1961; Mylrea, 1966; Lister, 1971 pers,comm.); and secondly, as the poor health developed prior to the commencement of the balance periods, it was considered unlikely that sufficient useful data would be obtained from these calves had the scouring continued any longer. An attempt was made to continue the experiment using spray-dried milk powder, but after five days feeding of this diet no reduction in scouring was apparent. This experiment was therefore abandoned in its present form and a new lot of animals were procured for the experiment already described where B.M.P. was used as the basal diet.

TABLE 11

Liveweights and Daily Liveweight Gains of Calves
Fed Skim Milk Powder

Calf	Initial Weight (kg)	Final Weight (kg)	Change of Age (days)	Liveweight Gain (kg/day)
LS1	38.14	43.13	10	0.50
LS2	33.37	37.45	10	0.41
LS3	43.81	45.63	7	0.26
HS1	47.22	48.58	6	0.23
HS2	48.12	45.17	6	-0.49
HS3	33.37	38.82	9	0.61
HTS1	44.04	46.31	6	0.38
HTS2	44.09	47.22	6	0.45
HTS3	46.76	58.85	6	0.68

CHAPTER FOUR

DISCUSSION

The results of this trial conclusively confirm the ameliorating effects that supplementary non-milk fats have been shown to have on calves fed low-fat milk diets, (Olson and Williams, 1959; Bush et al.,1963; Mathieu and Barre, 1964), since in the main experiment only one instance of scours was recorded against a tallow-fed calf, compared with twenty being recorded against those fed B.M.P. In the first experiment using S.M.P. the high incidence of scouring in most calves, but particularly in those not receiving the fat supplement, was almost certainly induced as a result of the high heat treatment given the milk during the roller-drying process (Shillam, et al.,1960; Shillam, et al., 1962a, b; Shillam and Roy, 1963a, b). Even in the second trial it was likely that the buttermilk was subjected to excessive heating during the spray-drying process - as indicated by the burnt lumps of powder observed in the reconstituted milk - which would have caused some protein denaturation and which consequently resulted in poorer abomasal clot formation (Lister, 1971). However, when using either of these apparently low quality milk powders beef tallow was found to be highly beneficial in reducing calf scours. Whether its mode of action was through the formation of soaps, which Cheng et al., (1949) have suggested, removes the laxative dietary Mg^{++} and Ca^{++} ions, or whether it was through some other action, such as improved clot formation, is not known. In this experiment it is unlikely that the higher intake of lactose by calves on treatments L and H caused the greater incidence of scouring as the calves on the latter treatment, although having a greater intake of lactose per unit of liveweight, did not void faeces of a significantly different dry matter content to those voided by the calves on treatment L. Hence the slightly lower intake of lactose by the tallow-fed calves relative to the other animals would not be expected to have had any significant effect on the incidence of scouring. Because the basal diets of the S.M.P. and B.M.P. experiments differed in both fat content and method of manufacture, it is not possible to attribute the reduced

reduced incidence and severity of scouring in the B.M.P. trial to any particular cause or causes. However, as the increase from 8.6% to 12.7% mean fat content between the B.M.P. and B.M.P. plus tallow diets resulted in significantly firmer faeces, it is reasonable to expect that in changing from S.M.P. (1% butterfat) to B.M.P. (8.6% butterfat) the higher level of fat in the basal B.M.P. diet would have contributed towards the increased faecal dry matter content found in this experiment.

Although the faecal dry matter and subjective faecal consistency classifications both showed significant differences between the high and low fat diets, the coefficients digestibility of dry matter, crude protein and ether extract did not significantly differ; a finding which concurs with the report of Roy et al., (1970b) who found that one group of calves which had a significantly higher incidence of scouring than another group did not significantly differ in their digestibility of either dry matter or crude protein. These findings appear at first sight to be in conflict with data presented by Roy (1970) which shows an approximately seven-fold increase in excreted faecal dry matter, fat, crude protein and ash, and an eighteen fold increase in faecal water by diarrhoeal calves compared to healthy calves. However, because of the high animal variance within treatments in the extent of digestion of dietary components, the difference between treatment means did not attain significance. Secondly, it is to be remembered that although a faecal dry matter difference did exist between the high and low fat dietary treatments, the incidence of scouring during any one treatment period was in no case recorded against all three calves for the duration of the five-day balance period. Therefore any effects of scouring which may have occurred during a collection period would have been masked when the data for all calves was collated in the analyses of variance of apparently digested dietary components. Because of the high digestibility of dietary fat in all three treatments it would appear that there was no significant shortcoming in the method used to homogenise the tallow in the milk diet; a conclusion also borne out by the fact that the fat globule

