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FAO ANIMAL PRODUCTION AND HEALTH

manual

REARING YOUNG RUMINANTS ON MILK REPLACERS AND STARTER FEEDS

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REARING YOUNG RUMINANTS ON MILK REPLACERS AND STARTER FEEDS

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
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Preface

This manual presents comprehensive information on the preparation and feeding of milk replacers and starter feeds for young ruminants before activation of rumination (pre-ruminants). It keeps in view the situation prevailing in developing countries and the demand for ruminant milk for human consumption. Although the substitutes for dam's milk can be prepared from by-products of milk and feed ingredients that are not preferred for human consumption, awareness about such alternatives is limited in many developing countries. Therefore, popularisation of preparation and feeding of milk replacers and starter feeds using locally available ingredients is useful in promoting survivability and growth of young stock. The target audiences for this manual are livestock extension workers engaged in developing countries. The manual is also useful for students and teachers of ruminant production and for small scale industries and researchers that wish to produce milk replacers and starter feeds.

The manual is presented in five sections covering (1) importance of pre-ruminant rearing, (2) characteristics of pre-ruminant digestive systems, (3) nutritional needs of pre-ruminants, (4) sources of nutrients, and (5) formulation and feeding of milk replacers and starter feeds. One special feature of this manual is that it is restricted to information related to milk replacers and starter feeds but widened to cover all major domestic ruminant species whose milk is used as a human food. This manual then serves as a reference when dealing with pre-ruminants in mixed farming, where more than one species of ruminants are reared.

To reduce the size of the manual, too much detail has been avoided. However, to compare the use of milk replacers and starter feeds in ruminant species in developing compared with developed countries, it was inevitable to list several references in two of the sections. In all other sections, bibliographic references have been kept to a minimum. The manual presents the general principles and some examples that are relevant to developing countries, but does not deal with all variations across different regions.

We hope that this manual will be of use for the pre-ruminant rearing in developing countries and will stimulate research and development work for the preparation and feeding of milk replacers and starter feeds.

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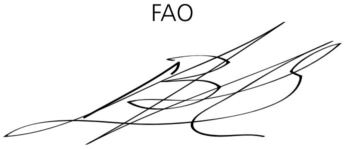

Introduction

Livestock production in developing countries needs greater attention because of its role in food production, livelihood support, and environmental change. One of the major constraints the livestock sector is faced with in developing countries is the scarcity of feed resources resulting in low productivity and poor growth and reproduction of animals. Demand for livestock products has been steadily increasing as shown in Table 1.1. on trends in consumption and on projected future demand for livestock products.

In developing countries, per capita consumption of meat has doubled since 1980 from 14 kg to 29 kg/person/year in 2002 and total meat supply has tripled from 47 million tonnes to 139 million tonnes. Most of the expansion in supply comes from increased production, and only a relatively small part from imports (Steinfeld *et al.*, 2006). A combination of high population growth and growing per person incomes in many developing countries has led to a dramatic increase in demand for livestock products, and this trend is expected to continue for another 20 years (Delgado *et al.*, 1999).

While intensive livestock production is booming in large emerging countries, there are still vast areas where extensive livestock production and its associated livelihoods persist. Extensive systems of production, specially the ruminants, are largely supported by grazed pasture, and degradation of grassland and pasture have become widespread issues generally related to a mismatch between livestock density and the capacity of the pasture to be grazed and trampled. For example, about half of the 9 million ha of pasture in Central America is estimated to be degraded (Szott, Ibrahim and Beer, 2000, cited by Steinfeld *et al.*, 2006)

TABLE 1.1
Past and projected trends in consumption of meat and milk in developing and developed countries

	Developing countries					Developed countries				
	1980	*1990*	*2002*	*2015*	*2030*	*1980*	*1990*	*2002*	*2015*	*2030*
Annual per capita meat consumption (kg)	14	18	29	32	37	73	80	78	83	89
Annual per capita milk consumption (kg)	34	38	46	55	66	195	200	202	203	209
Total meat consumption (million tonnes)	47	73	139	184	252	86	100	102	112	121
Total milk consumption (million tonnes)	114	152	222	323	452	228	251	265	273	284

Source: Steinfeld *et al.* (2006).

while Jansen *et al.* (1997, cited by Steinfeld *et al.*, 2006) estimate that over 70 percent of the pastures in the north Atlantic zone of Costa Rica are in an advanced stage of degradation due to overgrazing and poor management.

The livestock producers in many of these countries are resource-poor landless labourers and marginal farmers who own ruminants and depend on common grassland for feed resources. For example, in India, over 90 percent of the small ruminant population are owned by landless and marginal farmers. One way of minimising grassland degradation is to reduce animal density. Therefore, strategies and policies to encourage livestock farmers to transform extensive system of production to semi-intensive systems (with additional importred feed inputs) would reduce grazing pressure and facilitate rejuvenation of grassland. Further, the growth rate of animals in sole pasture-based production system is inferior if their diets are not adequately supplemented with required nutrients.

Although the extensive system of livestock production is generally more economical than the stall-fed system, there is considerable loss of young ones due to stress, diseases, unfavourable weather and predator attack. In India, for example, lamb mortality of 20 to 30 percent was reported under extensive system of sheep rearing (cited by Karim and Sankhyan, 2009; Parthasarathy, 1991). High mortality, inadequate milk production by the nursing mothers, also affects the growth rate of those who survive. The low productivity in ruminants in developing countries is characterised by high mortality, poor growth rate of young ones, delay in onset of puberty, and long interval between successive parturition all of which are largely attributable to poor feed resources, feeding and management. Further, rearing of young ones is not given much attention. This is largely due to economic compulsion to sell

PHOTO 1.1
a. Rearing of adult sheep flock under extensive system

b. Weaned lambs under stall feeding

milk for human consumption (Ranjhan, 1992) and perhaps not realising the potential value of these animals in their adulthood. Since the young ones are the future meat and milk producing stock, it is vital to minimise mortality and improve growth rate. Under extensive production system, weaning of young ones can shorten their lactation (Photo 1.1).

This would not only improve nutritional status of the dam, but also the reproduction efficiency by early onset of post-parturient heat. Therefore, one of the strategies to improve productivity of ruminant livestock could be to promote early weaning of young ones. However, weaning of young ones necessitates additional care in feeding and management. The pre-ruminant young ones depend solely on milk for their nutritional needs during initial stages of life and gradually adapt to solid food as the rumen becomes functional. Depending on the age at weaning, pre-ruminants need to be nourished with food that can substitute for dam's milk. The alternative to milk, commonly known as milk replacer (liquid food) and starter feeds (solid food), can be prepared respectively, from by-products of milk and feed ingredients that are not preferred for human consumption. The preparation and use of milk replacers and starter feeds are generally accepted practices in developed countries but not in many of the developing countries. Therefore, promoting preparation and feeding of milk replacers and starter feeds using locally available ingredients can be useful in improving the survivability and growth of young ones while diverting milk for human consumption. In order to achieve this objective, this manual has been prepared. The main target audiences for this manual are the extension workers engaged in livestock development activities who have some background knowledge of ruminant production systems. The manual is also useful for teachers and students of animal production, and for the small scale industries and the researchers who wish to produce milk replacers and starter feeds using locally available feed resources. Since feeding of milk replacer and starter feed to pre-ruminants is not a practice in many of the developing countries, there is a greater need to emphasise the importance of milk replacer and starter feeding at the diploma and undergraduate teaching. Therefore, the topics of milk replacer and starter feed formulation and feeding have to be broadened to provide an understanding of the basic aspects of digestive physiology of the pre-ruminants, the role of different nutrients and the status of research and development on milk replacer and starter feed in the developing countries. The manual is presented in five sections covering, importance of pre-ruminant rearing, characteristic features of pre-ruminant digestive system, nutritional needs of pre-ruminants, sources of nutrients, formulation and feeding of milk replacers and starter feeds. It covers comprehensive information on the role of pre-ruminant rearing in strengthening food security in developing countries, constraints in meeting nutritional needs of pre-ruminants and alternatives to feeding of milk.

The published literature is the major source of basic information for this manual. However, this information has to be translated into adoptable recommendations by taking into consideration the wide range of feed resource availability. Based on the available information and keeping in view the constraints of milk by-products and feed resource availability in developing countries, suggested formulations and feeding guidelines have been provided. Although the socio-economic conditions of the regions may impose constraints on the adoption of some of the suggested interventions in formulation and feeding of milk replacer and starter feeds, the information provided will serve as guidelines to motivate a search for alternatives to feeding of milk and to improve nutritional status of pre-ruminants.

It is hoped that the manual would serve as a hand guide to the field level extension workers for the preparation and feeding of milk replacer and starter feed on-farm by making use of locally available feed resources; and help promote milk replacers and starter feeds among the farmers.

This manual has covered two of the key inputs of successful pre-ruminant rearing, these being the formulation and feeding of milk replacers and starter feeds. Rearing pre-ruminant requires close attention to many more management inputs such as:

- Providing the quality roughage necessary for rumen development;
- Understanding the health and welfare needs of infant pre-ruminants;
- Housing and minimising climatic stress;
- Implementing a successful animal health programme, particularly to ensure transfer of passive immunity against common diseases and to control scours;
- Successful weaning process; and
- Post-weaning feed and herd management.

These usually depend on the knowledge and the skills of the farmer. So this manual is but one part of the jigsaw of a successful pre-ruminant rearing enterprise.

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Digestive system of pre-ruminants

The ruminants are the animals that are capable of ruminating or chewing the cud. The distinct feature of digestive system of an adult ruminant is that the stomach is divided into three or four compartments namely, rumen, reticulum, omasum and abomasum. Those species of ruminants which possess four compartments are termed true ruminants, which include cattle, buffalo, sheep, goat, deer and antelope. Those which possess three-compartmented stomach with omasum being absent are called pseudo-ruminants, which include camel and llama (Van Soest, 1994). The forestomach compartments (rumen, reticulum, omasum) are non-glandular and the abomasum is glandular and hence considered as the true stomach.

The digestive system of infant ruminants at birth differs from that of adult ruminants in anatomical structure and physiological functions. As the age advances, adaptations occur in response to the environment and acquire characteristic features of an adult ruminant. At birth, the infant ruminant is more like a monogastric animal in its digestive functions. Because of these differences, the diet of adult ruminants is not compatible with the digestive system of pre-ruminants. Therefore feeding management of pre-ruminants needs special attention with reference to the type of food to be given and the way they are fed.

DEVELOPMENT OF THE FORESTOMACH

At birth the rumen is undeveloped and constitutes a small proportion of the total stomach (Table 2.1). The tissue percentage of the reticulo-rumen increases from 10–38 percent at birth to 64–80 of the total stomach in the adult. Rumen development depends on access to fibrous diet and inoculation by rumen bacteria. The development of rumen wall and the papillae depends on stimulation by volatile fatty acids.

- The rumen in adult ruminant is the largest compartment and is lined with finger-like projections called papillae. These papillae, varying in size up to 1.5 cm in length, are larger and denser in the ventral regions where nutrient absorption is most pronounced.
- The reticulum is smaller in size and partially separated from the rumen only by the reticulo-ruminal fold. Therefore the rumen and reticulum are often considered as a single compartment. Unlike the rumen, the surface of the reticulum is thrown into numerous folds of hexagonal shape resembling a honeycomb.
- The omasum lies to the right of the reticulo-rumen and connects with the reticulum via the reticulo-omasal orifice at the bottom of the oesophageal groove. The inner surface of omasum has numerous flat parallel folds of tissue, because of which omasum is also known as manyplies. Along the lesser curvature of the omasum, is an extension of the oesophageal groove from the reticulo-omasal orifice to the opening into the abomasum, known as the omasal groove.

TABLE 2.1
Proportion (as percent) of total tissue weight or volume contributed by different compartments of pre-ruminant stomach as influenced by age

	Age in weeks						
Cattle*, 1	**0**	**4**	**8**	**12**	**16**	**20–26**	**34–48**
Reticulo-rumen	38	52	60	64	67	64	64
Omasum	13	12	13	14	18	22	25
Abomasum	49	36	27	22	15	14	11
Buffalo, 2**							
Reticulo-rumen	69	88	93			95	
Omasum	2	2	1			4	
Abomasum	29	10	6			1	
Sheep*, 3							
Reticulo-rumen	8–10					70–80	
Omasum	15–20					15–20	
Abomasum	70–80					8–10	

* By weight, ** by volume

Sources:
[1] Warner and Flat (1965).
[2] Sengar and Singh (1970), cited by Ranjhan (1992).
[3] Brandano, Rassu and Lanza (2005).

- The abomasum is the true stomach, lying on the right side of the rumen and connecting omasum with the small intestine. In pre-ruminant young ones it receives milk directly from the oesophagus via the oesophageal groove which functions as a bypass of the rumen-reticulum and omasum. The abomasums corresponds to the pyloric portion of stomach of nonruminant animals being capable of producing mucus, pepsin and hydrochloric acid.

Oesophageal groove

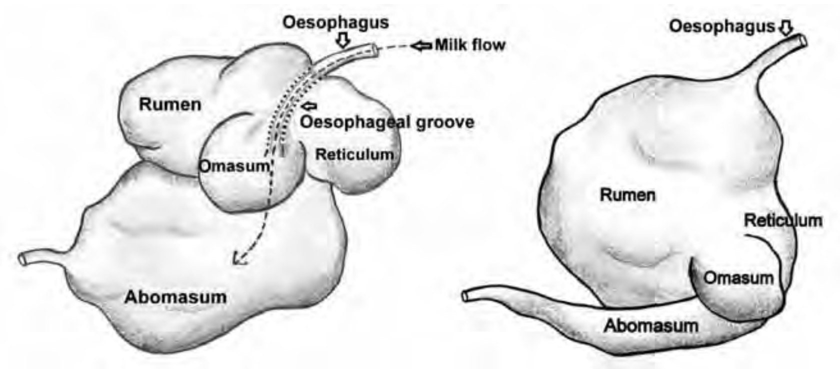
The oesophageal groove is a muscular fold extending downwards from the opening of oesophagus (cardia) to the omasum on the wall of the reticulum. The act of suckling induces reflex closure of oesophageal groove into a tubular structure, directing milk to pass through this tube into the abomasum. Incomplete closure of the groove, due primarily to the lack of suckling reflex, as in force feeding, allows milk or any liquid food to enter the rumen or reticulum resulting in indigestion. Although the closure of oesophageal groove under natural suckling is certain, under nipple or bucket feeding non-closure can occur due to poor stimulus while young ones are being trained to feed artificially from a nipple or feeding buckets.

The characteristics of oesophageal groove closure (Ørskov, 1992) are:

Behaviour. The reflex closure of oesophageal groove is stimulated by the act of sucking or of drinking, and not by the act of drinking to quench thirst.

Age. The reflex action is retained regardless of age if groove closure response is evoked daily.

FIGURE 2.1
Comparative size of stomach compartments of a pre-ruminant showing oesophageal groove and of an adult ruminant



Composition of diet. The composition of liquid does not influence the reflex action. While whole milk is an ideal substrate to stimulate reflex action, non-milk proteins included in milk replacer diets are equally effective.

Physical form of the diet. The closure of the groove occurs when liquid feeds are sucked or drunk. Physical form of the solid diet has no effect on the reflex closure.

Method of feeding. The closure of the groove is effective whether milk or milk replacer is given by teat feeder or open bucket, as long as feeding practice differentiates motive (thirst versus excitement) of drinking.

Factors affecting forestomach development

In the newborn ruminant, abomasum is as large as the reticulo-rumen and omasum together. At this stage, digestive function of the stomach is carried out almost completely in abomasum. While the reticulo-rumen attains the proportionate size of the adult by 8 to 12 weeks in calves, the omasum continues to develop until 34 to 48 weeks to attain the adult size (Table 2.1). The function of abomasum in the pre-ruminants is to digest milk whereas that of forestomach is to digest solid food with the help of rumen microbes. Since the forestomach is not fully developed until 8 weeks, the pre-ruminant cannot digest significant amount of solid food. Therefore, the rate of reticulo-rumen development determines the time at which the pre-ruminants can reduce their dependence on milk as the source of food.

Establishment of rumen microbes. Early establishment of microbes in the reticulo-rumen hastens the development. Establishment of anaerobic microbes in the rumen might take place through trans-inoculation from the dam in the process of dam licking the young ones especially in the region of muzzle. Active microbial population in the rumen, facilitates digestion of solid food ingested by the young ones.

PHOTO 2.1
a. Lambs of 3 to 5 weeks of age being fed with germinated horse gram

b. Grain mixture

Ingestion of solid food. Generally newborn ruminants have little or no inclination to consume solid food. They start nibbling at grass and solid food at the age of 7 to 10 days, although there may be instances of this activity seen as early as on the second day. The young one's desire to eat solid food is perhaps driven by curiosity and hunger. They learn to eat solid food faster when herded with other young ones of similar age group who are habituated to eat solid food (Photo 2.1). Feeding restricted quantity of milk, is another way to stimulate solid food intake. In case the young ones have free access to nursing and are solitary, as is the case with most small holding farms, there could be a delay in establishment of microbial population and solid food intake.

Production of volatile fatty acids. The rate at which the rumen papillae increase in size is a function of the production of volatile fatty acids (VFAs). Since VFAs are the end products of carbohydrate fermentation by the rumen anaerobic microbes, and adequate intake of fermentable carbohydrates hasten early establishment of anaerobic microbes.

Rate of digestion. The presence of VFAs in the rumen stimulates papillary development that is responsible for increasing surface area for absorption of end products of digestion. Therefore, solid food that promotes a higher concentration of VFAs could facilitate faster rumen development (Photo 2.2). This can be achieved by higher intake of solid food. Solid food with higher rate of digestion allows higher rate of VFA production and rapid removal of solid food from the rumen thereby allowing higher intake. Accumulation of indigestible feed particles eventually leads to a reduction in food intake. In early weaned lambs, oats being less digestible than barley, are consumed in lower quantities (Andrews, Kay and Ørskov, 1969). Cereals are generally rapidly fermented and give rise to indigestible particles

PHOTO 2.2
Note the difference in papillae development as a result of feeding grain

a. The rumen wall of a 12 week old calf fed entirely on milk & hay

PENNSTATE, 2000

b. Combination of milk, hay & grain

PENNSTATE, 2000

which can be rapidly removed from the rumen. Similarly, high quality grass or legumes are also rapidly fermented. Therefore, young ruminants can survive on solid feed alone from the age of 4–5 weeks, provided the solid food is rapidly digested (Ørskov, 1992).

By hastening the rumen development the pre-ruminant young ones such as calves, kids and lambs can be successfully weaned on to solid food at 4–5 weeks of age. Until then the young ones have to be nourished with milk or suitable milk replacer diets.

ENZYME ACTIVITY IN THE DIGESTIVE SYSTEM

The pre-ruminants are functionally similar to simple stomached animals and hence are solely dependent on their own digestive enzymes. In general, the enzyme activity in the digestive system is low at birth and increases rather quickly in the next two days.

Saliva

The saliva of pre-ruminant calves contains lipase known as pregastric esterase (PGE) secreted by the palatine glands into the saliva. This brings about hydrolysis of dietary fat and acts preferentially on the triglycerides of butterfat that contain butyrate groups to release butyric acid. The optimum pH for its activity is 4.5 to 6.0. With a maximum for butter oil in evaporated milk (100), the relative activity of PGE varies with the source of fat: colostral fat - 87; coconut oil - 71; white pork grease - 29; soybean oil - 23; maize oil - 18; refined lard - 14; and tallow - 14 (Siewert and Otterby, 1971; Roy 1980). The activity of PGE decreases with age and normally disappears by about third month in calves fed with whole milk. However the decrease is more rapid in calves given liquid skim milk or high roughage diets.

Abomasum

As the milk enters the abomasum via the oesophageal grove, it is subjected to digestive process. Clotting of milk in the abomasum is an important aspect of milk digestion. Abomasal curd formation consisting primarily of casein and milk fat, slows down the passage of protein and fat to the small intestine. This allows a gradual and complete digestion and absorption of nutrients between feedings (Cruywagen, Brisson and Meissner, 1990). The clotting of casein with entrapped fat occurs within 3–4 min. As the clot contracts, whey is released and nearly 85 percent of the whey passes into the duodenum within 6 h of feeding (Roy, 1980). The casein retained in the abomasum is degraded by the action of rennin (chymosin) and/or pepsin and HCl. However, as the age advances, only pepsin is produced. An increase in milk intake induces an increase in proteolytic activity. However, milk replacers containing severely preheated skim milk powder, fish protein concentrate or soy flour tend to reduce proteolytic activity in the abomasum. Incomplete curd formation in the abomasum leads to swift flow of liquid diet into the small intestine, which often leads to diarrhoea (Roy, 1980; Longenbach and Heinrichs, 1998).

Intestine

The pre-ruminants have many limitations in their ability to digest carbohydrates. Because of the non-functional rumen, carbohydrate digestion occurs in the small intestine and is largely restricted to milk sugar, lactose. They lack sucrase and secrete limited amounts of amylase. Therefore their ability to digest sucrose is almost absent, and starch is digested to a limited extent. A summary of the enzyme activity in the pre-ruminant and ruminant calf is presented in Table 2.2.

Pancreatic secretions. The carbohydrates used by the young ones are lactose, galactose and glucose. Fructose is absorbed poorly or not at all. However, their ability to digest starch gradually improves after 4 weeks as the activities of enzymes, amylase and isomaltase increase with age. Therefore, diets containing starch are likely to cause diarrhoea because of indigestion if given before 3 weeks. A condition of depression and food refusal has been reported in young calves given starch (Roy, 1980) which is considered to be associated with the fermentation of starch in the gut and the presence of large numbers of yeast cells and a high blood alcohol concentration. Starch digestion in pre-ruminant calves can be facilitated by cooking or gelatinisation and with supplementation of enzyme, amyloglucosidase.

