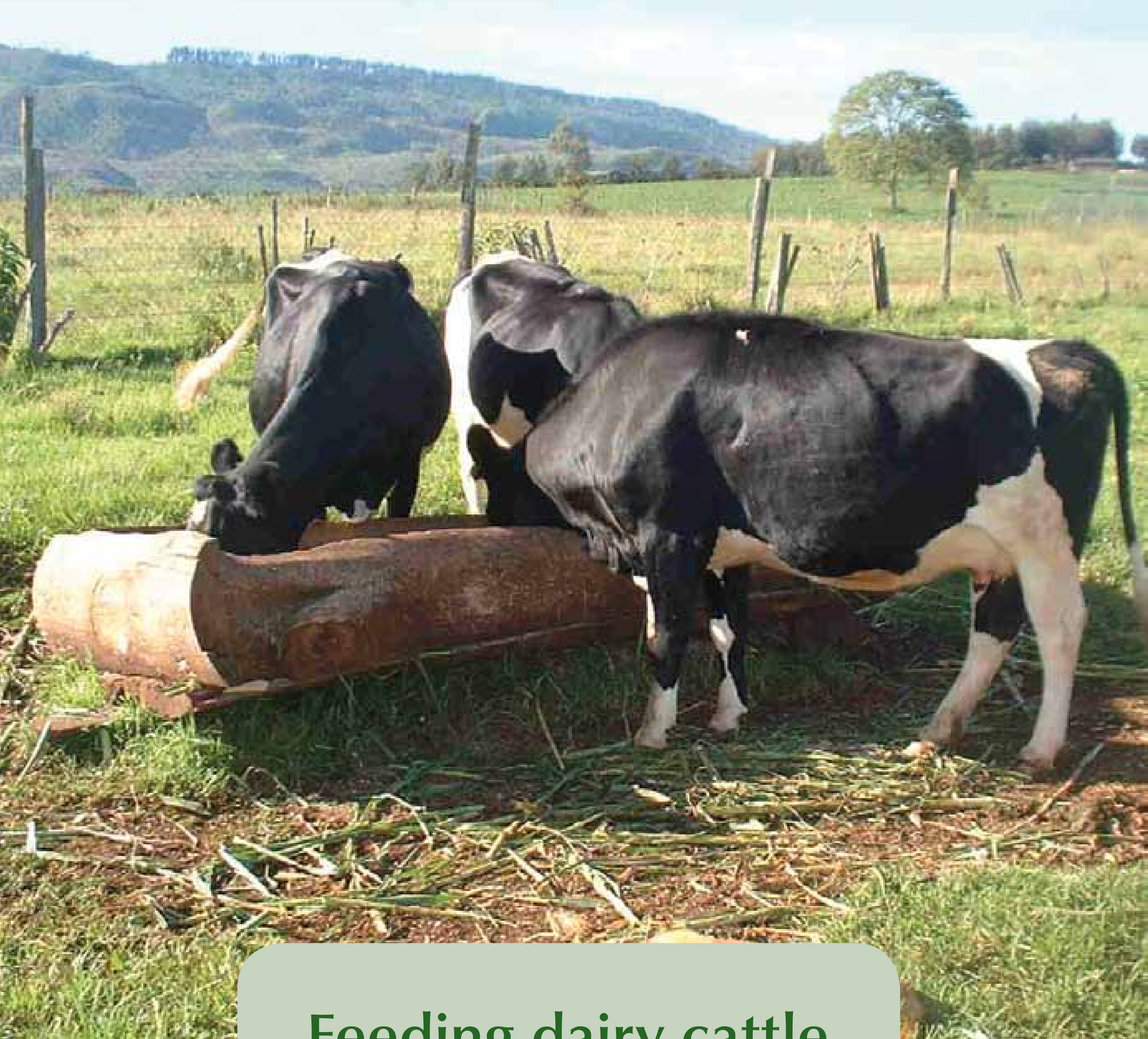

Feeding dairy cattle in East Africa

Technical editors: Ben Lukuyu and Charles Gachuiri
Compiled by Charles Gachuiri, Margaret Lukuyu,
Charles Lusweti and Solomon Mwendia

EAST AFRICA DAIRY DEVELOPMENT PROJECT

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East Africa Dairy Development Project

The East Africa Dairy Development project is a regional industry development program led by Heifer International in partnership with the International Livestock Research Institute (ILRI), TechnoServe, the World Agroforestry Centre (ICRAF) and the African Breeders Services Total Cattle Management (ABS TCM). The project is being implemented in Kenya, Rwanda and Uganda.

Funded by the Bill & Melinda Gates Foundation, the goal of this project is to help one million people—179,000 families living on small 1–5-acre farms—lift themselves out of poverty through more profitable production and marketing of milk.

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PREFACE

Dairy cattle production in East Africa has increased recently due to the high demand for fresh milk for a growing population and demand for value-added milk products for an expanding urban middle class. To meet this increased demand, there is need to increase the amount of available milk. This increase can be either by increasing the milk yield per cow or by increasing the number of animals. Due to pressure on land, increasing the milk yield per cow is the preferred option.

Dairy farmers have taken up this challenge but are constrained by the lack of technical information on managing their animals. At times the available information is too complicated for them to understand.

Though increasing milk production is a combination of good genetics, good management and good feeding, feed costs constitute the major day-to-day expense. In East Africa, this cost has been further exacerbated by the progressive shift from an extensive to an intensive system of dairy in both the high and the medium-to-low potential areas due to the shrinking land sizes and a lucrative milk market.

With the recent advances in breeding technologies, farmers have gained access to high-quality dairy genotypes. To realize the full milk production potential of these genotypes, there is need for proper managerial practices, especially with regard to feeding. Farmers need to be knowledgeable on how to maximize productivity while minimizing costs of feeding.

A lot of research has been carried out on various aspects of dairy production, particularly in the area of feeds and feeding. This information has either remained on the shelf or been communicated in a form not appropriate to the farmer. This manual synthesizes and simplifies the information on feeding dairy cows for the farmer, extension worker and student. Whereas the information has been synthesized in such as way as to be applicable to the East African region, some information may be site specific, and in some instances information that is generalized may need to be customized to suit specific areas.

The manual covers information on the basic nutrients a dairy cow requires, the available feed resources that provide these nutrients and practical aspects of feeding the animals.

ABBREVIATIONS

ABS TCM	African Breeders Services Total Cattle Management
ASN	ammonium sulphate nitrate
CAN	calcium ammonium nitrate
DAP	diammonium phosphate
EADD	East Africa Dairy Development
ICRAF	World Agroforestry Centre
ILRI	International Livestock Research Institute
KES	Kenya shilling, valued at KES 85 to USD 1 in this manual
SSP	single superphosphate
TSP	triple superphosphate
USD	US dollar

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April 2012, Nairobi, Kenya

CHAPTER 1: INTRODUCTION

1.1 Importance of dairy cattle

Dairy cattle make a major contribution to both national and household economies as well as provide milk, which contains essential nutrients. Milk contributes significantly to meeting the human requirements for animal protein and is especially important in the diet of children and the sick.

Regionally, dairy cattle farming contributes to employment on the farm (production), during value addition (processing) and marketing. The farming also supports a large service sector that offers specialized services in nutrition and health.

Increase in human population has resulted in pressure on arable land leading to deterioration of soil fertility and deforestation. Manure from dairy cattle plays a major role in improving soil fertility and it is a source of energy (biogas) for the household.

1.2 Qualities of a good dairy cow

Though milk production may not be 100% related to the external appearance of a dairy cow, some physical features are related to milk yield and the longevity (length of time animal is productive) of the animal in the herd. These features (Figure 1.1, Table 1.1) are commonly used in judging the goodness of a dairy cow from its external appearance. These characteristics should be considered by dairy farmers while buying, selling or culling dairy animals.

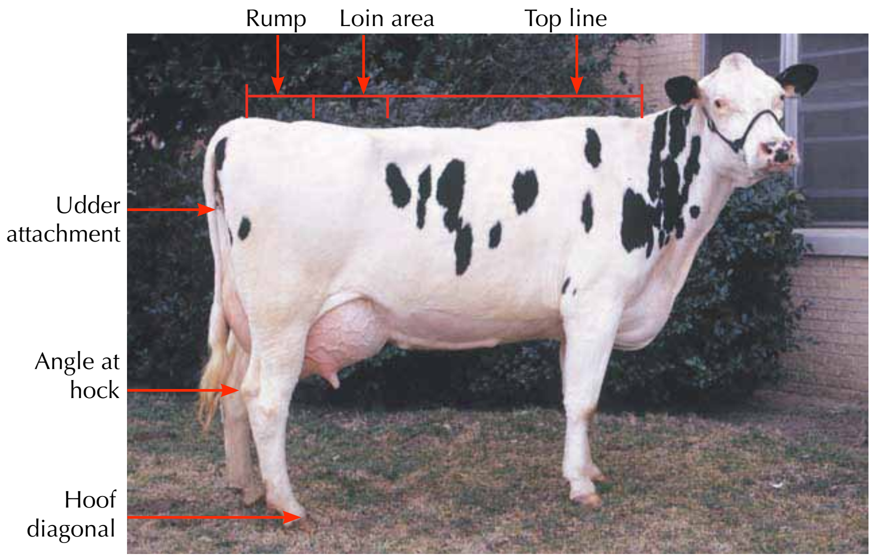

Figure 1.1. Parts of the dairy cow.

Table 1.1. Characteristics used in judging dairy cattle

Physiology	Character	Description	Desired
Size	Size	Stature (height in cm at rump or withers)	Jersey = 120, Guernsey = 125, Ayrshire = 130, Friesian = 135
	Chest width	Distance between the front legs	Should be large to give room for the heart and lungs
	Rump width	Distance between the pin bones	Should be big to ease calving and allow wide rear udder attachment
Dairy character	Angularity Body frame Dairy type	Reflects the appearance that the cow has the will to milk	Rib structure: ribs wide apart, rib bones wide, flat, long and free from excess flesh Neck: long, lean and blending smoothly into shoulders Barrel: width tending to increase towards rear
	Rump angle (pelvic angle)	Angle from hooks to pins	Pins should be slightly lower than hooks (about 2.5 cm). Improper angle can hinder reproductive performance and mobility
	Topline	Level of backbone from shoulders to pelvis	Should be strong and level
Udder	Fore udder attachment	Attachment to trunk	Attachment of fore udder to trunk should be almost level
	Udder depth	Distance between bottom of udder and ground in relation to height	Should be shallow and above the hock. Deep udder is prone to injury. Consider age and stage of lactation
	Rear udder height	Distance between vulva and udder fold	Should be attached high
	Udder suspension	Udder cleft—suspensory ligament	Should be clearly visible and continue upwards. Should be strong to keep udder firm and prevent teats from pointing outwards
	Teat placement	Direction of teats	Should point straight down or slightly inwards (for ease of milking)
	Teat length		5 cm ideal for machine milking; slightly longer for hand milking
Legs and feet	Rear leg set	Angle at hock viewed from side should not be straight	Ideally, pin bone, hock and dew claw should be in one line. Should be straight from the rear
	Hoof diagonal	Distance between point of toe and top of heel	Intermediate desirable

1.3 Basic needs of a cow for optimum production

The aim of keeping a dairy cow is to obtain the maximum amount of milk. A cow will perform at its best only if its basic needs are met. These include:

- freedom from hunger and thirst (good feed and clean water)
- freedom from pain, injury and diseases (good health)
- freedom from discomfort (comfortable environment, e.g. temperature, clean floor)
- freedom from fear and distress (friendly, loving, gentle and caring handler)

To exploit the cow's full genetic potential, there is need to have a good nutrition program and meet all other needs.