size of the homogenised tallow was only slightly larger than that of fat in whole milk. A contributing factor to the high coefficient of digestibility of fat in treatment HT is that no digestibility data were collected until the calves were at least seventeen days of age, by which time Huber et al., (1961) have shown the activity of pancreatic lipase to be very nearly maximal. However, the results of this trial confirm those of Raven and Robinson (1964b) which showed an increasing fat digestibility with increasing age, thereby suggesting that although the activity of the enzyme may have been maximized, the rate of synthesis and/or secretion continues to increase up to at least five or six weeks of age in the milk-fed calf.

Although the mean rate of liveweight gain reflected the mean intake of M.E. by calves on each of the three treatments, no such relationship is apparent for individual calves. In some instances severe scouring coincided with poor growth rates but, in others, calves grew well even though they passed very loose or diarrhoeal faeces; a finding also reported by Davey (1962a, b) with milk fed calves at pasture. There is also no good relationship between the amount of energy retained per calf per day and the average growth rate of the calf during the coinciding ten day period. This however is not altogether surprising since the energy retention data were only collected on two of the ten days within a period, although some relationship could have been expected as retained energy must be in the form of muscle, fat or bone.

Errors which may have significantly affected the calculated growth rate during a period include: the weight of gut and bladder contents at the time of weighing, and the amount of body water lost as a consequence of scouring prior to the time of weighing. This latter cause is likely to have been of greater significance since weight gains were calculated on the basis of the average of two consecutive daily weighings at the end of each period, which should have helped reduce any bias due to gut and bladder content. Scouring on the other hand, is associated with large losses of body water (Roy, 1970)

which would not fluctuate to the same extent so long as scouring continued. Another factor contributing to the lack of significant treatment differences in liveweight gain would be that the planned levels of G.E. intake were too close. This problem became particularly apparent when calves on the high intake treatments refused some of the milk offered them, and the converse appeared when calf L3 was inadvertently fed above its estimated food requirement. These factors led to the almost similar mean G.E. intakes (per $kg^{0.75}$) shown in the energy balance for period one. Secondly, because of the erratic liveweight gains made by some calves, in some instances related to the persistent voiding of loose faeces, the number of animals within each treatment was insufficient to counteract the high animal variability.

Since Brody (1945) has shown that the overall relationship between the metabolic processes within an animal are more closely related to an exponent of liveweight (b) of less than 1.0, and because the derived exponent in this experiment was more closely related to Kleiber's recommended value of $W^{0.75}$ (Kleiber, 1965) than to $W^{1.0}$, the author felt justified in reducing all balance data to the common base of $W^{0.75}$ in order to reduce the between animal variability associated with age and carcass composition which have a poorly defined influence on the animal's metabolic activity. Gridgeman and Heroux (1965), in commenting on this matter, said that within a species of animal the exponent of liveweight can vary considerably owing to increasing age and changing environmental factors and therefore only the exponent derived from a particular experiment should be used in analysing the results. Holmes and Mount (1967) found with pigs fed in direct proportion to their liveweight that the rate of metabolic activity decreased as the animals increased in liveweight; a finding which supports the observations of the previous authors. However Kleiber (1967) has pointed out that owing to the errors associated with animal experiments, in order that a significant difference may be attained between $b = 0.66$ and $b = 0.75$ there must be a nine-fold increase in liveweight. It is on these grounds that he justifies the universal use of the value $b = 0.75$ which he has found best fits the interspecies data.