The addition of enzyme amyloglucosidase to milk replacers containing ground sorghum grain wherein gelatinisation had occurred, facilitates starch digestion and improves growth performance. Feeding cooked grain mixture as a gruel rather than in dry form is also an effective way to improve starch digestion in pre-ruminants.

Activities of pancreatic enzymes such as amylase, chymotrypsin, lipase and ribonuclease increase with age. Lower pancreatic enzyme activity in early ages predisposes the calves for indigestion when fed with milk replacers containing plant or animal proteins. The inclusion of severely heat treated skim milk powder, soy flour or fish protein concentrates and absence of fat in milk replacers cause reduction in pancreatic enzyme activity (Roy, 1980). Pancreatic lipase hydrolyses milk fat and also the vegetable oil releasing glycerol and fatty acids.

Intestinal secretions. In calves, maltase and isomaltase activities increase up to 4 weeks of life and stabilises thereafter. Pancreatic amylase secretion is also very low in the newborn ruminant. However as the age advances, activity increases and by about 6 weeks maltase,

TABLE 2.2
Enzymes in the pre-ruminant (up to 30 days of age) and ruminant (from 30 to 60 days of age) calves

Pre-ruminant			Ruminant		
Enzyme	**Age (day)**	**Action**	**Enzyme**	**Age (day)**	**Action**
Intestinal lactase	1	Hydrolysis of lactose in the intestine	Carbohydrases and proteases in rumen bacteria and protozoa	30	Hydrolysis and fermentation of carbohydrates and proteins
Chymosin	2	Coagulation of casein and entrapment of fat	Intestinal isomaltase, maltase and sucrase	60	Digestion of carbohydrates
Pregastric esterase	Birth	Hydrolysis of fat	Intestinal amylase	60	Digestion of starch
Pancreatic lipase, Somatostatin	Birth	Regulation of gastric motility from abomasum to duodenum	Pancreatic lipase, Somatostatin	No change	Regulation of gastric motility
Pepsin	Birth	Digestion of proteins	Pepsin	No change	Digestion of proteins
Isomaltase, maltase and intestinal amylase are absent. Rumen bacteria and protozoa are limited or not present			Chymosin is reduced or absent after 30 days, intestinal lactase is reduced or not present after 60 days		

Source: Longenbach and Heinrichs (1998).

isomaltase and amylase activities increase. Sucrase activity is almost absent. Unlike other carbohydrases, lactase activity in the intestine is high at birth and declines with age, but the decline depends on the type of diet fed. Lactase activity remains high as long as calves are fed with whole milk or milk replacers containing lactose.

During the first 4 weeks of life, it seems that the only nutrients that can be satisfactorily utilised when given in liquid form are milk proteins, butterfat or fat of vegetable and animal origin, and the sugars, lactose and glucose. Non-milk proteins, when added more than 20 percent of the total protein in the diet, invariably cause some depression in growth rate during this period.

The anatomical and physiological characteristics of digestive system of pre-ruminants impose constraints on their ability to consume and digest food other than the natural whole milk for a few days after birth. However as the age advances, activities of carbohydrases and proteases increase in pancreatic secretions and in intestine apart from initiation of rumen microbial fermentation, which facilitate digestion of nutrients of feed origin including those of milk. Therefore, feeding management of pre-ruminants and formulation of alternatives to whole milk should take these characteristics into careful consideration. The pre-ruminants from birth to 3 weeks should be fed with liquid food in the form of whole milk or milk replacers formulated from milk by-products. At later age milk replacer formulations can have substantial portion of milk proteins replaced by alternative protein sources of feed origin. By three weeks the rumen fermentation begins, and then formulated solid feeds of higher digestibility can also be offered as a substitute for whole milk.

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Nutrients, their role and requirement for pre-ruminants

A nutrient is an element or a compound that is essential for the normal functioning of a living organism. This may be organic or inorganic in nature. The nutrients required for animals may be classified as water, carbohydrate, protein, fat, minerals and vitamins (Figure 3.1)

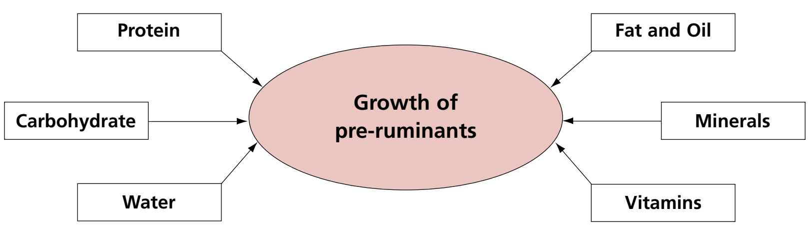
WATER

Water is the most important nutrient required for digestion, metabolism and transport of nutrients, excretion of waste products, regulation of body temperature and maintenance of fluid and ion balance in the body. The water content in the body of pre-ruminants is more than 80 percent and it declines as the animal grows. Severe water restriction can upset metabolic functions and lead to death. The major source of water for the pre-ruminant is milk or milk replacer. When the concentration of dry matter in liquid diet is increased, water requirement increases. Water content in milk replacers for pre-ruminant of cattle, camel and goat should be in the range of 86 to 88 percent; and for buffalo and sheep, 80 to 82 percent. Although, generally water requirement is met from milk or milk replacers, providing water free choice in addition to the liquid diet improves weight gain and facilitates an early start on dry feed (Kertz, Reutzel and Mahoney, 1984).

CARBOHYDRATES

The carbohydrates in food serve as the major source of energy. Their nutritional value depends on sugar components and their linkages. Carbohydrates of interest from the nutritional point of view may be classified as monosaccharides, disaccharides, and polysaccharides.

FIGURE 3.1
Nutrients required for growth of pre-ruminants



Monosaccharides are simple sugars consisting of only one sugar molecule. The most abundant of monosaccharide is glucose. This is the major source of energy for most organisms and is the building block of the most abundant polysaccharides such as starch and cellulose.

Disaccharides consist of two monosaccharides joined by a glycosidic linkage. The most common disaccharides are maltose, lactose, and sucrose. Maltose, which is formed as an intermediate product of starch hydrolysis by amylase, contains two D-glucose units. Lactose is found in milk and is made of two monosaccharide units, D-galactose and D-glucose. Sucrose is also a disaccharide made of two monosaccharide units, D-glucose and D-fructose. It is abundant in the plant kingdom and is familiar as cane sugar. Infant pre-ruminants up to the age of 3 weeks can not digest significant amount of any of the disaccharides except lactose. However, as the age advances their ability to digest these disaccharides increases (Chapter 2). By-products of milk such as skim milk and whey are the source of carbohydrate often used in milk replacers (Chapter 4).

The polysaccharides are complex carbohydrates and are classified as storage polysaccharides and structural polysaccharides. Storage polysaccharides are starch in plants and glycogen in animals. The structural carbohydrates are those components that make up the plant cell wall. These include pectin, hemicellulose, cellulose and lignin. Analytically they are represented by different terms such as crude fibre, neutral detergent fibre, acid detergent fibre indicating different components of structural carbohydrates. Infant pre-ruminants can not digest these polysaccharides. As they grow, they acquire the ability to digest starch to some extent, and on transition from pre-ruminant to ruminant stage, they are able to digest significant amount of both starch and fibre with the help of rumen anaerobic microbes (Chapter 2).

The foods of plant origin are rich in carbohydrates, but are generally in the form of starch or fibre. Cereal grain, millets, roots and tubers are rich in starch whereas cereal by-products such as bran and seed coat and all vegetative parts of plants are rich in fibre.

PROTEIN

The proteins are sources of amino acids that are essential for maintenance and growth. Pre-ruminants depend solely on dietary source of protein until the functional rumen is developed. Proteins are the structural components of all tissues, blood, enzymes, hormones and immunoglobulins. Therefore deficiency of protein or an imbalance in amino acid supply in the diet of pre-ruminants leads to depressed growth. The term ‘crude protein’, or ‘CP’, is a crude estimate of the total protein. Crude protein includes true protein and also non-protein nitrogen constituents such as amino acids, short peptides, amines, heat damaged Maillard products, etc. Therefore, crude protein may be viewed as digestible protein and indigestible protein. True proteins, amino acids and peptides are generally regarded as digestible protein. The major protein component of milk is casein. Infant pre-ruminants digest casein, but their ability to digest other proteins is very limited up to 4 weeks of age (Chapter 2). Therefore, in formulation of milk replacers protein sources from milk by-products are preferred (Chapter 4). Examples of such by-products are dried whole milk, dried skim milk, whey powder, whey protein concentrate and casein. Protein isolates from fish, and plant proteins such as soy protein isolates are also good source of high quality protein but their use in milk replacers should be restricted to 20 to 40 percent of the total protein depending on the age of the pre-ruminant. Weaned transition pre-ruminants can digest protein from plant sources. Plant protein sources are cheaper compared to animal protein sources. Most commonly used plant protein sources are soybean meal, groundnut cake, cottonseed cake, linseed cake and gingelly cake. Fish meal is also a good source of protein although some countries may have restrictions on their use (Chapter 4).

FATS AND OILS

Fats and oils are the rich source of energy. The energy content of fats is 2.25 times that of carbohydrates. Fats constitute a major source of energy in pre-ruminants, although adult ruminants are seldom fed diets with high levels of fat. The fat content in milk of ruminants, although variable, contributes a little more than 50 percent of the total digestible energy of milk. Therefore, fat is an important source of energy for the pre-ruminants. The ability of pre-ruminants to digest fat varies with the source of fat and the age of animal. In early age, butter fat is digested efficiently but not the other fat sources. As the age advances their ability to digest other sources of fat improves (Chapters 2 and 4). Fats and oils are analytically represented by the term, 'ether extract' (EE). Fat improves palatability of the food. It also contributes to satiety by facilitating longer retention of food in the stomach. Fats are also the carriers of fat soluble vitamins and essential fatty acids.

Sources of fat preferred in milk replacer diet are fat of animal or plant origin such as lard, tallow, vegetable oil such as coconut oil, palm oil, groundnut oil and maize oil (Chapter 4).

ENERGY

Energy is the capacity to do work and the animals obtain their energy needs from digested carbohydrate, protein and fat. The feed energy is expressed in different terms indicating their use to the animals.

Gross energy (GE). This is the total energy contained in a feed. Its usefulness to the animal depends on the extent of its digestibility.

Digestible energy (DE). That fraction of GE in a feed that is not recovered in the faeces. To determine DE, the GE in the faeces is subtracted from GE in the feed.

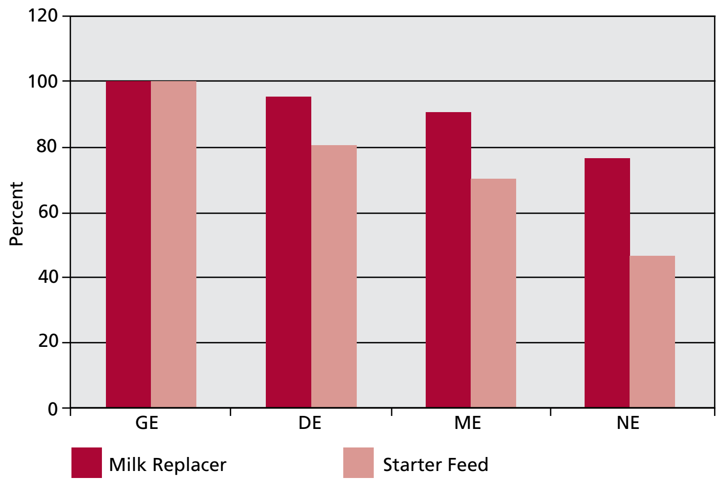
Total digestible nutrients (TDN). In reality, TDN is a simplified representation of DE. This is the sum of digestible organic nutrients present in a feed. This is calculated by the equation, TDN = Digestible crude protein + digestible crude fibre + digestible nitrogen-free extractives (NFE) + (Digestible ether extract x 2.25). The NFE is arithmetically derived estimate in the traditional feed analysis, presumed to represent easily digestible carbohydrates. Owing to the findings that NFE is not representing easily digestible carbohydrates, currently this term is less frequently used in feed evaluation.

Metabolisable energy (ME). This is the energy in a feed that is not recovered in the faeces or in urine. ME is determined by subtracting energy lost in urine, gas production during digestion, and endogenous sources, from DE.

Net energy (NE). This is the feed energy that is converted into animal products. In growing animals this is the sum of energy that is deposited in body weight gain and the energy required by the animal to maintain its activities.

The partitioning of gross energy into different energy components is shown in Figure 3.2. In pre-ruminants, because of the liquid diet bypassing the rumen, net energy of liquid diet such as milk or milk replacer is higher than that of starter feed (Roy, 1980; NRC, 1989).

FIGURE 3.2
Partitioning of gross energy in milk replacer and starter feed in pre-ruminants



ENERGY
GE, gross energy; DE, digestible energy; ME, metabolizable energy;
NE, net energy

MINERALS

Diets fed to ruminants contain many minerals that are required to support various body functions. Minerals are generally divided between those that are required in relatively larger quantities (i.e., macro-minerals) and those that are required in relatively lower quantities (i.e., micro-minerals or trace minerals). All feeds contain some levels of all macro- and micro-minerals. However it is very common to supplement diets of cattle and buffalo with minerals in order to assure that the animals consume enough of each mineral to meet their nutritional needs.

Macro-minerals

The common macro-minerals are calcium (Ca), phosphorus (P), potassium (K), magnesium (Mg), sulphur (S), sodium (Na) and chloride (Cl). These minerals are mainly involved in bone growth, reproduction and muscle function.

Calcium

Calcium is the most abundant mineral in the body. Of the total Ca in the body, about 98 percent is found in bones and teeth and 2 percent in soft tissue and body fluids. Calcium is required for bone and teeth development, muscle contraction, conduction of nerve impulses, activation of enzymes, and alteration of cell permeability, blood clot formation and synthesis of milk. A condition known as rickets may be caused by deficiencies of calcium, phosphorus, or vitamin D. The signs of rickets are swollen tender joints, enlarged bone ends, arched back, stiffness of legs, and the development of beads on ribs. Bones are subject to spontaneous fracture. Absorption of calcium decreases from 98 percent in milk-fed calves to less than 30 percent in aged animals. The availability of calcium from feedstuffs varies from 45–68 percent.

Milk and milk by-products are good source of calcium and phosphorus. Other sources include fish meal, bone meal, limestone, shell grit, rock phosphate, and dicalcium phosphate.

Phosphorus

About 86 percent of phosphorus in animal body is found in the skeleton and teeth, and the remainder in soft tissue and body fluids. Phosphorus is essential for skeletal growth, plays an important role in carbohydrate, protein and fat metabolism, and is a component of nucleic acids and many coenzymes. A deficiency of phosphorus causes loss of appetite, reduced efficiency of feed utilisation, poor skeletal development, lethargy and unthriftiness in young ones. The sources of phosphorus are milk and milk by-products, fish meal, bone meal, oil seed meal, rock phosphate, and dicalcium phosphate.

Magnesium

Magnesium is an essential constituent of bones and teeth, and hence functions in skeletal development. It is an activator of many enzymes in the cells, and also plays a role in neuromuscular transmission. Magnesium deficiency can occur in pre-ruminants fed all milk diets for prolonged periods, during which their body reserves of magnesium are depleted. The condition resulting from magnesium deficiency, known as hypomagnesaemia tetany or grass tetany is characterised by anorexia, increased excitability, intermittent convulsions (tetany), frothing at the mouth, profuse salivation, falling on its side with its legs alternately rigidly extended and relaxed. Milk is low in magnesium. Magnesium oxide or dolomite and magnesium chloride are the source of magnesium.

Sodium, Potassium and Chlorine

These minerals are required to regulate water metabolism, maintain acid base balance and osmotic pressure in tissues, and for gastric secretion. Sodium is also required for transport of glucose and amino acids and in nerve transmission. Signs of salt deficiency are licking and chewing of objects, loss of appetite, lustreless eyes, rough hair coat and reduced weight gain.

Potassium is the third most abundant mineral in animal tissues. The signs of potassium deficiency are muscular weakness, poor intestinal tone, decreased feed intake, reduced weight gain, and/or decreased milk production. The animal's requirement for these minerals, along with magnesium, will be higher during heat stress.

Chlorine is found in gastric secretions responsible for digestion. It is also found in high concentrations in pancreatic juice, bile and other intestinal secretions. Since chlorine is generally associated with sodium, adequate supply of sodium takes care of meeting chlorine requirement as well unless the sodium requirement is met from sources other than sodium chloride or common salt.

Sulphur

Sulphur is a component of the amino acid methionine and of the vitamins thiamine and biotin. Sulphur is important in formation of horn, hoof and hair. In pre-ruminants, since the rumen microbes are not established in the rumen, sulphur containing compounds such as methionine, thiamine and biotin are to be supplied in the diet. Milk is the major source of sulphur containing nutrients to pre-ruminant young ones.

Micro-minerals (or trace minerals)

The nutritionally important trace minerals are zinc (Zn), copper (Cu), iron (Fe), manganese (Mn), selenium (Se), iodine (I), fluorine (Fl), molybdenum (Mo) and cobalt (Co). Trace minerals have many functions in the body, and are highly inter-related nutritionally, but in general they are involved with body systems that convert nutrients to animal tissues.

Iron, Copper and Cobalt

These minerals have important roles in erythropoiesis. Their deficiency results in an anaemia characterised by paleness of conjunctiva, tongue and vagina. Iron is an essential component of haemoglobin and is involved in transport of oxygen to cells. Iron deficiency rarely occurs in adult ruminants except under conditions of parasitic infestations. Deficiencies are likely to occur in pre-ruminant young ones because of low iron in milk. The iron reserves of the calf are sufficient to prevent anaemia if calves are started on dry feeds at 4–8 weeks of age.

Copper deficiency results in weight loss, unthrift-ness, diarrhoea, rough hair coat and/or stiff gait.

Cobalt is essential for synthesis of vitamin B_{12} by rumen microbes. In pre-ruminant young ones, vitamin B_{12} is the dietary requirement and milk is the major source. Deficiency of vitamin B_{12} results in severe anaemia, loss of appetite, retarded growth and muscle wasting, rough hair coat and stumbling gait.

Iodine

Iodine is necessary to synthesise thyroid hormones that regulate energy metabolism. The sign of iodine deficiency is an enlargement of thyroid gland (goitre) in the newborn.

Manganese

Manganese is required for bone formation, growth and reproduction, and a deficiency results in impaired growth, skeletal abnormalities including ataxia of the newborn.

Zinc

Zinc is an important constituent of most enzymes, and a deficiency is characterised by decreased weight gain, low feed consumption and feed efficiency, swollen feet with open scaly lesions, alopecia and/or a dermatitis that is most severe on the legs.

Fluorine, Molybdenum and Selenium

Fluorine is required for teeth and bone formation. Molybdenum and Selenium are important constituents of many enzyme systems. However, their required levels in the diet are too low and generally not listed in the nutrient requirement table except for selenium.

VITAMINS

There are two groups of vitamins, namely fat-soluble vitamins, A, D, E and K, and water soluble vitamins, which include B-complex vitamins and vitamin C. B-complex vitamins include thiamine, riboflavin, niacin, biotin, pantothenic acid, choline, pyridoxine, folacin, and cyanocobalamin. All vitamins are dietary essential for pre-ruminants. As they become ruminants, vitamin K and B-complex vitamins are synthesised in the rumen. Adult ruminants do not have the dietary requirement for vitamin K and B-complex vitamins. Vitamin C is generally regarded as not dietary essential in ruminants and pre-ruminants as well.

Fat soluble vitamins

Fat soluble vitamins are necessary for normal development of muscle and skeleton and also for building immunity against diseases. The deficiency signs include poor growth, rough hair coat, and increase in susceptibility to infection.

Vitamin A is necessary for growth, vision and to provide protection against infection. A deficiency of vitamin A is characterised by degenerative changes in the mucosa of respiratory and digestive tact and the animals become susceptible to infection, leading to cold, pneumonia and diarrhoea. Blindness or night blindness is also a noticeable symptom of vitamin A deficiency in rapidly growing calves fed a high concentrate diet. Beta carotene is a good source of vitamin A and these are present in green grass and legume forages.

Vitamin D is necessary for skeletal development in pre-ruminants. Although Vitamin D is synthesised in the body from sterols on exposure to sunlight, animals in confinement can suffer from deficiency. The signs of deficiency include stunted growth, the knee and hock joints become swollen and stiff, bending of legs forward or sideways and the back humped. Supplementation of pre-ruminant diet with vitamin D is recommended when there is minimum exposure to sunlight. Sun cured legume hay is a good source of vitamin D.

Vitamin E is regarded as an antioxidant. The deficiency of vitamin E is characterised by degenerative changes in the muscle. The signs include weakening of leg muscles, so that the calves walk with a typical crossing of the hind legs. The musculature of the tongue is affected, impairing the pre-ruminant's ability to suckle. In advanced stages, the animal may be unable to hold up its head and stand. Pre-ruminants fed with skim milk are prone for vitamin E deficiency.

Vitamin K facilitates blood clotting and minimises haemorrhages. Normally this is synthesised in sufficient quantity by the microorganisms present in the gastrointestinal tract and hence generally not considered as dietary essential. However, when mouldy sweet clover hay high in dicoumarol is fed, signs of inadequacy may appear.