1.4 The ruminant digestive system

Ruminants are various cud-chewing hoofed mammals having a stomach divided into four compartments (rumen, reticulum, omasum and abomasum), each one with a specific role to play. The most important is the rumen. Cattle, sheep and goats are ruminants. All ruminants 'chew the cud'. This means that the food they consumed earlier is returned to the mouth for a second thorough chewing before it is re-swallowed.

The rumen is full of tiny microorganisms (bacteria and protozoa) that digest fibrous feed, such as fresh grass and hay, foodstuffs that humans and most other animals cannot digest. After digesting the fibre, the animal makes use of the end products for growth and milk production. The microorganisms can also convert non-protein nitrogen-containing ingredients (e.g. urea) into protein that the animal can use.

These microorganisms also manufacture some vitamins, such as the vitamin B group.

1.5 The cow as a milk factory

A dairy cow can be thought of as a milk manufacturing factory. Into any manufacturing factory go raw materials, which are processed, and out of the factory comes a new product. The quality and quantity of the product are a combination of both the quality and the quantity of the raw materials and the efficiency of the factory.

The raw materials that go into milk manufacturing are the nutrients. The quantity and quality of these nutrients depend on the feed consumed by the cow. If the cow is fed on poor-quality feed in large quantities or high-quality feed in small quantities, little milk will be manufactured. The size of the factory can be compared to the size of the cow—where a large factory will hold more raw materials, so will a large cow have a larger rumen.

The machinery that converts raw materials into milk constitutes the digestive system (stomachs and intestines) and the udder (mammary gland). All cows can be assumed to have a similar digestive system but the capacity of the udder will vary depending on the number of milk-making units (alveolar cells), which is determined by the genetics of the cow.

These cells are housed within the cow, which provides a conducive environment for them to function (the cow must be comfortable and free from pain). In a factory, this can be equated to the workers (their number and their comfort).

The factory concept is diagrammatically illustrated in Figure 1.2:

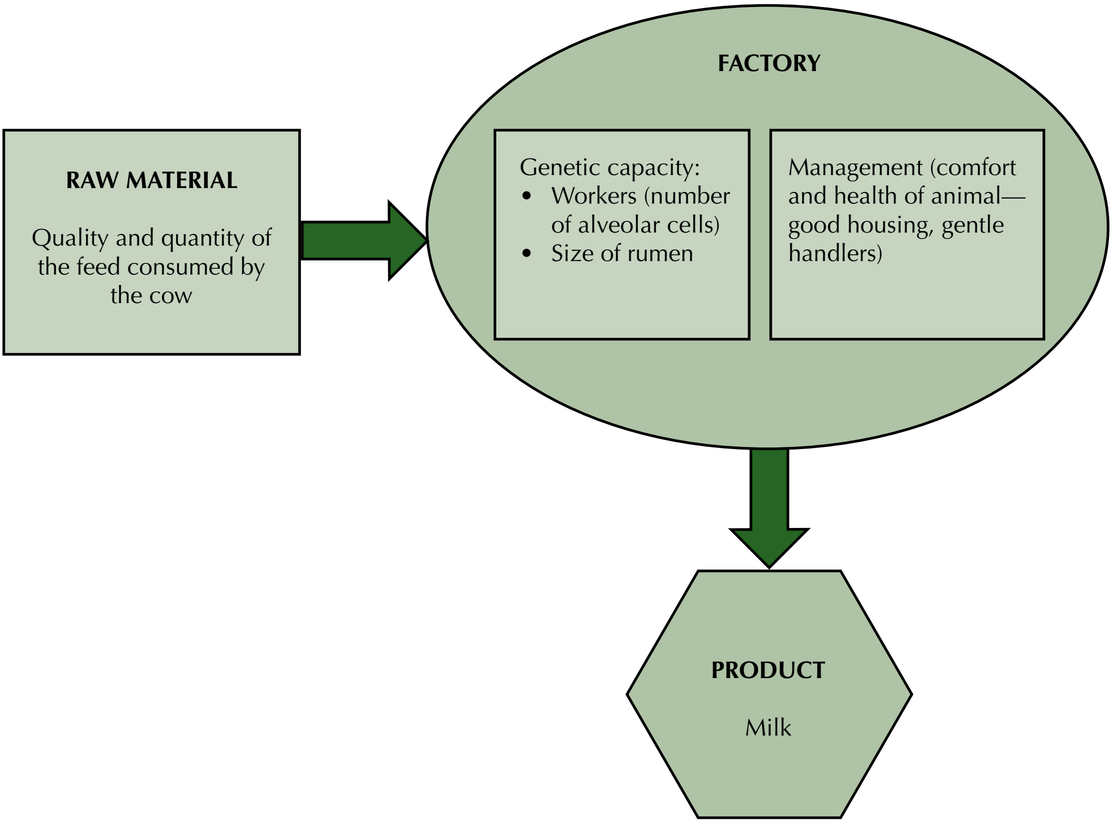

Figure 1.2. The cow as a factory.

CHAPTER 2: NUTRIENTS

Nutrients are substances obtained from food and used in the body to promote growth, maintenance, reproduction and production. Feedstuffs contain the nutrients animals require to perform normal body functions (such as breathing, pumping blood, fighting diseases, growing, gaining weight, reproducing) and to produce milk. The feedstuff must be digestible and the products (nutrients) absorbed if the feed is to be useful to the animal.

Some components of a feedstuff have no nutritive value because they are indigestible and not absorbable (e.g. some woody plants) and pass out through faeces. In addition, some plants contain compounds that are toxic to the animal.

The essential nutrients are energy, proteins, minerals, vitamins and water.

2.1 Energy

The energy portion of the feed fuels all body functions, enabling the animal to undertake various activities including milk synthesis. This is the major nutrient (in terms of quantity) that dairy cows require.

2.1.1 Functions

Maintenance: Simply to maintain itself, an animal requires energy. The body weight does not increase or decrease, the animal does not produce; this energy is only for survival and the amount is affected by body size and the environmental temperature.

Growth and weight gain: Gain is especially important for young animals, who need to attain the recommended weight for a particular age.

Reproduction: A cow requires more energy during pregnancy for the foetus to grow and develop normally.

Milk production: The energy requirement of a lactating cow increases with increase in milk production and butter fat content of the milk.

2.1.2 Sources

Energy can be obtained from several types of feedstuffs that contain either carbohydrates or lipids (fats and oils).

Carbohydrates are the major source of energy in the diet of dairy cows. They are found in the staple foods consumed by humans (e.g. rice, maize, wheat, potatoes). Carbohydrates constitute between 50% and 80% of the dry matter in forages and grains.

Feeds contain three major types of carbohydrates:

- *Sugars:* Sugars are soluble in water, making them readily available to the animal. Sources are molasses, sugar beets and sugar cane.
- *Starch:* Starch is the main form of carbohydrate stored in plants. It is the main component of cereal grains and some roots (potato tubers).
- *Fibre:* Forming the structural part of plants, fibre is present in large quantities in roughages. The fibre is broken down by microorganisms in the rumen (microbial enzymes) into products that the animal can use. It is also important in maintaining high levels of milk fat. Sources include grasses, fodder crops and crop residues.

Lipids (fats) contain about 2.25 times more energy than carbohydrates per unit weight. Generally, plants are good sources of oils while animal products contain fats. Most plant seeds contain a small amount of lipids. The exception is oilseed plants, which may contain as much as 20% lipids (cotton, sunflower and soybean seeds) and are better sources of lipids than animal fats.

2.1.3 Consequences of energy deficiency

The most obvious sign of energy deficiency is poor body condition due to excessive weight loss. Lactating cows are unable to reach peak milk production in early lactation resulting in low lactation yields.

2.1.4 Consequences of excessive amounts of energy

Cows consuming too much energy become too fat, resulting in low conception rates. They are prone to difficult calving, retained placenta, and higher incidence of milk fever and ketosis.

In early lactation, feeding too much energy, especially in the form of grain, may lead to too much acid in the rumen (acidosis), increased risk of displaced abomasum, depressed feed intake and low milk fat percentage.

2.1.5 Special considerations

Usually forages are high in fibre and low in energy, and concentrates are low in fibre and high in energy. Therefore there is need to balance the two, as too much forage limits the intake of energy while too much concentrate results in milk fat depression, rumen acidosis and other health problems.

2.2 Protein

Protein is quantitatively the second most important nutrient in feeding the dairy cow. Proteins are made up of building blocks referred to as amino acids.

2.2.1 Functions

Proteins provide the building material for all body cells and tissues (e.g. blood, skin, organs and muscles). Proteins are also major components of products such as milk and meat. Lack of protein therefore adversely affects milk production.

2.2.2 Sources

Good sources of protein for dairy cows include:

- *Oilseeds and oilseed cakes:* Residues after the oil is removed from oilseeds, e.g. cottonseed meal or cake, whole cottonseed, whole soybeans (cracked) or meal and sunflower meal or cake.
- *Products of animal origin:* Such as fish meal, blood meal, meat and bone meal, feather meal and by-products from milk processing (e.g. skim milk and whey).
- *Herbaceous legumes:* Such as lucerne, desmodium and fodder trees (e.g. calliandra and sesbania).
- *Non-protein nitrogen:* Cows can obtain protein from sources that do not contain true proteins, such as urea and poultry waste (contains uric acid). These sources are referred to as non-protein nitrogen sources. Microorganisms in the rumen use the nitrogen in urea to synthesize protein for their own growth.

2.2.3 Consequences of protein deficiency

For lactating cows, there is a sudden drop in milk production if the amount of protein in the diet is suddenly reduced. Severe deficiency may cause excessive weight loss in lactating cows, reduced growth rate in calves and heifers, and result in underweight calves being born.

2.2.4 Consequences of feeding excess protein

Protein is an expensive nutrient and feeding excess is a waste of money as protein is not stored in the body but is broken down by microorganisms in the rumen and excreted in the form of urea.

2.2.5 Protein and rumen microbes

Most of the protein in feed is broken down by microorganisms in the rumen (rumen-degradable protein) and re-synthesized into bacterial protein. *Bypass proteins* are proteins resistant to microbial breakdown in the rumen (undegradable protein), and pass intact to the small intestines where they are digested and absorbed directly into the body.

2.2.6 Protein and milk production

Milk contains approximately 3.2–3.5% protein. Thus a cow producing 25 kg milk per day secretes 800–900 g protein daily. Cows have little ability to store protein in the body and so it must be supplied in the diet daily to maintain the milk yield. Protein should be 15–18% of the total ration of a dairy cow depending on milk yield.

2.3 Minerals

Minerals are nutrients required in small amounts in the feed. They are required for the body to function properly, i.e. remain healthy, reproduce and produce milk (Table 2.1). Some minerals are required in large quantities in the ration dry matter (macro-minerals) while others are required in small quantities (microminerals). Some minerals are stored in the body (e.g. iron in the liver and calcium in bones) while others are not (e.g. sodium, potassium) and have to be supplied in the diet all the time.

Table 2.1. Minerals required in ruminant diet

Macrominerals	Microminerals
Calcium	Cobalt
Chlorine	Copper
Magnesium	Iodine
Phosphorus	Iron
Potassium	Manganese
Sodium	Molybdenum
Sulphur	Selenium
	Zinc

2.3.1 Functions

Specific minerals may have different functions in the body but the minerals are generally required for

- bone formation
- formation of components of enzymes, vitamins and red blood cells
- production of hormones that control body functions
- control of water balance in the body
- milk synthesis

Requirement for minerals is affected by several factors:

- *Age:* Mineral requirements for young growing animals are higher.
- *Physiological status:* Pregnant animals require more.
- *Level of production:* High-producing cows require large quantities of calcium; deficiency is more likely to occur in early lactation rather than late.

