WEANING OF MALE HOLSTEIN CALVES AFTER FEEDING MILK REPLACER FOR 3 OR 5 WEEKS WITH DIFFERENT TYPES OF COMMERCIAL GRAIN MIXTURES

by

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ABSTRACT

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WEANING OF MALE HOLSTEIN CALVES AFTER FEEDING MILK REPLACER FOR 3 OR 5 WEEKS WITH DIFFERENT TYPES OF COMMERCIAL GRAIN MIXTURES

Studies were conducted in three trials to determine the effect of limiting use of milk replacer (≤ 0.7 kg/day) to 3 or 5 week periods, and limited quantities (≤1.4 kg/day) of different types of grain mixtures (varying costs), on the growth of week-old male Holstein calves raised over a 12-week period for use in beef production.

In the first two trials, calves fed milk replacer (MR) for 5 weeks and the cheaper grain mixture (Milk-Maker) had the best overall growth and economic performance. In the third trial, however, calves fed milk replacer for 3 weeks and the more costly grain mixture (Calf Starter) gave the best overall performance.

Therefore, dairy beef calves may be raised successfully and economically by feeding: (1) MR for a longer period (5 weeks) with a cheaper grain mixture; or (2) by feeding MR for a shorter period (3 weeks) with a more expensive grain mixture.

RESUME

Christian A. Stephens M.Sc. Sciences Animales

SEVRAGE DE VEAUX MALES HOLSTEIN AYANT ETE NOURRIS PENDANT 3 A 5 SEMAINES DE SUBSTITUTS DE LAIT ET DE DIFFERENTS TYPES DE MELANGES DE GRAINS COMMERCIAUX

Trois expériences furent conduites afin de determiner l'effet limité de substituts de lait ($\leq$ 0.7 kg/jour pendant 3 à 5 semaines) et de quantités limitées de mélanges de grains de coûts variés ($\leq$1.4 kg/jour) sur la croissance, de la deuxième à la douzième semaine inclusivement, de veaux mâles Holstein élevés pour la boucherie.

Dans les 2 premières expériences, les veaux nourris de substituts de lait pendant 5 semaines et du mélange de grains le plus économique (Milk-Maker)ont présenté la meilleure croissance générale et la meilleure performance économique. Dans la troisième expérience, les veaux nourris de substituts de lait pendant 3 semaines et du mélange de grains le plus coûteux (Calf Starter) ont donné la meilleure performance générale.

Les Taurillons laitiers peuvent ainsi être élevés avec succès et économie en les nourrissant: (1) de substitut de lait pendant une plus longue période (5 semaines) et d'un mélange de grains plus économique, ou (2) de substitut de lait pendant une plus courte période (3 semaines) et d'un mélange de grains plus coûteux.

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TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

I. INTRODUCTION

The rearing of calves plays an important role in a dairy operation. The most critical period in rearing young calves is during the first few weeks of life. Calves are then very susceptible to a variety of diseases, in particular diarrhea and respiratory infection. During this early period calf performance and mortality can be markedly affected by their nutritional regimen (Gorrill, 1972), hence it is important to have diets corresponding to the type of weaning practised.

Dairy beef producers postponed the weaning of potential beef calves, fearing that limited consumption of milk would hinder their growth. However, in the early 1950's it was realised that even though early-weaned calves initially grew more slowly than late-weaned calves, after three months they could gain just as much or more by compensatory growth (Roy, 1970a).

Early-weaned calves differ from late-weaned calves in that: (1) they are fed limited amounts of milk or milk replacer for a short period (under six weeks); and (2) they are encouraged to ruminate early by feeding a calf-starter ration.

The early weaning of dairy calves is advantageous to both the farmer and the consumer. The farmer may benefit in three ways: (1) lower feed cost by using less milk or milk replacer to feed calves; (2) reduced labour costs; and (3) fewer problems with diarrhea and digestive upsets. The consumer can benefit by: (1) more meat being on the market at a cheaper cost; and (2) more milk being available for human consumption.

At present most bull calves produced on farms in the dairy provinces of Canada (Ontario and Quebec) are either slaughtered as vealers or sold to the United States (Canadian Federal Task Force on Agriculture, 1970). This practice represents a loss in beef production potential. The Federal Task Force on Agriculture stated that Canadian exports of calves increased from less than 7,000 per year in the period 1955 - 1957 to 137,000 in 1968. They indicated that since Canada imported beef, many of the calves which were exported could have been retained and subsequently become part of the feeder cattle or fed cattle supply. This would necessitate raising dairy beef calves as economically as possible.

This study was conducted to: (1) demonstrate that male Holstein calves can be weaned successfully on to a commercial grain mixture and hay after being fed limited amounts of milk replacer for 3 or 5 weeks; and (2) determine how efficiently this can be done.

II. REVIEW OF LITERATURE

A. PHYSIOLOGICAL CHARACTERISTICS OF THE NEWBORN CALF

1. Characteristics of the Gastrointestinal Tract of the Newborn Calf

In the newborn calf only the abomasum is functional (Grossman, 1949; Foley *et al.*, 1973). The reticulo-rumen, although non-functional, has an inherent capacity of about 2 litres at birth (Warner *et al.*, 1956). In the adult ruminant, however, less than 12% of the stomach capacity is in the abomasum, whereas the volume of the rumen represents about 64% of the total (Phillipson, 1970).

In the young calf liquid food can by-pass the reticulo-rumen and go directly to the abomasum by flowing through a tube formed by the closure of the oesophageal groove. The closure of this groove, which extends from the cardia to the reticulo-omasal orifice, occurs when milk is fed (Wester, 1926) and when the glossopharyngeal nerve is stimulated (Comline and Titchen, 1951). Observations of groove function in fistulated animals by Benzie and Phillipson (1957) have demonstrated that the reticular groove functions primarily in the young suckling calf to by-pass milk from the oesophagus to the abomasum. It has been suggested that closure of the groove is initiated by the suckling reflex (Watson, 1944) and can also be stimulated by sodium salts and glucose (Riek, 1954). Roy (1970b) has observed that the oesophageal groove reflex is stimulated equally by water, milk and milk by-products for the first 8 weeks of the calf's life; thereafter milk is more effective.

2. Enzyme Activity of the Digestive Tract of the Newborn Calf

The fore-stomachs of ruminant animals do not develop fully and perform their characteristic digestive function until the young animals begin to eat substantial quantities of solid food (Porter, 1969).

a) Pregastric Enzyme Activity

Salivary lipase is present in young calves. This enzyme, which is secreted by the palatine glands, hydrolizes butyric acid esters of glycerol. Its optimum pH for hydrolyzing tributyrin is between 4.5 and 6.0, and at pH 2.4 its activity is completely inhibited. The abomasal contents of a newborn calf have a pH of 3.5 and it is believed that salivary lipase would still have some activity in the abomasum. The secretion of salivary lipase is increased in calves consuming milk containing triglycerides consisting of butyrate groups and decreases with increasing consumption of roughage (Grosskopf, 1965).

b) Enzyme Activity in the Abomasum

One of the characteristic features of the neo-natal calf's abomasum is its milk coagulating ability. Many authors (Berridge *et al.*, 1943; Berridge, 1945; Fish, 1957; Henschel *et al.*, 1961b; Preston, 1964) agree that the enzyme rennin is responsible for milk clotting and is to a large extent specific for the breakdown of casein. Berridge *et al.* (1943) and Berridge (1945) stated that milk separates into a casein clot and whey. Mylrea (1966) demonstrated that whey appears in the duodenum within 5 minutes after feeding milk only, but the casein clot is slowly degraded and its products eventually discharged into the duodenum.

Berridge *et al.* (1943) and Henschel *et al.* (1961a) found that rennin was the main enzyme secreted in the abomasum of the young milk-fed calf, but that some pepsin (though not in appreciable quantities) was secreted. In addition, Henschel *et al.* (1961a) found that the relative amounts of each enzyme secreted varied among calves but, in general, at about 4 weeks of age large quantities of pepsin were secreted.

c) Intestinal and Exocrine Pancreatic Enzyme Activity

Dollar and Porter (1957) and Huber *et al.* (1961a) have demonstrated that the calf is born with large amounts of lactase which are essential to hydrolyze lactose. However, with advancing age, lactase levels gradually decline, perhaps due to the animal's decreasing dependence on milk.

A study conducted in 1969 by Bywater and Penhale showed that depressed lactase activities occurred in calves which had scoured for a few days. It is now established that a relative deficiency of lactase would result in excessive quantities of lactose in the small intestine, which could predispose the animal to fermentative diarrhea as described in man (Weijers and Van de Kamer, 1965).

The activities of maltase, sucrase and pancreatic amylase are low in the gastrointestinal tract of the neonatal calf. This explains why young calves cannot digest maltose (Dollar and Porter, 1957) nor sucrose (Okamoto *et al.*, 1959; Huber *et al.*, 1961a; Huber *et al.*, 1961b; Huber, 1969; Siddons *et al.*, 1969). The pancreatic amylase enzyme activity is also low in the newborn calf (Larsen *et al.*, 1956; Huber *et al.*, 1961a).

The level of pancreatic protease was found to be low in newborn calves and remained low up to 44 days of age (Huber *et al.*, 1961a). However, Gorrill *et al.* (1967) in studying the activities of trypsin and chymotrypsin on calves, found that those calves on an all-milk diet secreted significantly greater quantities of pancreatic juice and higher concentrations of trypsin and chymotrypsin than the calves on a high soybean-protein diet. This indicates that vegetable protein in the diets of very young calves may decrease secretion of pancreatic proteases.

Bile salts are important in the digestion of fats. Wilson (1962) in a number of experiments demonstrated that bile salts and pancreatic lipase were both necessary for maximum digestion of fats.

3. <u>Limitations of the Digestive Tract of the Newborn Calf</u>

The intestinal tract of the newborn calf is capable of absorbing antibodies from the colostrum only within the first 24 hours of the calf's life. These antibodies provide a passive immunity in the calf to many diseases (Schmidt and Van Vleck, 1974).

At birth the capacity of the calf's stomach is small and its only functional part is the abomasum. At this stage, the calf can only digest nutrients of milk origin with high efficiency. Although lactose is the major carbohydrate in milk, it can only be utilized by calves in relatively small amounts (Rojas *et al.*, 1948; Fischer and Sutton, 1949; Blaxter and Wood, 1953; Duncan, 1955).

Radostits and Bell (1970), after reviewing many articles, concluded that the size of the fat globule was critical. Fat Globules in cow's milk vary from 0.1 to 1.0 μ in diameter, while fats from other sources are much larger; hence the young calf cannot digest non-milk fats properly unless they are homogenized (Roy *et al.*, 1961; Gorrill, 1972). Other investigators found that the type of fat was important. Ma *et al.* (1964) showed that monoglycerides and triglycerides of unsaturated fatty acids were more efficiently absorbed than the monoglycerides and triglycerides of saturated fatty acids.

Several investigators (Henschel *et al.*, 1961a; Henschel *et al.*, 1961b; Pierce, 1962; Huber and Slade, 1967; Gorrill and Thomas, 1967; Gorrill and Nicholson, 1969) have shown that very young calves did not thrive well when 100% of their dietary protein was of non-milk origin. Calves are not well equipped to digest proteins of non-milk origin because the appropriate enzymes are lacking (Henschel *et al.*, 1961b).

The rumen of a calf may be fully functional 4 or 5 weeks after birth. Nevertheless, some investigators (McNeekan, 1954; Preston, 1957) have found that calves can start to digest the dry matter of grass as early as 7 days after birth. However, only small quantities of dry matter are utilized at that age and only when the calves are about 3 weeks old could they utilize 75% of the dry matter of grass. If digestion takes place in the rumen, then the end products are volatile fatty acids (VFA) which may be absorbed and utilized as sources of energy by calves. McCarthy and Kessler (1956) and Martin *et al.* (1959) pointed out that newborn calves cannot absorb VFA within the first week of life, but are able to do so subsequently. Liang *et al.* (1967), on the other hand, have produced evidence that pre-ruminant calves with a non-functional rumen were able to utilize VFA, probably produced in the large intestines.

B. MILK REPLACERS

The dairy farmer wishing to keep bull calves for 3 to 4 months before selling them to a feedlot is faced with the prospect of either feeding whole milk to his calves, or selling the whole milk and buying cheaper milk replacers. Many farmers feed limited amounts of whole milk to their calves for about a week after birth, then they switch over to milk replacer.

1. Definition

Milk replacers are substitutes for whole milk. The composition of a milk replacer is determined primarily by the rate of gain required and the age and weight of the calf (Preston and Willis, 1970). In order to reduce the risk of diarrhea and possibly fatal infections, a milk replacer must be composed of highly digestible ingredients. The choice of protein and fat sources should take into account the various limitations imposed by physiological aspects relating to their utilization.

2. Sources of Nutrients in Milk Replacer

a) Protein

Generally milk replacers contain some protein. There are three common sources of milk protein used in milk replacers: skim milk powder, dried whey and buttermilk powder. Skim milk is probably the most widely used. However, although it usually provides good quality protein, improper processing of skim milk may have a negative effect on calf performance (Gorrill, 1972).

Whey powder is a relatively cheap source of protein and the cost of milk replacers could be reduced considerably if it were well utilized by young calves. However, Roy (1970a) indicated that when calves receive large quantities of whey they tend to have diarrhea, presumably due to its high lactose or mineral content. Sweet whey is considered a better source of protein for calves than acid whey (Gorrill, 1972). Volcani and Ben-Asher (1974) successfully used sweet whey powder in a limited feeding system to replace part or all of the skim milk powder in commercial milk replacers with no harmful effects; but calves on whey performed 20 to 25% less efficiently than those on skim milk. It was also suggested that the system only works well when sufficient concentrates are consumed.

Buttermilk powder has been used as part of or the entire protein source in liquid calf diets (Gorrill, 1972). It has a relatively high fat content (about 9%) compared to whey powder (1.1%) and skim milk powder (0.7%). It therefore gives almost normal calf growth without the addition of extra fat. In New Zealand, Fraser (1961) found that veal calves performed as well on reconstituted buttermilk as on whole milk.

In the past, calves reared on milk replacers containing non-milk proteins performed poorly. However, much work has been done on the non-milk protein source of milk replacers with a fair amount of success. Satisfactory results have been obtained by replacing 50% or more of the milk protein in milk replacers by specially processed soyflour.

Gorrill and Thomas (1967) and Gorrill and Nicholson (1969) reported that calves can utilize a highly purified soyflour with 71% crude protein (CP) and perform as well as calves fed on whole milk. However, these authors indicated that when calves were fed regular soyflour (50% CP) to furnish 60% of the dietary protein, their growth rates were retarded and the incidence of diarrhea was high. On the other hand, Nitsan *et al.* (1972) were able to replace up to 90% of the total protein by a soyprotein concentrate in a milk replacer formula, provided the animals had free access to concentrates and hay. They reported that, under their circumstances, the incidence of diarrhea was low.

Other vegetable proteins have been tried as protein sources in milk replacers with limited success. Bell *et al.* (1974) used a pea protein concentrate and enzymatically hydrolized pea flour to provide half the dietary protein in milk replacers. They observed that calves under 2 weeks of age could only digest 25% of the vegetable protein.

Huber and Slade (1967) used fish flour to furnish some of the dietary proteins in milk replacers fed to calves from 3 to 45 days of age. There were no significant differences when 40% of the milk replacer protein was supplied by fish meal. However, at levels of 60% and over, marked decreases of growth rate occurred.

b) Fat

The fat content of dried whole milk of most domestic animals is in the region of 30 to 40% (Maynard and Loosli, 1969). Therefore, it could be presumed that milk replacers designed to simulate whole milk should be prepared with a relatively high fat content. The energy derived from the fat seems necessary for maximal utilization of nutrients in milk and for high nitrogen retention. Griffiths and McGann (1966) also held this theory and added that improved weight gains would be expected. Bush *et al.* (1963) observed that additional fat reduced the incidence of diarrhea.

Fats successfully used in milk replacers include tallow, lard, coconut oil, peanut oil and palm oil. Calf performance has usually been better on lard (Gorrill, 1972).

Early attempts to incorporate inexpensive vegetable and animal fats in a satisfactory milk replacer led to unfavorable results. Inadequate homogenization of the fat before adding it to the milk replacer ingredients reduced its digestibility. Now, with proper homogenization and emulsification, the utilization of fat by calves is markedly improved (Gorrill, 1972). Roy *et al.* (1970) reported that there is no advantage to be gained by increasing the fat content of a milk replacer above 20% (dry matter basis) unless fat deposition is required. The recommended level of fat in milk replacer is 10% of the dry matter (National Research Council, 1971).

c) <u>Carbohydrates</u>

As previously mentioned, young calves cannot utilize large amounts of carbohydrate (Dollar and Porter, 1957; Weijers and Van de Kamer, 1965; Siddons *et al.*, 1969). The types of carbohydrate which can be used as "fillers" in milk replacers are limited. Burt and Irvine (1970), in a review on this subject, concluded that lactose and glucose were the only two carbohydrates that could be used at relatively high levels. Sucrose is not digested. Starch is very poorly digested even by older calves. However, Morrill *et al.* (1970) indicated that a combination of processed starch and an amylolytic enzyme may be used in a milk replacer for very young calves. Burt and Irvine (1970) reported that the addition of invertase to milk replacer containing 25% sucrose reduced diarrhea in calves and increased nutrient digestibilities by as much as fifteen percent.

d) Vitamins and Minerals

Supplemental minerals and vitamins are only required in milk replacers if the basic ingredients of these formulas are deficient in them. However, as a safety factor they are added routinely to exceed the nutrient requirements (Gorrill, 1972).