Water soluble vitamins

Water soluble vitamins are required in many cellular functions related to nutrient metabolism. Unlike the fat soluble vitamins, these are not stored in the body. Therefore daily supply of these vitamins is necessary. Deficiency of water soluble vitamins is generally characterised by poor appetite, incoordination of movement, lack of vigour, digestive disturbances, rough hair coat and poor growth. Thiamine deficiency is responsible for poor coordination of the legs and inability to rise and stand. These signs are accompanied by lack of appetite, severe diarrhoea, followed by dehydration and death. Riboflavin deficiency is characterised by hyperaemia of the mucosa of the mouth, loss of hair, especially on the abdomen. Pyridoxine deficiency in calves, apart from resulting in loss of appetite and growth retardation, may also result in epileptic fits. Pantothenic acid deficiency results in scaly dermatitis in calves. Calves also become weak and may develop convulsions. Diets low in nicotinic acid leads to sudden loss of appetite and severe diarrhoea. Biotin deficiency is characterised by paralysis of the hind quarters in calves. Vitamin B_{12} deficiency results in poor growth, muscular weakness, and poor general condition. Folic acid deficiency in lambs leads to diarrhoea, pneumonia and death. Choline deficiency in calves results in extreme weakness and laboured breathing.

TABLE 3.1
Daily energy and protein requirements of Friesian pre-ruminant replacement calves fed on milk replacer and starter feed

BW (kg)	BWG (g/day)	DM[1] (kg)	Milk replacer DM (kg)	TDN (kg)	ME (MJ)	DP (g)	CP (g)
20	0	0.65	0.21	0.25	4.3	15	16
	250		0.37	0.44	7.6	72	77
	500		0.53	0.63	10.8	130	138
30	0	0.90	0.28	0.34	5.8	20	21
	250		0.44	0.53	9.1	78	83
	500		0.60	0.71	12.3	135	143
	1000		0.95	1.13	19.4	250	266
40	0	1.10	0.35	0.41	7.2	25	26
	250		0.51	0.61	10.5	83	88
	500		0.67	0.80	13.7	140	149
	1000		1.05	1.25	21.5	260	277
50	0	1.30	0.41	0.49	8.5	28	30
	250		0.58	0.69	11.8	88	94
	500		0.73	0.87	15.0	148	158
	1000		1.14	1.36	23.4	268	285
60	0	1.50	0.47	0.56	9.7	30	32
	250		0.63	0.75	13.0	90	96
	500		0.79	0.94	16.2	150	160
	1000		1.23	1.47	25.3	270	287
70	0	1.65	0.53	0.63	10.9	35	37
	250		0.69	0.82	14.2	95	101
	500		0.85	1.01	17.4	155	165
	1000		1.32	1.57	27.1	275	293

BW, body weight; BWG, body weight gain; CP, crude protein; DM, dry matter; DP, digestible protein; ME, metabolisable energy; TDN, total digestible nutrients.
[1] Potential dry matter intake.
Source: Adapted from Roy (1980).

TABLE 3.2
Daily energy and protein requirements of weaned Friesian ruminant replacement calves fed on starter and hay diet

BW (kg)	BWG (g/day)	DM[1] (kg)	TDN (kg)	ME (MJ)	DP (g)	CP (g)
50	0	1.9	0.80	12.1	30	40
	250		1.02	15.1	90	120
	500		1.24	18.8	150	200
	1000		1.83	27.6	260	347
70	0	2.0	0.96	14.5	38	51
	250		1.16	17.5	98	131
	500		1.40	21.2	157	209
	1000		2.00	30.3	280	373
100	0	2.8	1.22	18.4	50	67
	250		1.45	22.0	110	147
	500		1.66	25.1	170	227
	1000		2.32	35.1	290	387

BW, body weight; BWG, body weight gain; CP, crude protein; DM, dry matter; DP, digestible protein; ME, metabolisable energy; TDN, total digestible nutrients.
[1] Potential dry matter intake (NRC, 2001).
Source: Adapted from Roy (1980).

NUTRIENT REQUIREMENT OF PRE-RUMINANTS

The nutrient requirement of pre-ruminants varies with the stage of growth. Because of the anatomical and physiological changes taking place in the gut (Chapter 2), pre-ruminants solely depend on milk or such similar liquid food in the early stages and gradually adapt to solid food. Liquid food used as a substitute for whole milk is known as milk replacers and the solid food used to supplement or replace milk replacers is known as starter feed.

The daily requirement of energy and protein for the pre-ruminant replacement calves fed whole milk or milk replacers and starter feed are presented in Tables 3.1 and 3.2. The requirements for dry matter, total protein, apparent digestible protein and metabolisable energy are given for body weights varying from 20 to 70 kg and for three different weight gains. Recommended dietary concentration of nutrients in milk replacer and starter feed is in Table 3.3 (NRC, 1989). NRC (2001) recommendations are upward revision of the requirements to meet higher growth potential of purebred Holstein calves. Since such growth rates are difficult to achieve under scarce feed resources, these requirements are not included in this section.

The daily nutrient requirements of pre-ruminant cattle and buffalo, referring primarily to crossbred cattle (*Bos taurus* x *Bos indicus*) and buffalo in tropical climate are in Table 3.4 (Ranjhan, 1998). Here the requirements are presented for a single body weight gain, and are based on whole milk feeding system.

TABLE 3.3
Nutrients recommended for milk replacer and starter diets of pre-ruminant calves

Nutrient	Milk replacer	Starter feed
ME, MJ/kg	15.8	13.0
TDN (%)	95	80
CP (%)	22	18
EE (%)	10	3
Calcium (%)	0.7	0.60
Phosphorus (%)	0.6	0.40
Magnesium (%)	0.07	0.10
Sodium (%)	0.10	0.10
Potassium (%)	0.65	0.65
Chlorine (%)	0.20	0.20
Sulphur (%)	0.29	0.20
Iron (mg/kg)	100	50
Manganese (mg/kg)	40	40
Zinc (mg/kg)	40	40
Copper (mg/kg)	10	10
Iodine (mg/kg)	0.25	0.25
Cobalt (mg/kg)	0.10	0.10
Selenium (mg/kg)	0.30	0.30
Vitamins[1]		
A (IU/kg of DM)	3800	2200
D (IU/kg of DM)	600	300
E (IU/kg of DM)	40	25

CP, crude protein; EE, ether extract; ME, metabolisable energy; TDN, total digestible nutrients.
[1] B-complex vitamins are necessary only in milk replacer diets. Required concentrations (mg/kg of DM): thiamine 6.5, riboflavin 6.5; pyridoxine 6.5; pantothenic acid 13.0; niacin 2.6; biotin 0.1; folic acid 0.5; B12 0.07; choline 0.26 percent. Adequate amounts of these vitamins are furnished when calves have functional rumens (usually at 6 weeks of age) by a combination of rumen synthesis and diet components.
Source: NRC (1989).

TABLE 3.4
Daily nutrient requirements of pre-ruminant cattle and buffalo

Body weight (kg)	Body weight gain (kg/d)	TDN (kg)	ME (MJ)	DP (g)	CP (g)	Ca (g)	P (g)	Vitamin A (x 1000 IU)	Vitamin D (IU)
25	0.20	0.37	6.3	80	82	2.5	1.5	1.5	200
30	0.30	0.41	7.1	90	96	3.0	2.0	1.5	250
40	0.30	0.58	10.0	125	146	3.5	2.5	1.7	250
50	0.35	0.88	15.1	150	172	4.0	3.8	2.0	300

Ca, calcium; CP, crude protein; DP, digestible protein; ME, metabolisable energy; TDN, total digestible nutrients; P, phosphorus.
Source: Adapted from Ranjhan (1998).

TABLE 3.5
Daily energy and protein requirements of pre-ruminant lambs fed with milk and milk replacers

BW (kg)	BWG (kg/d)	DM[1] (kg)	TDN (kg)	ME (MJ)	DP (g)	CP (g)
5	0	0.27	0.09	1.5	9	10
	0.1		0.14	2.35	30	33
	0.2		0.19	3.20	52	56
	0.3		0.25	4.25	73	79
10	0	0.45	0.15	2.60	10	11
	0.1		0.22	3.70	30	33
	0.2		0.28	4.85	51	56
	0.3		0.35	6.10	72	78
15	0	0.61	0.21	3.55	11	12
	0.1		0.28	4.90	30	32
	0.2		0.37	6.40	51	56
	0.3		0.46	7.95	72	78
20	0	0.76	0.26	4.40	12	13
	0.1		0.35	6.05	31	34
	0.2		0.45	7.80	51	55
	0.3		0.57	9.75	70	76

BW, body weight; BWG, body weight gain; CP, crude protein; DM, dry matter; DP, digestible protein; ME, metabolisable protein; TDN, total digestible nutrients.
[1] Potential dry matter intake.
Source: Adapted from ARC (1980).

TABLE 3.6
Daily energy and protein requirements of weaned lambs fed on starter feed and hay

BW (kg)	BWG (kg/d)	DM[1] (kg)	TDN (kg)	ME (MJ)	DP (g)	CP (g)
20	0	0.61	0.25	3.7	21	28
	0.05		0.31	4.7	30	40
	0.1		0.38	5.7	41	55
	0.2		0.55	8.3	62	83
30	0	0.87	0.33	5.0	29	38
	0.05		0.42	6.3	38	50
	0.1		0.52	7.8	45	60
	0.2		0.76	11.5	71	95
40	0	1.12	0.42	6.3	36	48
	0.05		0.53	8.0	47	63
	0.1		0.65	9.9	56	75
	0.2		0.77	11.6	85	113

BW, body weight; BWG, body weight gain; CP, crude protein; DP, digestible protein; ME, metabolisable energy; TDN, total digestible nutrient.
[1] Potential dry matter intake.
Source: Adapted from ARC (1980).

TABLE 3.7
Daily energy and protein requirements of goat kids

BW (kg)	BWG (g/d)	DM[1] (kg)	TDN (kg)	ME (MJ)	DP (g)	CP (g)
5	0	0.22	0.10	1.5	10	15
	25		0.14	2.1	15	22
	50		0.19	2.9	20	29
10	0	0.37	0.16	2.4	17	25
	25		0.21	3.2	22	32
	50		0.25	3.8	26	39
	75		0.30	4.5	31	46
15	0	0.50	0.22	3.3	23	33
	25		0.24	3.6	25	36
	50		0.31	4.7	33	18
	75		0.36	5.5	37	55
20	0	0.62	0.27	4.1	28	41
	25		0.32	4.8	33	49
	50		0.36	5.5	38	56
	75		0.41	6.2	43	63
	100		0.46	7.0	48	70
25	0	0.71	0.32	4.8	33	49
	25		0.37	5.6	38	56
	50		0.41	6.2	43	63
	75		0.46	7.0	48	71
	100		0.51	7.7	53	78
	125		0.56	8.5	58	86

BW, body weight; BWG, body weight gain; CP, crude protein; DM, dry matter; DP, digestible protein; TDN, total digestible nutrient.
[1] Potential dry matter intake.
Source: Kearl (1982).

The nutrient requirements of pre-ruminant sheep fed milk or milk replacer and starter feed are presented in Tables 3.5 and 3.6 respectively. The requirements for growing kids fed solid food in the body weight range from 5 to 30 kg for daily gain in weight ranging from 25 to 125 g are given in Table 3.7 (Kearl, 1982).

Energy, protein and fibre levels recommended for milk replacers and starter feeds of different ruminant species are presented in Table 3.8.

The pre-ruminants require specific amounts of nutrients to support growth and provide immunity against diseases. The nutrients required by pre-ruminants are broadly classified as water, carbohydrate, protein, fat, minerals and vitamins. Milk is the sole source of these nutrients to pre-ruminant. As the rumen develops, they acquire the ability to digest feed ingredients to obtain nutrients.

TABLE 3.8
Recommended energy, protein, fibre, calcium and phosphorus in milk replacer (MR) and starter feed (SF) for pre-ruminant of cattle, buffalo, sheep, goat, camel and yak

Species	Feed	ME (MJ/kg of DM)	CP (%)	EE (%)	ADF (%)	NDF (%)	Ca (%)	P (%)
Cattle*	MR	15.8–20.1	18–22	10–20	–	–	1.0	0.7
	SF	13.0–14.6	16–18	3–5	4–8	12–18	0.6–0.7	0.4–0.5
Buffalo	MR	20.0–21.0	18–22	15–25	–	–	1.2	0.9
	SF	13.0–14.6	16–18	3–5	4–8	12–18	0.8–0.9	0.6–0.7
Sheep	MR	20.0–21.0	20–24	20–30	–	–	1.2	0.9
	SF	13.0–14.6	18–20	5	2–4	8–12	0.8–0.9	0.6–0.7
Goat	MR	15.8–20.1	18–22	10–20	–	–	1.0	0.7
	SF	13.0–14.6	16–18	3–5	2–4	8–12	0.6–0.7	0.4–0.5
Camel**	MR	15.0–20.0	20–24	10	–	–	1.0	0.7
Yak	MR		25–30	25–30	–	–	0.8	0.9

ADF, acid detergent fibre; Ca, calcium; CP, crude protein; EE, ether extract; ME, metabolisable energy; NDF, neutral detergent fibre; P, phosphorus.
Sources: *NRC(2001), **Coventry (2010).

The nutrient requirement varies with the species of pre-ruminant, their body weight and rate of weight gain. The requirements are expressed either in terms of daily needs or as a proportion of the diet fed to pre-ruminant species. The nutrient requirements for different pre-ruminant species obtained from different sources are presented to serve as the guidelines for diet formulation and feeding.

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Ingredients used in milk replacers and starter feeds

Raising pre-ruminant young ones involves feeding of colostrum, milk or milk substitute in the liquid form followed by solid food. While the infant pre-ruminant depends on liquid food, as the rumen develops and fermentation begins, dependence on liquid food gradually declines and intake of solid food increases. Milk replacers are those food ingredients or a mixture of such ingredients that can be used as substitute for whole milk. They are made from by-products of milk with the addition of some ingredients in such a way that the final product is comparable to whole milk. A good milk substitute should have physical (flowability, density, flavour, homogeneity and taste), chemical and nutritional characteristics comparable to milk and meet the recommendations for energy and nutrient supply of the animals. As the rumen develops, pre-ruminants explore on solid food such as grain mixture and grasses. Ingestion of solid food hastens development of the rumen. Solid food specially formulated for pre-ruminants to supplement liquid feeding is generally termed as 'Starter feed' or 'Creep feed'.

INGREDIENTS USED IN MILK REPLACERS

Milk replacers are usually made up of ingredients such as skim milk powder (60–75 percent), vegetable or animal fat (15–25 percent), butter milk powder, whey protein (5–10 percent), soy lecithin (1–2 percent) and vitamin-mineral premix. A small proportion of other ingredients like glucose, non-milk protein and cereal flour can also be used. As a consequence of increased cost of traditional ingredients and also due to availability of new by-products from food industries, milk replacer formulations have undergone considerable changes. Taking into consideration the basic composition of milk and its physical form, milk replacers should contain such ingredients to provide protein, fat, lactose, minerals and vitamins and dissolve readily in water to facilitate feeding in a physical form similar to milk. The chemical composition of ingredients most commonly used in milk replacer diets is presented in Table 4.1.

Protein sources

Milk by-products originating from milk processing industries, and protein sources other than milk by-products are used in milk replacers. Based on the protein source used in formulations, milk replacers are generally classified as 'all-milk protein milk replacers' or 'alternative-protein milk replacers'. All-milk protein milk replacers contain skim milk, whey protein concentrate, dried whey, and delactosed whey as protein sources. Alternative-protein formulations are those in which portions of milk proteins (typically 50 percent) are replaced with low cost ingredients such as fish protein concentrates, soy protein concentrate, soy protein isolates, and modified wheat gluten (Davis and Drackley, 1998).

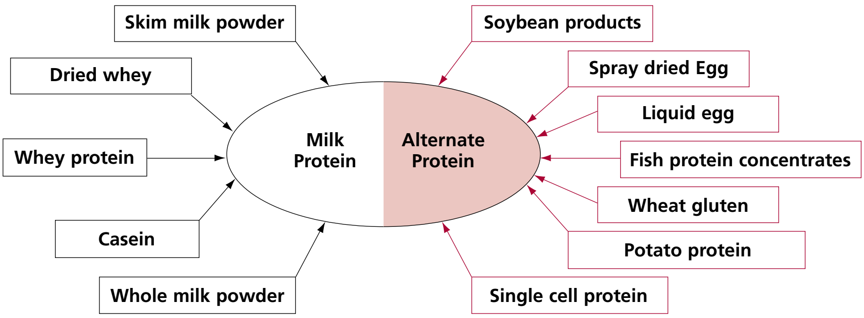
TABLE 4.1
Composition of ingredients commonly used in milk replacer formulation

Ingredient	DM (% as is)	ME (MJ/kg DM)	CP (% of DM)	EE (% of DM)	Ca (% of DM)	P (% of DM)	Ash (% of DM)
Milk by-products							
Whole milk	12.5	22.5	25.4	30.8	1.00	0.75	6.3
Skim milk, fresh	10.0	16.8	35.5	0.3	1.35	1.02	6.9
Skim milk, powder	94	17.1	37.4	1.0	1.29	1.08	6.9
Whey powder	93	15.3	13.5	1.0	0.76	0.68	8.1
Whey protein concentrate	93	17.5	37.1	2.2	0.54	0.60	6.0
Whey fresh	7	15.2	14.2	0.7	0.73	0.65	8.7
Whey, delactosed	93	14.2	17.9	0.7	1.71	1.12	16.5
Whey, permeate	98	14.3	3.7	0	1.77	0.97	9.0
Casein	91	21.3	92.7	0.7	0.40	0.35	4.0
Non-milk by-products							
Distillers solubles[1]	93	14.5	29.7	9.2	0.35	1.37	7.8
Fish protein concentrate			80.0	1.0			10.0
Potato protein isolate[2]			75.0				
Soy protein concentrate, alcohol treated[3]	93.0		65.0	1.0			6.0
Soy protein concentrate, enzyme treated[3]	93.5		57.5	2.5			6.8
Soy protein isolate[3]	93.5		90.0	1.0			5.0
Wheat gluten, hydrolysed[4]			80.0	1.0			
Fat, animal, hydrolysed	99	30.5		99.5			
Fat, swine (lard)	99	30.5		100.0			
Oil, soybean	100	30.5		99.9			

Ca, calcium; CP, crude protein; DM, dry matter; EE, ether extract; ME, metabolisable energy; P, phosphorus.
[1] Contains 5 percent crude fibre.
[3] Contains 1–3 percent oligosaccharides.

Sources:
[2] Meuser and Smolnik (1979), NRC (1989, 2001).
[3] Peisker (2001).
[4] Merick, Inc. (2006).

FIGURE 4.1
Protein sources commonly used in milk replacer formulation



Skim milk powder. This is the largest component of milk replacers constituting at least 50 percent of the dry matter. The quality of skim milk powder used has a great impact on the quality of milk replacers. Higher levels of denatured whey protein present in skim milk can result in poor clotting of milk replacer in the abomasum, reduced digestibility, increased incidence of enteric infection and reduction in weight gain. The content of non-casein nitrogen is a measure of the extent of denaturation of whey protein in skim milk powder. A level of up to 170 mg non-casein nitrogen per g total nitrogen may be regarded as safe for use in milk replacer diets. The true digestibility of protein is nearly 100 percent and apparent digestibility is about 94 percent with a slightly lower digestibility at one week of age (Roy, 1980).

Whey. The common milk source of protein for milk replacers is whey. Whey is a by-product of cheese making. The products made from whey include dried whey, whey product or whey protein concentrate (WPC). The difference in these products is the amount of lactose and mineral removed from the whey. For example dried whey contains 13.5 percent protein and WPC contains 37.1 percent protein. The digestibility of whey protein varies depending on the source of whey or the type of cheese, processing and handling methods. The inclusion of dried whey in milk replacers is limited to less than 20 percent of the dry matter. Feeding pre-ruminants with large amounts of whey results in diarrhoea.

Whey protein. This is the protein obtained from heat coagulation in the presence of lactic acid (serac) or hydrochloric acid (lactoproteins). Whey protein does not coagulate in the abomasum. Due to lack of coagulation, abomasal emptying of food is much faster for the whey protein diets than for whole milk. The digestibility of protein varies from 90 to 93 percent, however before two weeks of age it is substantially low at 61–67 percent (Roy, 1980).

Fish Protein Concentrate (FPC). There are two types of FPC, namely, soluble and insoluble. The soluble FPCs are produced by controlled hydrolysis of protein in ground fresh fish. This includes polypeptides with a solubility of 80–100 percent. After the removal of fat and bones, the product is sterilised and spray dried. This product has a strong odour, but this does not appear to affect the appetite of the calf. This contains 85–90 percent protein, 2–5 percent fat, 4–6 percent ash. Insoluble FPC is produced by solvent extraction of the fat from ground fresh fish or fish meal. The product is ground to a particle size of 35 micrometer. It contains 80 percent crude protein, 1 percent fat, 10–15 percent ash. Fish protein concentrates, in general give better results than soybean products. Soluble and insoluble FPC can replace up to 50–60 percent of the protein of a milk replacer for the first 8 weeks of feeding, with antibiotic as one constituent in milk replacer. However, it is to be noted that since there are variable restrictions on the use of fish by-products and antibiotics in ruminant feeds in some countries, their use may be considered depending on regulations in your country. In early age, FPC tends to affect gastric function, but to a lesser extent than other non-milk protein sources. Inclusion of FPC in milk replacers also necessitates the use of higher level of Vitamin E and incorporation of antibiotics.

Spray dried whole egg (SDWE). It is a high quality alternative feed ingredient that contains significant amount of fat and protein. While protein is of high biological value, the fat contains lecithin which can give emulsifying properties to milk replacers if included as an ingredient. Although non-edible SDWE is produced in significant quantities by the egg processing industry, the limitation to its use in animal feeds is the presence of anti-nutritional proteins, including protease inhibitors and avidin, which irreversibly binds biotin. Inclusion of SDWE at 10 percent in milk replacers as a substitute for whey protein concentrate reduced growth performance of pre-ruminant calves in spite of supplementing biotin to overcome the effect of avidin and balancing of milk replacer for amino acids lysine, methionine, threonine and leucine (Quigley, 2002).