2.3.2 Sources

Although roughages and concentrates contain minerals, the types and amounts vary widely and hence may not meet the requirements. During ration formulation, macro-minerals calcium, phosphorus and magnesium are taken into account. Roughages will supply adequate amounts of potassium and common salt can adequately provide sodium.

Some ingredients (supplements) are added to supply a specific mineral (e.g. limestone, salt, magnesium oxide).

2.3.3 Consequences of mineral deficiency

Signs of mineral deficiency may not be obvious but they include

- poor fertility: lack of heat signs and low conception rate
- low milk production
- poorly developed bones in young animals (rickets)
- health disorders, for example, milk fever
- poor body condition, which may be accompanied by a change in coat colour

2.4 Vitamins

Vitamins are nutrients in the feed required by the body in tiny amounts for normal functioning of the body, through their involvement in many body processes. Some are synthesized by rumen microbes and/or stored in the body of the animal while others must be supplied in the diet. The vitamins that must be supplied in the diet include A, D and E; those that are produced in the body include B complex, C and K.

2.4.1 Functions

Important functions of vitamins include

- maintenance of healthy protective tissues such as skin, stomach, intestinal and cell linings (vitamin A)
- improvement of appetite, hence feed intake (vitamin B)
- production of red blood cells, hence preventing anaemia (e.g. vitamins B6 and B12)
- enhanced calcium and phosphorus utilization, hence play a role in bone formation and growth (vitamin D)

- enhancing immunity (vitamin E)
- help in blood clotting (vitamin K)

2.4.2 Consequences of vitamin deficiency

Vitamin requirements of dairy cows are normally met through diet, rumen microbial synthesis or tissue synthesis. Deficiencies are rare under normal conditions but may occur under certain conditions, shown in Table 2.2.

Table 2.2. Situations in which vitamins may become deficient in dairy cattle

Situation	Affected vitamins			
	A	B	D	E
Feeding poor quality roughage (overgrown), frost-damaged maize silage or long-term stored forage, heat-damaged forage; periods of prolonged drought	X			
Very high grain-to-forage ratio	X		X	X
Cattle kept indoors throughout			X	
Feeding of milk or milk replacer rations alone	X		X	X
Crop residues as a major component of diet	X		X	
Prolonged stress period or disease	X	X	X	X
Very young calves (rumen not functional)		X		
Deficiency of cobalt		X		

Adapted from Wattiaux MA. 1999. *Dairy essentials*. Babcock Institute for International Dairy Research and Development, Madison, Wisconsin, USA.

2.4.3 Consequences of feeding excess vitamins

There is no important health consequence of excess vitamins as the body is able to get rid of the excess. However, vitamin supplements are expensive and hence feeding too much is an economic loss to the farmer.

2.5 Water

Water, though not classified as a nutrient, is essential for life in all animals. Water accounts for 74% of the calf's weight at birth and 59% of that of a mature cow. Every 100 kg of milk contains up to 87 kg of water.

The amount of water consumed at free will is influenced by several factors:

- moisture content of feed. When the diet has a large proportion of dry feeds, e.g. hay and grains, the cow drinks more water than when the diet has a larger proportion of young or succulent feeds, e.g. young grass and legumes
- amount of dry matter consumed
- milk yield
- environmental temperature
- salt intake

An increase in any of the factors above increases the water requirement for lactating cows. The amount of water consumed will also depend on the quality and quantity of water provided (Table 2.3).

Table 2.3. Estimated water requirement by calves, heifers and lactating dairy cattle

Dairy cattle type	Level of milk production (kg milk/day)	Water requirement, average range (litres /day)
Dairy calves (1–4 months)		5–15
Dairy heifers (5–24 months)		15–40
Milking cows	14	65–85
Milking cows	23	85–105
Milking cows	36	115–140
Milking cows	45	130–155
Dry cows		35–50

Adapted from McKague K. 2007. F*act sheet on water requirements of livestock*. Ontario Ministry of Agriculture, Food & Rural Affairs, Toronto, Canada.

2.6 Concept of dry matter

Dry matter is what remains of a feed when all the water has been removed and it contains the nutrients described above (Figure 2.1). This dry matter portion can be divided into organic matter comprising energy, protein and vitamins, and inorganic matter comprising minerals. Animals must consume enough dry matter to obtain the required nutrients to keep them healthy and to let them grow, reproduce and produce milk.

Dry matter is expressed as a percentage of fresh feed; hence a feed comprising 40% dry matter means that for every 100 kg of the feed, only 40 kg is dry matter. It is from the 40 kg that the animal will obtain its nutrient requirements. If the same feed contains 10% crude protein, the amount supplied by the feed will be 10% of 40 kg, which is 4 kg. Banana stem containing 10% dry matter means that if you feed 100 kg of fresh stems, the cow will have only 10 kg dry matter and 90 kg water.

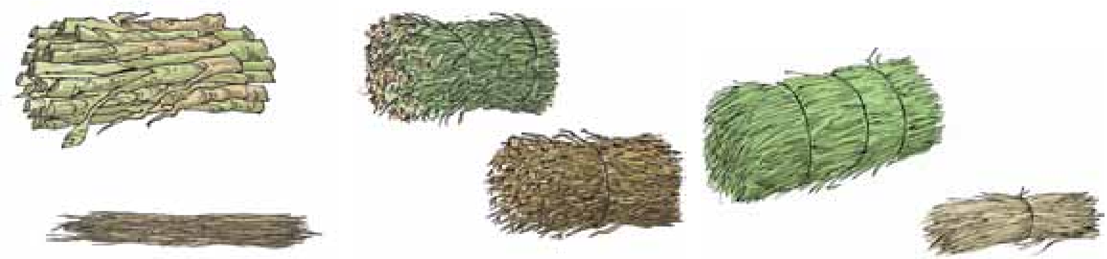

Figure 2.1. Difference in bulk of feeds before and after water is removed.

CHAPTER 3: PRODUCTION SYSTEMS AND PASTURE MANAGEMENT

3.1 Production systems

Dairy cattle can be reared in ways that vary depending on the resources available to the farmer. Farmers in East Africa practise three main systems: intensive, extensive and semi-intensive.

3.1.1 Intensive system

In the intensive system, dairy cattle are enclosed in zero-grazing units (see design of zero-grazing unit in Appendix 8), where they are provided with all their requirements for feed and water. This method is mainly practised where grazing land is scarce. In Kenya it is mainly practised in high-potential areas of central Kenya and also by urban and peri-urban farmers; in Tanzania it is practised on the slopes of Mt Kilimanjaro and in Uganda around Kagada. The forage can be grown on farm or purchased.

This system has its advantages and disadvantages.

Advantages

- The cow does not waste energy walking in search of pasture.
- It avoids diseases associated with communal grazing.
- It allows dairy farmers with no grazing land to produce milk and make money.
- The manure can be accumulated for improving soil fertility or used to generate biogas for domestic energy use.

Disadvantages

- The method is labour intensive as feeding and cleaning the unit must be done daily.
- The initial cost of putting up a zero-grazing unit is high.
- It may be difficult to detect when a cow is on heat, especially a singly housed cow. This is because when cows are housed in a group they mount each other and when in the open they show signs of restlessness by moving around.

3.1.2 Extensive system

In the extensive system, the cattle are reared on pasture. It is practised where grazing land is available. In East Africa the grazing land mainly comprises natural unimproved grass. In Kenya it is practised in most parts of the Rift Valley, where farmers own large tracts of land.

Advantages

- It is cheaper than the intensive system.
- It is not labour intensive.

Disadvantages

- It requires dedicating much more land to grazing.
- Cows waste a lot of energy by walking while grazing in the field.
- It is difficult to accumulate manure for improving soil fertility in crop fields.

Natural grasses can be improved by oversowing with herbaceous legumes (e.g. *Trifolium)* or planting grasses (e.g. Rhodes grass). Oversowing is the method of choice.

3.1.3 Semi-intensive system

In the semi-intensive system, the cattle graze for some time during the day and in the afternoon or evening they are supplemented with other forages like Napier grass. This method is a compromise between intensive and extensive systems, whereby land is not limiting as in the intensive system but on the other hand is not enough to allow free grazing throughout the day.

Due to population pressure leading to subdivision of land, this system tends towards the intensive system.

3.1.4 Other systems

Other methods include 'roadside grazing' and 'tethering'. Roadside grazing involves herding cattle on the roadside where they graze on natural unimproved pastures. It is popular in areas with land shortage. Tethering restricts the cow to a grazing area by tying it with a rope to a peg. This can also be done on the roadside or any other public land. However, in either of these systems the animals may not get enough to satisfy their requirements.

3.2 Pasture management

Efficient pasture management results in high yields of good-quality pasture that can be fed to dairy cattle for high milk production. Key activities to be considered include weed control, grazing management and fertility management.

3.2.1 Weed control

Weeds can reduce the productivity of the sown pastures, particularly during the establishment year, and should be controlled during the first year by either hand weeding or using herbicide (2-4D amine at the rate of 2.5 litres per hectare [ha]). In subsequent years fields are kept clean by slashing, hand pulling or mowing the weeds.

3.2.2 Grazing management

The following should be observed:

- In the establishment year grasses reach the early flowering stage 3–4 months after planting. At this stage the plant is not firmly anchored in the soil and therefore it is usually advisable to make hay rather than graze the pastures to avoid the risk of the cattle pulling out the young shoots.
- If the pasture must be grazed during the establishment year, grazing should be light enough (use calves) to allow the plants to establish firmly in the soil.
- For maximum benefit, use the pasture not later than the start of the flowering stage. Graze or cut at intervals of 4 to 6 weeks, leaving stubble at 5 cm height.
- Graze animals when the grass is at the early flowering stage by moving animals from paddock to paddock.
- One animal will need 1–2 acres of improved pasture per year in areas receiving over 900 mm rainfall.
- Conserve excess pasture in the form of hay for dry-season feeding.

3.2.3 Fertility management

To attain maximum production from pasture, the grass requires additional nutrients from inorganic fertilizer or farmyard manure.

- During the establishment year, soil nitrogen is adequate for grass productivity.
- In subsequent seasons, topdress grass with 5–7 bags of calcium ammonium nitrate (CAN) or ammonium sulphate nitrate (ASN) per hectare per year in three splits during the rainy season or 5–10 tonnes of farmyard manure.
- In areas with phosphate deficiencies topdress with 2 bags of single superphosphate (SSP) or 1 bag of triple superphosphate (TSP) per hectare per year after the establishment year. This is in addition to nitrogen fertilizer.
- Nitrogen fertilizer may be applied on 1 or 2 months before the dry season to increase yields during the dry season.

3.3 Stocking rates for different grasses

Stocking rate is the number of animals (animal unit) for which a grassland unit (hectare) can provide adequate dry-matter forage for a specified length of time. Stocking rate influences animal performance, pasture recovery, long-term pasture production and long-term pasture species composition.

Stocking rates should represent a balance between grazing pressure (pasture demand) and carrying capacity (pasture supply). The ultimate goal should be to optimize both animal and pasture production over the long term, as opposed to maximizing only one or the other. In general, improved pastures can support higher stocking rates than native or unimproved pastures. Table 3.1 gives examples of recommended stocking rates for different improved pastures. Yields of commonly used grasses and legumes are in Table 3.2.