C. COMPOSITION OF DIETS FOR EARLY-WEANED CALVES

1. Milk Replacer Nutrient Levels

a) Dry Matter

The voluntary dry matter (DM) intake of palatable foods by the young calf depends in part on the form in which the food is given. Roy (1970b) has shown that up to a live weight of 70 kilograms (kg), more dry matter can be consumed in the liquid form than in the dry form. Pettyjohn *et al.* (1963) indicated that calves achieved the greatest efficiency of feed conversion when their liquid diet had a DM content of 15 percent. Under practical farm conditions, the DM content of liquid milk replacers is quite variable (Radostits and Bell, 1970).

b) Protein

The factors which must be taken into account in determining the protein level of milk replacers are: (i) physiological development of the calf; (ii) desired level of animal performance; (iii) origin and amino acid composition of the protein; (iv) quantity and quality of fat; and (v) composition and actual intakes of other components of the diet (i.e. hay, dry concentrates).

Roy *et al.* (1970) found that calves on a high fat (30%) and high protein (26 to 29%) milk substitute diet performed better than calves on a high fat with lower protein (19%) diet. Bowman *et al.* (1965) in an earlier study found no significant difference in growth performance between calves fed milk substitutes with 20 and 25% CP respectively. It would seem then that 20% CP was adequate to maximise growth. But, it has been shown that a milk substitute containing 19.3% CP did not sustain maximum growth in 80 kg calves (Stobo *et al.*, 1967). However, it is not necessary for dairy beef calves to grow maximally, and Roy (1970b) suggested that the minimum CP content required in a milk substitute for a 60 kg calf with an average daily gain (ADG) of 0.5 kg is 17% of the dry matter.

c) <u>Fat</u>

The quantitative fat requirements for optimum growth in the diet of young calves are not known (Radostits and Bell, 1970). Prior to 1960, most milk substitutes contained about 1.0% fat (DM basis). However, with increasing evidence that starch and its degradation products were poorly digested, milk substitutes containing 15 to 50% fat (DM basis) began to be commercially produced (Roy, 1970b).

Griffiths and McGann (1966) have shown that calves on high fat (15 to 20% DM basis) milk substitute diets in an early weaning system perform better after weaning. Roy (1970b) suggested that the feeding of high fat milk substitutes results in increased fat deposition in the carcass, and that this fat may be drawn upon to supply energy during the transition stage from pre-ruminant to ruminant. Roy also stated that 17 to 20% homogenized fat of animal or vegetable origin is adequate for milk substitutes.

d) <u>Carbohydrate</u>

The preparation of milk replacers containing low fat (5% DM basis) and relatively low protein (19% DM basis) dictates that large amounts of carbohydrate are incorporated as a source of energy (Gorrill, 1972). The three carbohydrates which are commonly used in milk replacers are lactose, glucose and starch. Raven and Robinson (1958) found that calves receiving a milk substitute with as much as 66% lactose did not scour. However, Gorrill (1972) stated that any liquid diet fed to calves containing more than 50% lactose will cause diarrhea.

Huber and his associates (1968) concluded that the maximum level of starch in milk replacers fed to calves under 3 weeks of age should be 10 percent. They also mentioned that after 3 weeks of age the starch content in a liquid diet could vary from 9 to 27% without retarding calf growth. The literature contains little information about the use of glucose in milk replacers. However, Gorrill and Nicholson (1969) have used up to 25% of this sugar in a formula for calves without encountering any serious problems.

e) Vitamins and Minerals.

Vitamin and mineral requirements of milk replacer fed calves have been studied over a number of years. Recommended levels of vitamin and mineral additions to milk replacer powder are listed in a review article by Radostits and Bell (1970).

The two minerals most commonly added to milk replacers are calcium and phosphorus. Blaxter and Wood (1951 and 1952), and Raven and Robinson (1958) showed a linear relationship between rate of body weight gain and retention of calcium and phosphorus. The present recommended levels of calcium and phosphorus in milk replacer powder are 0.55 and 0.42% respectively (National Research Council, 1971).

f) Antibiotics

Antibiotics are routinely added to milk replacers although under ideal conditions (adequate feed, experienced herdsmen, well ventilated buildings, and small number of calves per unit) they should not be necessary (Gorrill, 1972). Calves brought in from unknown sources should be treated with antibiotics, particularly if they did not receive sufficient colostrum. Preston (1964) has demonstrated that the addition of 50 milligrams (mg) chlortetracycline daily to milk replacer during the first 3 weeks of life increased calf growth by 10 percent.

Lassiter *et al.* (1958) reported that crystalline aureomycin or bacitracin added to calf milk replacer (23 mg/kg) increased daily gains significantly to 7 weeks of age. Gorrill and Nicholson (1969) also reported good results from calves treated with aureomycin (11 mg/kg of milk replacer).

Preston and Willis (1970) are of the opinion that it is economical to feed antibiotics to this class of animals. However, Radostits and Bell (1970) suggested that the need for antibiotics in milk replacers should be re-examined. Their main reason for this suggestion is the development of multiple drug resistance of the intestinal microflora of calves which may result in a potential public health hazard.

2. Calf Starter Rations

a) Definition

Calf starters are dry rations which are fed to young calves from 1 to 16 weeks of age. Formulas of some common calf starters are shown in Table 1. Calf starters should be palatable, high in energy (75% total digestible nutrients (TDN)), and contain about 16% CP (Foley *et al.*, 1973; Schmidt and Van Vleck, 1974).

b) Protein

The percentage CP of starters fed to calves weaned at 3 to 7 weeks should be over 16% (Schmidt and Van Vleck, 1974). Roy (1970a) indicated that calves weaned at 3 weeks of age should have a calf starter ration with a CP content over 12 percent. Jacobson (1969) in a review on energy and protein requirements of the calf concluded that the optimum CP level for calf starters is about 16%, but lower levels (to about 12%) often resulted in maximum growth response. However, Daniels and Flynn (1971), in a study on the evaluation of protein levels in calf starter rations, found that calves weaned at 6 to 8 weeks can perform very well on calf starters with 15%, but not 12.5% CP. Stobo and Roy (1973) and John and Chandler (1974) supported this observation.

Morrill and Melton (1973) reported satisfactory performance when calves weaned at 6 weeks were given a starter ration containing 13.5% CP. Tinnimit and Thomas

TABLE 1. CALF STARTERS

	Starters (%)[1]				
	1	2	3	4	5
Corn (coarsely ground)	35	40	21	27	46
Oats (crimped, crushed)	30	27	20	20	30
Wheat bran	-	-	15	10	-
Soybean meal	22	20	11	15	21
Linseed meal	-	-	10	-	-
Corn distiller's dried solubles	-	-	-	15	-
Dehydrated alfalfa meal	-	-	5	-	-
Dried whey	-	-	10	-	-
Molasses (blackstrap)	10	10	5	10	-
Calcium and phosphorus supplement	2	2	2	2	2
Trace mineral	1	1	1	1	1

[1] Add per pound of starter: 2,500 IU vitamin A, 300 IU vitamin D, 10 mg chlortetracycline (Aureomycin) or oxytetracycline (Terramycin).
Source: Van Horn and Jacobson, 1966. Hoard's Dairyman 111:1015. Cited from Schmidt and Van Vleck, 1974.

(1974) observed that a portion of the protein requirement in calf starters could be supplied by non-protein nitrogen compounds such as urea, biuret and ammonium propionate, without having any adverse effect on calf performance. Gardener and Kung (1973) noted gains of over 1 kg/day when calves weaned at 6 to 8 weeks of age were fed a 15.7% protein starter with 1.25% protein equivalent supplied by urea.

c) <u>Fat</u>

Preston *et al.* (1960) reported that the inclusion of tallow at a level of 5%, replacing an equivalent amount of cereals in a concentrate mixture, resulted in improved body growth. But there is some indication that the animals on this diet had reduced nitrogen retention. Chandler *et al.* (1968) found that when corn oil at levels above 4% was included in the ration of dairy calves, digestibilities of dry matter, energy and lipid were reduced, feed intake declined, and growth was inferior. Gardener and Wallentine (1972) found that calves on starter with 5% added renderer's grease did not gain as much as calves on starter without renderer's grease. However, it has been reported (Brown and Lassiter, 1962; Schurman and Kessler, 1974) that the protein to energy ratio is important and that some fat should be added to the calf starter ration. In addition, a little fat in the ration helps to reduce dustiness.

d) Fibre

Calf starter rations generally contain a low level of fibre. No difference in calf performance was observed when calves weaned at 9 weeks were given starter rations containing 5, 9, or 13% crude fibre up to a maximum starter intake of 1.8 kg/day (Whitaker *et al.*, 1957). John and Chandler (1974) found that the higher the fibre content in a starter ration, the greater the response to increased protein levels. It is feasible that a low crude fibre content might be important at high levels of concentrate feeding, but at low levels increased fibre content tends to dilute the available energy.

e) Palatability

Calves receiving limited amounts of whole milk and weaned at 3 to 7 weeks of age must receive a good quality palatable starter until approximately 4 months of age (Schmidt and Van Vleck, 1974). The addition of a sweetener such as molasses to the calf starter improves the acceptance of the feed by the young calf (Roy, 1970a; Schmidt and Van Vleck, 1974). Coarsely ground starters stimulate greater intake than finely ground material, even if the latter is pelleted (Gorrill, 1972), and may be more palatable (Bakker, 1968; Schmidt and Van Vleck, 1974). Bakker (1968) noted that pelleting starters had no beneficial effect on intake unless a complete high-roughage diet was fed. Schmidt and Van Vleck

(1974) indicated that pelleted starters are as palatable as a coarse-textured meal if the pellets are soft enough to be easily broken by the calf. Bartley (1973) found that newborn calves fed milk and a self-fed pelleted mixture of 3 parts calf starter and 1 part ground sun-cured alfalfa hay consumed significantly more feed and gained more weight than calves fed milk, starter, and hay separately in the conventional manner.

3. Hay

When calves are weaned on to concentrates alone the susceptibility to bloat is greater, especially if the concentrate mixture contains little material with roughage characteristics. However, Roy (1970a) reported that calves have been weaned successfully at 3 weeks of age on to a concentrate diet containing 10% dried grass meal.

Hay should be offered as soon as the calves will begin to eat it, usually at 1 to 2 weeks of age. The quantity of hay consumed by a calf depends on the quality of the hay and the amount of starter available. Schmidt and Van Vleck (1974) suggested that a calf's diet should consist of at least 10 to 20% roughage. Roy (1970a) suggested that good quality, well-cured, and leafy hay should be offered with a restricted milk feeding program. Two of the better types of hay used in Canada are alfalfa and timothy.

a) Alfalfa

Sun-cured alfalfa hay contains, typically, about 92% DM, 20% CP and 32% crude fibre. Hinders and Owen (1968) observed that alfalfa is more easily digested when fed whole rather than pelleted. Stiles *et al.* (1970) found that dairy calves fed alfalfa pasture and alfalfa green chop gained significantly more weight than did calves fed alfalfa hay. Although alfalfa hay is very nutritious, it deteriorates rapidly when cut and left in the fields (Voelker *et al.*, 1970). Leaves are lost, dry matter increases, carotene is lost, and protein is reduced. It also deteriorates under storage,though to a lesser degree.

b) Timothy

Timothy is not as nutritious and palatable as alfalfa, but it stores better. The CP content of timothy is 7 to 9% (Hogan *et al.*, 1967; Stiles *et al.*, 1970). These authors found that the energy digestibility of timothy hay decreases when fed *ad libitum* rather than on a limited feeding rate.

D. CALF RAISING TECHNIQUES

1. Early Weaning

a) Definition

Early weaning describes the practice of introducing the young calf to feeds other than milk or milk replacer early in life, so that by 3 to 5 weeks of age liquid feeding could be cut off entirely; no debilitating effect on the health of the animal should occur. The performance of calves after early weaning must not be adversely affected to the extent that mature performance is lowered (Gorrill, 1972).

b) Weaning Age

The criteria used for weaning calves include: age, body weight, body weight gain, total intake of liquid diet and daily starter intake. Although on the farm a combination of two or more of these factors is generally involved, only weaning by age will be discussed.

Early weaning at 3 to 5 weeks differs from 8 week weaning in that: (a) milk volume is restricted; (b) the calf is given a highly palatable and nutritious calf starter; and (c) milk is completely replaced by calf starter between the third and the fifth week. One of the advantages of early weaning is that the calf has fewer problems with diarrhea and digestive upsets.

It is easier to wean calves according to age than by any of the other factors mentioned above. Bakker (1968) and Roy (1970a) have shown that calves can be successfully weaned at 3 to 5 weeks of age, provided that the feeding of concentrates is instituted early. Gorrill (1972) has indicated that calves can be successfully weaned at 2 to 3 weeks of age if at least 0.5 kg of starter is being consumed daily.

Ruminating calves at the age of 3 weeks can digest grass as efficiently as the adult ruminant and this efficiency is achieved within two days of the grass being fed (Preston, 1957). The factor limiting performance is the amount of grass ingested by the young calf. Roy (1970a) also mentioned that for early weaned calves to gain weight at the rate of late weaned calves, the former must gain weight at a level at least 1% of body weight per day.

Weaning may be gradual, over one week, or abrupt. The advantages of abrupt weaning outweigh the disadvantages. Bakker (1968) and Clark and Whiting (1961) indicated that growth of calves, given the same total amount of liquid diet, is no more affected by abrupt weaning at 3 to 5 weeks of age, than by gradual weaning over 1 to 2 weeks. Calves weaned abruptly will generally consume dry feed more readily after weaning. However, some calves will not eat solid feed as long as liquid diet is fed, and gradual weaning delays the time when the calf is forced to eat solid feed (Gorrill, 1972).

Little compensatory growth appears to occur with calves that have been early weaned on to pasture alone and have made low weight gains during the first 12 weeks of life (Roy, 1970a). The key to early weaning is to get the animals on to a good quality and palatable starter and good quality roughage to supply all the nutrients no longer supplied by milk.

2. Feeding Routines

a) Once Versus Twice Daily Milk Feeding

Traditionally, calves have been fed liquid diets at least twice daily. Farmers operated under the belief that nutrients given in small quantities at short intervals were more efficiently utilized than when given in large quantities over long intervals. Much research has been carried out on this and the present consensus is that the overall performance of calves is not adversely affected by feeding milk or milk replacer once daily (Owen *et al.*, 1965; Burt, 1968; Ackerman *et al.*, 1969; Davis *et al.*, 1970; Fieber, 1972; Morrill and Melton, 1973; Fowler *et al.*, 1974; Schmidt and Van Vleck, 1974).

Calves fed liquid diets once daily tend to eat dry feed more readily, and consequently may be weaned earlier than calves fed twice daily. Generally, there is no difference due to feeding frequency on body weight and weight gains. Scouring may be more prevalent in calves fed once daily (Davis *et al.*, 1970; Gorrill, 1972). Feeding once daily reduces the cost of labour, but less time is spent observing the calves. It has been suggested that calves on a once-a-day liquid feeding regimen should be fed at about the same time every day, and should be checked at other intervals for any signs of ill health (Gorrill, 1972).

b) Nipple Versus Pail Feeding

Nipple feeders simulate the cow's teat, and calves obtain milk in a fashion similar to normal sucking. Moreover, sucking through a nipple appears to cause an increased production of salivary lipase and oesophageal groove closure which may lead to fewer digestive disturbances (Roy, 1970a). Experiments have shown that calf performance is about the same whether they are nipple fed or pail fed (Roy, 1970a; Schmidt and Van Vleck, 1974). Although it is easier to get young calves to nipple feed than to drink from a pail, it is more sanitary and less time consuming to use pails.

3. Calf Scours and Liquid Diets

A common problem of liquid fed calves is diarrhea of nutritional origin. This condition results in progressive dehydration and death in hours or days if treatment is not instituted. Several workers have indicated the possible causes of this disorder in calves. Shillam *et al.* (1962) concluded that improperly processed skim milk powder in milk replacers may be one of the causative agents. Owen *et al.* (1958) studied the influence of different components of milk diets on the consistency of feces and found that the addition of lactose at twice normal levels (10%) resulted in loose feces. Pettyjohn *et al.* (1963) stated that a high dry matter intake predisposed young calves to diarrhea. Mylrea (1966) demonstrated that overfeeding can cause this disorder in young calves.

Good managerial practices can control calf scours and reduce mortality (Hartman *et al.* , 1974). Gay (1965) indicated that colostrum fed calves are usually protected from *Escherichia coli* septicema, a cause of diarrhea. Roy (1969) concluded that the composition of chyme is of great importance in maintaining a balanced bacterial flora and in preventing diarrhea. Stiles *et al.* (1974) stressed that the level of fluid intake is important in calf scours. It is generally accepted that antibiotics reduce or prevent diarrhea and increase weight gain by lowering the activities of the less desirable gastrointestinal microflora (Gorrill, 1972).

III. OBJECTIVES OF THE RESEARCH

The high cost of beef in Eastern Canada is due in part to the scarcity of locally produced beef animals. One solution would be to reduce the export of dairy beef calves which would be raised locally to beef slaughter weights. In order to produce beef successfully the calves should be weaned as early as possible without hindering their growth potential.

The work presented in this thesis attempted to: (1) demonstrate the successful weaning of male Holstein calves after being fed limited amounts of milk replacer for 3 or 5 weeks with different types of grain mixtures of varying costs; and (2) determine how efficiently this can be done, in terms of feed conversion and feed cost ratios.

IV. TRIAL I

A. EXPERIMENTAL PROCEDURE

1. Management

Thirty-two Holstein bull calves were purchased at local auctions or from the Macdonald College farm in April and May, 1971. On arrival the calves were about 1 week old and 51 kilograms (kg) average body weight. They were numbered and injected with antibiotics (Penicillin, 200,000 IU) and vitamins (vitamin A, 500,000 IU; vitamin D_3, 50,000 IU; vitamin E, 50 IU).

Each calf was individually housed in a pen with a concrete floor approximately 1.88 square meters (sq. m) in size. The four sides were made from meshed wire (1 centimeter (cm) x 5 cm). Each side was 1.37 meters (m) long and about 1.0 m high. The pen contained a hay bin, an automatic water bowl, and a grain tray.