Liquid egg. Inclusion of liquid egg as a substitute for protein from milk based by-products at a level of 5 percent in the milk replacer (13.5 percent of milk-based protein) resulted in higher weight gain than in calves fed all-milk protein, but as the level of liquid egg increased beyond 10 percent in milk replacer (replacing 27 percent of milk-based protein), affected weight gain adversely. These findings indicate that liquid egg can be an effective alternative protein source in milk replacers when fed at levels up to 10 percent of the diet in a conventional feeding program of 0.45 kg per head per day (Touchette, O'Brien and Coalson, 2003).

Soybean products. Scarcity of skim milk powder favours the use of non-milk protein, including soybean in milk replacers. However these protein sources result in poor animal performance in spite of adequate amino acid balance (Lallès, 1993). Presence of enzyme inhibitors, lectins and flatulence factors has been implicated in impairment of digestion and metabolism in farm animals. However with refined soybean products such as soybean protein isolates or soybean protein concentrates results have been satisfactory, although higher levels of inclusion affected growth in calves (Toullec, Lallès and Bouchez, 1994).

Soy protein concentrate (SPC). Although varieties of soybean products are commercially available, their use in milk replacer diets has not met with great success because of the presence of anti-nutritional factors such as the trypsin inhibitors, haemagglutinins and oligosaccharides. From among the soybean products, SPC subjected to steam treatment seems to have the potential for use in milk replacer diets. This is prepared from high quality, ground and dehulled soybeans by removing most of oil and water soluble non-protein constituents from selected, sound, cleaned and dehulled soybeans (CFIA, 2003), and must contain not less than 65 percent protein on a dry matter basis. Digestibility of protein in fully toasted (steam at 120 °C for 25 min) SPC at 4 weeks of age is 89 percent in calves.

Soy protein isolates (SPI). This is much more refined than SPC possessing all the characteristics of SPC. The crude protein content is 90 percent (Hill, 2004).

Soy flour. Soy flour is also not a good choice for milk replacer, as it can decrease available protein and result in diarrhoea. It is available in different grades with protein content varying from 50–53 percent, fat from 3–15 percent and contains variable trypsin inhibitor activity depending on the heat applied while processing. This can be used in small quantities in calf milk replacers after three weeks of age.

Soy lecithin and soy phosphate. This is the mixed phosphatide product obtained from soybean oil recovered by a degumming process. It contains lecithin, cephalin and inositol, phosphatides, together with glycerides of soybean oil and traces of tocopherols, glucosides and pigments. The level of inclusion in milk substitute diets is 1–6 percent of the dry matter of the diet. Apart from acting as an emulsifying agent, lecithin may have a beneficial effect in supplying phospholipids.

Hydrolysed wheat gluten protein. This is a high quality, economical protein source, produced by separating the gluten protein from wheat starch. Hydrolysed wheat gluten is ideally suited for incorporation into milk replacers. It is low in fibre and ash, and contains 80 percent protein as against 37 percent protein in whey protein concentrate (Merrick, Inc. 2006). Digestibility of organic matter and crude protein is as high as 95 percent. It is also free from anti-nutritional factors such as those common to soy proteins that are known to reduce animal performance.

Potato protein isolates. This has the carbohydrate (fibre) fraction removed through special processing during which it also removes the allergens, inhibitors and other anti-nutritional factors usually associated with plant proteins. This is a by-product of potato starch production. The biological value of protein is about 80 compared to that of egg protein as 100.

Single cell proteins. These are proteins of bacteria or yeast grown on energy yielding substrates. Single cell proteins can be used to replace at least 20 percent and probably up to 40 percent of milk protein.

Energy sources

Fat. Generally tallow, choice white grease or lard are used as fat source in milk replacers, although presently tallow is not permitted in some countries to avoid the risk of transmitting BSE. With these fat sources, the extent of homogenisation influences digestibility. Vegetable oil and fat sources containing large amounts of free fatty acids are poorly used by the pre-ruminant young ones. Although there is no consensus on the optimal concentration of fat in milk replacers, and the recommendations vary from 10–25 percent, a fat content beyond 10–12 percent is not needed for calves (NRC, 2001). For pre-ruminants of buffalo and sheep this can be higher at about 20–25 percent. The fat content of dried whole cow-milk is about 30 percent. Calves less than two weeks of age do not digest non-milk fat as good as milk fat. Therefore, milk replacers high in milk fat lower the risk of diarrhoea. Common fats used are tallow, lard and coconut oil.

Incorporation of fat into milk replacers. Although calves can be reared solely on a skim milk diet with additional vitamin A and D after the colostrums feeding period, the growth rate will be lower than with a diet of whole milk and there will be a tendency for more diarrhoea. Fat is incorporated either by homogenisation into liquid skim milk, followed by drying, if necessary, or by blending with skim milk powder with the aid of an emulsifying agent. Homogenisation of the fat into liquid skim milk, prior to drying, gives the best quality product. Homogenisation results in globule size of 3–4 micrometer, whereas blended globules are usually 10–20 micrometer in diameter. Vegetable or animal fat should not be directly added to liquid skim milk or reconstituted dried skim milk unless correctly emulsified to reduce fat globules to a size of 3–4 micrometer in diameter. Older calves can tolerate larger fat globules. With 2–3 week old calves, emulsification of coconut oil with crude soybean lecithin results in a large increase in digestibility, which is not enhanced by homogenisation. Nevertheless, for the young calf and for calves of the smaller breeds, fat globules of small size are more efficiently digested than those of larger size. If the fat is homogenised, there should be no necessity to add an emulsifying agent, unless the fat being used is of low inherent digestibility, as is the case with beef tallow versus margarine containing 39 percent groundnut oil, 24 percent palm oil and 37 percent coconut oil (Roy 1980). The fats used in milk replacer diets and their digestibility are given in Table 4.2.

TABLE 4.2
Apparent digestibility of fats commonly used in milk replacers

Source of fat	Mean digestibility (%)	Range (%)
Butterfat	97	95–98
Coconut	95	93–96
Unhydrogenated palm- unhydrogenated palm kernel (2:1)	94	
Groundnut (partially hydrogenated)-palm (partially hydrogenated)- coconut (1:1:1)	94	90–97
Bone fat	94	93–95
Unhydrogenated palm	93	90–95
Groundnut	93	
Lard	92	87–96
Tallow-coconut (2:1)	91	
Hydrogenated palm kernel	91	87–95
Palm (50% hydrogenated)- coconut (1.5:1)	91	
Tallow-lard (1:1)	90	80–95
Maize	88	
Hydrogenated maize	88	
Unhydrogenated palm kernel	88	
Tallow	87	85–93

Source: Roy (1980).

Emulsifying agent. Emulsifiers improve mixing characteristics of fat and increase digestibility. Normal emulsifying agents used in milk replacers are lecithin and glycerol monostearate. Saccharoglycerides, which are the products of trans-esterification of a triglyceride of natural origin with sucrose, has been claimed to improve digestibility of palmitic and stearic acids, and reduce the incidence of diarrhoea in young calves.

Carbohydrates. The only carbohydrate the pre-ruminants can digest is lactose. Starch and its degradation products such as dextrin and maltose are not digested efficiently during the first three weeks of life. As low as 2 percent starch in the dry matter of milk replacers causes a depression in digestibility and growth during the first three weeks of life.

Feed additives

Pre-ruminant calves separated from the dam at birth and fed colostrum and milk artificially in a nipple bottle or a bucket, and those fed with milk replacers, are often affected by diarrhoea commonly known as "scours". In order to minimise the occurrence of scours, the practices adopted include improvement in sanitation and housing to reduce pathogen transmission, use of oral antibiotics to prevent bacterial infections and the use of fortified colostrum and milk replacers to improve immune defences. In spite of this, the calf mortalities in the United States of America range from 8 to 11 percent (National Animal Health Monitoring System, 1993, 1996, cited by Muscato, Tedeschi and Russell, 2002), and nearly 60 percent of the milk replacers fed to dairy calves of less than 3 weeks of age are medicated (Heinrichs, Wells and Losinger, 1995). Against the background of growing public concern on the use of antibiotics in food animals, interest in finding alternatives to antibiotics has been increasing. Some potential alternatives include probiotics (Di Frania *et al*., 2008; Frizzo *et al*., 2010; Kowalski *et al.*, 2009), and oligosaccharides (Cannon *et al.*, 2010). Some of these products have shown benefits in improving health and performance, but the responses have been variable and inconsistent (NRC, 2001). Hill *et al*. (2009) reported that supplementation of live yeast product or mannan-oligosaccharide product in starter diet had no effect on dry matter intake (DMI) and average daily gain (ADG).

Interestingly, Muscato, Tedeschi and Russell (2002) reported that feeding rumen fluid at 8 ml/calf daily along with colostrum and milk replacers until weaning resulted in a significantly higher weight gain and lower incidence of scours than controls that did not receive rumen fluid, suggesting the scope for further refinement of milk replacers. Similarly addition of sodium butyrate at the rate of 3 g/kg dry matter in milk replacer was found to improve body weight gain (Guilloteau *et al*., 2009) and reticulo-rumen weight (Gorka *et al.*, 2009).

One of the criteria in completely withdrawing calves from milk replacers is the daily intake of starter feed. When calves consume starter feed at 0.5 to 0.75 kg/day for 2 to 3 consecutive days, milk replacer can be completely withdrawn. Since the birth weight and growth rate of pre-ruminants vary over a wide range, the general guideline to withdraw pre-ruminants from milk replacers can be starter feed intake of 0.75 to 1.0 percent of the body weight. Therefore, milk replacers and feeding system that encourage pre-ruminants to eat more starter in early age are preferred. Lactoferrin (LF), an iron-binding glycoprotein found in whole milk is beneficial as an antimicrobial (Robblee *et al*., 2003), and as an immuno-modulator (Joslin *et al*., 2002). Calves fed lactoferrin in milk replacers at 1 g daily gained higher body weight and consumed more starter feed during preweaning period.

INGREDIENTS USED IN STARTER FEED

The pre-ruminants that receive limited amounts of whole milk or milk replacers and are to be weaned at 4 to 6 weeks of age, need to be supported with alternative solid feed. The solid feed used as a substitute for liquid food at the time of weaning is known as starter feed or the creep feed. It is the normal behaviour of the young ones to explore solid feed while being fed with liquid food. However, the intake of solid feed does not increase substantially until the young ones learn to eat solid feed and the rumen develops into a functional organ to support normal rumen fermentation. In order to motivate pre-ruminants to eat starter or creep feed, the quality and palatability of such feeds need to be compatible with their choice. Therefore, adequate attention should to be given for selection of ingredients in preparation of starter feed. Starter feed should be palatable, easily digestible and should contain adequate amount of the required nutrients. Coarsely ground starter seems to be somewhat more palatable than finely ground material. Pelleted starters are as palatable as a coarse-textured meal if the pellets are soft enough to break them down rather easily. Composition of feedstuffs commonly used in preparation of starter feed are presented in Table 4.3.

Energy sources

Cereal grains and grain by-products are the most commonly used energy sources in starter feed.

Maize. Maize is a coarse cereal, rich in energy. The protein content is low (7–14 percent) and the protein quality is also low being deficient in lysine and tryptophan. It is also a rich source of linoleic acid. Maize grain contains about 65 percent starch and is low in fibre. In the manufacture of starch, a number of by-products are produced, which can be used in animal feeds. The most important of these are germ meal, bran and gluten meal. Maize is more susceptible for infestation with mycotoxin producing fungi than other grains such as wheat, sorghum and millets.

Millets. Millets are smaller in size and much coarser than maize. The most common millets are, Pearl or Bulrush millet (*Pennisetum typhoideum*), Foxtail, Italian or Hungarian millet (*Setaria italica*), Prosa, Brown corn millet (*Panicum miliaceum*) and Japanese, or Barnyard millet (*Echinochloa frumentacea*), Finger, African or Indian millet, (*Eleucine coracana*), Koda, Ditch or Scrobis millet (*Paspalum acrobiculatum*). The crude protein content varies from 10 to 12 percent, fat from 2 to 5 percent and the crude fibre from 5 to 9 percent. It is usually ground or crushed before feeding.

Oats. Oats is coarser than other cereals because of its hull content. The crude protein content is from 6 to 13 percent, but the protein quality is poor. The oil content is high. A number of oat by-products can also be used in starter feed.

Barley. The crude protein content of the grain varies from 7 to 15 percent. The oil content is low, usually below 2 percent. Barley is a hard grain and must be crushed, rolled or ground before feeding. Otherwise they will pass through the alimentary tract largely undigested. A number of by-products originate following brewing which can be used as starter feeds. These include malt culms, brewers grain, dried brewers yeast and distillers grain.

Rice. The polished rice is commonly termed as ‘Rice’ and the hull removed, unpolished grains are termed ‘Brown rice’. Rice is the staple cereal food for human in many countries. It is low in protein (6–8 percent). Rice unfit for human consumption, such as the broken rice are used for animal feeding. One of the by-products obtained from milling rice is the rice bran. It contains 8–14 percent crude protein and 14–18 percent oil. The oil is highly unsaturated and prone to rancidity. Solvent extracted rice bran is stable against rancidity and is a good source of B vitamins.

Sorghum. Sorghum grains are smaller than maize, and contains 6–15 percent protein. Some varieties contain tannins which can affect protein digestibility and palatability. The grains must be processed before feeding, by grinding, dry rolling, steam rolling, flaking and popping. Following extraction of starch from sorghum, the by-products, sorghum gluten feed and sorghum gluten meal are available for animal feeding. The former has a bitter taste and requires mixing with other palatable feedstuffs such as molasses.

Wheat. Wheat grains consist of about 85 percent endosperm, 13 percent bran or seed coat and 2 percent germ. Rolled or crushed wheat is suitable for use in the diet and contains 9 to 16 percent protein (Moran, 2002). However, if too finely rolled, it may form a pasty mass in the mouth making it unpalatable. A number of by-products are available following milling which can be used in starter diets. Wheat germ contains 22 to 32 percent crude protein, is low in fibre and high in thiamine and vitamin E. Bran, which is essentially the grain husk, is the most fibrous of the by-products, containing 8 to 12 percent crude fibre. The crude protein content ranges between 12 and 16 percent. It has a good laxative effect.

Molasses. Molasses is a major by-product of sugar industry. Molasses is produced from sugar cane or sugar beet. Cane molasses contains 25 to 40 percent sucrose and 12 to 25 percent reducing sugars. Crude protein content is low and the ash content varies from 8 to 10 percent. High level of potash in molasses tends to induce diarrhoea when used at higher levels in replacers and starters. In milk replacers inclusion level of 2 to 3 percent may be recommended whereas in starters 5 to 10 percent can be incorporated. It is used as a sweetener, binder and dustiness-reducer.

Root crops. Root crops are characterised by high carbohydrate, low fibre and low protein and fat. Carbohydrates range from 50 to 75 percent of dry matter. Tropical root crops such as cassava (*Manihot esculenta*), and yucca are potential ingredients for starter feeds. Dried cassava is equal in energy value to other root crops and tubers and can be used to replace grains.

Protein sources

The residues of oil seeds after extraction of oil are excellent protein sources. Oil extraction from oil seeds is done by hydraulic pressure, expeller process or solvent extraction. Oil seed cake or meal produced by hydraulic pressure and expeller process contain 6 to 8 percent fat whereas that produced by solvent extraction contains less than 1 percent fat. In general oil seed cakes and meals contain 20 to 50 percent protein with variable amino acid composition. Although oil seed cakes and meals are good source of protein, some of them also contain anti-nutritional factors, which affect their utility in starter feeds.

Soybean meal. This is regarded as the best protein source for animal feeding. The protein content of dehulled soybean meal ranges from 46 to 59 percent. It is an excellent source of lysine, tryptophan and threonine but is deficient in methionine. Unprocessed soybean meal contains a number of anti-nutritional factors, such as the trypsin inhibitors that affect the digestibility of protein, and allergenic proteins such as conglycinin and beta conglycinin which cause scours in young animals. However, in heat processed soybean meal much of the anti-nutritional factors are destroyed by the heat rendering them safe for feeding.

TABLE 4.3
Composition of feedstuffs commonly used in starter feed of pre-ruminants

Feedstuff	DM (%)	Ash (% DM)	CP (% DM)	EE (% DM)	CF (% DM)	NDF (% DM)	ADF (% DM)	TDN (% DM)	ME (MJ/kg DM)	Ca (% DM)	P (% DM)
Barley											
Grain rolled	91	2.9	13.5	2.2	5.7	20.8	7.2	84.0	12.7	0.05	0.38
Malt sprouts	90.5	7.4	20.1	2.3	16	47	21.5	66.4	10.0	0.23	0.75
Brewers grains, dried	92.0	4.8	25.4	6.5	14.9	46	24	66.0	10.0	0.33	0.55
Maize											
Distillers solubles	93	7.8	29.7	9.2	5	23	7	88	13.3	0.35	1.37
Distillers grains, dehydrated	94	2.4	23	9.8	12.1	43	17	86	13.0	0.11	0.43
Gluten feed, dried	89.4	6.8	23.8	3.5		35.5	12.1	74.1	11.2	0.07	1
Gluten meal, dried	86.4	3.3	47	2.4	4.8	11.1	8.2	86.0	13.0	0.06	0.6
Grain ground	88.1	1.5	10.0	4.0	2.6	9.5	3.4	85.0	12.8	0.04	0.3
Oat grain, rolled	90	3.3	13.2	5.4	12.1	30	14.6	77.0	11.6	0.07	0.38
Rice bran	90.6	12.8	14.1	15.1	12.8	33	18	70	10.6	0.08	1.7
Rice broken	89	0.8	8.6	0.8	0.7	16	1	89	13.4	0.03	0.3
Sorghum grain, dry rolled	88.6	2	9.7	3.1	2	18	9	80.6	12.2	0.04	0.34
Wheat bran	89.1	6.3	17.1	4.4	11.3	42.5	15.5	70.0	10.6	0.13	1.38
Wheat grain, rolled	89.4	2	16.0	2.0	2.9	13.4	4.4	88.0	13.3	0.04	0.42
Millets											
Pearl millet	90	1.5	8.3	5.2	1.5					0.02	0.3
Foxtail millet	89	4	13.5	4.6	9.3			85	12.8		0.22
Proso millet	90	2.9	12.9	3.9	7.6		17	84	12.7	0.17	0.34
Japanese millet	90.7	6	8.4	3.6	5.9					0.11	0.45
Finger millet	90.5	3.1	11.5	3	2.8					0.6	0.45
Scrobic (Koda) millet	88.4	5	12	4.8	11.3					0.57	3.21
Sugar cane											
Molasses	74.3	13.3	3.0	0.2		0.4	0.2	72	10.9	1	0.11

(Continued)

TABLE 4.3
Composition of feedstuffs commonly used in starter feed of pre-ruminants *(Continued)*

Feedstuff	DM (%)	Ash (% DM)	CP (% DM)	EE (% DM)	CF (% DM)	NDF (% DM)	ADF (% DM)	TDN (% DM)	ME (MJ/kg DM)	Ca (% DM)	P (% DM)
Tubers											
Cassava	28.5	5.2	1.7	0.7	1.6					0.1	0.04
Potato by-product meal	35.4	12.8	10.5	10.8		22.1	16.5	80.7	12.2		
Yam, white	26.2	4.3	5.9	0.5	2.4						
Yam, white, peelings	17.7	9.8	1.2	1.2	9.5						
Legume seeds											
Bengal gram *(Cicer arietinum)*	90	3.48	21.6	3.1	9.7						
Horse gram (*Dolichos biflorus*)	90	7.8	22.4	1.3	6.1						
Red gram *(Cajanaus cajan)*, dehulled	90	4.2	21.8	1.4	8.4					0.14	0.45
Pea *(Pisum spp)* seeds	89	3.3	25.3	1.4	6.9			87	13.1	0.15	0.44
Oil seeds and seed meal											
Canola meal, m.e[1]	90.3	7.4	37.8	5.4	13.1	29.8	20.5	76	11.5	0.72	1.14
Canola meal, s.e[2]	91	7.5	40.6	1.8	13.2			69	10.4	0.67	1.04
Coconut meal, m.e	92	7.3	22.4	6.9	12.8		19	82	12.4	0.22	0.66
Coconut meal, s.e	91	7.4	23.4	2.7	16		24			0.19	0.66
Cottonseed meal, m.e	93	6.6	44.3	5	12.8	28	20	78	11.8	0.21	1.16
Cottonseed meal, s.e	90.5	6.3	45.6	1.3	14.1	30.8	19.9	76	11.5	0.17	1
Linseed	92.7	4.9	20.0	40.0	6.5			120	18.1	0.2	0.6
Linseed meal, m.e	91	6.3	37.9	6	9.6	25	17	82	12.4	0.45	0.96
Linseed meal, s.e	90.3	6.5	38.3	1.5	10.1	25	19	78	11.8	0.43	0.89
Peanut meal, m.e	93	5.5	52	6.3	7.5	14	6	83	12.5	0.2	0.61
Peanut meal, s.e	92.3	6.3	50.0	1.4	10.8	21.4	13.5	77	11.6	0.29	0.68
Sesame meal, m.e	93	12.1	49.1	7.5	6.1	17	17	77	11.6	2.2	1.5

(Continued)

TABLE 4.3

Composition of feedstuffs commonly used in starter feed of pre-ruminants *(Continued)*

Feedstuff	DM (%)	Ash (% DM)	CP (% DM)	EE (% DM)	CF (% DM)	NDF (% DM)	ADF (% DM)	TDN (% DM)	ME (MJ/kg DM)	Ca (% DM)	P (% DM)
Soybean	91		37.0	18.0	5.5			98.0	14.8		
Soybean meal, m.e	90	6.7	47.7	5.3	6.6			85	12.8	0.29	0.68
Soybean meal, s.e	89.1	6.6	49.0	0.8	7.3	14.9	10	84	12.7	0.30	0.68
Sunflower meal,dehulled,m.e	93	7.1	44.6	8.7	13.1			74	11.2	0.42	1.14
Sunflower meal, dehulled, s.e.	92.2	8.1	49.8	3.1	12.2	40.3	30	65	9.8	0.44	0.98
Other by-products											
Bakery waste, dried	92.0	4.4	10.7	12.7	1.3	18.0	13.0	89.0		0.14	0.26
Fish meal											
Fish meal, Anchovy , m.e	92	16	71.2	4.6	1.1			76.1	11.5	4.08	2.7
Fish meal, Menhaden , m.e	91.2	20.8	68.5	10.4	1			79.9	12.1	5.65	3.2
Yeast, brewers dehydrated											
Saccharomyces cerevisiae	93	7.1	46.9	0.9	3.1			79	11.9	0.13	1.49
Minerals											
Calcium carbonate	100									39.39	0.04
Calcium phosphate, monobasic	97									16.40	21.6
Calcium phosphate, dibasic	97									22	19.3
Limestone	100									34	0.02
Oyster shell	99									38	0.07

ADF, acid detergent fibre; Ca, calcium; CF, crude fibre; CP, crude protein; EE, ether extract; DM, dry matter; NDF, neutral detergent fibre; Ca, calcium; P, phosphorus.