The advantage of collecting both energy balance and liveweight data can be

each treatment,as highly significant differences were able to be obtained for energy retained by the calves on treatment H and HT compared to those on treatment L in the second and third periods. This result reflected closely the significant differences which existed between the high and low G.E. intakes. That there were no significant differences found in the efficiency of utilization of M.E. intake between treatments is understandable since the difference in M.E. intake between treatments,as a percentage of the total intake of M.E.,was so small and the standard error of the individual treatment regressions so large. On theoretical grounds Blaxter (1971) has shown that dietary fat surplus to the maintenance energy requirement can be more efficiently converted into adipose tissue than can protein and carbohydrate,owing to the different metabolic pathways involved. It could therefore be expected that the tallow-fed calves,because their diet contained more fat and less protein than the B.M.P.-fed calves,would have had a higher efficiency of utilization of M.E. In support of this contention Walker and Norton (1971) with young milk-fed lambs found"...a significantly linear decrease in the net efficiency of M.E. utilization as the protein content of the diet decreased.", although Cooke, Lodge and Lewis (1972) failed "...to demonstrate any significant interaction between dietary energy and protein in terms of growth rate and food conversion efficiency..." by pigs fed diets of varying energy and protein content. The pooled data of all nine calves showed that the M.E. was used for growth with an efficiency of 78% which agrees with the statement of Roy's (Roy,1970) that "...the net availability of M.E. for growth is very similar to that for maintenance i.e. between 79.5% and 84%..." for calves fed a restricted intake of milk, but which is considerably higher than the 68% efficiency found by van Es et al.,(1969) who used a similar type of diet fed at near ad lib. levels to calves in the liveweight range 50-150kg;and the 69% efficiency found by Walker and Norton (1971) with milk-fed lambs. As the calves in the present experiment were only in the 33-66kg liveweight range, it would be expected that their efficiency of utilization of M.E. for growth may have been greater than that of the heavier calves used by van Es et al., since Blaxter et al.,(1966) have found with young steers, and Graham (1967) with young sheep, that the efficiency of

There is at present a lack of agreement as to whether the energy requirement for maintenance is constant for all planes of nutrition, and for diets of different composition fed at a standard level of intake relative to a unit of liveweight (e.g., Kortabínska and Keilanowski, 1969; Corbett, Langlands, McDonald and Pullar, 1966; Schiemann, 1969; Blaxter, 1971). The problem arises when one tries to partition the available M.E. into that required for maintenance and that required for growth, when in fact there is only one all-embracing system within an animal and not separate 'compartment for maintenance and growth where energy is used with different levels of efficiency. Notwithstanding these limitations of interpretation it is nonetheless interesting from a practical point of view to extrapolate to zero energy retention to estimate the maintenance energy requirements of the calf under the given set of conditions. In the present trial the estimated requirement of 54 kcals D.E./kg liveweight for a 60 kg calf was higher than the values cited by van Es et al., (1969) -42 kcals; Brisson et al., -45 kcals; Bryant et al., (1967) -48 kcals; and Blaxter and Wood (1951) -52 kcals. However, considering that only a limited number of observations were made, that experimental conditions differed, e.g., environment and the breed and age of animal; and finally that the efficiency of utilisation of M.E. in this trial was higher than that found by other workers, the agreement of the present estimate with those listed above is reasonably good.

As the liveweight gains of individual calves within each period were so erratic, no attempt was made to estimate the energy requirement for liveweight gain.

Contrary to the work of Roy et al., (1970a, b) which showed no difference in nitrogen retention between calves fed a skim milk diet supplemented with either 20% or 30% margarine, calves fed a 3-4% tallow supplement in the present trial retained more nitrogen than those calves fed an iso-nitrogenous diet containing less energy (viz. treatment L). Since the calves fed the high intake of protein retained significantly more nitrogen than did either of the

other two groups, it would appear that the maximum potential for protein deposition by these latter two groups had not been attained and was therefore not a limiting factor to the retention of nitrogen by these animals. Secondly, as the intake of protein by all calves was approximately twice the minimum protein requirement recommended by the A.R.C. (1965), although only slightly higher than Roy's estimated requirements (Roy, 1970), it would seem that the amount of dietary protein consumed would have been adequate to support the liveweight gains aimed for in this experiment. Thus it may be assumed that energy was the main factor limiting increased nitrogen retention by the calves on treatment L.