The pens were cleaned and bedded with wood shavings every day.

Light was provided for approximately 8 hours each day and the temperature was controlled in a range of 18 - 24°C.

2. Experimental Design

The trial was conducted as a completely randomized design in a 2 x 2 factorial experiment. The treatment factors were length of milk replacer feeding (3 and 5 weeks) and types of grain mixtures (calf starter-grower (SG) and "Milk-Maker" grain concentrate (MM)).

The design of the trial is shown in Table 2.

TABLE 2. EXPERIMENTAL DESIGN - TRIAL I

Length of Milk Replacer Feeding (weeks)[1]	Type of Grain	
	SG[2]	MM[2]
3	8[3] (I)[4]	8 (III)
5	8 (II)	8 (IV)

1 Weeks on trial
2 SG: Starter-Grower; MM: "Milk-Maker"
3 Number of calves
4 Group number

3. Rations

Calves were fed whole milk for one week, then they were gradually switched to milk replacer. During the second week all calves were fed a commercial milk replacer (MRI) containing 24% crude protein (CP) and 5% ether extract (EE) (Table 3). From the beginning of the third week until weaning at 30 or 45 days they received a second commercial milk replacer (MRII) containing 20% CP and 20% EE (Table 3). This change in milk replacers was due to the manufacturer altering specifications.

The protein sources of the milk replacers were predominantly dried skim milk powder and dried whey powder. The fat source was mainly dried butterfat powder (personal communication, Robin Hood Multifoods Ltd., 1971).

Two groups of 16 calves each were fed either SG or MM from the first week on trial. SG was a formula for young calves and MM for mature dairy cows. The composition of the grain mixtures, which is based on information supplied by the feed manufacturer, is listed in Table 4; and the chemical analyses in Table 7 (Results).

Hay composed mainly of alfalfa and timothy species (7:3 respectively) was chopped to a length of about 3 cm and fed to the calves *ad libitum* from the first week of the trial.

TABLE 3. GUARANTEED ANALYSES OF MILK REPLACERS[1]; CALF STARTER-GROWER[2] 400; AND MILK MAKER DAIRY RATION[3] 402.

Components	MRI*	MRII**	SG	MM
Crude Protein (min) (%)	24.0	20.0	16.0	16.0
Crude Fat (min) (%)	5.0	20.0	2.0	2.5
Crude Fibre (max) (%)	0.5	0.25	7.0	9.0
Sodium Chloride (%)	2.75	3.0	1.0	0.5
Calcium (%)	1.25	1.0	0.7	0.6
Phosphorus (%)	0.75	0.75	0.6	0.5
Vitamin A (min) (IU/lb)	15,000	15,000	2,000	2,000
Vitamin D (min) (IU/lb)	5,000	5,000	-	-
Vitamin E (min) (IU/lb)	-	10	-	-
Chlortetracycline (Aureomycin) (mg/lb)	-	25	-	-

1* Lactone, Reg. No. 4767)
** Supervealer, Reg. No. 4767) Robin Hood Multifoods Ltd., Montreal, Que.
2 CSG 400, Reg. No. 2843)
3 MM DR 402, HS-16, Reg. No. 9718)

TABLE 4. COMPOSITION OF CALF STARTER-GROWER AND MILK MAKER DAIRY RATION (%)

Ingredient Composition	SG	MM
Barley	42.9	46.4
Wheat bran	5.4	5.8
Shorts (wheat)	5.4	5.8
Middlings (wheat)	5.4	5.8
Wheat mill run	5.3	5.8
Wheat	17.1	18.6
Corn	4.3	4.6
Soybean meal	7.0	-
Molasses	3.0	3.0
Sodium chloride, Calcium, Phosphorus (Mineral mix)	4.2	3.2
Urea	-	1.0

Water and salt (Cobalt Iodized Sodium Chloride) were available at all times.

4. Feeding Programme

a) Liquid Feeds

During an initial 6 day period calves were fed whole milk only. This was followed by an adaptation period of 3 days (days 7 to 9) during which milk replacer feeding superseded whole milk as the liquid diet (Table 5).

The dry milk replacer was added to water (40°C) and mixed with a piece of wire (shaped in the form of an egg beater) attached to the motor of an electric drill.

All liquid diets were nipple fed in two equal portions: in the morning (8:30 a.m.) and afternoon (3:30 p.m.).

Calves were weaned abruptly after the 3 or 5 week milk replacer feeding period.

b) Dry Concentrates

After the adaptation period, 0.23 kg of grain mixture was made available to each calf, with the amount gradually increased up to a maximum of 1.4 kg per day. The uneaten portion of the grain mixture was weighed and discarded daily.

c) Hay

Chopped hay was available at all times and the amount consumed by each calf was recorded daily.

TABLE 5. DAILY AMOUNTS OF WHOLE MILK AND MILK REPLACER FED TO EACH CALF IN THE PRE-WEANING FEEDING PROGRAMME.

Period	Whole Milk (kg)	Milk Replacer Powder (kg)	Water Added (kg)
<u>Pre-experimental Programme</u>			
Day 1 - 6	2.80	-	-
Day 7	2.73	0.08	0.68
Day 8	1.82	0.15	1.82
Day 9	0.91	0.23	2.73
<u>Experimental Programme</u>			
Week 1	-	0.30	2.73
Week 2	-	0.38	2.73
Week 3	-	0.53	2.84
Week 4	-	0.61	3.30
Week 5	-	0.68	3.30

d) Feed Data

Collection of experimental data for discussion in the thesis was begun after the adaptation period (days 7 to 9), hereafter called week 1. The trial continued through weeks 1 to 12 inclusive.

5. Weighings

Each calf was weighed on the first two days of week 1 and the mean was considered the initial trial weight. Throughout the 12 week trial calves were weighed on the same day of each week, prior to feeding. They were also weighed on the last two days of the trial and the mean recorded as the final weight.

6. Evaluation of Feed Samples

a) Collection of Feed Samples

Feed samples were collected once a week in polyethylene bags, sealed, and stored at room temperature. At the end of the trial, all samples of a particular feed were pooled and the composite sample analysed.

b) Chemical Analysis

All feed samples were ground using a Raymond hammer mill fitted with a 1 millimeter (mm) diameter mesh screen. Samples were analysed for (i) absolute dry matter, by the vacuum oven drying method (A.O.A.C., 1970); (ii) crude protein according to the Kjeldahl method (A.O.A.C., 1970); (iii) calcium, using a Unicam Sp. 90 Atomic Absorption Spectrophotometer; and (iv) phosphorus, by the photometric method (A.O.A.C., 1970).

7. Statistical Analyses

Data were analysed according to least squares procedures for unequal subclass numbers (Harvey, 1960) using the following model:

$$Y_{ijk} = U + T_i + g_j + (rg)_{ij} + e_{ijk}$$

where Y_{ijk} = a trait measured on the ijk^{th} calf; U = the population mean; Ti = the effect on the i^{th} milk replacer treatment; g_j = the effect of the j^{th} grain treatment; rg_{ij} = the interaction effect of the i^{th} milk replacer and j^{th} grain treatment; and e_{ijk} = random error.

The following parameters were analysed statistically weekly: weight gain; daily intakes of milk replacer, hay, grain; total daily intake of dry matter; and total daily estimated metabolizable energy (EME); EME per kg of gain; dry matter intake per kg of gain; total feed cost; and feed cost per kg of gain.

Significant differences between means at the $P < .01$ and the $P < .05$ levels were determined by Duncan's New Multiple Range Test (Steel and Torrie, 1960).

8. Feed Cost Analysis

The costs of feed used in this trial are listed in Table 6. It may be noted that the formula for young calves (SG) is 28% more expensive than the formula for mature cows (MM).

TABLE 6. APPROXIMATE FEED COSTS IN TRIAL I (1971)

Feedstuff	$/Metric Ton	¢/kg
Fluid Whole Milk (Manufacturing grade)	123.00	13.20
Milk Replacer (powder)	495.00	49.50
Calf Starter-Grower	126.28	12.63
Milk-Maker	90.64	9.06
Hay	33.00	3.30

B. RESULTS AND DISCUSSION

1. Chemical Composition of Feeds

Although in the guaranteed analysis provided by the manufacturer the crude protein contents of milk replacers MRI and MRII were listed as having minimum amounts of 24 and 20% respectively (Table 3), the chemical analysis of a composite sample determined the crude protein content to be only 19 percent (Table 7).

The crude protein analysis for the grain mixtures revealed higher values than those stipulated in the guaranteed analyses, with starter SG having a higher content than starter MM (Table 7).

The protein content of hay was relatively high, probably because of the alfalfa component (Table 7).

TABLE 7. CHEMICAL COMPOSITION OF FEEDS (%). TRIAL I.

Feed	Dry Matter	Protein	Ca	P
		←	As Fed	→
Milk Replacer[1]	95.3	19.3	0.80	0.66
Starter-Grower (SG)	93.2	19.3	0.88	0.76
Milk-Maker (MM)	93.5	17.7	0.96	0.42
Hay	92.6	12.2	1.02	0.22

[1] Composite sample of MRI and MRII.

2. Animal Performance

a) 0 - 5 Week Period

A summary of calf performance during the first five weeks of the trial is shown in Table 8. Group II (fed SG mix and milk replacer for 5 weeks) performed better than Groups I, III and IV. It had a higher average daily gain (ADG) (0.51 kg) and the highest feed efficiency (2.78 kg DM per kg of gain). This group was fed milk replacer for a longer period, and was fed the better grain mix (without urea). Group IV was next to Group II in feed efficiency, although Group I had a slightly higher ADG. Group III had the lowest ADG probably because of the shorter period on milk replacer and the lower quality of the grain mix.

In general the calves fed milk replacer for 5 weeks (Groups II and IV) performed better, though not significantly ($P > .05$), than those fed milk replacer for 3 weeks (Groups I and III), probably because of the higher intake of milk replacer.

Although the calves fed milk replacer for 3 weeks (MR3) consumed more grain mix (22.6 kg/calf) than those fed milk replacer for 5 weeks (16.6 kg/calf), still the MR3 groups had lower total DM and EME intakes (Table 9), because they could not consume enough grain and hay to compensate for the DM provided by the milk replacer.

When the nutrient intakes (DM, CP and EME) of the four treatment groups were compared with the nutrient re

TABLE 8. CALF PERFORMANCE, 0 - 5 WEEKS. TRIAL I.

Grain Mix	Starter-Grower		Milk-Maker		SE[1]
Weeks on MR	3	5	3	5	
Groups	I	II	III	IV	
No. of Animals	8	7	8	8	
Av. Initial Wt (kg)	51.4	51.0	51.0	51.9	4.2
Av. 5 Week Wt (kg)	67.4	68.8	63.3	67.2	6.4
A.D.G. (kg)	0.45	0.51	0.35	0.44	0.10
Total Feed Intake (kg/calf)					
Milk Replacer (powder)	10.8	21.6	10.6	21.6	0.1
Hay	10.6	11.0	6.9	10.6	3.9
Grain Mix	21.3	17.0	23.9	16.1	5.0
Total Av. Daily DM Intake (kg)	1.14	1.33	1.11	1.30	0.07
Feed Efficiency (kg.DM/kg.gain)	3.57	2.78	3.46	3.07	0.87

1 Approximation of standard error (SE) of the mean. In this table, as well as in all others of similar format, only the significant ($P < .01$ or $P < .05$) differences among means are indicated by different superscripts (A,B,C or a,b,c respectively) within a given line. Absence of letters should be interpreted as lack of significance ($P > .05$).

requirements recommended by NRC (1971), estimated DM intakes were lower (Table 9). Only two groups (II and IV) apparently met the total protein and ME intakes set by the NRC standards (Table 9).

TABLE 9. DAILY DRY MATTER (DM), PROTEIN AND ENERGY (EME) INTAKES OF CALVES[1] (0 - 5 WEEKS, TRIAL I) AS A PERCENTAGE OF NRC RECOMMENDATIONS.[2]

Group	Wks on MR	Grain Mix	DM[3]	Protein[3]	ME (EME)[4]
I	3	SG	78.6	98.2	89.5
II	5	SG	92.9	114.1	113.2
III	3	MM	84.6	102.5	97.1
IV	5	MM	92.9	108.7	110.5

1* The mean value between the average initial and average 5 week weight was used.

2* The NRC values were determined by assuming linearity between 40 - 100 kg for growing bulls of large dairy breeds (NRC, 1971).

3* DM and Protein values were obtained as follows:

Feed intake X percentage composition

4* EME was calculated by using the following formula:

$$EME = 0.82\ DE$$ (Crampton and Harris, 1969)

DE was obtained from the manufacturers for the milk replacers and grain mixtures. For hay, values of NRC (1971) were used.

* These methods were used throughout the text.

It was shown in Table 19 that calves on milk replacer for 5 weeks had a relatively greater DM intake than those on milk replacer for 3 weeks. It is possible that those calves on milk replacer for 3 weeks were not able to compensate in their total DM intake by increasing intake of solid feed. This is in keeping with the conclusions of Radostits and Bell (1970), that milk replacer plays an important part in the DM intake of pre-ruminant calves.

The energy requirements of the pre-ruminant calf are not well established. Several workers (Blaxter and Wood, 1951; Brisson *et al*., 1957; Bryant *et al*., 1967) have estimated that the pre-ruminant calf requires 36.6, 39.5 and up to 42.9 kilocalories (Kcal) of metabolizable energy (ME) per kg body weight per day. These workers also found that calves growing at about 0.5 kg per day require additionally between 1.1 and 1.5 megacalories (Mcal) of ME. Therefore a 60 kg calf growing at about 0.5 kg daily needs a total Mcal of ME of about 3.3 to 4.1 per day. All groups except Group I apparently consumed adequate feed to supply at least the minimum requirement of ME in the first 5 weeks.

Digestible protein is very important in the nutrition of pre-ruminating calves. Jacobson (1969) summarized the existing information concerning the digestible protein requirements of a 50 kg non-ruminating calf. He quotes an average value of 113 gm of digestible protein per day for maintenance plus a daily gain of 0.5 kg. In the present trial, at least the total crude protein intake seemed adequate compared with the NRC recommended requirements with the possible exception of Group I (Table 9). However, since no digestibility studies were carried out, there is no value for the amount of protein actually digested. It is known that properly processed milk protein is well digested by the pre-ruminant calf. The milk replacers used in this trial presumably contained only milk proteins, hence the crude protein obtained from this source could be readily digested.

After the first week or two of the trial the non-ruminating calves began to nibble at hay and grain mix. By this time the rumen presumably had started to function and a fair proportion of the protein utilized would be obtained from hay and grain. The protein supplied by hay was small (16 - 18%) compared to the milk replacer (25 - 50%) and the grain mixture (35 - 55 percent).

Calves fed milk replacer for 5 weeks (MR5) grew better though not significantly ($p > .05$) than calves fed milk replacer for 3 weeks (MR3); also the MR5 calves utilized total DM slightly more efficiently (Table 10). The possible reasons for the apparently better performance of the MR5 calves are: (1) the longer period on milk replacer; and (2) they utilized the liquid portion of the diet as "monogastrics", and it is known that pre-ruminants are more efficient in utilizing both dietary protein and energy of liquid diets than ruminants of similar weight (Black, 1971).

It is also indicated in Table 10 that while the feed efficiency for SG calves and MM calves were apparently similar, SG calves grew better, though not significantly (P > .05), than MM calves. Two possible reasons may explain this: (1) the protein content of the SG mix was higher (Table 7); and (2) the MM mix contained urea which is not utilized by non-ruminating calves (NRC, 1971).

The diets fed to calves on this trial had adequate amounts of calcium and phosphorus when compared to NRC standards.

TABLE 10. LEAST SQUARE ESTIMATES OF TREATMENT DIFFERENCES IN WEIGHT GAIN (KG) AND FEED EFFICIENCY (KG.DM/KG.GAIN); 0-5 WEEKS. TRIAL I

Variable	Treatment Difference	Estimated Values	SE[1]
Weight gain	MR5[2] - MR3[3]	2.38 NS[4]	2.23
"	SG[5] - MM[6]	3.12 NS	2.23
Feed efficiency	MR5 - MR3	-0.58 NS	0.50
"	SG - MM	-0.09 NS	0.50

1 SE Approximation of standard error of the mean.
2 MR5 Milk replacer fed for 5 weeks
3 MR3 Milk replacer fed for 3 weeks
4 NS Not significant (P > .05)
5 SG Starter-Grower
6 MM Milk-Maker

N.B. The above abbreviations (1 - 6) are used throughout the text in tables of similar format to Table 10.

b) 6 - 12 Week Period

The average performance of calves from the 6th to 12th week of the trial is shown in Table 11. As in the first 5-week period, the calves fed SG and milk replacer for 5 weeks (Group II) had the highest rate of gain. Although it did not differ significantly ($P > .05$) from Groups I and IV, Group III (calves fed MM and milk replacer for 3 weeks) was the only one that had a significantly ($P < .05$) lower ADG. Total feed efficiency was similar except for Group I which had a significantly ($P < .05$) lower efficiency than Groups II and IV.

Overall, calves which had been fed milk replacer for 5 weeks performed better than calves fed milk replacer for 3 weeks. Feed efficiency and weight gain were significantly ($P < .05$) better with these calves (Table 12). Two questions arise: (1) Is the additional cost of feeding milk replacer for two more weeks justifiable? (2) Will the animals fed milk replacer for only 3 weeks compensate in performance later in life? An attempt will be made to answer these questions later.

Group II tended to perform better than all the other groups in the 6 to 12 weeks period (Table 11). The nutrient intake of this group during the first 5 weeks of the trial compared favorably with the NRC recommended requirements (Table 9). It is believed that the higher nutrient intake of Group II in the earlier period may be partially responsible for its slightly better performance in the 6 to 12 week period.