[1] m.e, mechanically extracted.

[2] s.e, solvent extracted.

Sources: Göhl Bo, 1981; NRC, 1989, 2001.

Groundnut meal (Peanut meal). Groundnut meal is rich in protein (32–53 percent) among the oilseed meals, but deficient in methionine, lysine and tryptophan. The most common undesirable constituent found in groundnut meal is aflatoxin produced by the fungus *Aspergillus flavus* that infests groundnuts before, during and after harvest. The nutrient composition of the meal varies according to the oil extraction method. The quality of hulls directly affects fibre level, and therefore energy content of the meal. Solvent extracted groundnut meal generally has less than 1.5 percent fat and about 43 percent protein. With prolonged storage under warm and humid conditions in the tropics, residual oil becomes rancid and reduces its palatability.

Copra meal (Coconut meal). It is brownish or white in colour with a protein content of 18–22 percent (Moran, 2002). When dry it is tasteless and absorbs large quantities of water and increases the bulk. When meal contains a high residual oil it is a valuable source of energy, and copra oil is predominantly short chain saturated fatty acids that are easily digested. However protein quality is poor in both amino acid balance and digestibility, and digestibility may be further reduced when excessive temperature is used for processing. The amino acid composition of copra meal is inferior to many other protein sources as it is deficient in the essential amino acids lysine, methionine, threonine and histidine, although high in arginine.

Sesame meal (Til cake, Gingelly cake). Sesame (*Sesamum indicum)* is an important oilseed crop in India, Iraq, Egypt and Pakistan. It is known as benne, til, teel or gingelly. As the hull of the sesame seed accounts for 15–29 percent of the whole seed, its removal reduces crude fibre and increases protein content, digestibility and palatability of the meal. Expeller processed sesame meal contains 37 percent CP, 4.9 percent CF and 11.1 percent ether extract. Solvent extracted meals contain slightly higher crude protein (2–45 percent) and lower fat (<3 percent). Almost 80 percent of sesame protein is digestible. The energy content is lower than in soybean meal and appears to be related to its high ash content of 10–12 percent. Sesame meal is an excellent source of methionine, cystine and tryptophan, but is very low in lysine and threonine. The amino acid composition of sesame meal compliments most other oil seed proteins, including soybean meal in particular. Sesame seeds are known to contain high levels of oxalic acid which interferes with mineral metabolism and decreases digestibility of calcium, phosphorus, magnesium, zinc and iron.

Rapeseed meal and canola meal. Canola was developed from rapeseed by Canadian researchers in the 1970s, and differs from rapeseed in having much lower levels of secondary compounds (glucosinolates and erucic acid). These meals have lower protein and energy than soybean meal. In addition to higher fibre content, the lower energy value is also attributed to compounds such as pentosan polymers that have low digestibility. Rapeseed meal has 37 percent protein, 2 percent fat and 3.1 percent crude fibre, while canola meal has 38 percent protein, 3.7 percent fat and 11.1 percent crude fibre. Rapeseed meal has a pungent flavour and taste because of the glucosinolates and erucic acid. Rapeseed meal and canola meal have higher calcium and phosphorous levels than soybean meal, although 65 percent of the phosphorous is in the phytate form and not digestible. Rapeseed and canola meals have a reasonably well-balanced amino acid profile, but is lower in lysine than soybean meal. Canola meal is free of glucosinolates and erucic acid.

Cotton seed meal. Two types of cottonseed meals (CSM) are available, decorticated and undecorticated. The decorticated CSM is high in protein (40–46 percent) and low in crude fibre (11–13 percent). The fat level is about 3.5 percent. The chemical composition parameters vary depending on the fat extraction process. However CSM is inferior in four of the most important essential amino acids, lysine, methionine, threonine and tryptophan than soybean meal, and the digestibility of these amino acids is also lower than in soybean meal. It is rich in phosphorus but low in calcium. Some varieties contain a toxic substance gossypol which can be harmful to pre-ruminant calves. Cottonseed meal can be used as a complete substitute for soybean meal in calf starters, provided the gossypol content of CSM is less than 200 ppm (Bangani, Muller and Botha, 2000).

Maize gluten products. Maize gluten feed contains 20–25 percent protein and 7–10 percent crude fibre, and is mostly used in ruminant diets. Maize gluten meal contains 40–60 percent protein and 3 percent fat and is an excellent source of methionine and xanthophylls, but is very low in lysine. Use of Maize gluten meal is usually limited by its high price, and is susceptible to aflatoxin contamination due to mould growth during storage.

Maize germ meal. This is a by-product of wet milling of maize. Maize germ meal can be used as a substitute for maize and soybean meal in starter diet for calves (Dias Signoretti *et al*., 1997).

Wheat gluten. This is the soluble by-product obtained from wet milling of wheat.

Inclusion of wheat gluten up to 33 percent in milk replacer had no harmful effect in calves, and in starter feed, wheat gluten can be used as a partial substitute for soybean meal (Terui, Morrill and Higgins, 1996).

Sunflower meal. Sunflower (*Helianthus annu Ls)* is an important commercial crop in the former Soviet Union countries, Argentina, Eastern Europe, USA, China, India, France and Spain. The composition varies widely due to the method of oil extraction and the degree of dehulling. Sunflower meal is high in methionine but low in lysine and threonine. Sunflower meal generally has lower amino acid digestibility than soybean meal, and this should be considered when partially replacing soybean meal. De-hulled sunflower meal has a crude protein content in excess of 40 percent and crude fibre of 13 percent or less. Partial de-hulling produces meals of 30–35 percent crude protein, whereas whole sunflower meal has about 25 percent crude protein. The crude fibre of partially de-hulled or non-de-hulled meal exceeds 20 percent and the fat content is 1.5–2.0 percent. Sunflower meal contains high levels of chlorogenic acid, a phenolic compound that inhibits activity of digestive enzymes including trypsin, chymotrypsin, amylase and lipase.

Dried maize distillers grains with soluble. This is a product obtained in ethanol production containing 25–30 percent crude protein, 8–10 percent crude fat, 4–12 percent crude fibre and very low levels of soluble sugars. Since this is a yeast fermentation product, it contains residual yeast cells. The crude fibre is easily fermentable as that of beet pulp and soy hulls. In fuel ethanol production since poor quality grains are also used, the by-product should be checked for mycotoxin levels prior to use in animal feeds. Distillers grains with soluble has a 'malt' odour and a slight bitter taste. It varies in colour due to variable heat processing and ideally should be golden colour. Appearance varying from black spots to coffee colour is a reflection of heat damage and its use is not recommended. The supply of distillers grains with soluble is likely to increase due to increasing demand for ethanol-blended fuels.

Dried brewers grains. This is a by-product of beer and ale production and is primarily barley or wheat with less than 3 percent hops. It contains 26 percent crude protein, 7 percent crude fat, and 13–14 percent crude fibre. Also it is high in phosphorus and sulphur, and low in calcium and potassium.

Fish meal. The use of fish meal as an ingredient in starter feed may be considered in compliance with the regulations in your country. Fish meals are usually classified according to their oil content, varying from 5 to 15 percent. They are manufactured by direct drying (white fish meal, from non-oily fish) or cooking before drying (dark fish meal from oily fish). Fish meals are of fairly constant composition, containing approximately 65–70 percent crude protein. The protein is of good quality, but depending upon the method of extraction, the biological value may vary between 40 and 80 percent. The protein has high essential amino acids and is a valuable supplement in diets based on cereal protein. Fish meal, being high in mineral content, particularly calcium and phosphorus, the trace elements and the B vitamins is valuable as a feed source for young ruminants. Their inclusion is particularly suited where the demand for protein and essential amino acids is high and as much as 15 percent can be included in these diets. Prior to slaughtering, fish meal should be removed from the diet to avoid the risk of tainting meat with fishy smell.

Feeding of pre-ruminant young ones involves transition from colostrum to milk or milk replacer followed by solid food that comprises of starter feed and good quality hay. Milk replacers are generally made from milk by-products with addition of some ingredients as a source of protein, vitamins and minerals. Ingredients used in milk replacer formulation are dried whole milk, skim milk, whey, whey protein, fat, lecithin and mineral-vitamin premix. Small quantities of non-milk ingredients such as soy protein isolates, soy flour, soy protein concentrates, wheat gluten can also be used as source of protein. However, for starter feed formulation milk by-products are not necessary. Starter feed can be formulated using cereals, millets and pulses as energy source and oil seed meals as the protein source, apart from mineral and vitamin premix. Based on the nutrient composition, availability and cost, the ingredients are to be chosen to formulate replacer and statrter feed to fulfil the requirements.

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Formulating and feeding milk replacers and starter feeds to pre-ruminant stock in developing countries

Regardless of species, infant pre-ruminants are unable to digest solid food and hence liquid milk or milk replacers are indispensable for nourishment. However, the demand for milk for human consumption restricts availability of milk for pre-ruminant feeding, resulting in underfeeding or starvation with a consequence of stunted growth and mortality (Ranjhan and Pathak, 1979). If suitable substitutes for milk are made available, the nutrition of infant pre-ruminants can be improved and survivability can be increased. In developed countries, alternatives to whole milk feeding to pre-ruminants are formulated using by-products of milk processing industry. Such practice is not feasible in the developing countries where milk by-products are scarce and expensive. There have been attempts to restrict whole milk feeding by making use of alternatives such as milk from other ruminant species and/or milk by-products such as fresh skim milk together with starter feed.

CATTLE

Traditionally, fresh skim milk or butter milk are the most economic substitutes for whole milk wherein milk is processed to obtain cream or butter. The skim milk can be introduced when the calves are 15 days old by replacing 50 percent of the whole milk, and whole milk can be completely replaced by skim milk when the calves are 30 days old. If skim milk is given ad libitum, Friesian calves can drink about 14 kg at 3 weeks of age, 21 kg at 8 weeks and about 24 kg at 13 weeks (Roy, 1980).

However with changed scenario in milk production and milk processing sectors, fresh skim milk or butter milk are not easily available any more. In developed countries skim milk powder is widely used as one of the major ingredients in milk replacers. Generally, milk replacer diets are formulated to contain 60–75 percent skim milk powder, 15–25 percent vegetable or animal fat, 5–10 percent butter milk powder or whey protein, 1–2 percent soy lecithin and 1–2 percent vitamin and mineral supplements. Such milk replacers can be too expensive in developing countries because of inaccessibility to milk based by-products, as many of these countries depend on imported milk and milk products. Because of this reason, use of milk replacers for pre-ruminant feeding has not received much attention in these countries. However, there have been attempts to reduce whole milk feeding by using skim milk supplemented with starter feed.

Restricted use of milk and milk replacer and their replacement with starter feed

A gradual reduction in whole milk feeding promotes intake of starter feed and rumen development. Arora, Bajpai and Dave (1973); Arora *et al*. (1975) introduced starter feed in the feeding program for Karan-Swiss crossbred calves from day 10, with a gradual withdrawal of milk starting from day 14, and a complete withdrawal by day 65. Whole daily milk feeding at 10 percent of the body weight in two feedings was withdrawn at the rate of 0.5 kg for every 4 days, starting from day 14, by increasing starter feed by 50 to 100 g. The average daily gain from birth to 13 weeks was 303 g for whole milk fed calves and 277 g for the group fed with restricted whole milk and the starter feed. A similar finding was reported in Holstein x Gir crossbred calves (Leela Prasad *et al*., 1977). Pre-ruminant calves acquire the ability to digest solid food as the rumen develops and fermentation begins. Maglad *et al*. (1987) reported an average intake of 60 to 70 g of starter feed from day 4 through day 35, which increased to 0.5 to 0.6 kg per day from day 37 to 63 in crossbred calves.

The source and level of fibre in the starter feed influence rumen development. When alfalfa hay, cottonseed hulls and alfalfa-beet pulp were compared as source of fibre, calves fed cottonseed hull ration consumed more starter and gained more weight (Murdock and Wallenius, 1980). With a starter feed formulated for 18 percent crude protein and 14 percent acid detergent fibre, with 15 percent cottonseed hulls in a maize-soybean meal based diet, higher daily body weight gain (0.58 kg versus 0.52 kg) and narrower rumen papillae (0.32 mm versus 0.41 mm) were observed in Holstein calves (Hill *et al.*, 2009).

Because of the stimulatory effect of fibre on rumen development, introducing a prestarter feed in the feeding programme or incorporating a source of fibre in milk replacer can be beneficial (Klein *et al*., 1987). Holstein calves weaned from milk at day 17 and fed with a prestarter feed developed rumen earlier than those weaned at 28 day without feeding the prestarter feed. Feeding prestarter feed promotes faster rumen development, higher rumen bacterial activity and facilitates earlier weaning (Anderson, Nagaraja and Morrill, 1987; Anderson *et al*., 1987). Since soy milk contains soluble fibre and blends very well with whole milk, using soy milk as a partial substitute for whole milk hastens reticulorumen development and increases calves desire to eat calf starter earlier. When calves were offered 10 percent of the body weight, either whole milk or 75 percent whole milk and 25 percent soy milk or 50 percent whole milk and 50 percent soy milk, calves receiving 25 percent and 50 percent soy milk achieved weaning criterion (age at which starter intake of 900 g is achieved) about 10 and 12 days earlier than those receiving whole milk although all calves achieved a similar body weight at 49 days of age (Ghorbani *et al*., 2007).

Source and physical form of carbohydrate in starter feed

Although cereals and their by-products can be used as a source of starch in starter feeds, their effectiveness in promoting rumen development and dry matter intake differs. Maize, oats, molasses and soy hulls are commonly used carbohydrate sources in starter feeds. Replacing maize in a starter feeds with molasses, sucrose, or soy hulls reduce post weaning growth rate. Although molasses may be a cheaper source of energy, inclusion of molasses in texturised starter feeds at 12 percent resulted in growth depression compared with that obtained with starter feed containing 5 percent molasses in Holstein calves when fed from day 2 to 42 (Lesmeister and Heinrichs, 2005). Whole oats can be used as a substitute for maize (Hill *et al*., 2008).

From among ground maize, ground barley, ground wheat, and crimped oats, starter feed containing maize and wheat were more effective in promoting rumen development and dry matter intake (Khan *et al*., 2008).

The physical form and the type of grain also influence nutritional quality of starter feed. Coarse grains are preferred over the fine ground grains. Strusinska *et al*. (2009) reported that the addition of whole maize grains and whole oat grains at the rate of 25 to 50 percent improved weight gain in Holstein Friesian (HF) calves compared with fully ground cereal grains. In HF calves fed pelleted iso-starch (25 percent of starter dry matter) diets containing barley, maize, oat and wheat starch up to 12 weeks of age resulted in higher starter and grass hay intake in calves fed maize diet followed by those fed a wheat, barley and oat diets. Lesmeister and Heinrichs (2004) reported that method of processing maize in starter feed can influence intake, growth and rumen parameters in calves. In neonatal Holstein calves fed starter feeds differing in physical form and texture, containing 33 percent whole (WM), dry rolled (DRM), roasted-rolled (RM) or steam flaked (SFM) maize, dry matter intake was significantly higher for calves fed starter feed containing DRM than RM or SFM. The daily gain also followed the same pattern. However, blood VFAs level and papillary length and rumen wall thickness were higher for calves fed SFM containing starter feed than those fed DRM or WM containing starter feed.

Source and level of protein in milk replacer and starter feeds

Taking into consideration the digestive ability of the pre-ruminants, the sources of proteins and carbohydrates to be chosen for milk replacer need careful consideration (Chapter 2). The recommended specifications for protein levels in milk replacer and starter feed is discussed in Chapter 3. Although these recommendations exclude specifications for amino acid levels, recent studies have indicated that in calves with higher growth potential, apart from protein level in milk replacer diet, the level of amino acids (Hill *et al*., 2008) and the ratio of protein to energy (Hill *et al*., 2009) influence the performance of milk replacer fed calves. Further, the rate of feeding of milk replacer determines the optimum protein level. While 25 percent crude protein, 17 percent fat, 2.26 percent lysine and 0.68 percent methionine is optimum at metabolisable energy intake of 13.64 MJ/day, 27 percent crude protein, 17 percent fat, 2.44 percent lysine and 0.75 percent methionine is optimum at an intake at 15.52 MJ/day (Hill *et al*., 2009).

In starter feed formulations, much more flexibility can be exercised because of improved ability of calves to digest feed protein and carbohydrates. As long as the total crude protein in starter feed is maintained in the range of 18 to 20 percent, the source of protein does not influence the growth performance in crossbred calves (Dhiman, Sharma and Narang, 1983; Gupta *et al*., 1992; Sahoo and Pathak, 1998). The level of protein recommended for starter varies with the expected growth rate. The NRC (1989) recommends 18 percent crude protein for large breeds. Maglad *et al*. (1987) evaluated four calf starters varying in crude protein from 17 to 22.7 percent in Holstein x local crossbred calves and the findings suggest that 17 percent crude protein can support a daily body weight gain of 300 to 400 g when the feeding schedule comprised of, colostrum feeding for the first three days, followed by providing free access to starter feed from day 4 along with whole milk for the successive weeks at the rate (kg/day/calf) of 3.5 for 2 weeks, 2.7 for 3 weeks, 1.7 for 2 weeks and 0.9 for 2 weeks followed by weaning at 10th week.

The findings of the above studies also indicate that to achieve lower daily growth in the range of 300 to 400 g, starter feeds can be formulated with all plant protein sources. Plant proteins, apart from being low in essential amino acids, are also characterised by low availability of phosphorus in monogastrics because of the presence of phytates. However, in pre-ruminant calves, availability of phosphorus from plant protein sources was reported to be high and comparable to that in adult ruminants (Skrivanova, Marounek and Dvorak, 2004). Nonetheless, to achieve higher weight gain, protein sources from animal origin other than from milk and egg are being investigated, but owing to the risk of transmission of BSE, it is perhaps wiser to avoid such by-products in starter feed.

Duration, quantity and frequency of milk and milk replacer feeding

The earlier the calves start eating starter feeds, earlier they can be completely withdrawn from milk. It is generally recommended that in calves when the intake of starter feed of 0.5 to 0.75 kg/day is achieved, milk or milk replacer can be stopped. Krishnamohan, Das and Ranjhan (1987) compared three levels of milk feeding to calves: (i) 80 kg whole milk + 60 kg skim milk, (ii) 100 kg whole milk + 60 kg skim milk (iii) 120 kg whole milk + 60 kg skim milk to each calf up to 60 days of age and three types of calf starters differing in protein source (groundnut cake, linseed cake or til cake). The starter was introduced free choice from 2nd week of age up to three months. The average daily gain from birth to three months ranged from 320.7 to 428.1 g in different groups. There was no significant difference in the daily gain either between levels of milk or between types of starter feeds indicating that a total whole milk of 80 kg, skim milk of 60 kg fed over 60 days of life together with a free access to starter was adequate to achieve a daily growth of 300 to 400 g in crossbred calves with an average birth weight of 26.3 kg. However, reduction in whole milk feeding to less than 85 kg during the first 30 days results in growth retardation (Yanar, 1999; Jasmine Rani *et al.*, 2007) in crossbred calves. Babu, Pandey and Sahoo, (2006) observed that feeding whole milk at 10% of the body weight up to week 4 followed by replacement of whole milk with skim milk from week 5 to week 8 with a free access to starter feed and green fodder is as effective as feeding whole milk to support a daily weight gain ranging from 250 to 300 g.

Higher milk or milk replacer allocation to pre-ruminants retards rumen development. Therefore, the recommended feeding strategy is to restrict milk or milk replacer feeding to promote early start on solid food. Reducing milk feeding frequency from two times a day to once a day is reported to hasten intake of starter feeds in calves (Hussain *et al.*, 2009) without deleteriously affecting body weight gain or glucose metabolism (Stanley *et al.*, 2002).