In order to investigate the hypothesis "that supplementary tallow acts as a protein sparing substrate when fed with a low-fat basal milk diet"; where the intake of nitrogen between treatments is different, it is necessary to look at the ratio of nitrogen retained : digested nitrogen intake. In both the present trial and that reported by Roy et al., (1970b) the ratio was greater, although not significantly so ($p > 0.1$) in the present trial, with animals fed the fat supplement; thus lending support to the proposed hypothesis. Further supporting evidence is found when the above ratio is expressed in terms of unit M.E. intake (see Table 8) where, during the second and third periods, the tallow fed calves retained significantly more digested nitrogen/kcal M.E. intake than the calves on treatments L and H which were fed a diet composed of a higher protein : calorie ratio. But because butterfat in whole milk, which is found in a concentration greater than the total fat content found in the present trial, has been shown to promote a greater efficiency of utilisation of digested nitrogen by calves (Raven and Robinson, 1964b) than found with the use of tallow in this study, it would appear that the tallow has not been as efficiently used as butterfat to reduce inefficient protein catabolism. Thus it would appear that there is some inhibitory factor limiting the utilisation or availability of tallow. Two possible reasons are discussed below.

Since the fatty acid composition of tallow is markedly different to that of milk fat (Hilditch, 1956) it is possible that this may detrimentally affect the availability of energy from tallow compared with milk fat. If this is so then the limitation is most likely to occur prior to the absorption of the fatty acids into the circulatory system as Garton (1967), in a review of the incorporation of plasma fatty acids in to adipose tissue, has emphasised the constant flux of fatty acids between the plasma and adipose tissue. This would indicate therefore that any fats once within the metabolic system can be readily drawn on if the animal's energy requirements so demand. As no absorption of medium and long chain fatty acids is known to occur across the abomasal wall, any limitation on the availability of these dietary components would therefore need to be expressed as either a differential rate of absorption of different structural or molecular weight fatty acids through the wall of the small intestine or, a differential rate of release of these acids from the abomasal milk clot - a factor which has not yet been investigated.

The second suggested reason which could account for the apparently poor protein sparing effect of tallow (an effect which could equally well apply to milk fat) is related to Mylrea's observations (Mylrea, 1966b) on the differential rate of release of protein and fat from the abomasal milk clot. It is suggested that the more readily released protein has been largely absorbed and metabolised before a significant proportion of the fat has been released into the small intestine, and hence its energy contribution has come too late to spare unnecessary protein degradation to meet the animal's energy demands. This theory does not however take into account the availability of body fat reserves to meet short term energy deficiencies, but it could be debated that there is in fact no energy deficiency so long as the plasma protein levels are high. If the differential rate of release of the dietary components is the limiting factor, then it would seem that the only way to improve nitrogen retention through the use of an energy supplement would be to use a more readily available

energy component such as lactose which Mylrea has shown to be rapidly released from the abomasum. But as shown by Bush et al., (1962) and Mylrea (1966c), high concentrations of dietary carbohydrate are correlated with a high incidence of scouring and hence lactose at least would obviously be unsuitable as an energy supplement.

To date much of the work on the use of supplementary fats for milk diets has been conducted with fats of non-milk origin. Therefore little is known of the capability of very short chain fatty acids, such as those found in cow's milk, to reduce protein catabolism in the milk-fed animal. Although in the short term this information would be of no economic interest, a further experiment similar to that already described in this thesis using butterfat in the place of tallow could help identify the limiting factor in the inefficient utilisation of supplementary animal and vegetable fats.

The results of this trial concur with the findings reported by Mathieu and Barre (1964), Roy et al., (1970a, b) and Cook et al., (1972) that increased levels of dietary fat bring about an increased retention of fat in the tissues, although it is re-iterated that no carcass measurements were made in this trial. But, whereas Cook et al., (loc. cit.) observed that ".....energy and protein in the diet act independently in their effect on the important production parameters.", the conclusion to be drawn from this trial is that supplementary tallow does improve slightly the efficiency of nitrogen retention, but also increases the apparent fat deposition in the carcass.