TABLE 11. CALF PERFORMANCE, 6 - 12 WEEKS. TRIAL I.

Grain Mix	Starter-Grower		Milk -Maker		SE
Weeks on MR	3	5	3	5	
Groups	I	II	III	IV	
No. of Animals	8	7	8	8	
Av. 5 week wt (kg)	67.4	68.8	63.3	67.2	6.4
Av. 12 week wt (kg)	96.8	103.2	89.2	100.3	8.8
A.D.G. (kg)	0.60^{ab}	0.70^{a}	0.53^{b}	0.68^{a}	0.07
Total Feed Intake (kg/calf)					
Hay	63.0	67.0	40.2	60.7	12.7
Grain Mix	66.5	66.0	66.0	64.9	1.3
Total Av. Daily DM Intake (kg)	2.46	2.53	2.02	2.39	0.12
Feed Efficiency (kg.DM/kg.gain)	4.13^{a}	3.60^{b}	3.85^{ab}	3.58^{b}	0.25

a,b,c Mean values with different superscripts in the same row differed significantly ($P < .05$).

TABLE 12. LEAST SQUARE ESTIMATES OF TREATMENT DIFFERENCES IN WEIGHT GAIN (KG) AND FEED EFFICIENCY (KG.DM/KG.GAIN); 6 - 12 WEEKS. TRIAL I.

Variable	Treatment Difference	Estimated Values	SE
Weight gain	MR5 - MR3	6.19**	1.90
"	SG - MM	2.39	1.90
Feed efficiency	MR5 - MR3	-0.40*	0.15
"	SG - MM	0.15	0.15

* $P < .05$
** $P < .01$

The average daily nutrient intakes (DM and ME) of all four groups seemed favorable when compared with NRC recommendations (Table 13). However, Group III had a lower protein intake than the other three groups. This may help to explain the poor growth performance of the group (Table 11). The low protein intake of Group III is associated with a low hay intake by the group (Table 11).

It is known that early weaned calves should be introduced to good quality hay and a good calf starter ration as early as possible (Roy, 1970a; Foley *et al.*, 1973; Schmidt and Van Vleck, 1974). Although some authors are of the opinion that the calf starter should contain over 16% CP with total digestible nutrients (TDN) of 75% (Foley *et al.*,

TABLE 13. DAILY DM, PROTEIN AND EME INTAKES OF CALVES[1] (6 - 12 WEEKS, TRIAL I) AS A PERCENTAGE OF NRC RECOMMENDATIONS.[1]

Group	Wks on MR	Grain Mix	DM[1]	Protein[1]	EME[1]
I	3	SG	104.2	111.7	103.3
II	5	SG	96.2	108.9	98.5
III	3	MM	90.9	68.4	98.2
IV	5	MM	96.0	100.5	96.8

1 See Table 9, page 44, for derivation of values used.

1973; Schmidt and Van Vleck, 1974), there is some uncertainty as to the minimum amount each calf should be allowed to consume per day. In this trial each calf was limited to 1.4 kg of grain mixture per day, because it was estimated that this amount, in addition to good quality hay available free choice, would provide the calf with enough nutrients to gain up to 0.5 kg per day. However, calves in Group III were unable, for some reason, to consume enough hay and as they were offered restricted amounts of concentrates they did not consume sufficient total protein (Table 13). This was reflected in their significantly ($P < .05$) lower rate of gain (Table 11).

c) Overall Period (0 - 12 Weeks)

The overall performance of calves during the twelve weeks of the trial is shown in Table 14. This table represents the average additive effects of the 0 to 5 and 6 to 12 week periods. Group II had a significantly ($P < .05$) better feed efficiency (DM/unit gain) than Groups I and III, slightly better ADG than Groups I and IV, but significantly ($P < .05$) better ADG than Group III. Calves fed milk replacer for 5 weeks grew significantly ($P < .05$) more and were more efficient in the utilization of feed DM than those fed milk replacer for 3 weeks, as shown in Table 15.

When the concentrate or starter effects are analyzed independently it is seen that the animals fed starter SG showed a better performance (weight gain) than those fed starter MM, although this difference is not significant ($P > .05$) (Table 15). This can be attributed to the fact that both grain mixtures contained apparently an adequate minimum of nutrients (Table 7) and were fed only in limited quantities (1.4 kg per calf per day).

The nutrient intakes for all other groups except Group III during the trial were reasonable compared to the NRC recommendations (Tables 9 and 13). DM intake was generally low, and protein and EME intakes were marginal. Group III had a lower than recommended protein intake and this was probably responsible for its slower growth rate (Table 11 and Figure 1).

TABLE 14. CALF PERFORMANCE, 0 - 12 WEEKS. TRIAL I

Grain Mix	Starter-Grower		Milk-Maker		SE
Weeks on MR	3	5	3	5	
Groups	I	II	III	IV	
No. of Animals	8	7	8	8	
Av. Initial Wt (kg)	51.4	51.0	51.0	51.9	4.2
Av. 12 Week Wt (kg)	96.8	103.2	89.2	100.3	8.8
A.D.G. (kg)	0.54^{ab}	0.62^{a}	0.45^{b}	0.58^{ab}	0.07
Total Feed Intake (kg/calf)					
Milk replacer (powder)	10.8	21.6	10.6	21.6	0.1
Hay	73.6	78.0	47.1	71.3	16.1
Grain Mix	87.7	83.0	90.2	80.9	5.9
Total Av. Daily DM Intake (kg)	1.91	2.02	1.64	1.93	0.18
Feed Efficiency (kg·DM/kg·gain)	3.59^{a}	3.26^{b}	3.65^{a}	3.37^{ab}	0.18

a,b Means with different superscripts in the same row differed significantly ($P < .05$).

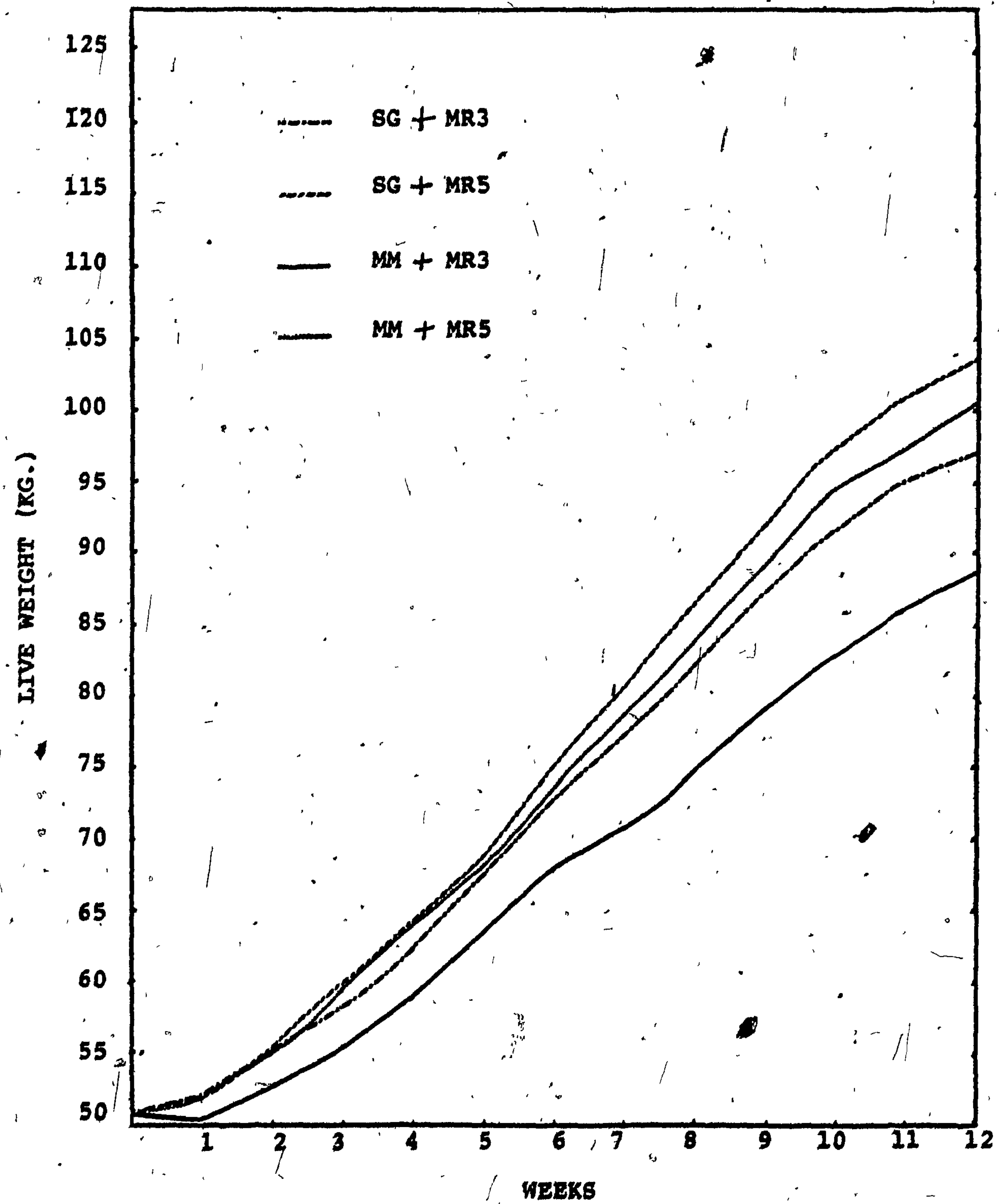

FIGURE 1. EFFECT OF DIET ON CALF WEIGHT GAINS IN TRIAL I.

TABLE 15. LEAST SQUARE ESTIMATES OF TREATMENT DIFFERENCES IN WEIGHT GAIN (KG) AND FEED EFFICIENCY (KG.DM/KG · GAIN); 0 - 12 WEEKS. TRIAL I.

Variable	Treatment Difference	Estimates Values	SE
Weight gain	MR5 - MR3	8.58*	3.39
"	SG - MM	5.51	3.39
Feed efficiency	MR5 - MR3	-0.31**	0.10
"	SG - MM	-0.09	0.10

* $P < .05$

** $P < .01$

3. <u>Calf Health</u>

Incidence of scours and antibiotic treatments are summarized in Table 16. Scouring only occurred in the first 5 week period and Group II (fed SG plus MR for 5 weeks) was most affected. Fifty percent of the calves in this group scoured compared to 25% in the other groups. The frequency of scouring was low, probably because the calves were treated promptly. It is believed that the scouring was mainly nutritional, although the possibility of bacterial scouring was not entirely ruled out. Entefur "A" and Terramycin tablets (see appendix Table I) were very effective against scouring.

TABLE 16. INCIDENCE OF SCOURS AND CURATIVE TABLETS USED. TRIAL I.

Group	No. of Calves	No. of Calves Scoured	Frequency[1]	Tablets Used	
				Entefur A	Diamycin
I	8	2	2.0		7
II	7	4	2.5	4	9
III	8	2	3.0	4	7
IV	8	2	1.5		3

1 Frequency = Number of times one calf scoured.

A number of calves suffered from mild throat infections, slight coughs and running nostrils, but most of these symptoms cleared up after administration of antibiotics (2 - 4 cc of Penicillin G). However, about 3 or 4 calves from different groups had to be given other medications besides penicillin. Calf no. 3 in Group III had an inflamed throat and had to be treated with flumethazone. Two other calves, no. 16 in Group III and no. 11 in Group I, had slight attacks of pneumonia, probably bacterial in origin. They were treated with large doses of sulfamethazine and smaller doses of chloramphenicol (Rogar-mycine). The amounts of antibiotic solutions and scouring tablets used in Trial I are shown in Appendix Table II and Table 16 respectively.

The mortality in this trial was low. Only one calf (no. 15) in Group II died before the end of the 0 - 5 week period from bacterial pneumonia. This calf scoured profusely when it was put on trial and had poor health up to the time it died. Therefore, the data from this animal were not used in the calculations. However, no group suffered any major health setback attributable to diets or feeding regime.

4. Feed Cost

Jacobson (1969) and Gorrill (1972) stated that the replacement calf is expected to have a daily weight gain of about 0.5 kg. This suggests that it will be fed limited milk or milk substitute and calf starters, and maximum hay.

The feeding system used in this trial was designed to minimize cost in a feeding system for replacement calves.

In the overall period, it is shown in Table 17 that calves fed milk replacer for 5 weeks had higher total feed cost per calf of about $5.58. Also calves fed SG mixture had an increased feed cost of $4.15 over calves fed MM mixture. However, when costs are expressed on a per unit of gain basis, the differences become insignificant ($P > .05$) (Table 17). Group II had a total feed cost significantly ($P < .01$) higher than all the other groups, while Group III had a total feed cost significantly ($P < .01$) lower than the others (Table 18). One question must still be answered: Is the extra cost per calf in Group II justifiable for raising dairy bull calves for the feedlot? An attempt will be made to answer this question in the summary of Trial I.

TABLE 17. LEAST SQUARE ESTIMATES OF TREATMENT DIFFERENCES IN TOTAL FEED COSTS (¢) AND FEED COST PER UNIT GAIN (¢/kg) IN TRIAL I.

Period	Treatment Difference	Total Feed Cost	SE	Per Unit Gain	SE
Week 0-5	MR5 - MR3	508.52**	37.92	2.95	18.55
	SG - MM	81.71*		6.50	
Week 6-12	MR5 - MR3	49.89	39.50	5.25**	1.46
	SG - MM	333.63**		8.31**	
Week 0-12	MR5 - MR3	558.42**	72.00	2.75	2.36
	SG - MM	415.34**		3.58	

* $P < .05$
** $P < .01$

TABLE 18. CALF FEED COST. TRIAL I.

Grain Mix	Starter-Grower		Milk-Maker		SE
Weeks on MR	3	5	3	5	
Group	I	II	III	IV	
Feed Cost ($), 0-5 Weeks					
Total FC[1]/calf	9.00[B]	14.02[A]	8.13[B]	13.26[A]	0.66
FC/kg gain[2]	0.97	0.85	0.76	0.94	0.32
Feed Cost ($), 6-12 Weeks					
Total FC/calf	12.05[A]	12.18[A]	8.37[B]	9.21[B]	0.68
FC/kg gain	0.42[A]	0.36[B]	0.33[BC]	0.28[C]	0.03
Feed Cost ($), 0-12 Weeks					
Total FC/calf	21.05[B]	26.20[A]	16.50[C]	22.47[B]	1.25
FC/kg gain	0.48	0.51	0.44	0.48	0.04

1 FC = Feed Cost
2 FC/kg gain mentioned in this table and others of similar format was calculated for each individual animal in a group and then the average for the group was found (see Appendix Tables V to XIII)
A,B,C Means with different superscripts in the same row differed significantly ($P < .01$).

C. SUMMARY OF TRIAL I.

As indicated in Table 14, ADG in Group III was significantly ($P < .05$) lower than that of Group II, but not the other groups. The anticipated ADG was 0.5 kg and, with the exception of Group III, all other groups achieved this level of performance. As stated earlier, Group II had a significantly ($P < .05$) better feed efficiency than Groups I and III. On performance alone, Group II was better than any other group.

Although there were some health problems, no group can be singled out as being worst than any other. In Group II more calves scoured than in any other group, but Group III had a greater frequency. More medications were administered to Group III than to any other group (Appendix Table II).In terms of veterinary expense, Group II had the lowest, followed by Group IV, then Group I. It is possible that the higher quality and quantity of nutrients made available to Group II at an early age produced healthy calves which needed less medications than the calves of the other groups. The calf lost from Group II was not considered as part of the group because of its unhealthy condition when it entered the group.

Group III had the lowest total feed cost (Table 18), but this group also had an ADG less than 0.5 kg (Table 14) which is considered inadequate. Group II had the highest ADG and the highest feed efficiency, but it also had the highest total feed cost (significantly ($P < .01$) higher than the other groups), and feed cost per unit gain. However, since the ADG of Group II was not significantly ($P > .05$) better than the ADG of Groups I and IV, and the feed efficiency was not significantly ($P > .05$) higher than that of Group IV (Table 14), the performance of Group II did not justify the feed expense.

When ADG and total feed costs were considered together, Groups I and IV were the best. Both groups may therefore be used as examples to the farmer. He could either use a shorter liquid feeding period (3 weeks) with a "better" and more expensive calf starter (Group I); or feed milk replacer for a longer period (5 weeks) with a "poorer" and less expensive calf starter (Group IV). Under both conditions the farmer may expect similar performance (ADG) and similar total feed costs.

The overall feed cost needed to raise a calf from about 52.0 kg to about 100.0 kg was $21.05 and $22.47 in Groups I and IV respectively (Table 18). This is in keeping with the findings of Forrest and Lister (1970) who estimated that feed costs should be less than $25.00 to raise Holstein steer calves to this weight.

V. TRIAL II

A. EXPERIMENTAL PROCEDURE

1. Management

Thirty-six Holstein bull calves were purchased at local auctions or from the Macdonald College farm in May 1972. They were about one week old on arrival, with an average body weight of 52 kilograms (kg). The calves were numbered and, as a preventitive measure, were injected with antibiotics (200,000 International Units (IU) penicillin each) for 3 consecutive days. On the fourth day each calf was injected with vitamins (Vitamin A 1,000,000 IU, Vitamin D_3 100,000 IU, Vitamin E 100 IU).

For the first week calves were housed in an arena. Then, for the remaining 11 weeks of the trial, they were transferred to pens similar to those used in Trial I. Pens were cleaned and bedded with wood shavings every day.

Light was provided for approximately 8 hours per day and the temperature was controlled in a range of 18 to 24 degrees centigrade.

2. Experimental Design

The trial was conducted in a manner similar to Trial I (Table 16), using the same type of design (Table 19).