Table 3.1. Recommended stocking rates

Grass type	Stocking rate (MLU/acre per year)
Cenchrus ciliaris (blue buffalo grass)	0.4–1.2
Panicum maximum (white buffalo grass)	1.2–2.4
Chloris gayana (Rhodes grass)	1.6
Pennisetum clandestinum (Kikuyu grass)	1.2–3.2

MLU – matured livestock unit, equivalent to 500 kg non-lactating bovine

Table 3.2. Yields of different types of fodder at different agroecological zones (AEZs)

Fodder type	AEZ	Dry matter yield (kg/acre per year)	Mature dairy cow supported (no. days)*
FODDER GRASSES			
Napier grass	LH1, LH2	4000–12,000	333–1000
Fodder sorghum (E6518)	LH 3	6800–8800	567–733
Boma Rhodes	LH 3, LH 4	4868	406
Elmba Rhodes	LH 3, LH 4	3944	329
Star grass	LH 3, LH 4	2988	249
Guinea grass	LH 3, LH 4	2564	214
Masaba Rhodes	LH4	4560	380
Guatemala grass	LH4	4080	340
Mbarara Rhodes	UM1	5640	470
Giant setaria	UH2–3	4000	333
Giant panicum	UM4	4720	393
Oat	UM4	2680	223
FODDER LEGUMES			
Silverleaf desmodium	LH2	3448	
Greenleaf desmodium	LH2	3060	
Sesbania sesban	LH4	10880	
Leucaena	LH4	5300	
Starleafed sweet potato	LH4	3868	
Purple-leafed sweet potato	LH4	3116	
Broadleafed sweet potato	LH4	2880	
Vetch	LH4	1480	

LH – lower highland, UH – upper highland, UM – upper midland
* A mature dairy cow weighing about 400 kg consumes about 12 kg dry matter per day

CHAPTER 4: FORAGE PRODUCTION AND UTILIZATION

4.1 Forage production and management

Inadequacy of high-quality forages on the farm is one of the major constraints limiting dairy production in East Africa. Various types of forages have been recommended for different agroecological zones (Table 4.1) depending on the climatic conditions and soils. They are cultivated on arable land and are either grazed or cut and fed either as fresh green fodder or conserved as hay or silage. The specific agronomic recommendations for growing of forages differ from species to species and may be site specific. Table 4.1 gives examples of different forages and their production potential in different agroecological zones.

4.1.1 Establishment and management of ley pastures

Pasture establishment can be by direct sowing, undersowing or oversowing.

Direct sowing

Direct sowing is establishing pasture grasses without a nurse or cover crop.

Seedbed preparation: On previously cropped land, plough towards the end of the preceding rainy season. Follow with dry-season ploughing and harrowing for weed control. On virgin land, three ploughings and two harrowings may be required to make a good seedbed.

Sowing time and method

- Sow as early as possible in the rainy season. In areas that recieve bimodal rainfall areas, sow during the short rains to eliminate annual weeds.
- Sow seeds close to the surface to get them in contact with moist soil so they will absorb moisture and germinate. Do not bury the seeds deep since initial vigour is not sufficient to push through a heavy cap of soil.
- Either broadcast grass seeds or drill in rows 30–40 cm apart.
- Mix the seeds with sawdust, rough sand or phosphate fertilizer for even distribution. If the seed is mixed with fertilizer, plant immediately to prevent the fertilizer from scorching the seed.
- Grass seeds are most effectively sown with a wheat drill. Hand sowing is recommended for small acreages.
- Immediately after sowing compact the seedbed to enhance germination of the grass seed by improving contact with the soil. Use tree branches or trample by foot on small plots. In mechanized farms, use a roller.

Table 4.1. Recommended forage species for different regions in East Africa

Region; altitude (m); *rainfall (mm/yr)*	Suitable forages			
	Legumes	DM yield (t/ha)	Fodder & ley grasses	DM yield (t/ha)
1 Semi-arid; 1000–1800 m; *< 650 mm*	*Siratro*	1.5–2.0	GRASSES	
	Stylosanthes scabra	0.6–15.0	*Andropogon gayanus*	5.30
			Cenchrus ciliaris	9.83
			Chloris roxburghiana	10.33
			Eragrostis superba	4.33
			Panicum maximum	10.0
2 Warm, wet, medium altitude; 1200–1850 m; *1000–2500 mm (bimodal or unimodal)*	*Calliandra calothyrsus*	2.5–6.0	FODDERS	
	Desmodium spp	6.3–8.4	Giant panicum	11.8
	Dolichos lablab	0.5–1.5	Giant setaria	9.1
	Leucaena spp	3.9–6.0	*Ipomea batatas* (sweet potato)	8.0
	Neonotonia wightii	0.4	Napier grass	17–25
	Sesbania sesban	3–5	*Sorghum almum* (Columbus grass)	15.0
	Stylosanthes guianensis	2.7–3.35	*Sorghum sudanense* (Sudan grass)	12.0
			Trifolium laxum (Guatemala grass)	8.4–10.3
			GRASSES	
			Chloris gayana (Boma, Elmba Rhodes)	10.0–18.0
			Coloured guinea	12.0–18.0
			Panicum maximum	9.0–14.0
			Setaria sphacelata (Nandi, Nasiwa)	10.0–16.0

Region; altitude (m); *rainfall (mm/yr)*	Suitable forages			
	Legumes	DM yield (t/ha)	Fodder & ley grasses	DM yield (t/ha)
3 Cool, wet, medium altitude; 1850–2400 m; *1000–2500 mm*	*Desmodium* spp	5.5–7	FODDERS	
	Dolichos lablab	1.6–2.5	*Avena sativa* (oats)	5.1–6.65
	Lupinus albus	6.3	*Chloris gayana* (Rhodes grass)	7–15
	Lupinus angustifolius	6.0–9.9	Coloured guinea	7–18
	Medicago sativa (lucerne)	3.0–8.0	Columbus grass	8–13.5
	Mucuna spp	1.6	Congo signal	8.8
	Neonotonia wightii	2.6–5	Giant panicum	9.0
	Stylosanthes guianensis (stylo)	2.67	Giant setaria	6.6–10.5
	Vicia spp (vetch)	3.76	Guatemala grass	6.4–8.4
			Kikuyu grass	5.0–8.0
			Napier grass	12.0–17.0
			Seraria sphacelata (setaria grass)	7.0–10.0
			Star grass	5.0–10.0
			Sudan grass	6.9–12.0
			Sweet potato	7.2–10.2
4 Cold, wet, high altitude; 2400–3000 m; *1000–2500 mm*	*Medicago sativa* (lucerne)	4.5	*Festuca arundinacea* (tall fescue)	5.02
	Trifolium semipilosum (Kenya white clover)	2.5	Kikuyu grass	7.04
	Vicia spp (vetch)	3.6–3.8	*Lolium perenne* (perennial ryegrass)	6.16–8.13
			Oats	7.0

Fertilizer application at planting

Apply phosphate fertilizer or farmyard manure to promote strong root development.

The recommended rates of fertilizer application are as follows:

- SSP 2–4 bags/ha or
- TSP 1–2 bags/ha or
- DAP 1–2 bags/ha or
- 10 t/ha of farmyard manure—should be broadcast and harrowed in before planting
- topdressing with 5 bags CAN/ha or 5 t farmyard manure/ha per year

Note: To prevent scorching the seed, use DAP only when rainfall is adequate, and use only well-decomposed farmyard manure.

Undersowing

Undersowing is establishing pastures under a nurse or a cover crop. The nurse crop is grown together with pasture for economical land use. The nurse is harvested after maturity and the pasture left for 2 to 3 years.

For successful undersowing observe the following:

- Broadcast or drill pasture seed mixed with fertilizer 3 days after planting wheat or barley.
- Where maize is the nurse crop, broadcast pasture seed mixed with phosphate fertilizer in the maize field after the second weeding of maize (4 to 5 weeks after planting maize) or when maize is knee high.
- After the nurse crop is harvested remove stovers or straws and cut back the weeds using a panga or slasher.
- During the establishment year, grazing is not recommended to avoid grass still with weak roots being uprooted by the livestock.

Oversowing

Oversowing is the introduction of improved pasture species (grasses or legumes) to a natural pasture. Oversowing increases forage quality and productivity of natural pastures. It is the easiest and most cost-efficient strategy for improving natural pasture. Although both grasses and legumes may be oversown, legumes are more suitable, as grasses do not establish readily, especially on soils that are not loose. Oversowing should be done in areas where soils are light and loose. Benefits become evident after about 2 years.

Advantages of oversowing

- land preparation is minimal hence cheap
- less seed and labour are required
- minimal management is needed
- forage output is improved
- soil erosion is controlled
- soil fertility is improved

4.2 Fodder crops

Fodder crops are annual or perennial or permanent crops, cultivated on arable land and grazed or fed to stock either green or in a conserved form like hay or silage. Fodder crops are usually grown in rotation with cultivated cash crops. They are characterized by their high productivity per hectare (dry matter yield) compared with permanent pastures. Further, these crops are grown as supplementary feed during the dry months of the year.

Fodder crops have been identified as the most important feed on smallholder farms in East Africa due to their high forage yield per unit area. The most common are

- Napier grass *(Pennisetum purpureum)*
- sweet potato vines *(Ipomea batatas)*
- oats *(Avena sativa)*
- fodder sorghums *(Sorghum sudanense)*

4.2.1 Napier grass

Varieties

Commonly grown Napier grass varieties

- Bana grass: leafy and with few silica hairs, which cause irritation during handling. However, it is susceptible to Napier grass headsmut disease (*Ustilago kameruniensis*).
- Clone 13: resistant to white mould disease. It is a high yielder but its thin stems make it difficult to establish. It is also susceptible to Napier grass headsmut disease.
- French Cameroon: a high yielder, established easily from canes. Susceptible to Napier grass headsmut disease.
- Kakamega 1 and 2: both are tolerant to Napier grass headsmut disease. High yielders. Kakamega 1 has a higher growth rate than Kakamega 2 or Bana.
- Pakistan hybrid: does well in dry areas.

Planting

Napier grass can be established from root splits or canes. It can also be planted alone or intercropped with forage legumes. Two methods of planting Napier grass are the conventional method and the tumbukiza method.

Conventional method

The conventional method involves planting one cane (with 3–4 nodes) or root split in holes 15–30 cm deep. The spacing is 0.5 m x 0.5 m in areas with over 1400 mm of rainfall. In areas with 950–1400 mm rainfall the spacing is 1 m x 0.5 m. When cane cuttings are used, bury the nodes, leaving one node above the soil surface. See Figure 4.1.

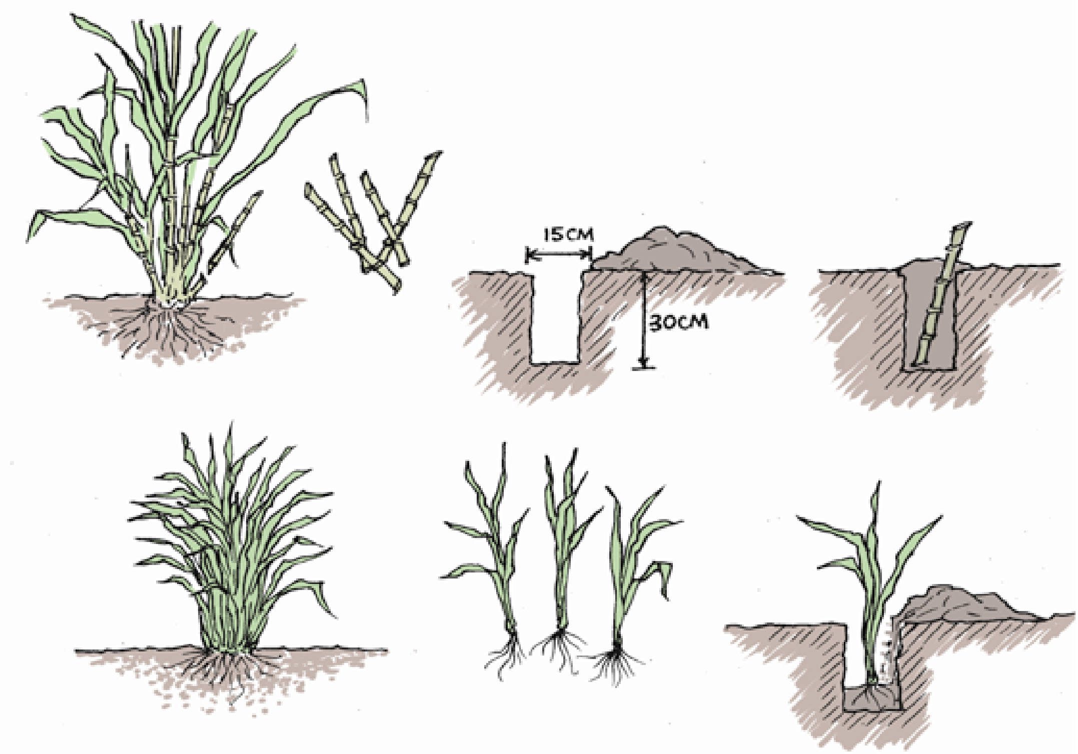

Figure 4.1. Planting Napier grass.