Restricting milk or milk replacer intake to not more than 10 percent of the body weight promotes early start on solid food (Jasper and Weary, 2002). Milk or milk replacer can be fed with the bucket or with nippled bottle, and it is easier to restrict quantity fed in the bucket feeding system. To avoid over-consumption of milk replacers in the nipple feeding system, acidification of milk replacer is considered as an alternative by adding formic acid to bring down the pH of milk replacers to 4.8. The acidified milk replacers are consumed in small quantities in more frequency which avoids the occurrence of scours (Jaster *et al*., 1990; Güler *et al*., 2006; Yanar, 1999).

BUFFALO

The published studies on the use of milk replacers and starter feeds in buffalo calves are few (Arora, Bajpai and Dave, 1973; Ranjhan, 1992; Ahmad *et al*., 2004). These studies suggested introducing starter feed from 2nd week along with ad libitum hay, while feeding whole milk at the rate of 8 to 10 percent of the body weight up to 4 weeks followed by gradual replacement of whole milk with skim milk, with a complete withdrawal of skim milk from day 60 to support a daily body weight gain of 0.35 kg. Although cow calves performed satisfactorily with this feeding programme, reduction in weight gain by almost 50 percent was observed in buffalo calves compared with the group fed with whole milk (Arora, Bajpai and Dave, 1973). Ahmad *et al*. (2004) compared starter feed with concentrate as a supplement to nipple feeding of milk in buffalo calves aged 45 days. Although the calf starter and herd concentrate had similar protein content (18 percent), starter feed with 5.8 percent crude fibre resulted in a daily gain of 0.47 kg as against 0.34 kg with concentrate containing 11.7 percent crude fibre indicating the advantage of restricting crude fibre level in starter feed for calves to not more than 6 percent.

SHEEP

From the point of convenience and cost, the calf milk replacers are often used for raising lambs and kids with a satisfactory performance (Heaney, Shrestha and Peters, 1982, McKusick, Thomas and Berger, 2001). However, when commercial calf milk replacer was compared with ewes milk, ewe reared (ER) Awassi lambs performed better than the lambs artificially fed (AR) with commercial calf milk replacer supplemented with lamb starter (Emsen *et al*., 2004). The commercial calf milk replacer contained (percent of DM), crude protein 24.5, fat 19, ash 9.5, fibre 0.5 and the lamb starter contained (percent as is) cracked maize 62, soybean meal 31, molasses 4.5, limestone 2 and trace mineral with selenium 0.5. The ER lambs were allowed to nurse their mothers until the weaning age of 45 days without allowing to reach their mothers diet, with the following feeding schedule for artificially reared lambs.

- Colostrum feeding within 6 hours after birth followed by natural suckling for 2 or 3 days
- Day 3 or 4: Nipple bottle feeding of calf milk replacer reconstituted to 20 percent DM at 37^{o} C, twice daily ad libitum
- Day 15: Lamb starter feed at 30 g daily and alfalfa hay ad libitum
- Day 30: Weaning initiated with attainment of body weight of 6 kg

The ER lambs had higher body weight (8.2 versus 6.72 kg, $P < 0.01$) than lambs fed calf milk replacer until 30 days of age. However, at the pre-grazing age of 6 weeks, the ER and the AR group had similar body weights (9.69 and 9.42 kg) and the lamb survival in AR was 85 percent compared to 75 percent in ER. These observations suggest that although calf milk replacer supplemented with lamb starter does not support as much growth as the ewe milk, reduced growth is made up by compensatory gain during the pre-grazing period.

TABLE 5.1
Composition (percent) of lamb starter feed

Ingredient	A	B	C
Grass-legume hay	70	35	–
Dried yam tuber peel	–	35	70
Cotton seed cake	15	15	15
Palm kernel cake	15	15	15
Total feed intake/lamb (kg)	71.3	111.6	88.0
Total gain (kg)	3.3	8.0	17.2

Systems of feeding

From the point of saving labour, different systems of feeding lambs have been investigated (Bimczok, Röhl and Ganter, 2005). In German Grey Heath lambs, three feeding and three weaning regimes were compared. Ad libitum feeding of milk replacer on an automatic lamb feeder, restricted milk replacer feeding on the modified calf feeder 'Stand alone II' or with buckets resulted in average daily gain of 0.262, 0.227 and 0.209 kg respectively ($P < 0.05$). However, feed conversion rate was found best for 'Stand alone-II' (1.17:1), compared to 1.2:1 in group Bucket and 1.23:1 in group ad libitum. Further, abrupt weaning at 12 kg body weight caused weight loss in lambs from the ad libitum and Bucket groups, but not in 'Stand alone' group. However, this post-weaning growth check could be avoided by gradual weaning with reduction of either quantity of milk replacer fed or the dry matter content of reconstituted milk replacer.

Starter feed formulation for lambs weaned at 30 days using yam tuber peel was reported (Anigbogu, 2003). Yam tuber peel is an industrial by-product originating from production of yam flour, yam fufu or yam chips. Three starter diets formulated with inclusion of varying levels of yam tuber peel is given in Table 5.1. The average daily gain for group A, B and C were 43, 104 and 223 g and finishing weight after 77 days of feeding were 11.7, 16.4 and 25.6 kg respectively.

GOAT

Source and level of protein in milk replacer and starter feed

Roasting full fat soybean at 100 ºC for 30 minutes reduces antinutritional properties such as antitryptic activity, immunoreactive glycinin and ß-conglycinin, thereby rendering it as a substitute for milk based protein in milk replacer for goat kids (Ouédraogo *et al.*, 1998). Feeding of Milk replacers formulated with heat treated full fat soybean (Table 5.2) from day 13 to day 50 resulted in similar growth and dry matter intake as in kids fed with milk replacer formulation containing skim milk and whey powder, suggesting that heat treated full fat soybean can be used in milk replacer formulation for goat kids at a level of about 25 percent contributing about 45 percent of the total protein.

The milk replacer formulated by restricting skim milk powder to only 30 percent and the remainder made up with wheat flour, soybean meal, coconut oil and mineral mixture was satisfactory for kids beyond 2 to 3 weeks of age (Dutta *et al.*, 2006; Table 5.3).

TABLE 5.2
Composition (percent as is) of milk replacers without and with roasted full fat soybean flour

Ingredient	**Without roasted soybean flour**	**With roasted soybean flour**
Skim milk powder	62.0	29.3
Fat	21.5	16.1
Soybean flour HSF30	–	26.5
Whey powder	9.5	13.4
Whey concentrate	1.2	8.8
Wheat starch	2.0	2.0
Mineral-vitamin	3.8	3.7
Lactose	–	0.2
	Chemical composition (% DM)	
Crude protein	23.7	26.2
Fat	21.5	23.1

HSF30, Full fat soybean roasted at 100 °C for 30 minutes.

TABLE 5.3
Ingredient composition (percent) of milk replacer (MR) for goat kids

	Proportion by weight (%)			
Ingredients	MR1	MR2	MR3	Whole Milk
Skim milk powder	30	47	63	
Soybean meal	9	9	9.33	
Wheat flour	52	35	18.67	
Coconut oil	7	7	7	
Mineral mixture	2	2	2	
Total	100	100	100	
	Energy (MJ/kg DM) and chemical composition (% DM)			
ME	16.23	16.31	16.44	
DM	92.77	94.08	95.37	16.05
OM	95.74	94.55	93.36	15.11
CP	20.35	24.21	28.15	3.19
CF	0.65	0.70	0.77	–
EE	9.23	9.84	9.35	6.34
Ash	4.26	5.45	6.64	0.94
Cost, Rs/litre	4.43	5.60	6.70	6.50

0.2 ml butyric acid, 2 g citric acid and probiotics (sporolac powder, one sachet having 1.5 x 10^8 spores) were added per kg of each replacer powder.
CF, crude fibre; CP, crude protein; DM, dry matter; EE, ether extract; ME, metabolisable energy; OM, organic matter; Rs, Indian rupee (1 US$ = *ca* 48 Rs).

Milk replacers formulated to contain 20, 24 and 28 percent crude protein when fed as a substitute for whole milk with a gradual increase from 10 percent in week 2 to 3 to 100 percent in week 8 with free access to starter feed and green grass. The kids were weaned from dam at 2 to 3 weeks of age. Whole milk and milk replacer allowances were ad libitum during the first 2 weeks, followed by 6 percent of the body weight from week 3 to 5 and 4 percent of the body weight from week 6 to 8. The kids were trained to drink reconstituted (13.5 percent solids) milk replacer in a nipple fitted bottle in 4 to 5 days. Thus, the daily quantity of milk or milk replacer fed varied from 250 to 350 ml per kid and was fed in two divided doses.

The dry matter intake in whole milk fed and milk replacer fed groups were similar, ranging from 3.28 to 3.93 percent of body weight. The kids fed whole milk gained 74.3 g and the kids fed milk replacer MR1, MR2 and MR3 gained 59.6, 65.5 and 67.8 g/day respectively. The cost of milk and reconstituted milk replacer was Rs 6.5, 4.43, 5.6 and 6.7 respectively (1US$ = *ca* Rs 45). Few cases of nonspecific diarrhoea (5 in whole milk fed group, 8, 2 and 7 in MR1, MR 2 and MR3 respectively) were observed which responded to antibiotic treatment. No mortality was observed in any of the treatment groups due to milk replacer feeding. Therefore it was concluded that milk replacer with 24 percent crude protein may be used safely for kids of 2–13 weeks having inadequate access to mother milk.

Dry matter content

The dry matter content of reconstituted milk replacer is generally kept at 12 to 20 percent. In ad libitum feeding of milk replacer, the voluntary intake is influenced by the dry matter content of milk replacer in calves (Ternouth, Stobo and Roy, 1985) and in lambs (Penning, Corcuera and Treacher, 1980). When the concentration of DM is low, the distension of the abomasum reduces feed intake and at higher DM concentration, energy requirement of the animals regulates voluntary intake (Stobo, Roy and Ganderton, 1979). Similarly in kids fed with milk replacers containing 12 percent or 20 percent DM from day 2 to 20 resulted in daily weight gain of 76 and 115 g ($P < 0.05$). However from day 21–40, this difference in weight gain was reduced resulting in daily weight gain of 135 and 139 g (Sanz Sampelayo *et al.*, 2003). Milk replacer with 120 g DM imposed energy restriction which was overcome at the age of 40 days.

Tacchini *et al*. (2006) compared home-made milk replacer with a commercial calf milk replacer for feeding goat kids. The composition of home-made milk replacer is presented in Table 5.4. Kids were fed with milk replacer ad libitum from day 6 to day 57. The replacers were given warm (at 37 °C) with 17 percent dry matter. The average daily gain for the home-made versus commercial calf milk replacer were 120.6 and 132.3 g ($P < 0.05$). However, the DM conversion index (kg DM/kg gain) was 1.4 and 1.64 respectively and the cost of home-made milk replacer was 40 percent of the commercial calf milk replacer.

Debasis and Chandra (2002) reported that a higher weight gain in kids can be achieved with restricted whole milk supplemented with kid starter feed at 50 g/day when the kids were one month old weighing 3.5 to 4.7 kg. The kid starter was formulated using (percent as is) maize 45, molasses 12, soybean flakes 30, wheat bran 10, mineral mixture 2.5 common salt 0.5 and vitamin mix.

TABLE 5.4
Composition (percent) of home-made kid milk replacer compared with commercial calf milk replacer

Ingredient	Proportion by weight (%)	
Cheese goat whey	29.03	
Yeast *(Saccharomyces cerevisiae)*	13.64	
Dehydrated cow milk	14.51	
Fish meal	5.81	
Maize starch	1.94	
Wheat flour	8.71	
Glucose	8.71	
Butter	3.86	
Maize oil	7.74	
Fish oil	0.48	
Sunflower oil	2.90	
Soy lecithin	1.50	
DL-methionine	0.59	
Min-vit mix	0.68	
	Chemical composition (% DM) and energy (MJ/kg DM)	
Constituent	**Farm made milk replacer**	**Commercial milk replacer**
CP	22.3	24.5
DP	20.1	23.3
EE	29.1	7.9
Ash	7.6	9.1
CF	0.4	0.25
ME	21.8	16.7

CP, crude protein; CF, crude fibre; DM, dry matter; DP, digestible protein; EE, ether extract; ME, metabolisable energy.

CAMELS AND YAKS

The publications related to feeding of pre-ruminant camel and yak are hardly any, although their dependence on milk for nourishment is likely to be as much as for other ruminant species, and the calves are generally in competition with human for milk (Wilson, 1984). Therefore, hand feeding of milk or milk replacer for camel and yak pre-ruminants may also be necessary. Orphan camel calves are often given very dilute milk to avoid indigestion due to overfeeding (Wilson, 1984). The number of feeding per day should be 6 to 8 until 4 weeks of age and this may be reduced to 3 to 4 until 3 months of age, and 1 to 2 from 4 to 5 months of age (Coventry, 2010).

Although the use of milk replacer in cattle but not in pre-ruminants of other animal species, is popular in developed countries, this is not the case in developing countries.

Traditionally, the whole milk or milk replacer feeding included a complex scheme in which the recommended amount fed to each calf is calculated as a percentage of body weight that is continually changing. The quantity of whole milk is started at 6 to 8 percent of birth weight for the first three days, with a gradual increase to 10 percent of the body weight, followed by a gradual reduction after 3 weeks of age until weaning. This procedure of determining the amount of whole milk or milk replacer requires more time and labour for record keeping. The studies conducted have revealed that a simple system of feeding the same amount after the pre-ruminant is trained to drink until weaning can be as effective as the complex scheme (Miller, 1979). However, to avoid diarrhoea, the amount fed during the first few days should not be excessive.

From the foregoing review it appears that in developing countries, the research on the use of milk replacers as substitutes for whole milk is limited and is confined more towards restricted whole milk feeding with introduction of starter feed rather than to a complete replacement of whole milk. However, there have been attempts to develop substitutes for whole milk. A large and rather interesting data on milk replacer formulation and feeding are available in the literature published in the developed countries, the principles of which can be adopted to prepare milk replacers using locally available ingredients.

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Guidelines for formulation and feeding milk replacers and starter feeds

Contrary to meagre research in the developing countries on the use of milk replacers and starter feeds for pre-ruminants, considerable information has been documented in developed countries. Although it is realised that the ingredients used in preparation of milk replacers and starter feeds and the method of feeding varies with geographic location, an understanding of the principles in formulation and feeding could be useful for adopting such practices with modifications to suit the socio-economic conditions of farmers and feed resources available in different regions.

MILK REPLACER

General consideration in formulation

Milk replacers are the substitutes for milk, having characteristics such as the physical form, texture, taste and nutrient content closely resembling whole milk.

- Milk replacer for calves should contain approximately 20–22 percent protein and 10–25 percent fat. This may be adequate for goat kids as well. However, for buffalo calves and lambs higher level of protein (24 percent) – and fat (20–30 percent) is recommended. Fat reduces incidence of scours. Animal fats are better than vegetable fats.
- Calves, lambs and kids of less than three weeks of age should preferably be on milk replacer made of all milk protein. Use of non-milk protein sources can decrease digestibility and result in increased occurrence of diarrhoea.
- After three weeks of age, non-milk protein sources can be used to a variable extent, but not exceeding 40 percent of the total protein. With non-milk protein based milk replacers, the protein level needs to be increased by 1 to 2 percent to compensate for lower digestibility of non-milk proteins.
- Options for non-milk protein sources include soy protein, soy flour, hydrolysed wheat gluten, wheat flour, fish protein concentrate, brewers dried yeast, distillers dried solubles, oat flour, at levels not more than 15 percent, all put together.

Characteristics of a good quality milk replacer

A good milk replacer should:

- contain a minimum of 50 percent spray dried skim milk powder;
- be comparable to whole milk in energy content. Therefore should contain a minimum of 10 percent stabilised high quality fat. However, generally recommended level of fat is between 15 and 20 percent (Moran, 2002);

- have adequate levels of vitamin A, D, E and B_{12};
- contain a minimum of 22 percent protein and should be highly digestible;
- not contain fibre and starch;
- flow well as a powder;
- be readily dispersible and soluble in warm water;
- be cream to light tan, free of lumps and foreign material; and
- have a bland to pleasant odour. A burnt smell is an indication of heat damage. An odour of paint, grass, clay or petrol is suggestive of rancidity of fat Moran 2002).

Formulation and preparation

When milk by-products are available, it may be economical to prepare milk replacers at the farm level. Some examples of milk replacer formulations with 'all-milk proteins' and 'alternate-proteins' for different species of ruminants are presented in Table 6.1.

- Add dried skim milk to the mixer followed by addition of dried whey;
- Mix thoroughly for 10 minutes (Mix 1);

TABLE 6.1
Examples of milk replacer formulation for different pre-ruminant species

Pre-ruminant of	Cattle		Buffalo		Sheep		Goat		Camel		Yak	
	1	2	1	2	1	2	1	2	1	2	1	2
	Ingredient (% as is)											
Whole milk, dried					10		20	6	30	10	7	7
Skim milk, dried	71	40	65	30	65	30	53	39	53	40	65	40
Whey, dried	17	10	12	15	5	15	15	10	5	5		
Fat, vegetable or animal	10	15	20	20	20	25	10	15	10	15	25	20
Lecithin	2	3	3	3		3	2	3	2	3	3	3
Soy protein concentrate		5		5		11		5		5		10
Fish protein concentrate		5		7								
Starch		11		11		8		11		11		9
Distillers dried solubles		10		8		7		10		10		10
Dicalcium phosphate		1		1		1		1		1		1
Vitamins[3]												
	Energy (MJ/kg DM) and chemical composition (% DM)											
ME	19.3	19.7	21.3	20.5	21.8	21.3	20.1	20.1	20.9	20.5	23.0	20.9
CP	28.8	26.5	25.9	24.5	27.5	22.5	26.9	23.7	28.1	24.4	26.1	26.2
Fat	12.3	18.7	22.9	23.5	23.8	28.2	18.2	20.4	21.2	21.6	29.9	25.6

CP, crude protein; DM, dry matter; ME, metabolisable energy; MJ, mega joules.
[1] For the age group from birth to three weeks.
[2] For the age group after three weeks.
[3] As per the recommendations of proprietary preparations to fulfil the requirements indicated in Chapter 3.
Source: Adapted from literature.

- Mix soy protein concentrate, fish protein concentrate, starch, dicalcium phosphate and Min-vit (Mix 2);
- Add Mix-2 to Mix 1 and continue to mix for 10 minutes (Mix 3);
- Mix dried fat with lecithin (Mix 4);
- Add Mix 4 to Mix 3 and mix for another 10 minutes; and
- Keep the mixture in an air tight container for one week.

If fat is not in a dried powder form:

- Heat the fat in a pot just enough to melt. Add soy lecithin and mix well (Mix 1);
- Make a mixture of dry ingredients separately (Mix 2); and
- Add Mix 1 to Mix 2 and mix thoroughly.

Mixers of different capacity can be used depending on the quantity to be mixed. One or two kg of milk replacers can be prepared using domestic food mixers.

Reconstitution

Follow the instructions on the feed tag for reconstituting milk replacer with water. However, in the absence of specific instructions, it is desirable to reconstitute milk replacer to match with the solid content of whole milk. Based on the composition of milk of different ruminant species (Table 6.6), general recommendations (Table 6.2) may be followed for reconstitution.

Material required. Measuring cup or a weighing scale, cooking vessel, stirrer, nippled bottle, bucket, pail or milk feeding equipment.

TABLE 6.2
Recommendations for reconstitution of milk replacers for different species

		Cattle	Buffalo	Sheep	Goat	Camel	Yak
	Weigh (g) milk replacer	125	175	200	145	125	175
	Add water at 60–65 °C (ml) and stir to dissolve	400	400	400	400	400	400
	Add water at 20–25 °C (ml) and mix well	475	425	400	455	475	425
	Transfer to feeding equipment						

Training of new born to artificial (hand) feeding

Once the pre-ruminants start suckling, it is easy to feed milk replacer. Most of the young ones learn to suckle milk from nipple or pail in 2–5 days. Once they learn to suckle, mere sound of milk feeding equipment or sight of milk and of the operator is enough to attract them for milk feeding (Roy, 1980).

Cow and buffalo calves

The calf should be restrained properly (without causing unnecessary stress to the calf) while being trained for artificial feeding. Suckling is a natural instinct in pre-ruminants. Just by inserting finger into the mouth suckling action can be initiated. However training to suckle milk from the pail or from a nippled bottle needs some effort by the trainer. Standing beside the calf, while allowing the calf to suck two fingers in a standing posture, guide the head of the calf gently down into the milk. This has to be done by gradually lowering the fingers to dip into the milk. The calf tends to give up as the fingers are lowered to dip into the milk in a bucket, because in the normal suckling, the head is kept high. The trainer needs patience at this point until the calf gets the taste of milk. It is important that the two fingers are spread apart by 2 to 3 mm to facilitate easy flow of milk into the mouth of the calf. As the calf gets a taste of milk, the fingers should be withdrawn from the mouth and the calf left to drink alone (Figures 6.1 and photo 6.1). This operation will have to be repeated several times before the calf can drink unaided. It is wise to leave the fingers in the calf's mouth for the shortest possible time to avoid the calf getting conditioned to take milk with warm fingers in its mouth. Regardless of whether the calf has been removed from its dam at birth or allowed to suck colostrum for the first four days, it should normally be drinking from a bucket or a pail without assistance at its third feeding.

Buffalo calves are slow in action. Therefore, training buffalo calves needs more time and patience.