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APPENDIX 1

CALCULATION OF HEAT PRODUCTION FROM RAW CALORIMETRIC DATA

Calf: 50

Date: 29/5/71

Atmospheric pressure	766 mm	urinary nitrogen (g) 15.9/day
Cooler temperature	5.0°C	
Meter-room temperature	29.3°C	
Air-flow rate	32.96 l/min	
Calorimeter volume	2200 litres	
O_2 flux in calorimeter between start and finish of measurement		+ 0.3 divisions
CO_2 flux in calorimeter between start and finish of measurement		+ 3.6 divisions
Average number of chart divisions between incoming and outgoing O_2		53.1 divisions
Average number of chart divisions between incoming and outgoing CO_2		51.2 divisions

Composition of reference gases

	CO_2	O_2
Bottle A	0.988%	20.339%
Bottle B	0.972%	19.842%

Chart readings of reference gases (divisions)

	CO_2	O_2
Bottle A	67.1	63.0
Bottle B	66.0	40.0
Purge	20.0	

i.e. 23 divisions ≡ 0.497% O_2

Assume 1°C rise in cooler temperature ≡ 1 mm rise in water vapour pressure

FLOW RATE

$$\text{flow rate} = (32.96 + 1) \times \left(\frac{273}{273 + 29.3}\right) \times \left(\frac{766 - 5}{760}\right)$$

$$= 30.7 \text{ l/min}$$

VOLUME OF OXYGEN CONSUMED

1 division on chart $\equiv \frac{0.497}{100} \times \frac{1}{23}$

$= 0.022\% O_2$

$\therefore$ 53.1 divisions $= 1.168\% O_2$

volume of O_2 consumed $= (1.168 \times 30.7) \div 100$

$= 0.358$ l/min

$= 510.749$ l/day

O_2 correction factor $= 0.3 \times \frac{0.022}{100} \times 2200$

$= 1.452$ l

corrected O_2 consumption $= 512.2$ l/day

VOLUME OF CARBON DIOXIDE PRODUCED

gas bottle A minus purge = 47.1 divisions

Enter the CO_2 calibration chart on the 0.988% CO_2 verticle line and locate 47.1 on the vertical scale, draw in a line parallel to the calibrated lines through this point. At the intercept of 51.2 divisions with this line, read off 1.09% CO_2 on the horizontal scale.

volume of CO_2 consumed $= \frac{1.09}{100} \times 30.7 \times 1440$

$= 481.867$ l/day

CO_2 corrective factor $= 2200 \times \frac{0.1}{100}$

$= 2.2$ l

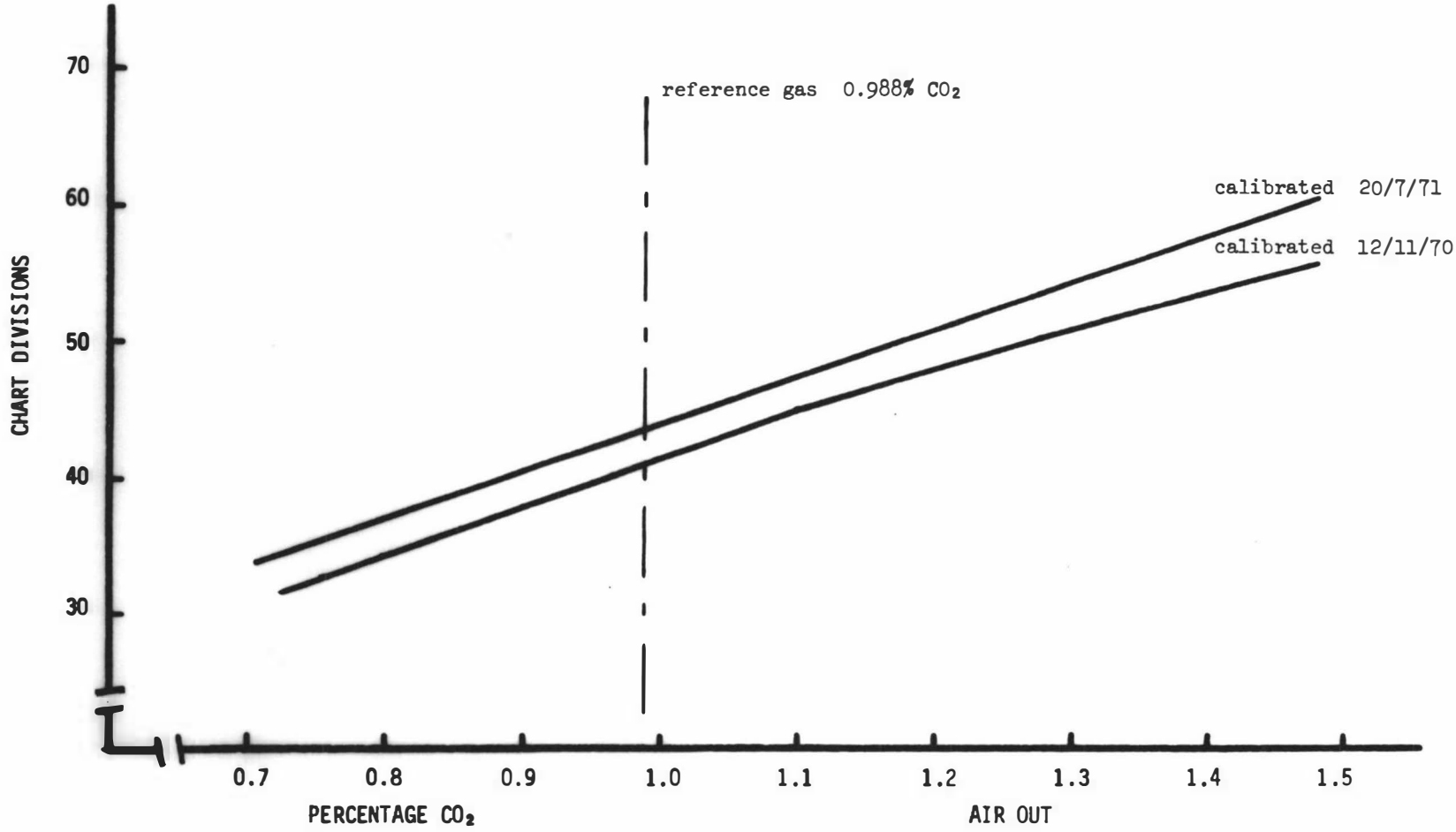
Corrected CO_2 production $= 484.1$ l/day