Forage legumes like silverleaf (*Desmodium uncinatum*), greenleaf (*Desmodium intortum*) and stylo (*Stylosanthes guianensis*) can be intercropped with Napier grass to improve the quality of the feed and reduce the cost of nitrogen fertilizer. Legume seeds at the rate of 3–5 kg/ha can be drilled along the Napier grass rows or between the rows when the Napier grass is planted.

Fertilizer and manure management practices

Four fertilizer and manure management practices are recommended for Napier grass. The choice depends on the financial resources of the farmer.

- Use 1–2 bags of TSP or DAP fertilizer per hectare at planting followed by 5–7 bags of CAN fertilizer in three split applications per year, applied after harvesting and weeding in subsequent years.
- Use 10 t/ha of farmyard manure at planting. In the following years apply the same amount, preferably after every harvest.

- Use ½–1 bag of TSP or DAP plus 5 t/ha farmyard manure at planting and apply 5 t/ha farmyard manure plus 2–3 bags of CAN in three split applications per year in subsequent years.
- Apply 60 kg of slurry in furrows at planting followed by split application of the same quantity twice a year or more frequently if possible after harvesting.

Management

- Weed after each harvest to maintain high productivity.
- Harvest when 1 m high or every 6–8 weeks to obtain optimal quality and quantity.
- Maintain a stubble height of 5–10 cm from the ground level at each harvest to avoid weakening the root system, which leads to low production in subsequent harvests.
- To increase yields during the dry season, one of the split applications of the recommended rate of nitrogen fertilizer should be done 1 or 2 months before the end of the rainy season.

Tumbukiza method

'Tumbukiza', a Kiswahili word meaning 'placing in a hole', is a new planting method started by farmers to increase productivity per unit of land. The method, which involves planting cuttings or root splits in well-manured holes, produces more herbage yields than the conventional method. Hence less land is required for one dairy cow.

Step 1: Dig round or rectangular pits 60 cm (2 ft) deep and 60–90 cm (2–3 ft) wide. Alternatively, make trenches 60 cm (2 ft) deep and 60–90 cm (2–3 ft) wide and of various lengths depending on the farmer's preference.

Step 2: Separate topsoil from subsoil as you dig the pit or trench.

Step 3: Mix every 20-litre container ('debe') of topsoil with 1–2 debes of farmyard manure and put it into the pit. For the trench, place topsoil and farmyard manure mixture every metre along the pit.

Step 4: Leave about 15 cm (6 in.) unfilled space at the top of each pit.

Step 5: Plant 5–10 cane cuttings or single root splits in the round and rectangular pits. In trenches plant 5–10 cane cuttings or single root splits every metre.

Step 6: Plant sweet potatoes or forage legumes between the pits to increase the quality of forage and to control weeds.

The initial labour cost for digging pits and trenches is higher than for the conventional method. See Figure 4.2.

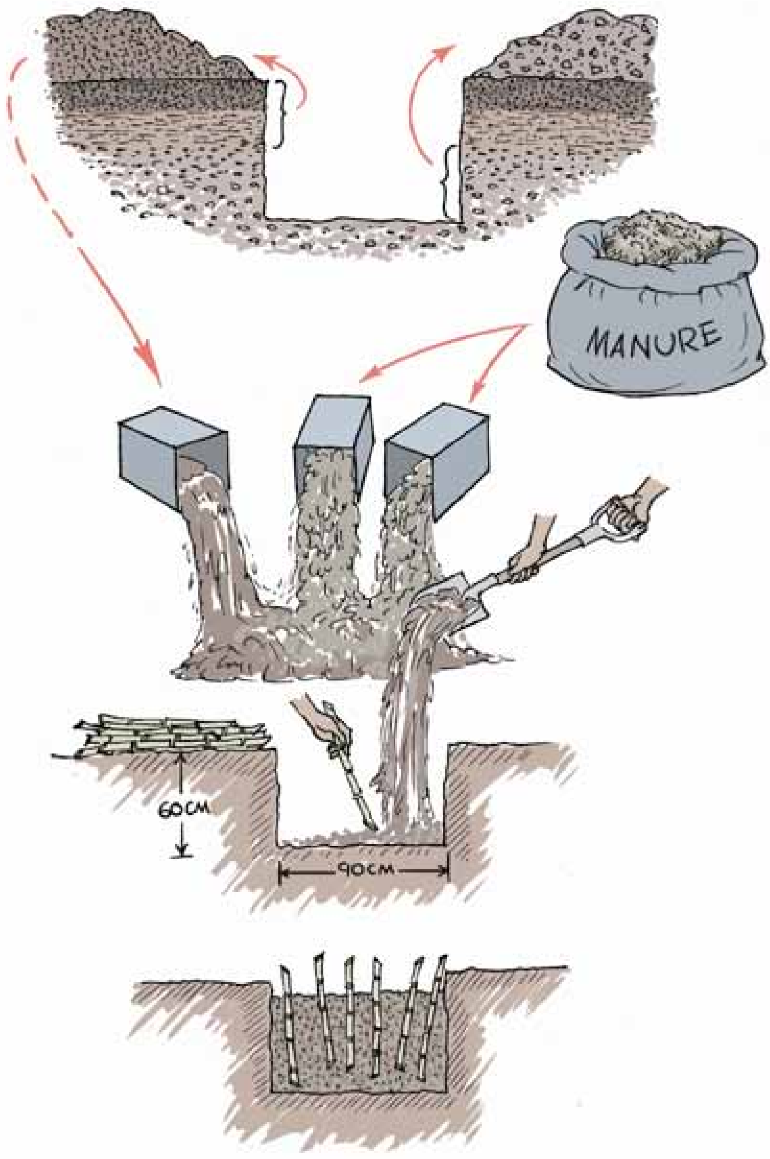

Figure 4.2. Planting Napier grass using the tumbukiza method.

Benefits of the tumbukiza method

- less land is required
- regrowth is faster in the dry season
- feed is available even during the dry season

4.2.2 Sweet potato

Sweet potato vines have a higher nutrient content than does Napier grass and are normally fed to cattle as a supplement. They are particularly recommended for calves as they increase the growth rate and promote rumen development. They are also good for recently calved and sick animals. They increase milk yield when fed to lactating cows.

Their main setback is high moisture content.

Varieties

The main local sweet potato vines varieties include

- Kiganda
- Muibai
- Sandak
- Mugande

Yields of some improved varieties are listed in Table 4.2.

Table 4.2. Yield of sweet potato varieties

Variety	Category	Yield t/ha (fresh weight)		
		Roots	Foliage	CP (%)
Kemb 23	dual purpose	10	24	16.6
Kemb 36	dual purpose	7	27	15.3
Musinyamu	fodder	2	70	18.5

CP – crude protein

Establishment

Plant sweet potato vine cuttings (30 cm long) at a spacing of 90 cm between rows and 30 cm within rows. Vines may be planted in ridges, mount or flat. For fodder production ridging or mounting has no advantage.

Apply 2 bags TSP fertilizer per hectare at planting.

Management

The first harvest is done when the vines cover the ground about 4–5 months after planting. There are three methods of harvesting.

- Harvest forage at intervals of 6 to 8 weeks leaving a stubble length of 25 cm for dual-purpose varieties and 5 cm for fodder varieties.
- Selectively pluck vines at the length of ½–1 metre from the tip at an interval of 3–4 weeks.
- For vines planted on ridges, cut those extending beyond the ridges.

Feeding

Cut and carry to the cow and feed up to 15 kg fresh material per day, as a supplementary feed to Napier grass or other basal feeds.

4.2.3 Oats

Oats are recommended as a fodder crop for the high-altitude regions of Kenya (over 2100 m) and may be grown in pure stand or as a mixture with vetch.

Establishment

- Drill oat seeds in rows 30–40 cm apart.
- When oat is being grown as a pure stand, 70–80 kg of seed per hectare is recommended. When grown as a mixture with vetch, 30–40 kg of oats and 20 kg vetch seed per hectare is recommended.
- Apply 2–3 bags TSP fertilizer per hectare at planting.

Management

- Hand weed or spray with herbicide 2,4-D amine 72% at the rate of 2.5 litres per hectare (spraying is done when oat is grown as a monocrop but not when grown with vetch).
- Cut at milk stage (4 weeks) leaving a stubble height of 5 cm from ground level.
- Topdress with 3 bags of CAN/ha to enhance growth and subsequent fodder yield.

Feeding

- Cut oats at milk stage and wilt it before feeding to prevent bloat.
- Oats can be cut and conserved as hay or silage.
- If being conserved either as silage or hay, oats should be cut when the grain is at milk or dough stage.

4.2.4 Fodder sorghums

Sorghums are drought resistant and grow well in dry areas. Sudan grass and Columbus grass varieties are recommended for the drier parts of the East African region.

Establishment

- Sorghums require a well-prepared seedbed to ensure even germination.
- Planting should be at the start of the rains.
- At planting drill 25–35 kg of sorghum seed per hectare at a spacing of 30–40 cm from row to row or broadcast.

- Use 1 bag of TSP fertilizer per hectare during planting and topdress with 2–3 bags of CAN fertilizer per hectare after cutting or grazing to stimulate new regrowth.

Management

- Sorghums should be cut every 6–8 weeks.
- After 5–6 cuttings it becomes uneconomical to maintain the crop and it should be ploughed.
- Do not graze sorghum earlier than 6 weeks to avoid prussic acid poisoning.

Feeding

The quantities required to feed a dairy cow per day are the same as for Napier grass.

4.3 Forage legumes

Forage legumes play an important role in the smallholder farming system as they

- improve soil fertility through nitrogen fixation.
- have high crude protein in the leaves and foliage, which can be used as a protein supplement for cattle. Legumes have high crude protein levels in the range of 15–34%, as compared with grasses, which are in the range of 5–19%.
- are rich in minerals (calcium, phosphorus) and vitamins A and D.

4.3.1 Desmodium

Desmodium can be grown as a sole crop or as an intercrop with grasses (Figure 4.3).

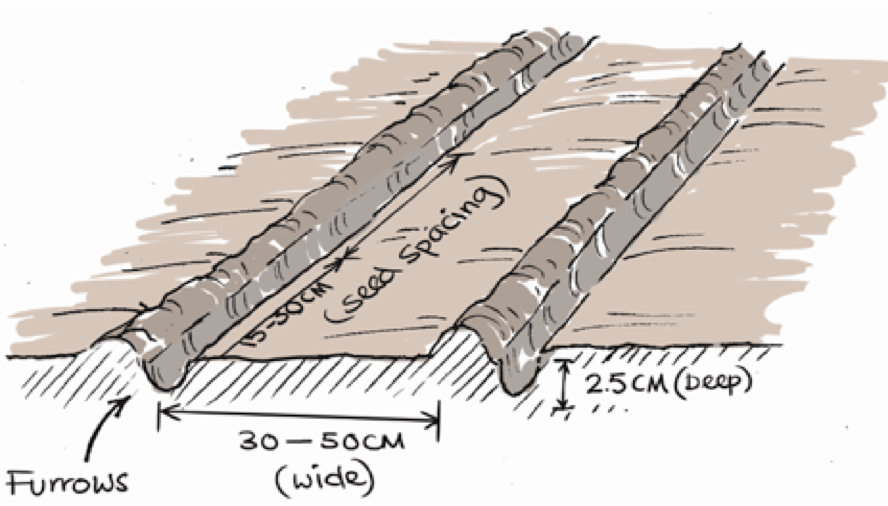

Figure 4.3. Planting desmodium.