TABLE 19. EXPERIMENTAL DESIGN - TRIAL II

Length of Milk Replacer Feeding (Wks)[1]	Type of Grain Mixture	
	SG[2]	MM[2]
3	9[3] (I)[4]	9 (III)
5	9 (II)	9 (IV)

1 Weeks on trial

2 SG : Starter-Grower; MM : "Milk-Maker"

3 Number of calves

4 Group number

3. Rations

From the first day of the trial to weaning, calves were fed a commercial milk replacer containing 21% crude protein (CP) and 8% ether extract (EE) (Table 20).

The grain mixtures offered were similar to those used in Trial I.

Hay, composed mainly of Alfalfa and Timothy species (1 : 3 respectively), was chopped to a length of about 3 centimeters (cm) and fed to the calves *ad libitum* from the first week of the trial.

Water and salt (Cobalt Iodized Sodium Chloride) were available at all times.

TABLE 20. GUARANTEED ANALYSIS OF CALF MILK REPLACER[1] USED IN TRIAL II.

Crude Protein (Minimum) (%)	21.0
Crude Fat (Minimum) (%)	8.0
Crude Fibre (Maximum) (%)	1.5
Sodium chloride (%)	3.0
Calcium (%)	1.0
Phosphorus (%)	1.0
Vitamin A (Minimum IU/lb)	10,000
Oxytetracycline Hydrochloride (mg/lb)	50

1 Lactone Reg. No. 1433 - Master Feeds, Que.

4. Feeding Programme

a) Liquid Feeds

The milk feeding programme (slightly modified from that recommended by the manufacturers) is shown in Table 19. As in Trial I, the liquid diet was nipple fed in two equal portions, in the morning (8:30 am) and afternoon (3:30 pm).

TABLE 21. DAILY AMOUNTS OF MILK REPLACER FED (KG PER CALF). TRIAL II.

Period	Milk Replacer Powder	Water Added
Day 1	0.18	1.64
Day 2	0.23	2.09
Day 3	0.27	2.45
Day 4	0.32	2.91
Day 5	0.36	3.27
Day 6	0.41	3.73
Day 7	0.45	4.09
Week 2 - 5	0.45	4.09

b) Dry Concentrates

The grain mixture was introduced to the calves approximately one week after arrival, at the rate of 0.23 kg per day, and was gradually increased up to a maximum of 1.4 kg per day. The uneaten portion of the grain mixture was weighed and discarded daily. The amount consumed by each calf was recorded.

c) Hay

Chopped hay was available at all times and the amount consumed by each calf was recorded daily.

5. Weighings

Calves were weighed in a manner similar to that described in Trial I (page 38).

6. Evaluation of Feed Samples

Feed samples were collected and analysed as in Trial I.

7. Statistical Analyses

Data were analysed as in Trial I. The parameters were the same as those in Trial I. Significant differences between means were determined by Duncan's New Multiple Range Test (Steel and Torrie, 1960).

8. Feed Cost Analysis

The prices of feed used in Trial II are listed in Table 22.

TABLE 22. APPROXIMATE FEED COSTS. TRIAL II (1972)

Feedstuff	$/Metric Ton	¢/KG
Milk Replacer (powder)	430.00	43.00
Calf Starter-Grower	140.00	14.08
Milk-Maker	104.50	10.45
Hay	37.10	3.71

B. RESULTS AND DISCUSSION

1. Chemical Composition of Feeds

The composition of the milk replacer used in this trial is indicated in Table 23. The grain mixtures were similar to those used in Trial I with CP contents of 19.4% (SG) and 18.1% (MM). The protein content of the hay was lower than that in Trial I, probably because of the lower alfalfa component (Tables 7 and 23). Calcium and phosphorus contents of all feeds were slightly different from those in Trial I (Tables 7 and 23).

TABLE 23. CHEMICAL COMPOSITION OF FEEDS (%). TRIAL II

Feed	Dry Matter	Protein	Ca As Fed	P
Milk Replacer	94.5	21.4	1.44	0.90
Starter-Grower (SG)	93.2	19.4	0.98	0.66
Milk-Maker (MM)	93.3	18.1	0.56	0.54
Hay	93.1	11.0	0.44	0.23

2. Animal Performance

a) 0 - 5 Week Period

Calf performance for the first five weeks of the trial is summarized in Table 24. Calves fed milk replacer for 5 weeks (MR5) (Groups I and IV) had slightly better weight gains and feed efficiencies than those fed milk replacer for 3 weeks (MR3) (Groups I and III) as is clearly shown in Table 25. As in Trial I, this was probably due to the greater efficiency of MR5 calves in utilizing both dietary protein and energy from the liquid diet. Grain mix consumption was slightly higher in MR3 calves although the difference was not significant ($P > .05$) (Table 24).

Calves fed SG grain mix grew slightly better and had relatively better feed efficiencies than those fed MM grain mix (Table 25). The SG groups (Groups I and II) also had a slightly higher average daily DM intake than the groups fed MM mix (Groups III and IV) (Table 24). This is quite unlike Trial I (Table 8) where the higher average daily DM intake in the first 5 weeks of the trial seemed to depend on the longer period of feeding milk replacer. In Trial II, there was no pre-experimental or adaptation period as in Trial I, therefore, the animals were less dependent on milk or milk substitute as a source of dry matter.

The average daily DM, protein and ME intakes for all four groups were below National Research Council (NRC) recommended requirements (Table 26). This is particularly

TABLE 24. CALF PERFORMANCE, 0 - 5 WEEKS. TRIAL II.

Grain Mix	Starter-Grower		Milk-Maker		SE
Weeks on MR	3	5	3	5	
Groups	I	II	III	IV	
No. of Animals	9	9	9	9	
Av. Initial Wt (kg)	53.0	52.7	53.6	51.7	2.4
Av. 5 Week Wt (kg)	69.0	71.1	66.1	70.2	5.2
A.D.G. (kg)	0.46	0.53	0.36	0.53	0.12
Total Feed Intake (kg/calf)					
Milk Replacer (powder)	8.0	14.5	8.0	14.5	0.5
Hay	11.5	11.4	8.0	8.8	2.5
Grain Mix	25.4	19.4	21.4	20.3	4.4
Total Av. Daily DM INtake(kg)	1.20	1.20	1.01	1.17	0.06
Feed Efficiency (DM/Unit gain)	3.00	2.74	5.30	2.35	1.90

TABLE 25. LEAST SQUARE ESTIMATES OF TREATMENT DIFFERENCES IN WEIGHT GAIN (KG) AND FEED EFFICIENCY (KG·DM/KG·GAIN), 0 - 5 WEEKS. TRIAL II.

Variable	Treatment Difference	Estimated Values	SE
Weight gain	MR5 - MR3	4.21 NS	2.43
"	SG - MM	1.73 NS	2.43
Feed efficiency	MR5 - MR3	-1.61 NS	1.10
"	SG - MM	-0.95 NS	1.10

NS P > .05

TABLE 26. DAILY DM, PROTEIN AND ME INTAKES OF CALVES[1] (0 - 5 WEEKS, TRIAL II) AS A PERCENTAGE OF NRC RECOMMENDATIONS[1]

Group	Wks on MR	Grain Mix	DM[1]	Protein[1]	ME[1]
I	3	SG	80.0	98.3	87.2
II	5	SG	80.0	97.3	87.5
III	3	MM	71.4	84.1	76.3
IV	5	MM	80.2	96.5	89.7

[1] See Table 9, page 44 for derivation of values used.

evident for Group III, fed MR for 3 weeks plus MM grain mix. This is unlike Trial I (Table 9) where the protein and ME intakes for Groups II and IV were considered adequate. Like Trial I, the calcium and phosphorus intakes were in excess of the NRC recommended requirements.

b) <u>6 - 12 Week Period</u>

A summary of calf performance from the 6th to the 12th week is shown in Table 27. There was no significant ($P > .05$) difference in average daily gain (ADG) between groups. However, calves fed milk replacer for 3 weeks and MM grain mix during the trial (Group III) had significantly ($P < .01$) lower hay intake and total DM intake, and better feed efficiency than calves fed SG grain mix (Groups I and II). Table 28 indicates that the MM groups (Groups III and IV) had significantly ($P < .01$) lower hay consumption and better feed efficiencies than the SG groups (Groups I and II). It is probable, then, that the SG groups by consuming so much hay diluted out the nutrients obtained from other feeds and consequently decreased feed efficiency.

Unlike the first 5 week period, all four groups in this period seemed to have satisfied the NRC recommended nutrient requirements for DM, protein and ME (Table 29), although Group III had lower nutrient intakes than the other groups.

TABLE 27. CALF PERFORMANCE, 6 - 12 WEEKS. TRIAL II.

Grain Mix	Starter-Grower		Milk-Maker		SE
Weeks on MR	3	5	3	5	
Groups	I.	II	III	IV	
No. of Animals	9	9	9	9	
Av. 5 Weeks Wt (kg)	69.0	71.1	66.1	70.2	5.2
Av. Final Wt (kg)	99.3	102.1	95.4	102.9	6.9
A.D.G. (kg)	0.62	0.63	0.60	0.67	0.05
Total Feed Intake (kg/calf)					
Hay	76.1^{A}	79.4^{A}	47.1^{B}	67.1^{AB}	11.1
Grain Mix	66.8	66.3	66.5	66.3	0.4
Total Av. Daily DM Intake(kg)	2.72^{A}	2.77^{A}	2.16^{B}	2.54^{A}	0.10
Feed Efficiency (DM/Unit gain)	4.39^{A}	4.40^{A}	3.65^{B}	3.84^{AB}	0.29

^{A,B} Means with different superscripts in the same row differed significantly ($P < .01$).

TABLE 28. LEAST SQUARE ESTIMATES OF TREATMENT DIFFERENCES IN WEIGHT GAIN (KG), HAY INTAKE (KG) AND FEED EFFICIENCY (KG·DM/KG·GAIN); 6 - 12 WEEKS. TRIAL II.

Variable	Treatment Difference	Estimated Values	SE
Weight gain	MR5 - MR3	2.07	1.42
"	SG - MM	-0.40	1.42
Hay intake	MR5 - MR3	11.65	6.49
"	SG - MM	20.61**	6.49
Feed efficiency	MR5 - MR3	0.10	0.17
"	SG - MM	0.65**	0.17

** $P < .01$

TABLE 29. DAILY DM, PROTEIN AND ME INTAKES OF CALVES[1] (6 - 12 WEEKS, TRIAL II) AS A PERCENTAGE OF NRC RECOMMENDATIONS[1].

Group	Wks on MR	Grain Mix	DM[1]	Protein[1]	ME[1]
I	3	SG	108.0	113.0	106.3
II	5	SG	107.7	111.1	104.5
III	3	MM	91.7	94.9	95.0
IV	5	MM	96.2	99.7	97.0

[1] See Table 9, page 44 for derivation of values used.

The results from this period of Trial II differed from those of the similar period in Trial I as follows: (1) In Trial II the ADG was not significant ($P > .05$) between groups (Table 27), but in Trial I it was (Table 11). (2) In Trial I length of milk replacer feeding was more important than type of grain mix in determining performance. In this Trial (Trial II) no significant ($P > .05$) difference attributable to type of grain mix or length of milk replacer feeding was found (Table 28), although calves fed liquid diets for 5 weeks tended to grow faster.

c) Overall Period (0 - 12 Weeks)

The results of the overall performance of calves in Trial II are shown in Table 30. There were no significant ($P > .05$) differences in ADG or feed efficiencies between the groups. However, Table 31 indicates that the calves fed "Milk-Maker" mix (MM) were significantly ($P < .05$) more efficient in dry matter utilization. In both Trials I and II, the calves fed Starter-Grower mix (SG) consumed more hay than the calves fed MM (Tables 14 and 30). One possible explanation for the lower consumption of hay by the calves fed MM is that the roughage content of MM was relatively high (Table 4) and this partially offset the appetite for hay consumption.

Although individual groups in Trial II differed in performance from those in Trial I (Tables 14 and 30), the weekly live weight changes of each group followed the same pattern as in Trial I (Figures 1 and 2).

TABLE 30. CALF PERFORMANCE, 0 - 12 WEEKS. TRIAL II

					SE
Grain Mix	Starter-Grower		Milk-Maker		
Weeks on MR	3	5	3	5	
Groups	I	II	III	IV	
No. of Animals	9	9	9	9	
Av. Initial Wt (kg)	53.0	52.7	53.6	51.7	2.4
Av. 12 Week Wt (kg)	99.3	102.1	95.4	102.9	6.9
A.D.G. (kg)	0.55	0.59	0.50	0.61	0.07
Total Feed Intake (kg/calf)					
Milk Replacer (powder)	8.1	14.5	8.0	14.5	0.5
Hay	87.6[a]	90.8[a]	55.2[b]	75.9[ab]	13.3
Grain Mix	92.2	85.8	87.9	86.6	4.7
Total Av. Daily DM Intake(kg)	2.08	2.12	1.68	1.96	0.16
Feed Efficiency (DM/Unit gain)	3.81	3.66	3.52	3.24	0.25

a,b Means with different superscripts in the same row differed significantly ($P < .05$).

TABLE 31. LEAST SQUARE ESTIMATES OF TREATMENT DIFFERENCES IN WEIGHT GAIN (KG), HAY INTAKE (KG) AND FEED EFFICIENCY (KG·DM/KG·GAIN); 0 - 12 WEEKS. TRIAL II.

Variable	Treatment Difference	Estimated Values	SE
Weight gain	MR5 - MR3	6.28	3.38
"	SG - MM	1.33	3.38
Hay intake	MR5 - MR3	12.02	7.72
"	SG - MM	23.64**	7.72
Feed efficiency	MR5 - MR3	-0.21	0.14
"	SG - MM	0.36*	0.14

* $P < .05$

** $P < .01$

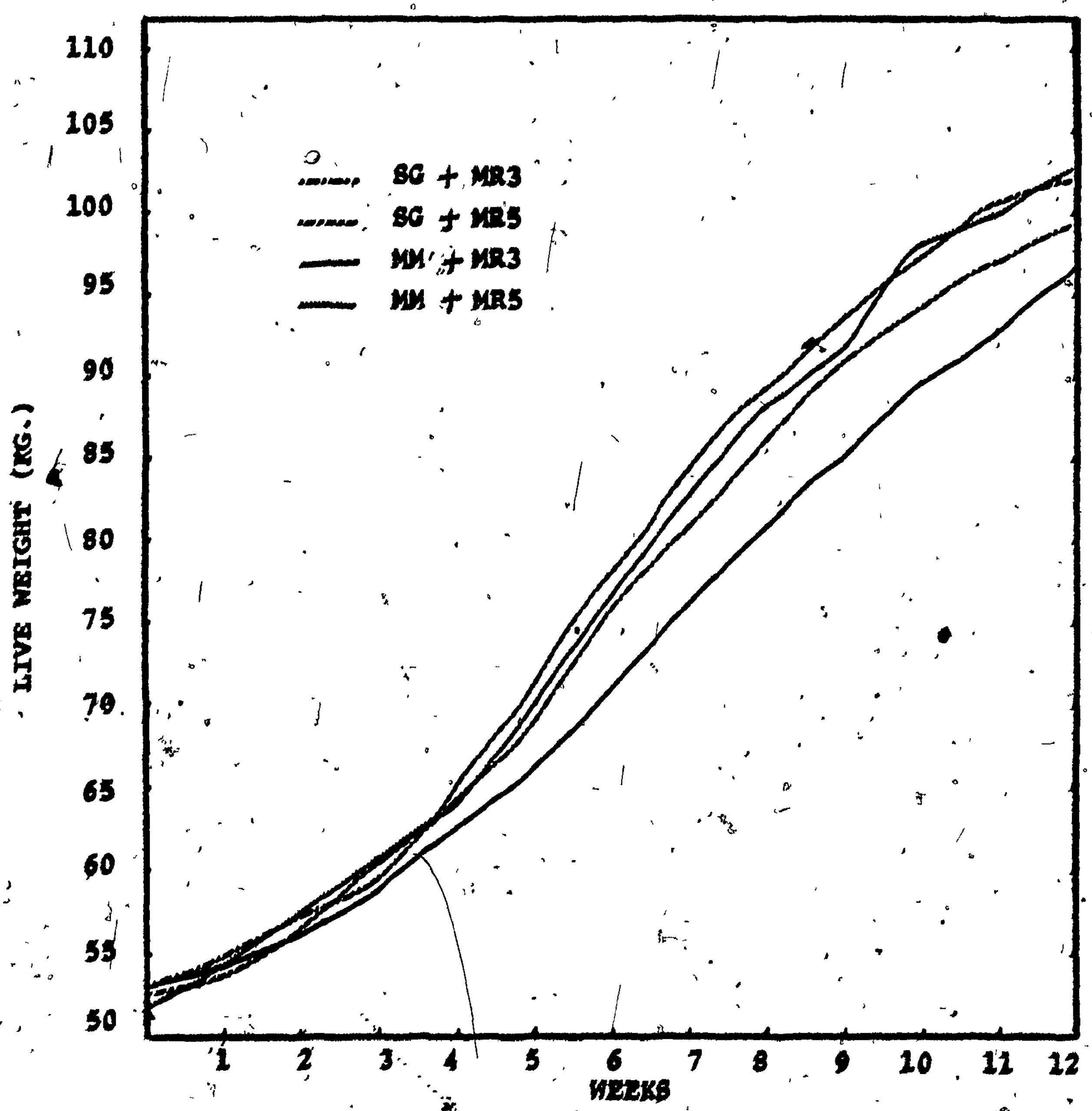

FIGURE 2. EFFECT OF DIET ON CALF WEIGHT GAINS IN TRIAL II.

3. Calf Health

The animals in Trial II had a higher incidence of scours than those in Trial I. Thirty-nine percent of the calves in Trial II scoured, compared to thirty-two percent in Trial I. The frequency of scouring was also higher in Trial II (Table 32) than in Trial I (Table 16). Scouring was apparently caused by digestive disorders, nervousness and bacteria; and was treated by reducing the liquid feed and administering Entefur "A" and Penbritin tablets (Appendix Table I).