DAILY HEAT PRODUCTION

$$Hp = 3.866 \times O_2 + 1.2 \times CO_2 - 1.431 \times N$$

$$= (3.866 \times 512.2) + (1.2 \times 484.1) - (1.431 \times 15.9)$$

$$= \underline{2537.8 \text{ kcals/day}}$$



Appendix Fig. 1 : Calibration chart for determination of percentage CO_2 in expired air.

APPENDIX 2

ANALYSIS OF CHI-SQUARE OF THE CLASSIFICATION OF FAECAL CONSISTENCY

(a) Buttermilk Powder Experiment

Treatment	Scours	No Scours	Total
L	11	109	120
H	9	111	120
HT	1	119	120
Total	21	339	360

Observed	Expected	X^2
11	7.0	2.28
9	7.0	0.57
1	7.0	5.14
		7.99

(b) Skimmilk Powder Experiment

Treatment	Scours	No Scours	Total
L	4	7	11
H	9	5	14
HT	0	13	13
Total	13	25	38

Observed	Expected	X^2
4	3.74	0.18
9	4.76	3.77
0	4.42	4.42
		8.21

Footnote: No scours = faecal classification 0 to 3
Scours = faecal classification 4 and 5

1% level of probability @ 2 d.f. p = 9.21
2% level of probability @ 2 d.f. p = 7.82

APPENDIX 3

ANALYSIS OF COVARIANCE OF LIVEWEIGHT GAINS

Source	d.f.	SSx	SPxy	SSy	d.f.	'SSy'	M.S.	F
Total	47	982.76	952.14	3558.90	46	2636.42		
Treatments	2	47.26	29.44	33.30				
Error	45	933.50	922.70	3525.60	44	2613.57	58.07	
Treatment + Error					2	22.85	11.42	< 1

b = 0.988

Deviation M.S. = 58.07

MEAN LIVEWEIGHTS FROM TABLE 5 CORRECTED BY COVARIANCE

Treatment	$\bar{X}_0$	$\hat{Y}_1$	$\hat{Y}_2$	$\hat{Y}_3$	$\hat{Y}_4$	L.W.gain/day
L	39.67	41.19	45.95	52.27	58.67	0.57
H	37.90	41.29	47.19	54.04	61.97	0.73
HT	40.22	42.12	46.64	53.32	60.49	0.61

APPENDIX 4

ANALYSIS OF REGRESSION OF LOG HEAT PRODUCTION ON LOG LIVEWEIGHT

y = log Heat Production (kcals/day)