Establishment

Two methods of establishing desmodium are common: from seeds and from cuttings.

Establishment from seeds

- Desmodium requires a fine, firm and weed-free seedbed.
- Seedbed preparation should be done well before the onset of rains.
- Use 3–5 kg/ha (2 kg/acre) desmodium seeds.
- During planting, mix seed with 2 bags of TSP or 4 bags of SSP fertilizer. Farmers can also use 5–10 t/ha of well-decomposed farmyard manure.
- Drill the seed into shallow furrows 2.5 cm deep spaced at 30 cm or 50 cm; cover with little soil.
- For intercropping with Napier grass, make furrows between or along the Napier rows and drill desmodium seed and fertilizer mixture in the furrows.

Establishment from cuttings

- Use mature parts of desmodium vines.
- Use freshly cut vines.
- Bury 2 nodes leaving 1 or 2 nodes above the ground.
- Space at 30 cm or 50 cm from row to row and 15–30 cm from vine to vine.
- Use the same rates of fertilizer as for seed but place it in holes.
- To maximize germination, ascertain that the amount of rain before planting has been adequate.

Management

- Keep the stand free of weeds, especially during the early stages before the crop covers the ground, by using hoe or herbicide 2,4-D amine 72% at the rate of 2.5 litres per hectare.
- Topdress with 2–4 bags of TSP or SSP fertilizer every year to maintain high yields of desmodium herbage and seed.
- For herbage production, make first cut 3–4 months from planting. Subsequent cuttings should be at intervals of 6–8 weeks.
- Spray against harmful pests, especially when producing desmodium seed.
- Harvest seed when the pods have turned brown by hand stripping the ripe pods and store in a dry place after threshing to avoid rotting.

Use

- Cut and feed in green form.
- Cut and conserve as hay, whole or chopped.

Yields

Yields of 9–10 t/ha dry matter per year of 18–20% crude protein have been reported under good management. An acre can produce 30–60 kg of seed.

Other benefits

When intercropped with maize it will

- provide nitrogen to the crop
- inhibit the growth of striga weeds
- reduce damage by the maize stemborer
- control soil erosion

4.3.2 Lucerne

Dairy farmers in the high-rainfall areas of East Africa prefer lucerne over any other forage legume, primarily because of its palatability and high nutritive value that can sustain high milk production levels when fed to dairy cattle. Commonly grown lucerne varieties:

- Cuf 101
- Hunter River
- Hairy Peruvian

Hairy Peruvian does well in high altitudes while Hunter River and Cuf 101 are suited to lower altitudes. Others that have been tested are shown in Table 4.3.

Table 4.3. Lucerne varieties

Lucerne variety	Agroecological zone	Altitude (m)	Average rainfall (mm)
SA Standard	Dry highland (LH5)	2190–2280	800–900
KKS9595, WL625HQ	Wet highland (LH2)	2070–2400	1000–1200
WL414, WL625HQ	Wet midland (UM4)	1830–2100	1000–1200
KKS3864, WL625HQ	Dry midland (UM4)	1840–2010	800–900

LH – lower highland, UM – upper midland

Seedbed preparation

Lucerne requires a fine, firm seedbed, prepared well before the onset of the rains. The subsoil should be well broken with a forked hoe. Apply 10 t of well-decomposed farmyard manure or compost manure and dig it in down to the subsoil (Figure 4.4).

Lucerne is deep rooted and requires deep soil.

Figure 4.4. Preparing the seedbed for lucerne.

Planting

- Make furrows 30–40 cm apart and 2.5 cm deep.
- Mix 10–15 kg seeds with 4–6 bags of SSP fertilizer or 2–4 bags of TSP fertilizer and drill into the furrows; cover with a little soil.
- Use 10–15 kg/ha lucerne seed.
- In areas where lucerne has never been grown use lucerne inoculants (available from the Faculty of Agriculture, University of Nairobi).
- If inoculant is not available, collect soil from areas where lucerne has been previously grown and mix with the seeds before planting.
- In acidic soils (pH less than 4.9) liming with agricultural lime is recommended at the rate of 10 t/ha.

Phosphate, inoculant and liming promote root development, nodulation and nitrogen fixation, respectively.

Management

- Weed control: hand weed at least 4–6 weeks after planting and thereafter whenever weeds appear.
- Spray against aphids and other pests with insecticides such as dimethoate at intervals of 2–3 weeks if necessary.
- Continue applying farmyard manure to lucerne field to improve soil fertility, structure, texture and herbage yields.

- Apply 1 bag of TSP fertilizer per hectare annually.
- Harvest lucerne when it starts flowering (about 30 cm high) to a stubble height of 4–5 cm from ground level. One can obtain 6–8 cuts in a year.
- The crop can last up to 4 years under good management.

Use

- Cut and feed lucerne in green form after wilting it to avoid bloating.
- Conserve the excess lucerne as hay, whole or chopped.
- Conserve as silage when combined with other types of fodder such as maize.

Yields

Yields of 5–6 t/ha dry matter per year of 20–25% crude protein have been reported under good management.

4.3.3 *Dolichos lablab*

A short-lived perennial or annual legume, *Dolichos lablab* is cultivated as human food, green manure, cover crop and animal fodder. Dolichos has several advantages:

- It provides better late-season grazing because it is tolerant to seasonal drought.
- It is more compatible than cowpea with forage sorghum or maize when intercropped.
- It gives higher yield of materials for conservation than do forages such as cowpea when drought sets in.
- It has better resistance to diseases such as phytophthora rust and stem rot, which wipe out many cowpea crops.
- It has better resistance than other forages, such as cowpea, to attack by insects like the bean fly.

Seedbed preparation

- Dolichos has a large seed thus does not require a fine seedbed as does lucerne.
- Highest yields are obtained on land that has not been previously cultivated (fallow land).
- It grows well on acidic soils.

Planting

- Space at 45 cm between rows and 30 cm from plant to plant, placing 2 seeds per hole.
- Use 60 kg/ha seed.
- Use 1–2 bags TSP per hectare or 5–10 t/ha of well-decomposed farmyard manure.

Management

- Harvest for fodder at an interval of 6 weeks (1½ months) leaving a stubble height of 15 cm from ground level.
- Weed as required.
- To get optimal yields in quantity and quality, harvest at early flowering stage.

Use

- Dolichos can be conserved as hay or ensiled.
- It can be fed green to dairy cattle as a legume supplement.

Dolichos analysed as a whole plant contains 16.8% crude protein with a dry matter yield of about 6 t/ha. The seed yield ranges from 1.1 to 3.4 t/ha with 20.25% crude protein content.

4.3.4 *Stylosanthes guianensis*

Stylo *(Stylosanthes guianensis)* performs well in wetter and warmer areas and on sandy soils. Its ability to grow well on soils of low fertility is particularly valuable both to provide good-quality grazing on these soils and to improve the fertility of the soil. It is useful for weed control and grows well in pasture mixtures containing Rhodes grass. It grows rather slowly in early establishment stages but persists better in grass–legume mixtures than does desmodium (see Figure 4.5).

Figure 4.5. A mature crop of stylo in the field.

Seedbed preparation

Prepare a firm, fine seedbed.

Planting

- Drill at a spacing of 30–40 cm rows or broadcast the seed, especially when oversowing.
- Sow 3–4 kg/ha of seed.
- Apply 1–2 bags TSP per hectare.

Management

- Weed as required.
- When grown in a grass–legume mixture, graze to reduce the shading effect of grass during the early establishment stage.
- Harvest or graze at 6 weeks at intervals of 1½ months, leaving a stubble height of 5 cm.

Use

- Graze or cut and carry.
- Cut and conserve as hay.

Yields

The whole stylo plant has a crude protein content ranging from 12.1% to 18% and dry matter yields ranging from 4.1 to 6.7 t/ha per year.

4.3.5 Fodder trees

Fodder trees are used by small-scale dairy farmers as a cheap source of protein for dairy cows.

Figure 4.6. A flourishing crop of calliandra in the field.

Common types of fodder trees:

Calliandra—does well in upland areas with medium to high rainfall (700–2000 mm). It regrows well after cutting and harvesting (Figure 4.6).

Leucaena—also does well in upland areas with medium to high rainfall. It is slightly more drought resistant but is more subject to attack by insect pests. Regrows well after cutting and harvesting (Figure 4.7).

Sesbania—grows better in high-rainfall areas and does better than other fodder trees in higher, cooler areas. In its early stages, it grows faster than calliandra or leucaena but it does not regrow as well after harvesting.

Figure 4.7. Leucaena in the field.

Use of fodder trees

- Leaves, pods and soft young twigs provide good feed for cows.
- They are a good supplement to straw, stover and poor grass diets.
- They provide high-quality forage in the dry season.

Establishment

- To achieve good germination, place the seeds in boiling water for 4 seconds then soak them in cold water for at least 12 hours before planting them.
- Sow the seeds either directly into hedge rows at a spacing of 30–60 cm from plant to plant or in a nursery for later planting when they have reached a height of 60 cm.

- Plant on the hedgerows around the homestead, on contour lines in the field, or as part of soil conservation structures.
- Apply 5 g (1 teaspoonful) of TSP fertilizer per hole during planting.

Management

- Protect young trees from livestock.
- Cut trees when they are about 2 m tall, leaving a row of hedge 1 m high.
- Harvest every 3–4 months.
- Leave a few trees to grow tall for firewood and seed.
- For seed, collect pods when they start to turn brown, before they split open.
- Dry pods on a sheet or gunny bag.
- Store collected seed in a tin or plastic container with a strong lid.

Feeding

- Can be either fed fresh cut or dried for later feeding.
- To encourage intake, mix with mineral salts or other feeds.

Other benefits

- Improves soil fertility by providing green mulch or by fixing nitrogen.
- Supplies fuelwood.
- Supplies wood for building.
- Provides live fencing.
- Furnishes food for bees.

Yields

Leucaena. Start harvesting at the beginning of the second wet season by cutting back to 50 cm above ground level. Cut twice during the wet season when the regrowth is 50–60 cm, or once at the end of the wet season, and conserve as dry leaf meal. Grazing or harvesting intervals can be 6 to 8 weeks or 12 weeks in less favourable conditions. When well managed, leucaena can yield up to 2 t/ha dry matter per year.

Calliandra. A well-established stand can be harvested 4 to 5 times a year with the harvesting interval varying with the rainfall. Cut again when the regrowth is 50–60 cm. Depending on rainfall and soil fertility, dry matter yields range from 5 to 10 t/ha per year. The edible fraction of calliandra has a crude protein level of 20–25% of the dry matter.

4.4 Forage conservation

4.4.1 Why conserve forage?

Because rain-based pasture and fodder production is seasonal, there are times of plenty and times of scarcity. It is thus imperative to conserve the excess for use in times of dry-season scarcity. The aim of conservation is to harvest the maximum amount of dry matter from a given area and at an optimum stage for utilization by animals. It also allows for regrowth of the forage.

The two main ways of conserving fodder are by making hay or making silage.