FIGURE 6.1
Illustration of training a calf for artificial feeding of milk replacer

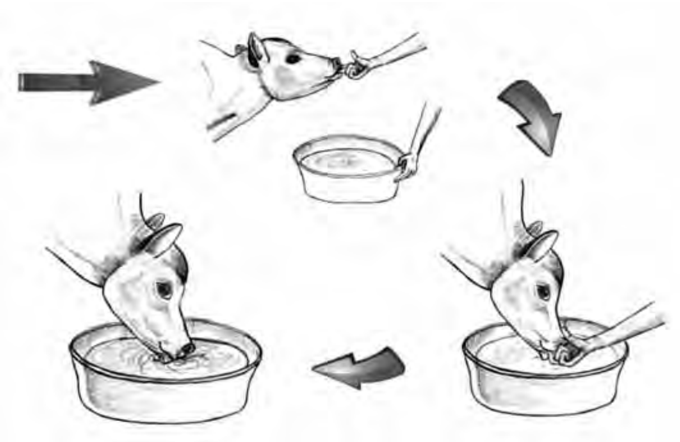


PHOTO 6.1
a. A trained crossbred Jersey calf being fed with milk replacer in a pail

b. A trained Holstein-Friesian calf drinking milk replacer unaided from a pail

Equipment used for milk replacer feeding of calves. Nipple feeding of calves is much easier and it can save time and labour. However, this requires specially designed nipples (Figure 6.2) and feeding equipment. The advantage of nipple feeding is that suckling of nipple stimulates salivation that promotes adequate mixing of milk with saliva thereby facilitating initiation of fat digestion. This also prevents gulping of milk which may predispose the calves to indigestion and scouring. The milk feeding equipment fitted with a single or multiple nipples (Figure 6.3), known as "Milk Bar Calf Feeders" are commercially manufactured and sold. They can also be made locally using a nipple and a plastic bottle. The nipples used for feeding babies, although can work well with lambs and kids, do not last longer.

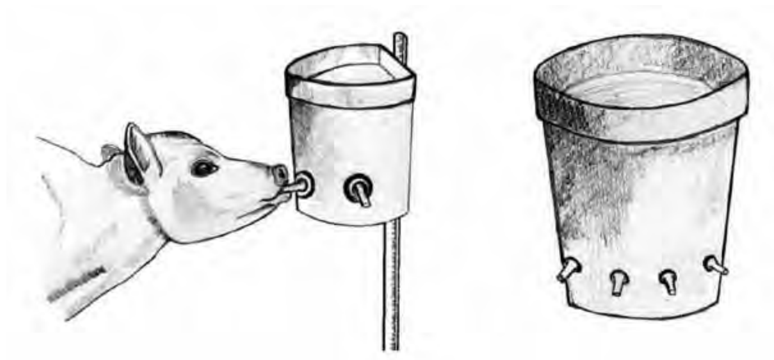
Lambs and kids

Lambs and kids need to be trained to drink from nipples. A simple infant feeding bottle will do well for lambs and kids. In bottle feeding, it is important to keep their mouths well up by supporting their lower jaw in one hand, while holding the neck of the bottle in the other hand (Figure 6.4). This prevents the lambs or kids losing the teat and enables them to swallow safely. Two points that are important when feeding lambs from a milk dispenser are: (i) teat height from ground and (ii) teat angle. If these are wrong, the saliva flow is likely to be affected. Therefore it would be wise to watch the angle a lamb suckles its dam and try to imitate it as best as possible. Once a lamb has been trained to suckle, it can feed from the bottle without supporting lower jaw (Figure 6.4).

Another way to teach the kid is to drink from a pail as is done with calves. The kids learn fast, but this may be difficult with lambs. However this method is not the best, as greedy

FIGURE 6.2
Types of nipples used for pre-ruminant feeding

FIGURE 6.3
Milk replacer feeding equipment for calves



kids are likely to gulp large quantity of milk without allowing proper salivation and mixing of saliva with milk, which may lead to indigestion.

Equipment used for milk replacer feeding of lambs and kids. Infant ruminants have a natural instinct to nurse. Therefore, adapting infant ruminants to nipple feeding is not difficult and this can be successfully done on the first day itself. While nipple fitted bottle is convenient for individual feeding, lamb-bar works better for group feeding. In large scale operations, lamb-bar system consisting of several nipples fitted to a single container is most convenient. Such systems are commercially available and they can also be made in the farm using plastic buckets, plastic tubes, rubber collars and nipples (Figure 6.5).

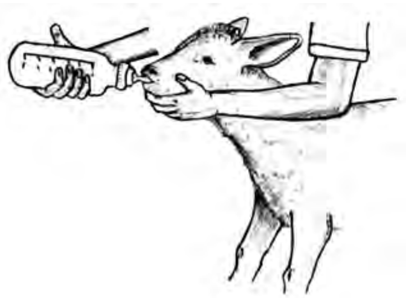
Guidelines for feeding of milk replacers

Cattle and Buffalo

Although the pre-ruminant rearing system varies with species of ruminant, following are the general recommendations for management and feeding new born pre-ruminants to improve resistance to stress and disease:

- Wipe the newborn dry. Normally the dam licks the newborn which would remove the amniotic fluid and the mucus covering the body and improves blood circulation in the skin.

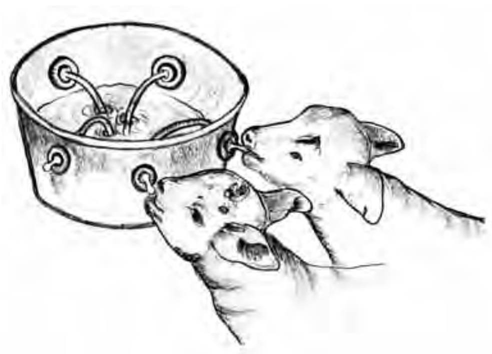
FIGURE 6.4
Milk replaces feeding using a bottle



a. A lamb being trained to suckle from a feeding bottle

b. A trained lamb suckling unaided from a baby-feeding bottle

FIGURE 6.5
Milk replacer feeding equipment for lambs and kids



- House the new born in a dry and draft free pen to protect them cold.
- Feed the first colostrum preferably as soon as possible within 3–6 hours after birth. The term colostrum generally refers to milk produced by dams up to 4–5 days after parturition, until it is acceptable for processing in milk factories. However, the appropriate term for milk produced after the second milking up to five days post-parturition is transition milk, since this no longer possesses the properties of first milk especially with reference to antibodies and nutrients (Moran, 2002). The concentrations of protein, vitamins A, D and E in dairy cow's colostrum are initially about five times those

of whole milk, with a protein content of 17 to 18 percent compared to 2.5 to 3.5 percent. A substantial amount of this protein is in the form of maternal antibodies or immunoglobulins that are responsible to provide passive immunity against many diseases.

- Time of colostrum feeding is crucial. As the time after birth progresses, absorption of immunoglobulins into the blood decreases. After 24 hours immunoglobulins are not absorbed intact.
- Quality of colostrum is also important and this can be assessed visually or more accurately with a colostrometer. A good quality colostrum is thick, rather sticky and creamy yellow. If pregnant dams are not well managed, colostrum quality is reduced. Good management includes feeding good quality diet during the dry period, ensuring they are in good health and minimise stress. The higher the colostrum quality, the faster and more efficiently the immunoglobulins are absorbed by the newborn (Moran, 2002).
- The current advice for feeding colostrum is to ensure two feedings during the first day, the first feeding soon after birth, preferably within 3–6 hours after birth at the rate of approximately 10 percent of the body weight (i.e., 3 to 4 kg for calves depending on their body weight) followed by, if the calf is willing to drink, about half the quantity of first feeding within the next 6 hours (i.e., 1 to 2 kg for calves) (Moran, 2002). Colostrum feeding can be done via teat by natural suckling, or artificially with a nippled bottle, bucket or stomach tube. However, feeding in a bucket takes more time and is difficult to feed the recommended quantity because the new born are not yet trained to drink from a bucket. Although feeding through a stomach tube is practiced in some farms in developed countries, this requires the skill and knowledge of passing stomach tube and hence it may be difficult to adopt. Regardless of the method of feeding, it is utmost important to feed colostrum as soon as possible after birth in order to facilitate absorption of intact immmunoglobulins that are responsible for providing resistance against many common diseases in calves (Moran, 2002).
- Subsequently feed transition milk or whole milk twice in a day at an interval of 10 to 12 hours, at the rate of about 4–5 percent of the body weight in each feeding.
- Over feeding a liquid diet may cause scours (diarrhoea). When the signs of scour are observed, reduce the amount of milk or milk replacer.
- Generally the calf milk replacer powders are reconstituted by mixing 7 or 8 parts of water with 1 part of powder by weight to make a liquid containing about 12 percent total solids comparable to whole milk (Table 6.2). Since buffalo milk has a higher solid content (Table 6.6), it may be desirable to mix 4.5 parts of water with 1 part of powder to get about 18 percent solids comparable to buffalo milk.
- Although whole milk can be completely replaced by milk replacers from day 4, a gradual introduction of milk replacers by blending with whole milk and complete replacement over 5 to 7 days is a good practice.
- Feed the calves regularly and twice in a day. A calf weighing 30 kg should be fed a total of 2.4 kg of milk per day split in two feedings. Although an interval of 12 hours between two feedings is ideal, feeding at intervals of 8 and 16 hours have been found

to cause no apparent discomfort to calves. Once a day feeding is also practiced by farmers but this requires more attention on the occurrence of scours especially in early age.

- Milk or milk replacers should be fed at the same temperature in each feeding. Although feeding at 35 to 38 °C is preferable, feeding at room temperature is also acceptable. The temperature at every feeding should be consistent, to minimise the incidence of scouring.
- Calves must receive milk or milk replacers for at least 4 weeks, and may be extended to 6 to 8 weeks depending upon the starter feed intake.
- Calves can be weaned from milk or milk replacers when the starter feed intake of at least 1 percent of the body weight is achieved. This amounts to about 0.5 kg/day for a calf weighing 50 kg (Gillespie, 2002; Moran, 2002).
- Feed calf starter feed and high quality hay free choice starting at 7 to 10 days of age. Fresh clean water must be made available. Teach the calf to eat starter feed by rubbing on the muzzle.
- Make sure to use clean feeding utensils and keep the surroundings clean and hygienic.

A simplified calf feeding programme using milk replacer and starter feed (Table 6.3) involves feeding four different diet components (Ensminger, 1980).

- Colostrum feeding on the first day followed by transition milk for the next four days of life
- Milk replacer from day 5 to a minimum of day 28 and preferably up to day 56
- Starter feed with approximately 70–80 percent total digestible nutrients (TDN) and 18–20 percent protein from day 7 to 4 months of age
- Good quality hay from day 10

Sheep and Goat

General care of the newborn calves applies to lambs and kids as well. Lambs and kids should be inspected more often, at least four times a day and feeding them often gives a clue to the onset of trouble. During the first crucial ninety days, the lambs can develop pneumonia, coccidiosis, secondary infections or just drop dead for no apparent reason. Many lamb problems are exacerbated by bad housing, insufficient air circulation, lack of water, unclean feeding equipment, damp bedding, and imbalanced feeding or any condition conducive to the growth of bacterial and viral diseases. Even with adequate colostrum intake, artificially reared lambs seem to be more susceptible to breakdown in resistance, leading to the incidence of scouring and other digestive trouble. This can be a function of stress, which could be nutritional and psychological.

- If the lambs or kids are to be taken off at birth, allow the dam to lick the newborn dry, put in a dry and draft free pen and start as soon as possible to bottle feed the colostrum drawn from its own dam.
- Newborn lambs can also be left with dam for the first 24 hours to suckle colostrum and then taken off. The longer the lambs are allowed with the dam, the more is the stress of separation.
- Feed colostrum at six hourly intervals for the first 24 hours either ad libitum or at the rate of approximately 4–5 percent of the body weight in each feeding (Brandano, Rassu and Lanza, 2005). For details on importance of colostrum feeding please refer to subsection on cattle and buffalo.

TABLE 6.3
Recommended calf feeding programme using milk replacer and starter feed

Age (days)	Milk replacer (Mix 1 part dry milk replacer with 7 parts of warm water (39ºC) just before feeding)	Starter diet (70 to 80% total digestible nutrients, 18 to 20% protein, fortified with vitamins and minerals)	Good quality hay
1	Colostrum at the rate of 3 to 4 kg within 6 hours after birth (approximately 0.1 kg per kg of body weight) followed by 1.5 to 2 kg within the next 6 hours (approximately 0.05 kg per kg of body weight)		
2–4	Colostrum or transition milk daily at 0.06 to 0.08 kg per kg of body weight per day, given in two equal feedings		
5–14	Switch from colostrum or transition milk to milk replacer Calves of 25 to 30 kg birth weight: daily 2.5 kg, given in two equal feedings Calves of 30 to 35 kg birth weight: daily 3.0 kg, given in two equal feedings.	Begin starter diet free-choice from day 7	Start hay free choice from day 10
15–28	Calves of 25 to 30 kg birth weight: daily 3.0 kg, given in two equal feedings Calves of 30 to 35 kg birth weight: daily 3.5 kg, given in two equal feedings.		
29–42	Calves of 25 to 30 kg birth weight: daily 2.5 kg, given in two equal feedings Calves of 30 to 35 kg birth weight: daily 3.0 kg, given in two equal feedings.		
43–56	Start weaning[1] Calves of 25 to 30 kg birth weight: daily 2.5 kg, given in two equal feedings. Calves of 30 to 35 kg birth weight: daily 3.0 kg, given in two equal feedings.		
57–120		Continue starter feed free-choice	Continue hay free- choice

[1] Age at weaning depends on the purpose for which the calves are raised. From the economic point of view, weaning should be done at the youngest age possible. Calves reared on too low a plane of nutrition during the first 3 months of life may be adversely affected as meat producing animals and do not compensate in growth during first year of life.

- If the mother milk is replaced by a milk replacer, feed three times a day at 4 to 5 percent of the body weight in each feeding (Eales and Small, 1986).
- Reconstitution of milk replacers depends on the purpose for which the lambs and kids are raised. For lambs, dry matter of 24 percent is recommended for those intended for fattening, and 20 percent for those to be raised as replacement stock (Brandano, Rassu and Lanza, 2005). For goat kids, dry matter of 20 percent is recommended

for fattening and 14 to 15 percent for replacement stock (Table 6.2). Dry matter concentrations in excess of requirement leads to digestive disturbances and higher feeding cost.

- Offer dry feed and good quality hay from 5th day of life. Lambs and kids start eating dry feed by about 7 days of age. Allowing younger and elder ones together in creep area hastens dry feed intake in younger ones.
- The lambs and kids are weaned gradually as the intake of solid feed increases. This may be about 6 weeks. The time for weaning depends on the age and body weight which are appropriate for that particular breed. In practice, the body weight is a more important criterion than the age. The recommended weight for weaning is at least 2.5 to 3 times the weight at birth.
- Weaning should last for about 2 weeks (6th and 7th). Gradual weaning is preferable, and the transition from a milk or milk replacer diet to solids-only should take at least 1 week.
- Weaning will depend on dry matter intake. In order to completely withdraw milk or milk replacer, either reduce the dry matter in the reconstituted milk replacer without reducing the total amount of liquid given per day, or give milk in their milk bar during the day and change over to drinking water at night. Young ones suffer more from thirst than actual hunger. Liquid gives them a sense of fill. As soon as they have trebled their birth weight and are chewing their cuds satisfactorily, they can be taken off milk or milk replacer. Once safely off milk replacer, they should be kept on clean pasture with plenty of water and fed with concentrates and a good quality hay ad libitum.
- The fattening animals are fed ad libitum of a milk replacer with high energy and high protein than the replacement animals. Dry matter content of 12–15 percent versus 10–12 percent, fat content of 25–30 percent versus 20 percent, protein content of 24 versus 20 percent are recommended. This results in increasing dry matter intake at 1.2 to 1.5 percent of body weight versus 1 to 1.2 percent.
- Delivery temperature of milk replacer can be one of the following (i) Refrigerated temperature (3–4 °C), or body temperature of 36–38 °C or the ambient temperature (Brandano, Rassu and Lanza, 2005). Delivering at the ambient temperature is the most convenient method. In this case the reconstituted milk should be distributed immediately to prevent spoilage. Alternately the milk replacer can be acidified and fed. Acidified milk replacers are not very appetizing and hence can be used for lambs that will be weaned and not for those being fattened for immediate slaughter, as lambs fed with acidified milk grow slowly and the meat produced is poor in taste and consistency.

A simplified feeding programme for lambs and kids using milk replacer and starter feed is given in Table 6.4. This programme involves feeding four different diet components:

- Colostrum feeding on the first day followed by transition milk for the next four days of life;
- Milk replacer from day 5 to day 56;
- Gradual withdrawal of milk replacer from day 43 to a complete stop by day 56;

TABLE 6.4
Recommended feeding programme for lambs and kids using milk replacer and starter feed

Age (days)	Milk replacer (Mix 1 part dry milk replacer with 4 parts of warm water (39 ºC) for lambs and 6 parts for kids just before feeding)	Starter diet (80–85% total digestible nutrients, 20–22% protein, fortified with vitamins and minerals)	Good quality hay
1	Colostrum ad libitum within 6 hours after birth or at the rate of 0.05 kg per kg of body weight followed by the same quantity at every 6 hours.		
2–4	Colostrum or transition milk daily at 0.05 kg per kg of body weight in each feeding, given in three feedings		
5–14	Switch from colostrum or transition milk to milk replacer Lambs and kids of 2.0 to 2.5 kg birth weight: daily 0.25 kg given in two or three equal feedings Lambs and kids of 2.6 to 4.0 kg birth weight: daily 0.4 kg, given in two or three equal feedings	Begin starter feed free-choice from day 7	Start hay free choice from day 10
15–28	Lambs and kids of 2.0 to 2.5 kg birth weight: daily 0.35 kg, in two or three equal feedings Lambs and kids of 2.6 to 4.0 kg birth weight: daily 0.6 kg, given in two or three equal feedings		
29–42	Lambs and kids of 2.0 to 2.5 kg birth weight: daily 0.25 kg, in two or three equal feedings Lambs and kids of 2.6 to 4.0 kg birth weight: daily 0.4 kg, given in two equal feedings		
43–56	Start weaning Lambs and kids of 2.0 to 2.5 kg birth weight: daily 0.15 kg, given in two or three equal feedings Lambs and kids of 2.6 to 4.0 kg birth weight: daily 0.2 kg, given in two equal feedings		
57–150		Continue starter feed free-choice	Continue hay free- choice

- Starter feed with approximately 80 to 85 percent total digestible nutrients and 20 to 22 percent protein from day 5 to 5 months or continue as long as needed; and
- Good quality hay from day 10.

Camel

Like other species of pre-ruminants, camel calves also need colostrum for their survivability. Normally camel calves can stand and suckle within two hours after birth. The general guidelines recommended for cow-calves apply to camel calves as well. The suggested milk replacer feeding programme for camel calves is presented in Table 6.5.

TABLE 6.5
Recommended feeding programme for camel calves using milk replacer and starter feed

Age (days)	Milk replacer (Mix 1 part dry milk replacer with 7 or 8 parts of warm water (39 °C) just before feeding)	Starter diet (70–80% total digestible nutrients, 21% protein, fortified with vitamins and minerals)	Good quality hay
1–2	Colostrum daily at 0.06 kg per kg of body weight, given in 12 equal feedings		
3–7	Switch from colostrum to milk replacer daily at 0.1 kg per kg body weight, given in 8 equal feedings		
8–28	Milk replacer daily at 0.2 kg per kg body weight, given in 6 equal feeding		
29–56	Milk replacer daily at 0.2 kg per kg body weight given in 4 equal feedings		
57–84	Milk replacer daily at 0.15 kg per kg body weight, given in 3 equal feedings	Provide starter feed	
85–112	Milk replacer daily at 0.07 kg per kg body weight, given in 2 equal feedings	Continue starter feed free-choice	Continue hay free- choice
113–140	Milk replacer daily at 0.03 kg per kg body weight, given in a single feeding	Continue starter feed free-choice	Continue hay free- choice

Source: Adapted from Coventry (2010).

ALTERNATIVES TO MILK REPLACERS

Using trans-species milk

The simplest of all the milk replacers is the milk from another species. The age old practice of substituting milk of one species of ruminant by that of another species is practiced even today to take advantage of availability, of a better price of the commodity, or of the survivability of young ones. The first choice is always cow milk because of its abundance. For example, cow milk is used for feeding goats, if goat milk fetches a higher price or if the doe has more kids to milk-feed than she can produce. Similarly cow milk is used as a substitute for buffalo milk for feeding buffalo calves because of the higher price of buffalo milk or the buffalo-cow not producing enough milk to feed the calf. Although trans-species milk can be used as the substitute for dam's milk, one should realise its limitations because of the differences in physical, chemical and nutritional qualities of milk from different species. From the composition presented in Table 6.6, milk of cattle, camel and goat are comparable, while that of sheep, buffalo and yak are similar. Therefore, milk substitution among cattle, camel and goat may be possible as is the case among sheep, buffalo and yak. Cow, goat and camel milk are low in fat and protein compared to sheep, buffalo and yak milk.

In a situation where there is no choice to feeding lambs, buffalo calves and yak calves other than with cow, goat or camel milk, milk of these species may be reconstituted as follows.

- Add two tablespoonful of maize oil or any edible oil to one litre of cow milk or goat milk and warm the milk to body temperature but do not boil (Gillespie, 2002). This will increase the fat content but not the protein.