Many calves in this trial were generally weak and about a quarter of them were apparently anemic (personal communication with the attending veterinarian). Unlike Trial I, not many suffered from colds; but, like Trial I, a number suffered from throat infections. Penicillin was very effective on some calves which were not eating well, and this indicated that these calves might have been infected with bacteria. Iron tablets were administered to the calves suspected of being anemic and recovery was remarkable. Streptomycin worked effectively on calves which had throat infections. Cortisone was administered to three calves with breathing problems and to two others which were in pain. More antibiotic solutions were used in Trial II (Appendix Table III) than in Trial I.

Two calves had to be operated on. Calf #125 of Group IV had an infected navel which was lanced; the bacterial cells were squeezed out and the opening was repacked with gauze soaked in iodine. Calf #136 of Group I had an infected left front knee which was lanced. One calf (#136) had a slight attack of pneumonia. The symptoms, however, disappeared after treatment with streptomycin. Group IV had the fewest health problems.

There was no mortality in this trial. Although Group IV had less sick calves than the other groups, there was no indication that these calves were healthier because of diet.

TABLE 32. INCIDENCE OF SCOURS AND CURATIVE TABLETS USED. TRIAL II.

Group	No. of Calves	No. of Calves Scoured	Frequency	Tablets Used		
				Fe[1]	Ent "A"[2]	Pen[3]
I	9	4	2.25	8	4	2
II	9	5	1.20	4	1	-
III	9	4	3.25	8	2	1
IV	9	1	4.00	2	3	-

1 Fe = Iron

2 Ent "A" - Entefur "A"

3 Pen = Penbritin

4. Feed Costs

A summary of total feed cost per calf and feed cost per kg gain in Trial II is shown in Table 33. In the first 5 weeks of the trial, Group III had the lowest total feed cost per calf and Group II had the highest. In general, the calves on milk replacer for 5 weeks (MR5) had significantly ($P < .01$) higher feed costs than those on milk replacer for 3 weeks (MR3). Also the calves fed SG mix had significantly ($P < .01$) higher feed costs than those fed MM mix (Table 34). Feed cost per kg of gain was not significant ($P > .05$) in the first 5 weeks of the trial. However, calves fed SG mix had significantly ($P < .01$) higher total feed cost per kg of gain in the 6 to 12 week period and this was reflected in the overall period (Table 34). This was also a reflection of the higher price of SG mix which was about one-third more expensive than MM mix (Table 22).

In the overall period MR5 calves had a higher total feed cost of $2.88 per calf in comparison with MR3 calves (Table 34). Likewise, calves fed SG mix had an increased total feed cost of about $4.61 per calf in comparison with MM fed calves (Table 34).

Group II had the highest total feed cost, while Group III had the lowest (Table 33). Feed costs per kg gain for the groups in the overall period were 47, 48, 40 and 38 cents in Groups I, II, III and IV respectively. It seems

TABLE 33. CALF FEED COST. TRIAL II.

Grain Mix	Starter-Grower		Milk-Maker		SE
Weeks on MR	3	5	3	5	
Group	I	II	III	IV	
Feed Cost ($) 0-5 Weeks					
Total FC[1]/calf	7.96^{BC}	10.01^{A}	6.35^{C}	9.23^{AB}	0.78
FC/kg gain[2]	0.60	0.68	1.03	0.55	0.41
Feed Cost ($), 6-12 Weeks					
Total FC/calf	13.13	13.19	9.35	10.12	0.46
FC/kg gain	0.44^{A}	0.43^{A}	0.33^{B}	0.31^{B}	0.02
Feed Cost ($), 0-12 Weeks					
Total FC/calf	21.01^{AB}	23.20^{A}	15.70^{C}	19.36^{B}	1.18
FC/kg gain	0.47^{ab}	0.48^{a}	0.40^{ab}	0.38^{b}	0.04

1 FC = Feed Cost
2 See page 59 for calculation.
A,B,C Means with different superscripts in the same row differed significantly ($P < .01$).
a,b Means with different superscripts in the same row differed significantly ($P < .05$).

clear then that Group II was (the most expensive feeding regime and Group IV the least expensive.

TABLE 34. LEAST SQUARE ESTIMATES OF TREATMENT DIFFERENCES IN FEED COSTS (¢) AND FEED COST PER UNIT GAIN (¢/KG). TRIAL II.

Period	Treatment Difference	Total Feed Cost	SE	Feed Cost per Unit Gain	SE
Week 0 - 5	MR5 - MR3	246.50**		-19.79	
			44.94		24.07
"	SG - MM	233.22**		1.29	
Week 6 - 12	MR5 - MR3	41.41		- 1.03	
			27.01		1.33
"	SG - MM	342.28**		11.33**	
Week 0 - 12	MR5 - MR3	287.91**		- 0.04	
			68.27		2.27
"	SG - MM	461.37**		8.27**	

** $P < .01$

C. SUMMARY OF TRIAL II

In Trial II there were no significant ($P > .05$) differences in ADG between groups, although Group IV had a slightly higher ADG than any other group (Table 30). Group IV also had the best feed efficiency, second lowest total feed cost and lowest feed cost per kg gain (Tables 30 and 33). Therefore, unlike Trial I, Group IV had the best overall performance.

All four groups had some incidence of scouring and throat infections. But Group IV had less calves scouring than any other group (Table 32), and veterinary expenses were lowest. Groups I and III had the highest veterinary expenses. There was no mortality.

In this trial (Trial II) Group IV may be used as an example to the farmer because of its relatively high overall performance and low feed cost per unit of gain. By using the feeding regime of Group IV, the farmer may expect his calves to have an ADG of 0.5 kg or more at a feed cost of about 38 cents per kg of gain. The total feed cost for raising a 52 kg calf to about 103 kg on the Group IV diet in Trial II was $19.36 (Table 33), which was $3.12 less than Trial I (Table 17).

VI. TRIAL III

A. EXPERIMENTAL PROCEDURE

1. Management

Thirty-four Holstein bull calves were purchased at local auctions or from the Macdonald College farm in June 1974. On arrival the calves were about one week of age and 43.3 kg average body weight. Unlike the calves in Trials I and II, no medications or vitamins were administered.

The calves in this trial were housed in individual raised (about 20 centimeters (cm) above ground) wooden or steel pens. The pens were 1.2 meters (m) x 0.75 m. The front end of each pen had a V-shaped opening, large enough for calves to push their heads through and reach both the water and feeding buckets fitted in slots outside the pen. The rear of the pen was open. The floor was slatted and it extended beyond the length of the pen to facilitate the larger calves.

The pens were cleaned everyday with a scrapper and were washed at least once a week.

There was no light and temperature control as in Trials I and II because the calves were in an open barn.

2. Experimental Design

The experimental design was similar to the previous trials but different grain mixtures (Calf Starter and Calf Grower) were fed this time (Table 35).

TABLE 35. EXPERIMENTAL DESIGN. TRIAL III

Length of Milk Replacer Feeding (wks)[1]	Type of Grain Mixture	
	CS[2]	CG[2]
3	8[3] (I)[4]	8 (III)
5	8 (II)	8 (IV)

1 Weeks on Trial

2 CS : Calf Starter; CG : Calf Grower (Table 36)

3 Number of calves in the group

4 Group number

3. Rations

Calves were fed a commercial milk replacer (MRI) containing 21% crude protein (CP) and 10.0% crude fat (CF) (Table 36) during the first two weeks of the trial. From the third week to weaning, they were fed a second commercial milk replacer (MRII) containing 20% CP and 20% CF (Table 36).

Two groups of 16 calves each were fed either starter mix CS or CG grain mix from the first week on trial. Starter CS was a formula for young calves (1 - 8 weeks of age) and CG grain mix for more matured calves (8 - 16 weeks of age). The composition of these grain mixtures, based on information supplied by the feed manufacturer is listed in Table 37, and the chemical analyses in Table 40 (Results).

Hay composed mainly of Alfalfa and Timothy species (1 : 6 respectively) was chopped to a length of about 3 cm and fed *ad libitum* from the first week of the trial.

Water and salt (Cobalt Iodized Sodium Chloride) were available at all times.

4. Feeding Programme

a) Liquid Feeds

The liquid feeding programme used in Trial III is shown in Table 38. The dry milk replacer was added to water (40°C) and mixed by hand to a smooth consistency. The calves were pail-fed twice daily: in the morning (8:30a.m.) and afternoon (3:30 p.m.).

TABLE 36. GUARANTEED ANALYSES OF MILK REPLACERS[1] AND GRAIN MIXTURES USED IN TRIAL III.

Components	MRI*	MRII**	Calf Starter[2] (CS)	Calf-Grower[3] (CG)
Crude Protein (Min)(%)	21.0	20.0	20.0	15.0
Crude Fat (Min)(%)	10.0	20.0	2.5	2.5
Crude Fibre (Max)(%)	0.5	0.1	9.0	9.0
Fluorine (Max)(%)	-	-	0.0035	0.0035
Sodium Chloride (%)	3.0	2.75	0.7	0.7
Calcium (%)	1.0	1.0	0.5	0.5
Phosphorus (%)	0.75	0.75	0.75	0.80
Vitamin A (Min)(IU/lb)	15,000	15,000	3,800	3,800
Vitamin D (Min)(IU/lb)	5,000	5,000	1,200	1,200
Vitamin E (Min)(IU/lb)	10	-	-	-
Aureomycin (Mg/lb)	25	-	-	-

1 * Supersweet Lactone MR for calves Reg. No. 4767 - Robin Hood Multifoods Ltd., Montreal, Qué.

** Bovo Milk Substitute for Veal Calves Reg. No.5330)

2 20% Calf Starter, Sweetened Ration M-412 Reg. No. 543) Coopérative Féderee de Québec

3 15% Calf Starter Sweetened Ration M-414 Reg. No. 6403) Montreal, Qué.

TABLE 37. INGREDIENT COMPOSITION[1] (%) OF CALF STARTER (CS) AND CALF GROWER (CG).

Ingredient		CS	CG
Barley Screenings		-	7.0
Brewer's Grain		6.25	15.0
Corn		-	39.0
Dehydrated Alfalfa		2.5	2.5
Distiller's Grain		20.0	15.0
Gluten Feeds		14.0	6.25
Middlings (Wheat)	Mill Feeds	2.5	-
Shorts (Wheat)	Mill Feeds	2.5	-
Wheat Bran	Mill Feeds	2.5	-
Wheat Mill Run	Mill Feeds	2.5	-
Oats		24.25	-
Rapeseed Meal		-	2.5
Soybean Meal		9.5	-
Urea		-	0.25
Micro Premix		3.5	2.5
Molasses		10.0	10.0

1 Information supplied by the Feed Manufacturer.

Calves were weaned abruptly after completing the third or the fifth week on trial.

TABLE 38. DAILY AMOUNTS OF MILK REPLACER FED (KG/CALF). TRIAL III.

Period	Dry Milk Replacer	Water Added
Week 1	0.45	1.6
Week 2	0.60	2.3
Week 3 - 5	0.45	2.3

b) Dry Feeds

Chopped hay and grain mixtures were offered within the first week on trial. The feeding programmes for grain mixtures and hay were similar to those of Trials I and II.

5. Weighings

Calf weights were obtained as described in Trial I.

6. Evaluation of Feed Samples

Feed samples were collected and chemically analysed as in Trial I.

7. Statistical Analyses

Data were analysed according to least squares procedures for unequal subclass numbers (Harvey, 1960) as described in Trial I.

8. Feed Cost Analyses

The prices of milk replacer and grain mixtures had increased substantially over those mentioned in Trial II, but there was very little change in hay prices (Tables 22 and 39). It may be noted that the Calf Starter (formula for young calves) is approximately 11% more expensive that the Calf Grower (formula for more mature calves).

TABLE 39. APPROXIMATE FEED COSTS IN TRIAL III.

Feedstuff	$/Metric Ton	¢/Kg
Milk Replacer (powder)	858.00	85.80
Calf Starter	184.80	18.48
Calf Grower	165.00	16.50
Hay	35.50	3.55

B. RESULTS AND DISCUSSION

1. Chemical Composition of Feeds

The chemical analyses of feeds used in this trial (Trial III) are listed in Table 40. The protein content of a composite sample of the milk replacers was 20.9% which was a little less than that of Trial II (Table 23), but more than that of Trial I (Table 7). The CP content of CS (20.1%) was slightly higher than those of SG in Trials I and II, but CG had a CP content of 16.1% which was lower than those of MM in Trials I and II (Tables 7 and 23). The protein content of hay (7.2%) in this trial was much lower than those of Trials I and II (Tables 7 and 23), probably because of its small proportion of alfalfa.

Calcium and phosphorus contents of the feeds in this trial differed slightly from those in Trials I and II (Tables 40, 7 and 23).

TABLE 40. CHEMICAL COMPOSITION OF FEEDS (%). TRIAL III.

Feed	Dry Matter	Protein	Ca	P
		←	As Fed	→
Milk Replacer[1]	92.3	20.9	0.70	0.64
Calf-Starter (CS)	88.6	20.1	0.58	0.80
Calf-Grower (CG)	87.3	16.1	0.53	0.79
Hay	91.4	7.2	0.25	0.19

1 Composite sample of MRI and MRII (Table 36).

2. Animal Performance

a) 0 - 5 Week Period

A summary of calf performance for the first 5 weeks of this trial (Trial III) is shown in Tables 41 and 42. Calves fed milk replacer for 5 weeks (MR5) (Groups II and IV) had higher but not significant ($P > .05$) average daily gain (ADG), consumed less grain mixture (Table 41) and were significantly ($P < .05$) more efficient in feed conversion (Table 42) than calves fed milk replacer for 3 weeks (MR3) (Groups I and III). Calves fed calf-starter grain mix (CS) had slightly better weight gains and were a little more efficient in utilizing feed (Table 42) than calves fed calf grower (CG).

The daily nutrient intakes (dry matter (DM), protein and metabolizable energy (ME)) for all groups were generally below the National Reserach Council (NRC) requirements (Table 43), but MR5 calves were particularly low in total DM intake. The MR5 calves consumed significantly ($P < .05$) less grain mix (Table 41) and also had a low intake of hay, particularly Group II (fed CS). This explains the low total DM intake observed in these groups.

TABLE 41. CALF PERFORMANCE, 0 - 5 WEEKS. TRIAL III.

					SE
Grain Mix	Calf-Starter		Calf-Grower		
Weeks on MR	3	5	3	5	
Groups	I	II	III	IV	
No. of Animals	8	8	8	8	
Av. Initial Wt (kg)	43.5	46.5	45.5	48.6	2.4
Av. 5 Week Wt (kg)	55.7	60.7	54.3	61.5	5.0
A.D.G. (kg)	0.35	0.41	0.25	0.37	0.09
Total Feed Intake (kg/calf)					
Milk Replacer (powder)	9.2	16.1	9.9	15.7	0.8
Hay	6.9	3.9	7.9	6.8	2.6
Grain Mix	17.2[a]	8.4[b]	14.0[ab]	8.9[b]	3.9
Total Av. Daily Intake (kg)	0.85	0.74	0.82	0.82	0.05
Feed Efficiency (DM/unit gain)	2.87[ab]	1.98[b]	4.37[a]	2.39[b]	1.00

a,b Means not sharing a common superscript in the same row are significantly ($P < .05$) different.

SE Approximation of standard error of the mean.

TABLE 42. LEAST SQUARE ESTIMATES OF TREATMENT DIFFERENCES IN WEIGHT GAIN (KG) AND FEED EFFICIENCY (KG·DM/KG·GAIN); 0 - 5 WEEKS. TRIAL III.

Variable	Treatment Difference	Estimated Values	SE
Weight Gain	MR5 - MR3	3.10	1.88
"	CS - CG	2.36	1.88
Feed Efficiency	MR5 - MR3	-1.43*	0.58
"	CS - CG	-0.95	0.58

* P < .05

TABLE 43. DAILY DM, PROTEIN AND ME INTAKES OF CALVES[1] (0 - 5 WEEKS, TRIAL III) EXPRESSED AS A PERCENTAGE OF NRC RECOMMENDATIONS.[1]

Group	Wks on MR	Grain Mix	DM[1]	Protein[1]	ME[1]
I	3	CS	88.9	107.1	70.3
II	5	CS	63.6	87.4	78.1
III	3	CG	88.9	89.2	92.6
IV	5	CG	66.7	82.3	81.8

1 See page 44 for derivation of values used.

b) 6 - 12 Week Period

Calf performance for the 6 to 12 week period in Trial III is summarized in Table 44. Calves which had been fed milk replacer for 5 weeks and were fed CG had the lowest rate of gain (significantly ($P \leq .05$) lower than Groups I and II). They also exhibited the poorest feed conversion (Table 44). Overall, calves fed CS grain mix grew faster although this difference was not significant ($P \geq .05$) (Table 45). Length of feeding milk replacer had no positive effect this time, and even calves fed the liquid diet for only 3 weeks had better growth, although not significant ($P \geq .05$), than calves fed liquid diet for 5 weeks (Table 45).