4.4.2 Haymaking

Hay is fodder conserved by drying to reduce the water content so that it can be stored without rotting or becoming mouldy (reducing the moisture content slows down the rate of growth of spoilage microorganisms). The moisture content should be reduced to about 15%.

Not all grasses and fodder are suitable for haymaking. Table 4.4 gives examples of fodders that can be conserved as hay in East Africa.

Table 4.4. Forages suitable for conservation as hay

Fodder type	Agroecological zone	Dry matter yield* (kg/acre)	20-kg hay bales (no.)
Boma Rhodes grass	LH3	4868	243
Elmba Rhodes grass	LH3	3944	197
Lucerne	LH3	2718	136
Vetch	UH1	1432	72

LH – lower highland, UH – upper highland
* Yields of Elmba and Boma Rhodes grass are based on 2 harvests a year, lucerne on 3 harvests a year and 1 harvest a year for vetch

Harvesting and curing

- Harvest the fodder for haymaking when the crop has attained 50% flowering. At this stage protein and digestibility are at maximum, after which they decline with age.
- The fodder should be harvested after 2 to 3 days of dry weather so that drying will be possible.
- Where possible, drying should be done under shade so that the dried fodder retains its green colour, which is an indicator of quality.
- Turn the fodder using a farm fork to ensure even drying.
- Check the dryness by trying to break the stem. If it bends too much without breaking, there is still too much water.

- Legumes and grasses can be mixed to make better-quality hay, e.g. Rhodes grass + lucerne.

Baling hay

Baling the hay allows more material to be stored in a given space. A good estimate of the amount stored makes feed budgeting easier. Baling can be manual or mechanized, manual baling being more economical for small-scale dairy farmers.

Manual hay baling is done using a baling box with dimensions 85 cm long x 55 cm wide x 45 cm deep, open on both ends (Figure 4.8). If the hay is well pressed, the box will produce an average bale of 20 kg.

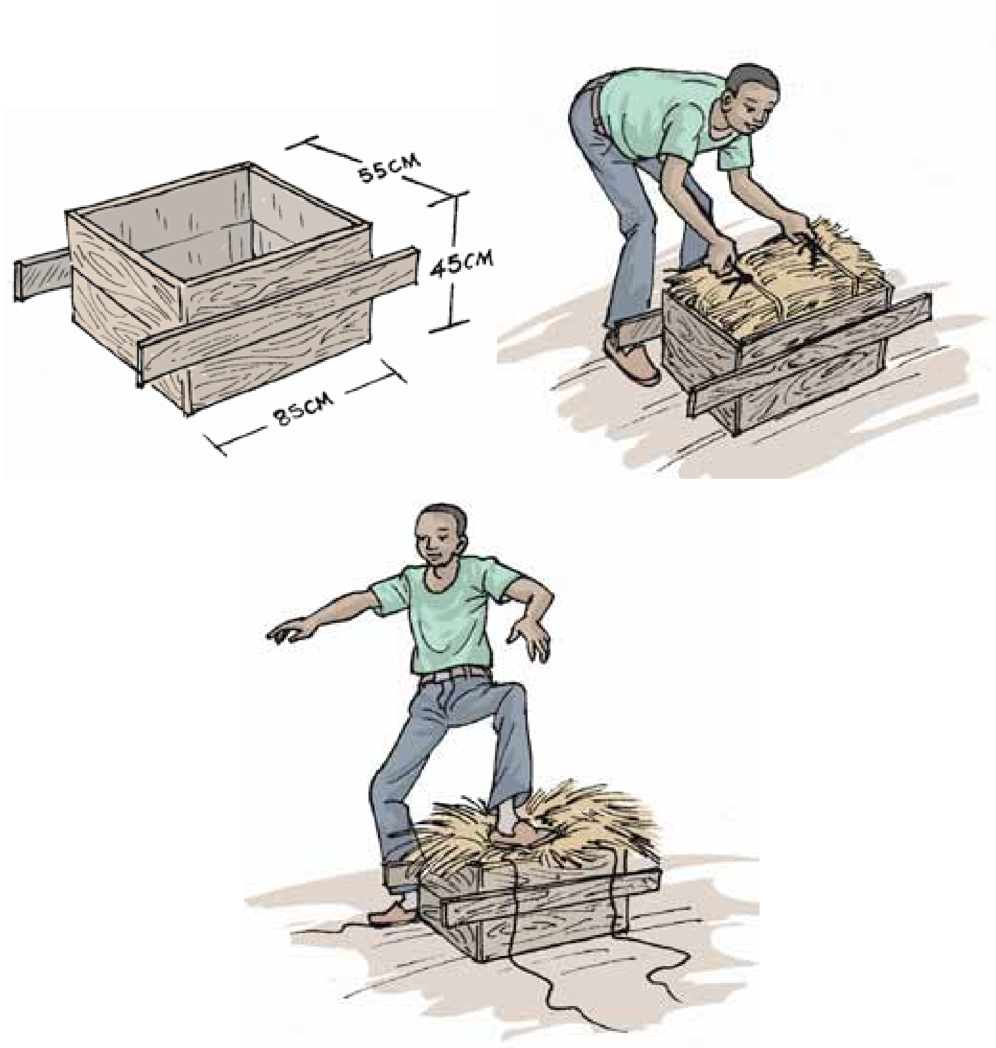

Figure 4.8. Box baling.

Hay can also be stored without baling by heaping it into a dome-shaped stack and covering it with a polythene sheet or a tarpaulin.

Storage

Hay should always be stored in a sheltered enclosure away from direct sunlight and rainfall, e.g. in hay barns. Rats and other rodents should be controlled as they can damage the hay.

Characteristics of good-quality hay

The quality of the hay should be evident on physical examination. Good-quality hay should

- be leafy and greenish in colour
- have no foreign material mixed with it
- have no smell

Feeding

A dairy cow weighing 400 kg will consume an equivalent of about 3% of its body weight in dry matter (12 kg dry matter) per day. Since hay contains 85% dry matter, if the cow consumes nothing else, it will require 14 kg of hay per day.

4.4.3 Leaf meal

Leaf meal is conserved material from the protein-rich fodder legumes, which include lucerne, calliandra, leucaena and dolichos.

How to make leaf meal

- Harvest the leaves and dry them on a clean floor (under shade).
- Collect the dry leaves and put them in a gunny bag.
- Store the leaf meal in a dry place and away from the sun.
- Feed as a supplement. The meal should not form more than 30% of a daily ration.
- Wet the leaf meal with water before feeding to reduce wastage through spillage.

4.4.4 Silage

Silage is high-moisture fodder preserved through fermentation in the absence of air. These are fodders that would deteriorate in quality if allowed to dry. Silage can be made from grasses, fodder sorghum, green oats, green maize or Napier grass.

An ideal crop for silage making should

- contain an adequate level of fermentable sugars in the form of water-soluble carbohydrates
- have a dry matter content in the fresh crop of above 20%
- possess a physical structure that will allow it to compact readily in the silo after harvesting

Crops not fulfilling these requirements may require pre-treatment such as

- field wilting, to reduce moisture
- fine chopping to a length of 2–2.5 cm to allow compaction
- use of additives, to increase soluble carbohydrates

Dry matter yield of common fodders used for silage making is 4–12 t/acre for Napier grass, 6.8–8.8 t/acre for sorghum E6518 and 9.6 t/acre for maize.

Harvesting stages

Napier grass should be harvested when it is about 1 m high and its protein content is about 10%. Maize and sorghum should be harvested at dough stage, that is, when the grain is milky. At this stage, maize and sorghum grains have enough water-soluble sugars so it is not necessary to add molasses when ensiling, However, when ensiling Napier grass, it is necessary to add molasses to increase the sugar content. To improve silage quality, poultry waste and legumes like lucerne and desmodium may be mixed with the material being ensiled to increase the level of crude protein. However, since protein has a buffering effect that increases the amount of acid required to lower pH, poultry waste and legumes should be incorporated within limits. Poultry litter should not exceed 5% and legumes should not exceed 25% of the total material ensiled.

Types of silos

A silo is an airtight place or receptacle for preserving green feed for future feeding on the farm. Silos can be either underground or above ground, the qualification being that the silo must allow compaction and be airtight. Five types are described here: tube, pit, above-ground, trench and tower.

- Silage can be made in large plastic sacks or tubes. The plastic must have no holes to ensure no air enters. This is popularly referred to as tube silage.
- Silage can also be made in pits that are dug vertically into the ground and then filled and compacted with the silage material.
- An above-ground silo is made on slightly sloping ground. The material is compacted and covered with a polythene sheet and a layer of soil is added at the top. When finished, it should be dome shaped so that it does not allow water to settle at the top but rather collect at the sides and drain away down the slope.
- The trench silo is an adaptation of the pit silo, which has long been in use. It is much cheaper to construct than a pit silo. Construction is done on sloping land. A trench is dug and then filled with silage material. This method is ideal for large-scale farms where tractors are used. Drainage from rain is also controlled to avoid spoiling the silage.
- Tower silos are cylindrical and made above-ground. They are 10 m or more in height and 3 m or more in diameter. Tower silos containing silage are usually unloaded from the top of the pile. An advantage of tower silos is that the silage tends to pack well due to its own weight, except for the top few metres.

Tube silage

- Chop the wilted material to be ensiled into pieces not more than 2.5 cm long (Figure 4.9).

Figure 4.9. Chopping fodder for ensiling.

- Sprinkle the chopped material with a molasses and water mixture; for every sack use 1 litre of molasses mixed with 2–3 times as much water. This is especially for material like Napier grass that has low sugar content. Maize bran or cassava flour can be added to improve the carbohydrate (energy) content (Figure 4.10).

Figure 4.10. Adding molasses.

- Place the chopped material, sprinkled with the molasses and water mixture, into the plastic tubing (1000 gauge) with a width of 1.5 m. Cut a 2.5-m length, tie off one end and fill with the material, compressing it well, then tie the other end to seal. Stack the filled sacks until needed. Fermentation is usually complete after 21 days (Figure 4.11).

Figure 4.11. Steps in making tube silage.

Qualities of good silage

Well-prepared silage is bright or light yellow-green, has a smell similar to vinegar and has a firm texture. Bad silage tends to smell similar to rancid butter or ammonia.

Natural microorganisms ferment the sugars in the plant material and in the added molasses into weak acids, which then act as a preservative. The result is a sweet-smelling, moist feed that cattle like to eat once they get used to it.

Storage and feeding

Tube silage should be stored under shade, for example in a store. Rats and other rodents that could tear the tube need to be controlled. When feeding, open the tube and scoop a layer and remember to re-tie without trapping air inside.

When feeding from the pit, scoop in layers and cover after removing the day's ration, making sure the pit is airtight. Drainage from the top should be guided to avoid rainwater draining into the pit.

When feeding from the above-ground method, open from the lower side of the slope, remove the amount you need for the day and re-cover it without trapping air inside.

To avoid off-flavours in milk, feed silage to milking cows after milking, not before, or feed at least 2 hours before milking.

Losses

Nutrient losses may occur during silage making. In the field during cutting, losses due to respiration during wilting will be about 2% per day. If it rains, leaching may cause some loss.

- Overheating due to poor sealing gives a brown product, which may smell like tobacco and result in severe damage to nutrients, e.g. proteins.
- Effluent losses of 2–10% that occur from moisture seepage contain soluble and highly digestible nutrients; seepage should be avoided by wilting the herbage.

Silage additives

During silage preparation, different types of additives can be incorporated to improve the quality. These include *fermentation stimulants*. Some crops may not contain the right type or the right number of lactic acid bacteria. Bacterial inoculants and enzymes can hasten and improve fermentation by converting carbohydrates to lactic acid. Most inoculants contain *Lactobacillus plantarum*.