TABLE 6.6
Chemical composition (percent) and energy content of milk of different ruminant species

	Water	Protein	Fat	Lactose	Ash	Calcium	Phosphorus	Energy MJ/kg
Species					**% as is**			
Camel	87.2	3.7	4.2	4.1	0.8			3.2
Cow	87.2	3.5	3.7	4.9	0.7	0.12	0.10	3.1
Goat	86.5	3.6	4.0	5.1	0.8	0.13	0.10	3.3
Buffalo	83.0	3.8	7.5	4.9	0.8	0.18	0.12	4.6
Sheep	80.1	5.8	8.4	4.8	0.9	0.25	0.17	5.4
Yak	82.7	5.1	6.5	4.8	0.9			4.8
					% Dry matter			
Camel		28.9	32.8	32.0	5.9			24.9
Cow		27.3	28.9	38.3	5.5	0.94	0.78	23.9
Goat		26.7	29.6	37.8	5.9	0.96	0.74	24.5
Buffalo		22.4	44.1	28.8	4.6	1.06	0.71	26.8
Sheep		29.1	42.2	24.1	4.6	1.26	0.85	27.1
Yak[1]		29.5	37.6	27.8	4.9			27.9

[1] Wiener *et al.* (2003).
Source: Maynard and Loosli (1969).

- Add 50 g of dried whole cow milk and two tablespoonful of maize oil to one litre of fresh cow or goat milk. This will increase the dry matter and other nutrients of reconstituted milk to make it comparable with sheep milk.
- On a similar principle, if pre-ruminants of cow, goat or camel are to be fed with buffalo, sheep or yak milk, reconstitute fresh milk of buffalo, sheep or yak by adding water in a ratio of 2:1.
- The thumb rule for daily milk allowance for any pre-ruminant species is approximately 8 to 10 percent of its body weight.

USING RESTRICTED WHOLE MILK OR MILK BY-PRODUCTS AND PRE-STARTER FEED IN PORRIDGE FORM

Preparation of milk replacers or starter feeds on-farm can be economical, if the required ingredients are locally available. The preparation of good quality milk replacers require milk based by-products such as dried skim milk, dried whey, animal fat and vitamin and mineral supplements which are often not available or even if available would be too expensive in many developing countries. Therefore, restricting whole milk feeding rather than complete replacement of whole milk can be adopted with substitutes such as dried or fresh skim milk or whey together with gruel or porridge made from cereal flour and oil seed cake (Roy, 1980). In this method of feeding, milk is replaced with gruel during the 3rd or 4th week of life and the gruel forms the sole liquid feed from 5 weeks of age. The calf is then weaned to a dry starter feed by about 8th week. Porridge feeding is labour intensive and hence, is not a common practice. However, small farmers in the developing countries practice porridge feeding as an economical substitute for whole milk.

Whole milk with porridge

In farms where no by-products of milk are available, gruel (or porridge) made from cereal flour and oil seed cakes can be used as a pre-starter to replace whole milk. Unlike the starter feed which is generally offered dry, it is desirable to heat the pre-starters to boil for a few minutes to make porridge. Heating to boil makes the pre-starters easily digestible and relatively free of contaminated micro organisms. Porridge is semisolid in consistency, and the suckling calves can easily be trained to eat porridge in the first week of age by smearing porridge on the lips. Making calves to eat porridge is a better practice than mixing with milk. The act of eating would allow porridge to enter the rumen, thereby contributing to hasten rumen development. Therefore it is desirable to feed porridge in the mid-interval of two successive milk feedings. Introduce porridge gradually, starting 100 g per day (equivalent to 20 to 30 g of dry matter) by about 10 days of age and gradually increasing to about 3 kg by 4 weeks and by 6 weeks replace this completely with dry starter feed. Porridge can be made from a starter feed by heating to boil with water in a ratio of about 1:4. The general formula for the porridge mixture is the following.

- Ground oil seed meal (groundnut meal, gingelly meal, decorticated sunflower meal, soybean meal, linseed meal,) 30 to 40 percent, ground oil seeds (roasted full fat soybean, linseed) 5 to 10 percent, ground cereal (wheat, oat, barley, maize, sorghum, broken rice) 40 to 50 percent, mineral and vitamin mixture 1 percent.
- Prepare a porridge by boiling this mixture with water in a ratio of 1: 4 (w/v).

The porridge mixture may either be mixed on the farm or obtained as a ready-mix. With porridge feeding, the total quantity of milk fed to a calf can be restricted to about 90 litres during milk feeding period of 30 days. Some examples of porridge formulations are given in Table 6.7. Porridge used as partial milk replacers should contain 20–24 percent protein, 4.5 to 7.0 percent fat, and preferably but not necessarily, not more than 6 per cent crude fibre. It should also contain 1 to 1.5 percent calcium carbonate (lime) and 0.5 per cent sodium chloride.

To prepare home-made porridge, add porridge mixture to water at a ratio of 1:4 (w/v).

- Measure required quantity of porridge mixture and water in two separate containers;
- Add porridge mixture to an equal quantity of water in a cooking vessel;
- Mix into a smooth paste;
- Add approximately half of the remaining water;
- Heat to boil for five to ten minutes; and
- Add the remaining water and stir well. Cool the porridge to 35 to 38 °C. It is ready for feeding.

Proprietary porridge should be prepared as per manufacturer's instructions.

The feeding programme for whole milk supplementation with porridge mixture for calves is given in Table 6.8.

Supplementation of skim milk

About 50 percent of the whole milk can be replaced by skim milk when calves are 15 days old; and by 30 days whole milk can be completely replaced. Since skim milk is obtained after removal of fat from whole milk, when skim milk is used as a replacer of whole milk, skim milk should be supplemented with cheaper vegetable fat and fat soluble vitamins.

TABLE 6.7
Ingredient proportion (percent by weight) of pre-starter mixture to supplement whole milk

	Pre-starter mixture				
Ingredient	**1**	**2**	**3**	**4**	**5**
Barley		10			
Coconut meal[1]		13			
Maize	25		20	40	65
Maize gluten meal				5	
Cotton seed meal	5		5	7	
Linseed			11		
Linseed meal, m.e.	15		5		
Molasses		2	2	2	
Oats	15				
Peanut meal	5	20		5	35
Rapeseed meal			5		
Rice bran		15			
Rice, broken		25			
Sesame meal, m.e.		10			
Sorghum			20		
Soybean meal	15			16	
Sunflower meal			20		
Wheat	20	5	12	20	
Wheat bran				5	
Mineral-vitamin mix[2]					
	Energy (MJ/kg DM) and chemical composition (% DM)				
ME	14.1	13.8	14.0	14.2	14.0
TDN	83	81	82.6	83.5	82.2
CP	24.8	23.9	24.3	23.2	24
CF	6.8	7	6.3	5.1	5.5
Fat	3.4	4.9	7.2	2.6	3.1

CP, crude protein, CF, crude fibre; DM, dry matter; ME, metabolisable energy; TDN, total digestible nutrients; m.e., mechanically extracted.
[1] Meal refers to solvent extracted unless indicated otherwise.
[2] To be added as per the recommendation of proprietary preparations.

Addition of fat (in a bucket)

- Measure 970 ml of fresh skim milk or reconstitute 100 g of dried skim milk to 970 ml with warm water;
  – Measure 100 ml warm water (50–60 ºC) in a tumbler,
  – Add 100 g skim milk powder,
  – Stir with a spoon to make into a paste,
  – Continue to add water and mix until the total volume is 970 ml.

TABLE 6.8
Feeding schedule for whole milk supplementation with porridge mixture for calves

Age (Days)	Whole milk	Cooked pre-starter porridge mixture
1	Colostrum at the rate of 3 to 4 kg within 6 hours after birth (approximately 0.1 kg per kg of body weight) followed by 1.5 to 2 kg within the next 6 hours (approximately 0.05 kg per kg of body weight)	-
2–4	Colostrum or transition milk daily at 0.06 to 0.08 kg per kg of body weight per day, given in two equal feedings	
5–7	Whole milk daily at 0.1 kg per kg body weight or 2.5 to 3.0 kg in two equal feedings	
8–21	Whole milk daily at 0.1 kg per kg body weight or 2.5 to 3.0 kg in two equal feedings	Train to eat porridge @ 100 g per day
22–35	Reduce whole milk by 0.5 kg from the previous week or provide daily 2 to 2.5 kg in two equal feedings	Daily 0.25 to 0.5 kg
36–49	Reduce whole milk by 0.5 kg from the previous week or provide daily 1.5 to 2.0 kg in two equal feedings	Daily 1.0 kg
50–56	Reduce whole milk by 0.5 kg from the previous week or provide daily 1 to 1.5 kg in two equal feedings	Daily 1.5 kg
57–63	Reduce whole milk by 0.5 kg from the previous week or provide daily 0.5 to 1.0 kg in single or two equal feedings	Daily 2.0 kg; provide dry starter free choice
64–70	Reduce whole milk by 0.5 kg from the previous week or stop milk feeding.	Daily 3.0 kg; provide dry starter free choice
71-120		Change over to dry starter free choice

- Add 30 g of edible vegetable oil or animal fat in a liquid form;
- Add 700 IU of vitamin A and 175 IU of vitamin D;
- Mix and pour the contents from one bucket to the other twice or thrice to ensure uniform mixing of fat with skim milk before serving to the calf.

Addition of porridge

As with whole milk, pre-starter porridge mixture can also be used as a supplement to skim milk. However, since the skim milk is low in fat and high in protein compared to whole milk, porridge mixture to supplement skim milk is formulated for high fat and low protein. Some examples of pre-starter porridge mixture as skim milk supplement are given in Table 6.9.

Whey

Measure 900 ml of fresh whey or reconstitute 70 g dried whey powder to 900 ml with warm water;

- Measure 100 ml warm water (50–60 ºC) in a tumbler,
- Add 70 g dried whey powder,
- Stir with a spoon to make into a paste,
- Continue to add water and mix until the total volume is 900 ml.

TABLE 6.9
Ingredient proportion (percent by weight) of pre-starter mixture to supplement skim milk

	Pre-starter mixture				
Ingredient	**1**	**2**	**3**	**4**	**5**
Barley		15	17		
Coconut meal[1]				5	
Maize	30	15		15	45
Cotton seed meal				5	
Linseed				10	
Linseed meal, m.e.	7				
Linseed meal				10	
Molasses		5	3	3	3
Oats	10		10		
Pea seeds		8			
Peanut meal, m.e.		9			25
Peanut meal	5				
Rapeseed meal			5		
Rice bran	5			5	
Rice, broken				15	
Sesame meal, m.e		5		5	
Sorghum				27	27
Soybean			15		
Soybean meal	15				
Sunflower meal		4			
Wheat	25	30	50		
Wheat bran		6			
Oil	3	3			
Mineral-vitamin mix[2]					
	Energy (MJ/kg DM) and chemical composition (% DM)				
ME	14.7	14.6	14.7	14.4	14.1
TDN	86.2	85.7	86.3	84.9	83
CP	20.8	20.0	19.3	17.9	18.5
CF	5.7	4.8	5.1	5	3.6
Fat	6.6	6.0	4.7	7.4	4.3

CP, crude protein, CF, crude fibre; DM, dry matter; ME, metabolisable energy; TDN, total digestible nutrients; m.e., mechanically extracted.
[1] Meal refers to solvent extracted unless indicated otherwise.
[2] To be added as per the recommendation of proprietary preparations.

Whey feeding is not as straight forward as feeding of skim milk. Since whey is high in lactose and low in protein and fat, its retention time in the abomasum is too short, hence can make calves prone to scours. Unlike skim milk, whey should not be introduced before a calf is at least two weeks old and the changeover from whole milk to whey should be gradual. However, with proper supplementation, whey can also be used effectively. Approximately 33 g fat and 25 g protein are removed from one kg of milk, which therefore need to be supplemented to whey. Whey supplements formulated to contain about 20 to 25 percent fat and 30 to 35 percent protein (Roy, 1980) can be used as whey supplement at 100 g per kg liquid whey. Such supplements may first be given as porridge and later in a dry form. Examples of pre-starter formulations that can be used in porridge form as a supplement to whey are presented in Table 6.10.

STARTER FEEDS

Starter feeds are the mixtures of feed ingredients intended to adapt pre-ruminants from milk feeding to dry feed and fodder, to hasten transition from pre-ruminant to ruminant stage.

Characteristics of a good quality starter feed

A good starter feed should:

- contain 18 to 20 percent protein;
- not contain more than 8 percent crude fibre or 15 percent neutral detergent fibre or 6 percent acid detergent fibre;
- contain a minimum of 3 percent fat. Fat reduces dustiness and improves taste.
- be easily digestible;
- be palatable;
- not be dusty;
- not be too hard to chew; and
- Should not have unpleasant flavour.

Methods to promote early starter feed intake in pre-ruminants

Starter feeds should be offered at the age of 7 days. Though the pre-ruminants may not eat significant quantity of starter feed at this age, they tend to explore and nibble at the starter feed. This would be a good practice to teach the young ones by rubbing on the muzzle or placing small amount in the milk pail following milk feeding.

The calves can be weaned easily and successfully when the starter feed intake of 0.75 to 1 percent of the body weight is achieved. In large breeds such as Holstein Friesian, the calves can be weaned easily when consuming at least 0.65 to 0.70 kg of a good quality starter feed daily for 3 consecutive days. Under good management, with restricted milk or milk replacer feeding this can occur as early as four weeks of age (Kertz, Prewitt and Everett, 1979). Excess milk or milk replacer feeding delays starter intake and weaning age (Huber *et al.*, 1984). Therefore, restricting milk or milk replacer to 8 to 10 percent of the birth weight is recommended (NRC 2001). The factors that promote early intake of dry feed are:

- Free access to clean drinking water (Kertz, Reutzel and Mahoney, 1984);
- Provision of palatable starter feeds; coarsely ground rather than finely ground, rolled or pelleted;
- Keeping feeds fresh, dry, and free of mould;
- Good health of calves, generally free of scours; and
- Establishment of stable ruminal fermentation with pH greater than 5.5.

TABLE 6.10
Ingredient proportion (percent by weight) of pre-starter mixture to supplement whey

	Pre-starter mixture				
Ingredient	**1**	**2**	**3**	**4**	**5**
Barley		30	10		
Maize	30		15	40	30
Maize gluten meal				5	
Cotton seed meal[1]		5	5	7	
Linseed meal, mech extd.			15		
Linseed meal,			15		
Molasses				2	
Peanut meal	30		25	15	
Rapeseed meal		5	5	5	
Soybean		30			20
Soybean meal	20	20		16	40
Wheat	10	5			
Vegetable oil	10	5	10	10	10
Mineral-vitamin mix[2]					
	Energy (MJ/kg DM) and chemical composition (% DM)				
ME	15.6	15.6	16.3	15.5	16.4
TDN	91.9	91.9	95.7	91.2	96.4
CP	28.4	29.1	28.4	26.2	28
CF	5.8	6.3	7.4	5.7	4.8
Fat	12	11.5	18.2	12.2	15.1

CP, crude protein, CF, crude fibre; DM, dry matter; ME, metabolisable energy; TDN, total digestible nutrients.
[1] Meal refers to solvent extracted unless indicated otherwise.
[2] To be added as per the recommendation of proprietary preparations.

Formulation and preparation

In general, starter feeds should include a minimum of 40 to 60 percent cereals and 30 to 40 percent oilseed cake as protein source, and 1 to 2 percent mineral and vitamin premix. It can also contain 10 to 15 percent by-products of cereals and pulses and up to 5 percent molasses. While cereals provide energy, oilseed cakes supply proteins, by-products act as fillers and molasses improves palatability. The starter feeds should be coarsely ground, rolled or pelleted. If the starter feed is ground too finely, palatability and feed intake decrease. Although pre-starter formulations can also be used as starters, for economic reasons starters can be formulated with cheaper feed ingredients and higher fibre content. Some examples of starter feed formulation are given in Table 6.11. These are general formula and can be used on any of the ruminant species discussed in this manual.

Equipment required: Hammer mill, mixer, weighing scale, buckets for weighing, water proof polythene bags.

Mixing and preparation:

- Grind each feed ingredient separately in a hammer mill. Feed ingredients should be ground coarsely;
- Turn on the mixer;
- Weigh required quantity of coarsely ground cereal and add to the mixer;
- Weigh required quantity of hammer milled oil seed meal and add to the mixer;
- Weigh required quantity of other feedstuffs used in formulation and add to the mixer one after the other as the mixer is rotating;
- Add mineral-vitamin premix;
- Finally add molasses slowly and continue mixing for about 15 minutes; and
- Turn off the mixer and transfer the contents to water proof polythene bags and close the bag with a tie knot.

The final words

Milk replacers are the substitutes for milk that provide a convenient way to feed pre-ruminant stock. They are generally made up of ingredients such as skim milk powder, vegetable or animal fat, butter milk powder, whey protein, soy lecithin and vitamin-mineral premix. A small proportion of other ingredients like glucose, non-milk protein and cereal flour can also be used. Pre-ruminant stock of less than three weeks of age should preferably be fed on milk replacer made of all milk protein. Preparation of milk replacers on-farm requires procurement of required ingredients and equipment for proper measurements, uniform mixing and proper storage in air tight containers. They can be stored long term as powder and reconstituted by mixing with water as per the recommendation. Young stock can grow equally well when reared on milk replacer and their rumen can develop just as well as they would on a diet of whole milk. The cost of milk replacer must be competitive with whole milk for livestock farmers to consider using it when they may have copious supplies of fresh milk from their own farm. In a mixed farming system, surplus fresh milk from one ruminant species can be reconstituted to formulate milk replacer for another ruminant species. If by-products of whole milk such as skim milk or whey are produced on-farm they can also be used as a partial replacer for whole milk or can be reconstituted as a milk replacer with the addition of required ingredients. Supplementing such milk replacers with pre-starter porridge is also a promising approach to whole milk replacement in the feeding system specially for cow and buffalo calves. Despite these options, most farmers in developing countries only use whole milk in their pre-ruminant rearing systems. By increasing awareness about the potential of preparing milk replacers and feeding to pre-ruminant young stock, their use can be enhanced to improve survivability and growth of pre-ruminant stock.

As the rumen develops, pre-ruminant's dependence on milk replacers declines and substantial proportion of their nutrient requirements can be met from starter feeds. Starter feeds are solid food prepared from mixing cereals, oilseed meals, mineral and vitamin mixture. Starter feeds should be offered to pre-ruminants along with good quality hay starting from 5 to 7 days of age. When the intake of starter feed reaches about 0.75 to 1 percent of the body weight milk replacers can be completely withdrawn. Excess milk or milk replacer feeding delays starter intake and weaning age. Free access

TABLE 6.11
Formulation of starter feed for pre-ruminants

	Starter feed				
Ingredient proportion (%)	**1**	**2**	**3**	**4**	**5**
Barley	10				10
Bakery waste		3			
Brewers grain	5				
Coconut meal[1]	5				
Maize	20		45	30	40
Maize gluten				5	
Cottonseed meal	5		5	7	5
Linseed meal	10				10
Molasses		2	2	2	5
Oat			35		5
Peanut meal	5	5		5	10
Rapeseed meal					5
Rice bran		20		10	
Rice, broken		5			
Sesame meal, mechanically extracted		10			
Sorghum	10	30			
Soybean meal			13	5	
Sunflower meal	10	10		5	
Wheat				16	
Wheat bran	20	15		15	10
Mineral-vitamin mix[2]					
	Energy (MJ/kg DM) and chemical composition (% DM)				
ME	13.1	12.7	13.8	13.5	13.6
TDN	77.2	75.1	81.4	79.4	80
CP	23.7	21.5	17.2	22.3	21
CF	8.4	7.3	7.1	7	6.8
Fat	3.9	6.2	3.9	4.2	3.4

CP, crude protein, CF, crude fibre; DM, dry matter; ME, metabolisable energy; TDN, total digestible nutrients.
[1] Meal refers to solvent extracted unless indicated otherwise.
[2] To be added as per the recommendation of proprietary preparations.

to clean drinking water and providing coarsely ground, fresh and palatable starter feed are the ways by which early intake of dry feeds can be promoted and thereby transition of pre-ruminants from milk replacers to solid food can be hastened. The transition of pre-ruminant feeding management from liquid milk to a diet based entirely on solid starter feeds (plus limited roughage) is one of the key management skills in rearing of young ruminants and this manual provides a good insight into how this can be best undertaken.

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He has been teaching and researching in the area of ruminant nutrition for more than 30 years with a focus on cattle, buffalo, sheep and goat production in India and abroad. He has published over 70 papers in peer reviewed journals and conference proceedings, apart from being the guest editor and the co-author for the occasional publications related to animal production. In addition to teaching and research, he has been working closely with livestock feed industries, government and non-government organisations on livestock development projects. In the last ten years he has visited Mongolia, Indonesia, Thailand, Malaysia, Sri Lanka, Bangladesh, Nepal and Sierra Leone as an expert on livestock production. Currently he is holding the position of Professor of Livestock Production and Management in Veterinary College, Bengaluru, and Head of the Division of Animal Sciences at the Karnataka Veterinary, Animal and Fisheries Sciences University, Bidar, India.

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John has written over 100 research publications and conference papers as well as numerous books and technical articles on dairy and beef production that are now widely read throughout Australia and Asia. John recently retired from the Victorian Department of Primary Industries following 30 years as a dairy research and advisory scientist. He now runs his own consulting company, Profitable Dairy Systems, based in his home town on Kyabram in northern Victoria. Profitable Dairy Systems advises large and small holder dairy farms on their management (feeding, herd, cow comfort and farm business), providing both on farm consultation and technical training workshops.

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This manual presents comprehensive information on the preparation and feeding of milk replacers and starter feeds for pre-ruminants. It keeps in view the situation prevailing in developing countries and the demand for ruminant milk for human consumption. Although the substitutes for dam's milk can be prepared from by-products of milk and feed ingredients that are not preferred for human consumption, awareness about such alternatives is limited in many developing countries. Therefore, popularisation of preparation and feeding of milk replacers and starter feeds using locally available ingredients is useful in promoting survivability and growth of young stock.

The target audiences for this manual are livestock extension workers engaged in developing countries. The manual is also useful for students and teachers of ruminant production and for small scale industries and researchers that wish to produce milk replacers and starter feeds.

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