The nutrient intakes of DM, protein and ME had improved in this period (Table 46). Calves fed milk replacer for 3 weeks had nutrient intakes above the NRC (1971) recommended requirements, whereas those fed milk replacer for 5 weeks were deficient (for some unknown reason). The poor performance of calves on the Group IV diet (Table 44) may be related to their insufficient total protein intake, as indicated in Table 46.

c) Overall Period (0 - 12 Weeks)

Calf performance for the overall period is shown in Tables 47 and 48. There were no significant ($P \geq .05$) differences in ADG among the individual groups (Table 47), although the groups fed CS grain mix grew significantly

TABLE 44. CALF PERFORMANCE, 6 - 12 WEEKS. TRIAL III

					SE
Grain Mix	Calf-Starter		Calf-Grower		
Weeks on MR	3	5	3	5	
Groups	I	II	III	IV	
No. of Animals	7	8	8	8	
Av. 5 Week Wt (kg)	55.5	60.7	54.3	61.5	5.3
Av. Final Wt (kg)	84.0	89.4	79.9	84.5	6.5
A.D.G. (kg)	0.58^{a}	0.59^{a}	0.52^{ab}	0.47^{b}	0.06
Total Feed Intake (kg/calf)					
Hay	41.8	37.5	49.7	53.1	10.5
Grain Mix	66.2	60.9	64.6	62.8	0.4
Total Av. Daily DM Intake (kg)	1.97	1.79	2.09	2.12	0.10
Feed Efficiency (DM/Unit Gain)	3.22^{BC}	3.09^{C}	3.97^{AB}	4.60^{A}	0.38

a,b Means not sharing a common superscript are significantly ($P < .05$) different

A,B,C Means not sharing a common superscript are significantly ($P < .01$) different

TABLE 45. LEAST SQUARE ESTIMATES OF TREATMENT DIFFERENCES IN WEIGHT GAIN (KG) AND FEED EFFICIENCY (KG·DM/KG·GAIN); 6 - 12 WEEKS. TRIAL III

Variable	Treatment Difference	Estimated Values	SE
Weight Gain	MR5 - MR3	-2.23	1.53
"	CS - CG	5.27	1.53
Feed Efficiency	MR5 - MR3	0.26	0.22
"	CS - CG	-1.15**	0.22

** $p < .01$

TABLE 46. DAILY DM, PROTEIN AND ME INTAKES OF CALVES[1] (6 - 12 WEEKS, TRIAL III) EXPRESSED AS A PERCENTAGE OF NRC RECOMMENDATIONS.[1]

Group	Wks on MR	Grain Mix	DM[1]	Protein[1]	ME[1]
I	3	CS	105.3	109.6	106.3
II	5	CS	85.7	87.8	87.0
III	3	CG	123.5	102.5	117.4
IV	5	CG	105.0	86.9	103.8

1 See Table 9, page 44 for derivation of values used.

TABLE 47. CALF PERFORMANCE, 0 - 12 WEEKS. TRIAL III.

					SE
Grain Mix	Calf-Starter		Calf-Grower		
Weeks on MR	3	5	3	5	
Groups	I	II	III	IV	
No. of Animals	7	8	8	8	
Av. Initial Wt (kg)	44.2	46.5	45.5	48.6	2.4
Av. Final Wt (kg)	84.0	89.4	79.9	84.5	6.5
A.D.G. (kg)	0.47	0.51	0.41	0.43	0.06
Total Feed Intake (kg/calf)					
Milk Replacer (powder)	9.1	16.1	9.9	15.7	0.8
Hay	49.0	41.4	57.6	59.9	12.5
Grain Mix	83.3^{a}	69.3^{b}	78.7^{ab}	71.7^{b}	6.0
Total Av. Daily DM Intake(kg)	1.51	1.36	1.56	1.58	0.15
Feed Efficiency (DM/Unit Gain)	3.07^{B}	2.66^{B}	3.83^{A}	3.75^{A}	0.24

A, B Means with different superscripts in the same row are significantly ($P < .01$) different.

a,b Means with different superscripts in the same row are significantly ($P < .05$) different.

($P < .05$) more (Table 48 and Figure 3).

Calves fed CS grain mix had significantly ($P < .01$) better feed efficiency than calves fed CG grain mix (Table 47). This is also indicated in Table 48 which shows that calves fed CS grain mix needed, on the average, 0.93 kg. less feed dry matter per unit of gain.

Finally it is clear from Table 48 that the length of liquid milk replacer feeding was less important than type of grain mix in determining calf growth.

TABLE 48. LEAST SQUARE ESTIMATES OF TREATMENT DIFFERENCES IN WEIGHT GAIN (KG) AND FEED EFFICIENCY (KG.DM/KG.GAIN); 0 - 12 WEEKS. TRIAL III.

Variable	Treatment Difference	Estimated Values	SE
Weight Gain	MR5 - MR3	1.35	2.79
"	CS - CG	7.15**	2.79
Feed Efficiency	MR5 - MR3	-0.24	0.14
"	CS - CG	-0.93**	0.14

** $P < .01$

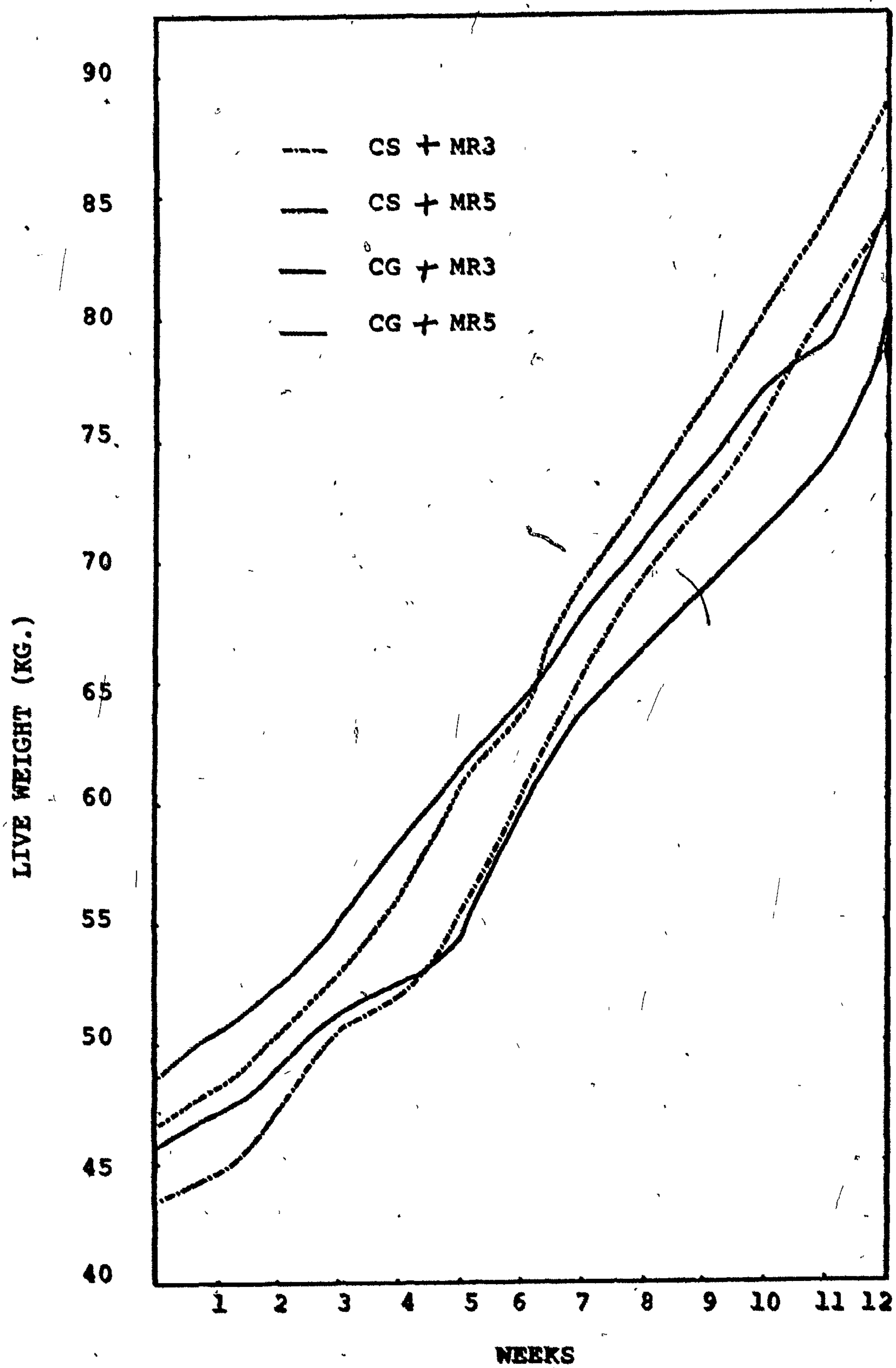

FIGURE 3. EFFECT OF DIET ON CALF WEIGHT GAINS IN TRIAL III.

3. Calf Health

More calves scoured in this trial than in the two previous trials although the frequency was about the same (Table 49). Unlike Trial I and II, no medications were given to the calves which were scouring. Instead, the liquid diet was reduced until the scouring cleared up. This may have set the calves back a little.

Apart from scouring, the main health problems were coughs and running noses. These symptoms disappeared when the animals were treated with penicillin. Unlike the two other trials, penicillin was the only antibiotic used, and it was used in much less quantities (Appendix Table IV).

Mortality was relatively high in this trial. Two calves in poor health were on the trial and they both died from pneumonia within 3 weeks. These calves were replaced and one of the replacement calves died accidentally in the 7th week. The data from the latter calf was used in the 0 - 5 week period only.

TABLE 49. INCIDENCE OF SCOURS DURING TRIAL III.

Group	No. of Calves	No. of Calves Scoured	Frequency[1]
I	8	3	2
II	8	6	1.3
III	8	4	3.0
IV	8	4	3.2

1 Frequency = No. of times one calf scoured.

4. Feed Costs

The cost of milk replacer and grain mixtures was much higher in 1974 than in 1971 and 1972 (Tables 39, 6 and 22). This explains the higher total feed cost per calf in Trial III (Tables 18, 33 and 50). However, the pattern of total feed costs in Trial III is similar to those of Trials I and II during the first five weeks of the trials. In the overall period, the total feed cost pattern was closer to Trial I than Trial II (Tables 18, 33 and 50), but the feed cost per kg. gain was different.

Calves fed milk replacer for 5 weeks (MR5) had significantly ($P < .01$) higher total feed costs than calves fed milk replacer for 3 weeks (MR3) during the first 5 weeks; this was reflected in the overall period of the trial (Table 51) with no significant ($P > .05$) difference in feed cost (FC) per kg. gain. On the other hand, although calves fed CS grain mix had slightly higher total feed costs than those fed CG grain mix during the 6 to 12 week period and the overall period, the feed cost per kg gain was significantly ($P < .01$) better (Table 51).

The calves in Group II had the highest overall total feed cost ($31.02 per calf). This is just 55 cents more than the total feed cost per calf in Group IV which had a lower ADG (Tables 50 and 47). The only other group which compared favorably with Group II in terms of weight gain and

TABLE 50. CALF FEED COST. TRIAL III.

Grain Mix	Starter-Grower		Milk-Maker		SE
Weeks on MR	3	5	3	5	
Group	I	II	III	IV	
Feed Cost ($), 0-5 Weeks					
Total FC[1]/calf	12.40^{B}	16.85^{A}	12.18^{B}	16.55^{A}	0.80
FC/kg gain[2]	1.29	1.35	2.13	1.40	0.63
Feed Cost ($), 6-12 Weeks					
Total FC/calf	15.43	14.17	14.14	13.92	0.80
FC/kg gain	0.52^{b}	0.50^{b}	0.56^{ab}	0.62^{a}	0.05
Feed Cost ($), 0-12 Weeks					
Total FC/calf	27.72^{AB}	31.02^{A}	26.33^{B}	30.47^{A}	1.50
FC/kg gain	0.68^{b}	0.73^{b}	0.80^{ab}	0.87^{a}	0.08

1 FC = Feed Cost
2 See page 59 for calculation.
A,B Means with different superscripts in the same row differed significantly ($P < .01$).
a,b Means with different superscripts in the same row differed significantly ($P < .05$).

feed cost was Group I which had a total feed cost per calf of $27.72. However, as indicated in Table 47, there was no significant (P > .05) difference between Groups I and II in ADG and feed efficiency. Moreover, apart from the fact that Group I had a lower total feed cost (Table 50), it also had a lower feed cost per kg of gain, and for this reason, the feeding regime of Group I is the preferred choice.

TABLE 51. LEAST SQUARE ESTIMATES OF TREATMENT DIFFERENCES IN FEED COST (¢) AND FEED COST PER UNIT GAIN (¢/KG). TRIAL III.

Period	Treatment Difference	Total Feed Cost	SE[1]	Feed Cost per Unit Gain	SE
Week 0 - 5	MR5 - MR3	440.96**		-33.25	
			45.30		36.30
"	CS - CG	25.90		-44.70	
Week 6 - 12	MR5 - MR3	-72.65		2.44	
			45.60		3.00
"	CS - CG	74.76		-8.53**	
Week 0 - 12	MR5 - MR3	378.80**		6.10	
			83.30		4.40
"	CS - CG	95.16		-12.53**	

1 SE Standard error of the mean
** P < .01

C. SUMMARY OF TRIAL III.

In Trial III, as in Trial II, there were no significant ($P > .05$) differences in ADG among groups (Tables 47 and 30). Group II was the only group which achieved the anticipated ADG of 0.5 kilograms. Overall, calves fed CS grain mix (Groups I and II) had significantly ($P < .01$) better feed efficiencies (Table 48) and lower feed cost per unit of gain (Table 51) than calves fed CG grain mix. However, it must be noted that Groups I and II were not significantly ($P > .05$) different in ADG, feed efficiency and feed cost per unit gain (Tables 47 and 50); and that Group I had a total feed cost per calf which was $3.30 less than Group II (Table 50).

There was some incidence of scouring in all four groups. Group I had the least number of calves scouring (Table 49) and, in addition, received the smallest quantity of antibiotics (Appendix Table XV); whereas Group II had the most calves scouring and also received the largest quantity of antibiotics (Table 49 and Appendix Table IV).

Although the Group II calves had a slightly higher ADG than the Group I calves, the latter were healthier and less expensive to feed. Therefore, in this trial (Trial III) Group I may be used as an example to the farmer. By feeding to calves the Group I diet, which included milk replacer for 3 weeks and the more expensive grain mixture (CS), the farmer should expect an ADG of about 0.5 kg at a feed cost of approximately 68 cents per kg of gain.

VII. INTEGRATED SUMMARY AND CONCLUSION

The effect of length of time of feeding milk replacer and different types (varying costs) of grain mixtures on the growth of male Holstein calves raised for beef production was studied in three trials. The grain mixtures used in Trials I and II were Starter-Grower (SG) and "Milk-Maker" (MM) which was 28% cheaper than SG. In Trial III, the grain mixtures used were Calf Starter (CS) and Calf Grower (CG) which was 11% less expensive than CS. Growth and feed efficiency results for the three trials are summarized in Table 52.

In Trials I and II it was found that calves fed milk replacer for 5 weeks (MR5) (Groups II and IV) grew better than calves fed milk replacer for 3 weeks (MR3) (Groups I and III). It was also found that in Trial I MR5 calves fed SG (Group II) had an average daily gain (ADG) significantly ($P < .05$) higher than MR3 calves fed MM (Group III). In Trial III, however, the results indicated that calves fed the more expensive CS grain mix (Groups I and II) had slightly higher ADG than calves fed the cheaper CG grain mix (Groups III and IV).

In Trial I length of milk replacer feeding was more important in feed efficiency than type of grain mix. MR5 calves had significantly ($P < .01$) higher feed efficiencies than MR3 calves (Table 15). However, in Trials II and III

TABLE 52. COMPARISON OF CALF PERFORMANCE IN TRIALS I, II, AND III (0-12 WEEKS)

	Grain Mix	SG[1] or	CS[2]	MM[1] or	CG[2]	SE
	Weeks on MR	3	5	3	5	
	Group	I	II	III	IV	
Trial						
I	ADG (kg)	0.54^{ab}	0.62^{a}	0.45^{b}	0.58^{ab}	0.07
	Feed Efficiency (kg/kg)	3.59^{a}	3.26^{b}	3.65^{a}	3.37^{ab}	0.18
II	ADG (kg)	0.55	0.59	0.50	0.61	0.07
	Feed Efficiency (kg/kg)	3.81	3.66	3.52	3.24	0.25
III	ADG (kg)	0.47	0.51	0.41	0.43	0.06
	Feed Efficiency (kg/kg)	3.07^{B}	2.66^{B}	3.83^{A}	3.75^{A}	0.24

1 Starter Grower (SG) and "Milk Maker" (MM) were used in Trials I and II.
2 Calf Starter (CS) and Calf Grower (CG) were used in Trial III.
a,b Means with different superscripts in the same row differed significantly ($P < .05$).
A,B Means with different superscripts in the same row differed significantly ($P < .01$).

type of grain mix had a greater effect on feed efficiency than length of milk replacer feeding. In Trial II calves fed MM grain mix (Groups III and IV) had slightly better feed efficiencies than those fed SG grain mix (Groups I and II); whereas in Trial III calves fed CS grain mix (Groups I and II) had significantly ($P < .01$) better feed efficiencies than calves fed CG grain mix (Groups III and IV) (Table 52).

During the trials feed prices fluctuated from year to year. Therefore, in order to make some meaningful comparison of feed cost between the trials, the feed prices of one year were chosen and used in all three trials. Table 53 shows the comparisons of total feed cost and feed cost per kg gain for Trials I, II and III, using 1971 feed prices. Overall, the total feed costs of calves were highest in Trial I and lowest in Trial III. The total feed cost in Trial I was definitely influenced by length of milk replacer feeding. Calves fed milk replacer for 5 weeks had higher total feed costs than calves fed milk replacer for 3 weeks. In Trials II and III, however, the type of grain mix was more important in determining total feed cost than length of milk replacer feeding. In Trial II calves fed SG grain mix had higher total feed costs than calves fed MM grain mix, and in Trial III calves fed CS grain mix had higher total feed costs than calves fed CG grain mix.