$\bar{x}$ = log Liveweight (kg)

$\bar{x} = 1.7227$ $\bar{y} = 3.4743$

antilog. $\bar{x} = 52.79$ antilog. $\bar{y} = 2983.0$

SSx = 0.0753 SSy = 0.0678 SPxy = 0.0642

b = 0.8519 S.E.$_b$ = $\pm$ 0.081 bSPxy = 0.0547

Test for significance of b

Source	d.f.	S.S.	M.S.	F	Result
lin. reg.	1	0.0547	0.0541	109.4	***
error	25	0.0131	0.0005		
total	26	0.0678			

$\hat{y} = 0.852 X + 2.0067$

APPENDIX 5

ANALYSIS OF REGRESSION OF ENERGY RETAINED ON METABOLISABLE ENERGY INTAKE

y = energy retained
x = energy intake

(a) Treatment L

$\bar{x}$ = 212.13
$\bar{y}$ = 62.10

SSx = 838.32 SSy = 648.96 SPxy = 580.63
b = 0.6926 S.E.$_b$ = ± 0.205 bSPxy = 402.16

Test for significance of b

Source	d.f.	S.S.	M.S.	F	Result
lin.reg.	1	402.16	402.16	11.41	* *
error	7	246.80	35.26		
total	8	648.96			

$\hat{y}$ = 0.693 X - 84.82

(b) Treatment H

$\bar{x}$ = 234.88
$\bar{y}$ = 81.11

SSx = 2090.00 SSy = 2039.02 SPxy = 1645.77
b = 0.7882 S.E.$_b$ = ± 0.225 bSPxy = 1297.18

Test for significance of b

Source	d.f.	S.S.	M.S.	F	Result
lin.reg.	1	1297.18	1297.18	12.24	* *
error	7	741.84	105.98		
total	8	2039.02			

$\hat{y}$ = 0.788 X - 104.02

(c) Treatment HT

$\bar{x}$ = 227.06

$\bar{y}$ = 72.57

SSx = 678.85 SSy = 655.10 SPxy = 504.79
b = 0.7436 S.E.$_b$ = ± 0.243 bSPxy = 375.37

Treatment HT (cont'd)

Test for significance of b

Source	d.f.	S.S.	M.S.	F	Result
lin. reg.	1	375.37	375.37	9.39	* *
error	7	279.73	39.96		
total	8	655.10			

$\hat{y} = 0.743 X - 96.26$

(d) Test for significance of differences between regressions

Source	d.f.	SSx	SPxy	SSy	SSy^1	d.f.	'M.S'	F	Result
A Treatment L	8	838.32	580.63	648.96	246.80	7			
B Treatment H	8	2090.00	1645.77	2039.02	741.84	7			
C Treatment HT	8	678.85	504.79	655.10	279.74				
Deviation from individual regressions					1268.38	21	60.40		
(A + B + C)	24	3607.17	2731.19	3343.08	1275.14	23			
Difference between regressions					6.76	2	3.38	< 1	N.S.

(e) Pooled data of all three treatments

$\bar{x} = 224.69$

$\bar{y} = 71.93$

SSx = 6010.22 SSy = 4975.61 SPxy = 4698.20

b = 0.7817 $S.E._b = \pm 0.093$ bSPxy = 3672.66

Test for significance of b

Source	d.f	S.S.	M.S.	F	Result
lin. reg.	1	3672.66	3672.66	70.46	***
error	25	1302.95	52.12		
total	26	4975.61			

$\hat{y} = 0.782 X - 103.71$

APPENDIX 6

ANALYSIS OF REGRESSION OF ENERGY RETAINED ON GROSS ENERGY INTAKE

y = energy retained
x = energy intake

Data pooled for all three treatments

$\bar{x}$ = 249.14

$\bar{y}$ = 71.93

SSx = 7035.00		SSy = 4975.61		SPxy = 4980.70	
b = 0.7080		$S.E._b$ = $\pm$ 0.090		bSPxy = 3526.28	

Test for significance of b

Source	d.f.	S.S.	M.S.	F	Result
lin. reg.	1	3526.28	3526.28	60.83	***
error	25	1449.33	57.97		
total	26	4975.61			

$$\hat{y} = 0.708\ X - 104.8$$