The feed cost per kg of gain (FC/kg gain) in all three trials ranged from 38 to 51 cents (Table 53). In Trial I

TABLE 53. COMPARISONS OF TOTAL FEED COST ($) AND FEED COST ($) PER KILOGRAM GAIN (FC/KG GAIN) IN TRIALS I, II AND III USING 1971 FEED PRICES

	Grain Mix	SG[1] or CS[2]		MM[1] or CG[2]	
	Weeks on MR	3	5	3	5
	Group	I	II	III	IV
Trial	Feed Cost				
I	Total	21.04	26.20	16.49	22.47
	FC/kg gain	0.48	0.51	0.44	0.48
II	Total	20.91	23.56	15.69	19.59
	FC/kg gain	0.46	0.49	0.38	0.39
III[2]	Total	18.37	19.75	15.55	17.99
	FC/kg gain	0.45	0.47	0.46	0.51

1 Starter-Grower (SG) and "Milk Maker" (MM) were used in Trials I and II.
2 Calf Starter (CS) and Calf Grower (CG) were used in Trial III.

Group II had the highest FC/kg gain (51 cents) and Group III the lowest (44 cents). In Trials II and III FC/kg gain was apparently influenced by either the type of grain mix or length of milk replacer feeding. Calves fed MM grain mix in Trial II had a lower FC/kg gain than calves fed SG grain mix, while in Trial III calves fed milk replacer for 5 weeks had a slightly higher FC/kg gain than calves fed milk replacer for 3 weeks (Table 53).

The groups which showed the best overall growth and economic performance were: Groups I and IV of Trial I; Group IV of Trial II; and Group I of Trial III. Because Group IV of Trial II had the highest ADG (o.61 kg) and the lowest FC/kg gain (39 cents), it was considered the best group of all three trials.

In conclusion, it seems possible that dairy beef calves could be successfully raised under conditions similar to those of Group IV in Trial II; that is, a longer time of feeding milk replacer and a cheaper grain mix (MM). The diet for this group included: (1) milk replacer (about 0.45 kg dry powder per day) for 5 weeks; (2) limited (up to 1.4 kg per day) quantities of a cheap grain mix (MM); (3) good quality hay *ad libitum*; and (4) water free choice. If feed price differentials dictate a shorter milk replacer period, results from Trial III indicate that a more expensive type of grain mixture should be used.

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APPENDIX TABLE I. ANTIBIOTICS USED

FLUMETHAZONE

6 , 9 - Difluoro - 11 ,
17 , 21 trihydroxy - 16 - methylpregna - 1 ,
4 - diene-3, 2-dione

SULFAMETHAZINE

N^1 - (4,6-dimethyl-2-pyrimidimyl) sulfanilamide

CHLORAMPHENICOL

D(-)-threo-2,2-Dichloro-N- -hydroxy- -
(hydroxymethyl)-p-nitrophenethyl acetamide

PENICILLIN G

Benezylpenicillin potassium

ENTEFUR "A" TABLET

Nifuraldezone Vitamin A bismuth subsalicylate

"DIAMYCIN" TABLET

Each tablet contains:

Streptomycin Sulfate (as base)	100 mg
Sulfamethazine	500 mg
Sulfamerazine	500 mg
Sulfathiazole	1,000 mg
Potassium Chloride	500 mg
Vitamin A	10,000 I.U.
Vitamin D	1,000 I.U.
Vitamin K	10 mg

"PENBRITIN" TABLET

Each tablet contains:

Ampicillin	100 mg

APPENDIX TABLE II. ANTIBIOTIC SOLUTIONS USED IN TRIAL I.

Period	Group	No. of Calves	Antibiotic Solutions (cc)			
			Penicillin	Chloram[1]	Sulfamet[2]	Flumethazone
Week 0-5	I	8	58	32	25	-
	II	7	48	-	-	-
	III	8	58	18	125	1
	IV	8	60	-	-	-
Week 6-12	I	8	14	-	-	-
	II	7	-	-	-	-
	III	8	2	-	100	-
	IV	8	-	-	-	-
Week 0-12	I	8	72	32	25	-
	II	7	48	-	-	-
	III	8	60	18	225	1
	IV	8	60	-	-	-

1 Chloramphenicol
2 Sulfamethazone

APPENDIX TABLE III. ANTIBIOTIC SOLUTIONS USED IN TRIAL II.

Group	No. of Calves	Antibiotic Solutions (cc)		
		Penicillin	Streptomycin	Cortisone
I	9	200	7	1
II	9	205	15	1
III	9	220	5	2
IV	9	168	5	1

APPENDIX TABLE IV. ANTIBIOTICS USED IN TRIAL III.

Period	Group	No. of Calves	Penicillin (cc)
Week 0 - 5	I	8	5
	II	8	35
	III	8	45
	IV	8	25
Week 6 - 12	I	7	5
	II	8	35
	III	8	10
	IV	8	10
Week 0 - 12	I	7	10
	II	8	70
	III	8	55
	IV	8	35

APPENDIX TABLE V. CALF FEED COST, TRIAL I: 0 - 5 WEEKS

Calf	Group	Wt. Gain (kg)	Total Feed Cost $	Feed Cost Per Kg. Gain $
1	I	19.09	9.05	0.47
2		28.18	9.72	0.34
3		2.73	7.39	2.71
4		17.27	9.12	0.53
5		17.73	9.28	0.52
6		16.82	9.62	0.57
7		23.18	10.96	0.47
8		3.18	6.83	2.15
			$\bar{x}$	0.97
1	II	11.82	12.65	1.07
2		25.00	14.41	0.58
3		19.09	14.39	0.75
4		21.82	15.36	0.70
5		10.00	12.92	1.29
6		17.73	14.12	0.80
7		19.09	14.33	0.75
			$\bar{x}$	0.85
1	III	8.64	6.90	0.80
2		6.36	7.73	1.21
3		17.73	8.31	0.46
4		5.91	6.73	1.14
5		16.36	9.44	0.57
6		15.00	9.13	0.61
7		9.55	8.25	0.86
8		19.09	8.51	0.44
			$\bar{x}$	0.76
1	IV	21.36	13.67	0.64
2		12.73	12.60	0.99
3		9.55	11.83	1.24
4		15.46	12.61	0.82
5		16.36	13.70	0.84
6		21.82	14.96	0.69
7		9.09	12.67	1.39
8		15.91	14.07	0.88
			$\bar{x}$	0.94

APPENDIX TABLE VI. CALF FEED COST, TRIAL I: 6 – 12 WEEKS

Calf	Group	Wt. Gain (kg)	Total Feed Cost $	Feed Cost Per Kg. Gain $
1	I	25.91	11.68	0.45
2		36.36	13.73	0.38
3		30.91	10.99	0.36
4		20.91	10.85	0.52
5		30.46	12.57	0.41
6		26.36	11.77	0.45
7		38.64	14.06	0.36
8		25.00	10.72	0.43
			$\bar{x}$	0.42
1	II	28.18	10.58	0.38
2		33.64	13.72	0.41
3		33.64	12.01	0.36
4		33.64	11.90	0.35
5		41.36	12.97	0.31
6		31.36	11.53	0.37
7		39.09	12.53	0.32
			$\bar{x}$	0.36
1	III	22.73	8.10	0.36
2		29.09	8.13	0.28
3		29.55	8.71	0.29
4		18.18	6.88	0.38
5		28.18	9.27	0.33
6		29.55	9.40	0.32
7		24.55	7.83	0.32
8		25.46	8.62	0.34
			$\bar{x}$	0.33
1	IV	28.18	9.07	0.32
2		33.64	9.46	0.28
3		20.00	7.15	0.36
4		35.00	8.94	0.25
5		35.91	9.16	0.25
6		37.73	11.34	0.30
7		33.64	8.51	0.25
8		40.91	10.06	0.25
			$\bar{x}$	0.28

APPENDIX TABLE VII. CALF FEED COST, TRIAL I: 0 - 12 WEEKS

Calf	Group	Wt. Gain (kg)	Total Feed Cost $	Feed Cost Per Kg Gain $
1	I	45.00	20.73	0.46
2		64.54	23.45	0.36
3		33.64	18.38	0.55
4		38.18	19.97	0.52
5		48.19	21.85	0.45
6		43.18	21.38	0.49
7		61.82	25.02	0.40
8		28.18	17.54	0.62
				$\bar{x}$ 0.48
1	II	40.00	23.33	0.58
2		58.64	28.13	0.48
3		52.73	26.39	0.50
4		55.46	27.26	0.49
5		51.36	25.89	0.59
6		49.09	25.64	0.52
7		58.18	26.86	0.46
				$\bar{x}$ 0.51
1	III	31.37	15.00	0.48
2		35.45	15.86	0.45
3		47.28	17.02	0.36
4		24.09	13.60	0.56
5		44.54	18.71	0.42
6		44.55	18.53	0.42
7		34.10	16.08	0.47
8		44.55	17.13	0.38
				$\bar{x}$ 0.44
1	IV	49.54	22.74	0.46
2		46.37	22.06	0.48
3		29.55	18.98	0.64
4		50.46	21.55	0.43
5		52.27	22.86	0.44
6		59.55	26.29	0.44
7		42.73	21.17	0.50
8		56.82	24.13	0.42
				$\bar{x}$ 0.48

APPENDIX TABLE VIII. CALF FEED COST, TRIAL II: 0 - 5 WEEKS

Calf	Group	Wt. Gain (kg)	Total Feed Cost $	Feed Cost Per Kg Gain $
1	I	9.55	7.09	0.74
2		14.09	9.75	0.69
3		20.23	8.67	0.43
4		17.73	8.94	0.50
5		20.00	8.29	0.41
6		29.32	9.83	0.34
7		18.41	7.53	0.41
8		4.32	5.45	1.26
9		10.46	6.08	0.58
				$\bar{x}$ 0.60
1	II	10.91	8.72	0.80
2		4.37	7.84	1.79
3		20.23	10.75	0.53
4		16.14	9.26	0.57
5		16.36	9.52	0.58
6		28.18	12.12	0.43
7		17.73	8.95	0.50
8		23.64	11.21	0.47
9		28.18	11.69	0.41
				$\bar{x}$ 0.68
1	III	13.41	7.40	0.55
2		18.41	6.91	0.37
3		17.50	7.04	0.40
4		18.18	6.32	0.35
5		0.00	4.37	4.37
6		15.91	6.73	0.42
7		11.36	6.65	0.58
8		3.18	5.69	1.79
9		14.32	6.05	0.42
				$\bar{x}$ 1.03
1	IV	12.05	8.55	0.71
2		15.68	9.36	0.60
3		29.55	16.81	0.37
4		8.64	6.61	0.77
5		11.82	7.90	0.67
6		17.73	9.19	0.52
7		26.82	10.37	0.39
8		17.27	9.56	0.55
9		26.82	16.73	0.40
				$\bar{x}$ 0.55

APPENDIX TABLE IX. CALF FEED COST, TRIAL II: 6 - 12 WEEKS

Calf	Group	Wt. Gain (kg)	Total Feed Cost $	Feed Cost Per Kg Gain $
1	I	27.27	11.94	0.44
2		32.27	13.35	0.41
3		30.91	13.63	0.44
4		35.91	13.81	0.38
5		26.82	12.64	0.47
6		35.91	14.54	0.40
7		28.18	13.80	0.49
8		25.46	11.47	0.45
9		29.55	13.01	0.44
				x̄ 0.44
1	II	30.00	12.96	0.43
2		28.64	12.10	0.42
3		26.82	12.90	0.48
4		25.91	12.99	0.50
5		32.27	12.36	0.38
6		34.09	14.46	0.42
7		34.55	12.99	0.38
8		32.27	14.38	0.45
9		34.55	13.54	0.39
				x̄ 0.43
1	III	33.64	9.37	0.28
2		30.46	9.87	0.32
3		37.27	9.91	0.27
4		31.82	9.90	0.31
5		25.00	8.46	0.34
6		28.18	9.31	0.33
7		30.91	9.19	0.30
8		19.55	8.25	0.42
9		27.27	9.89	0.36
				x̄ 0.33
1	IV	34.55	9.76	0.28
2		41.36	9.99	0.24
3		30.91	11.11	0.36
4		31.82	9.24	0.29
5		27.73	9.50	0.34
6		30.00	9.90	0.33
7		35.46	11.17	0.32
8		26.82	9.54	0.36
9		35.91	10.91	0.30
				x̄ 0.31

APPENDIX TABLE X. CALF FEED COST, TRIAL II: 0 - 12 WEEKS

Calf	Group	Wt. Gain (kg)	Total Feed Cost $	Feed Cost Per Kg Gain $
1	I	26.82	19.02	0.52
2		46.36	23.10	0.50
3		51.14	22.30	0.44
4		53.64	22.75	0.42
5		46.82	20.93	0.45
6		65.23	24.37	0.37
7		46.59	21.34	0.46
8		29.78	16.91	0.57
9		40.01	19.09	0.48
				$\bar{x}$ 0.47
1	II	40.91	21.68	0.53
2		33.01	19.94	0.60
3		47.05	23.65	0.50
4		42.05	22.26	0.52
5		48.63	21.88	0.45
6		62.27	26.59	0.43
7		52.28	21.94	0.42
8		55.91	25.59	0.46
9		62.73	25.23	0.40
				$\bar{x}$ 0.48
1	III	47.05	16.77	0.36
2		48.87	16.79	0.34
3		54.77	16.94	0.31
4		50.00	16.22	0.32
5		25.00	12.83	0.51
6		44.09	16.04	0.36
7		42.27	15.84	0.37
8		22.73	13.94	0.61
9		41.59	15.94	0.38
				$\bar{x}$ 0.40
1	IV	46.60	18.31	0.39
2		57.04	19.36	0.34
3		60.46	21.92	0.36
4		40.46	15.85	0.39
5		39.55	17.40	0.44
6		47.73	19.09	0.40
7		62.28	21.54	0.35
8		44.09	19.09	0.43
9		62.73	21.64	0.34
				$\bar{x}$ 0.38

APPENDIX TABLE XI. CALF FEEDING COST, TRIAL III: 0 - 5 WEEKS

Calf	Group	Wt. Gain (kg)	Total Feed Cost $	Feed Cost Per Kg Gain $
1	I	8.64	12.93	1.50
2		13.18	13.05	0.99
3		5.91	11.88	2.01
4		16.82	14.22	0.85
5		16.82	11.05	0.66
6		13.18	11.76	0.89
7		4.09	11.06	2.70
8		18.64	13.22	0.70
				x̄ 1.29
1	II	21.36	18.69	0.88
2		6.36	15.84	2.49
3		19.55	18.5[illegible]	0.95
4		11.36	15.41	1.36
5		15.00	16.53	1.10
6		9.09	15.99	1.76
7		13.18	16.64	1.26
8		17.73	17.21	0.97
				x̄ 1.35
1	III	7.27	11.67	1.65
2		5.45	11.70	2.15
3		1.82	11.59	6.37
4		10.91	13.88	1.27
5		9.09	11.59	1.28
6		7.27	10.44	1.44
7		5.00	11.15	2.23
8		23.18	15.45	0.67
				x̄ 2.13
1	IV	6.36	14.22	2.24
2		9.09	15.74	1.73
3		11.82	16.79	1.42
4		13.64	17.02	1.25
5		15.91	16.63	1.05
6		20.00	18.14	0.91
7		15.45	17.35	1.12
8		10.91	16.49	1.51
				x̄ 1.40

APPENDIX TABLE XII. CALF FEED COST, TRIAL III: 6 - 12 WEEKS

Calf	Group	Wt. Gain (kg)	Total Feed Cost $	Feed Cost Per Kg Gain $
1	I	26.14	14.57	0.56
2		42.05	15.60	0.37
3		25.91	14.48	0.56
4		31.36	16.53	0.53
5		29.32	16.43	0.56
6		27.27	15.39	0.56
7		31.14	15.03	0.48
				$\bar{x}$ 0.52
1	II	24.32	15.81	0.65
2		27.50	13.79	0.50
3		34.55	16.01	0.46
4		25.91	11.29	0.44
5		30.91	15.04	0.49
6		25.00	11.89	0.48
7		29.55	13.44	0.45
8		31.82	16.05	0.50
				$\bar{x}$ 0.50
1	III	26.36	13.78	0.52
2		25.00	13.85	0.55
3		21.82	12.39	0.57
4		26.14	14.66	0.56
5		27.73	14.66	0.53
6		29.09	14.36	0.49
7		19.09	13.09	0.69
8		30.00	16.36	0.55
				$\bar{x}$ 0.56
1	IV	23.64	12.85	0.54
2		15.00	12.94	0.86
3		27.73	14.79	0.53
4		20.23	13.46	0.67
5		22.27	13.84	0.62
6		22.73	14.92	0.66
7		23.18	14.48	0.62
8		29.09	14.10	0.48
				$\bar{x}$ 0.62

APPENDIX TABLE XIII. CALF FEED COST, TRIAL III: 0 - 12 WEEKS

Calf	Group	Wt. Gain (kg)	Total Feed Cost $	Feed Cost Per Kg Gain $
1	I	34.78	27.50	0.79
2		55.23	28.65	0.52
3		31.82	26.36	0.83
4		48.18	30.76	0.64
5		46.14	27.48	0.60
6		40.45	27.15	0.67
7		35.23	26.09	0.74
				$\bar{x}$ 0.68
1	II	45.68	34.50	0.75
2		33.86	29.63	0.87
3		54.10	34.51	0.64
4		37.27	26.70	0.72
5		45.91	31.57	0.69
6		34.09	27.88	0.82
7		42.73	30.08	0.70
8		49.55	33.26	0.67
				$\bar{x}$ 0.73
1	III	33.63	25.44	0.76
2		30.45	25.56	0.84
3		23.64	23.98	1.01
4		37.05	28.54	0.77
5		36.82	26.25	0.71
6		36.36	24.80	0.68
7		24.09	24.25	1.01
8		53.18	31.81	0.60
				$\bar{x}$ 0.80
1	IV	30.00	27.07	0.90
2		24.09	28.68	1.19
3		39.55	31.58	0.80
4		33.87	30.48	0.90
5		38.18	30.47	0.80
6		42.73	33.06	0.77
7		38.63	31.83	0.82
8		40.00	30.59	0.76
				$\bar{x}$ 0.87