Fermentation inhibitors include acids such as propionic, formic and sulphuric. Inorganic acids are more effective but are strongly corrosive thus not recommended. Of the organic acids, formic is more effective than propionic, lactic or acetic.

Substrate or nutrient sources (grains, molasses, urea or ammonia) are used when there are insufficient soluble carbohydrates in the material to be ensiled (e.g. legumes, Napier grass, crop residues). They are also used to increase the nutritive value of the silage. Molasses can be added at the rate of about 9 kg/t of silage.

Note: Use of additives is not a prerequisite for making good silage, but it is good for crops such Napier grass, lucerne and grasses such as *Cynodon dactylon* (star grass), *Brachiaria brizantha* (signal grass), and *Setaria sphacelata* (bristle grass) because it improves fermentation and nutritive value of the resultant product.

4.4.5 Fodder banks

Fodder banks refer to fodder left standing in the field to be used during times of feed scarcity. They can be used all year but are meant to cushion the farmer against forage scarcity expected during dry seasons. Fodder banks do not supply 100% of nutrients required but supplement the available dry-season forage. Suitable fodder bank species are shown in Table 4.5.

Table 4.5. Fodder bank species suitable for different agroecological zones

Arid and semi-arid tropics	Humid tropics	Highland tropics
Cajanus cajan	*Cajanus cajan*	*Calliandra calothyrsus*
Sesbania sesban	*Calliandra calothyrsus*	*Leucaena diversifolia*
	Leucaena diversifolia	*Sesbania sesban*
	Leucaena leucocephala	
	Sesbania sesban	

4.5 Crop by-products

4.5.1 Definition

Crop by-products are fibrous plant materials left behind after harvesting human food crops and are available in many areas where crop agriculture is practised. They are generally high in fibre, low in digestibility and low in crude protein. On small farms in developing countries they form the principal feed of ruminant livestock during dry seasons.

Crop residues include straw and chaff from cereal grains (rice, wheat, barley, oats), stover (maize, sorghum), maize cobs, bean haulms, and sugar cane tops and bagasse (see also Table 4.6).

Crop by-products have common characteristics:

- poor palatability
- low in crude protein (mostly below 6%)
- high in cellulose and other structural carbohydrates (crude fibre)
- low digestibility
- low in calcium and phosphorus

Straw has no vitamin A (carotene content, related to green colour of the plant.

Table 4.6. Typical nutrient content of some crop by-products

By-product	DM (%)	CP (%)	CF (%)
Sugar cane bagasse	95	3.0	43.1
Rice straw	92	4.2	42.3
Maize stover	91	6.0	42.0
Cassava leaves (dried)	90	24.7	17.3
Wheat straw	86	4.0	42.0
Barley straw	86	4.0	42.0
Sugar cane tops	26	5.0	32.6
Sorghum stover	25	6.0	28.1
Banana stem	5	3.2	19.1
Lucerne hay (for comparison)	90	19.0	25.0

DM – dry matter, CP – crude protein, CF – crude fibre

Crop residues can be used for feeding dairy cattle but cannot supply adequate nutrients without supplementation. Because of their low digestibility they remain in the rumen for a long time, limiting intake. The other major limitation is they do not contain enough crude protein to support adequate microbial activity in the rumen. It is therefore advisable to feed them with a true protein source (as opposed to a non-protein source, e.g. urea) such as fodder legumes or commercial supplements such as cottonseed cake.

Crop residues should not be fed in large amounts to growing animals. If used, they should make up no more than 25% of the diet with the remainder comprising high-quality feeds.

4.5.2 Improving the quality of crop residues

Several methods have been developed to improve the quality of crop residues, but chemical treatment has received the most attention.

Physical methods

Chopping straw to 5 cm or a little longer before feeding is a common practice. Scientific tests have shown that chopping does not improve straw digestibility, but it does increase intake, reduce wastage and make it easy to mix the straw with other feed components.

There is also the salting method, in which chopped straw is soaked in a dilute salt solution before feeding. Although this method has not been scientifically tested, many farmers practise it, considering it effective.

Supplementation

Supplementation of crop residues with grasses, legumes or concentrate feeds significantly improves feed intake and animal performance. In dryland farming systems where forages are scarce, crop residues are supplemented with concentrate feeds. Supplementation of the basal diet with good-quality forage or concentrates helps to overcome the problem of low palatability.

Urea treatment

Treating crop residues with 4% urea solution at 45–50% moisture improves the nutritive value by increasing the digestibility, palatability and crude protein content. The process is simple and farmers can easily practise it. The chopped material is soaked in urea solution mixed at the rate of 4 kg urea (fertilizer grade) in 100 litres of water (4%). The urea-water solution is sprinkled on batches of the chopped material as it is added to the pit. After each addition, the mixing should be thorough. The mixing can be done in the pit or on a plastic sheet on the ground before packing the pit. It is commonly recommended that the pit remains closed for at least 3 weeks and preferably 1 month, but treatment times longer than necessary do not have adverse effects.

The urea is converted to ammonia, which then breaks down some of the bonds in the fibrous material, making them accessible to microbial enzymes.

Urea–molasses blocks

Urea–molasses blocks provide both energy and nitrogen to the microorganisms in the rumen and thus improve the digestion of crop residues such as straw.

CHAPTER 5: SUPPLEMENTS

5.1 Concentrates

Concentrates are rich in nutrients (energy and/or protein) and provide far more nutrients than an equivalent weight of roughage. They are low in fibre and usually have higher dry matter content. They include compounded commercial feeds (e.g. dairy meals, cubes and pellets) as well as single ingredients, such as pollard, maize germ meal or cottonseed cake.

5.1.1 High-energy concentrates

Concentrates are added to a ration primarily to increase its energy density. They are mostly cereals or cereal by-products, roots and tubers, or liquid feeds like molasses, fats and oils. They also contain other nutrients—proteins, minerals and vitamins—but in small quantities. See Table 5.1 for a list of energy sources for dairy cattle.

Use of whole cereals for feeding dairy cows is not common due to their high cost and competing use as food for humans, thus their by-products are more commonly used.

5.1.2 High-protein concentrates

All the energy sources discussed earlier also supply protein but usually not in enough quantity to meet the animal's requirements. Protein supplements are defined as feedstuffs that contain more than 20% crude protein on a dry matter basis. The main sources are *animal, marine, plant, microbial or non-protein nitrogen*. The choice depends on availability and cost of the feedstuff (Table 5.2).

5.1.3 Non-protein nitrogen

Non-protein nitrogen includes nitrogen compounds that rumen microorganisms use to synthesize protein, which the animal can then use. Examples include ammonia, urea and DAP. In practical feeding, non-protein nitrogen refers to compounds added to feed such as urea. Non-protein nitrogen is used only in ruminant feeds, since simple-stomached animals cannot use ammonia from the urea breakdown.

Of all the non-protein nitrogen sources, urea is the cheapest, thus widely used. Animals fed on poor-quality roughage should not be fed non-protein nitrogen as the energy required to utilize urea may not be available. Under these circumstances, true proteins (e.g. cottonseed cake) should be fed or urea mixed with a good energy source such as molasses.

5.1.4 Urea toxicity

Urea can be toxic or lethal depending on the size and timing of the dose. The level of urea the animal can tolerate is affected by its adaptation to urea and the type of diet, among other things. Urea toxicity is treated by administering vinegar (acid) to reduce the rumen pH and prevent further absorption.

Table 5.1. Common energy sources for dairy cattle

Ingredient	Source	Remarks
Maize grain	Whole grain	Rarely used as feed except for high-yielding cows
Maize bran	Outer coating of the maize grain	Has moderate energy, CP 11%, CF 10%
Full fat maize germ	Embryo, which contains a lot of oil	High-energy content
Maize germ meal or cake	Left over after extraction of oil from germ	High-protein content
Wheat bran	Coarse outer covering—the husk and some adhering endosperm	Fibre highly digestible, CP 15%, CF 12%
Wheat pollard (middlings)	Part of endosperm, germ, bran particles and some flour	Not as palatable as bran due to its tendency to form a pasty mass in the mouth, CP 16%, CF 7.5%
Barley	Mostly rejected barley	Low starch content, high fibre. Best fed when steam-rolled to increase digestibility, CP 11%
Multiculms (multisprouts)	Sprouts and rootlets obtained from malted barley	Mostly used as protein supplement, CP 27%, CF 16%
Wet brewers grain ('machicha')	Insoluble residue left after fermentable substrates from barley are removed	High moisture content. Wet grains rapidly become rancid. Use immediately or ensile in absence of air, CP 18%, CF 15%
Sorghum	Resembles maize nutritionally	Should be fed to cattle and horses in ground form, CP 12%, CF 3%
Rice hull	Low nutritive value, very fibrous	Due to the high fibre, these hulls are of low digestibility and therefore of little value
Rice bran	Pericarp, aleurone layer, germ and some endosperm	Very palatable when fresh; CP 12.5%, CF 13%, fat 10–13%. Becomes rancid with storage due to high fat content
Rice polishing	Fine powdered material obtained when polishing rice grain after hulls and bran have been removed	CP 12%, CF 4%, fat 11%

Ingredient	Source	Remarks
Oats	Whole grain	Good cereal for cattle due to high fibre content from the hull, CP 11–14%, CF 12%
Cassava root	Whole	Freshly harvested cassava has a high level of prussic acid; boiling or sun drying destroys the poison
Cane molasses	By-product from sugar cane milling, dry matter 75%, CP 5.5%, CF 0.3%	Provides energy, improves palatability of poor-quality feedstuffs; levels > 25% can cause diarrhoea and reduced feed efficiency. Molasses is of value in reducing dust in feed, as a pellet binder, or as a liquid protein supplement when mixed with urea
Fats and oils	Waste fat from eateries	Used to increase the energy density and to reduce dust. High levels of fat in diets lead to rancidity; > 8% fat in ration can cause rumen disturbances

CP – crude protein, CF – crude fibre

Table 5.2. Common protein sources

Source	Comments
Soybean/ soybean meal	Very palatable and highly digestible. The *whole seed* has 40% CP and 15–21% oil, which is extracted to make the meal. Extracted meal contains 47% CP. *Raw beans* have less nutritive value than heated beans or soybean meal, due to toxic substances. The toxins are especially harmful to young animals (calves)
Cottonseed/ cottonseed cake	*Whole cottonseed* has been used with good results for early lactating cows for its energy (fat), protein and highly digestible fibre. CP of whole seed 23%, of cake 35%. Cattle digest it well
Sunflower cake	In cows has performance similar to soybean and cottonseed cake. CP 26%
Peanut (groundnut) meal	Remains after extraction of oil from groundnuts. CP 45%; aflatoxin contamination may be a problem
Corn gluten feed	Mixture of maize bran and gluten. By-product during wet milling of maize. CP 21–23%
Corn gluten meal	Dried residue from the maize after removal of the larger part of starch and germ and separation with bran in wet milling. CP 40–60%
Coconut (copra) meal	Residue after extraction and drying of coconut meat. CP 20–26%. Has high fat content and may become rancid if stored long
Dried brewers yeast	By-product from brewing. Rich in CP (42%)
Meat meal, meat and bone meal	Made from carcass trimmings, condemned carcasses, inedible offal and bones. High fat content increases energy. Ash content is high: up to 28–36%, 7–10% of this being calcium and about 4–5% phosphorus
Blood meal	Produced from dried (either spray or cooker dried) ground blood. It has a high by-pass rate, thus is good for cows. CP 85%
Dry poultry waste	Excreta collected from caged birds, CP 25–28% (dry basis) of which 30% is true protein
Poultry litter	Mostly from broiler operations. Can be fed as is or ensiled with other products
Fish meal	Clean, dried, ground tissue of undecomposed whole fish or fish cuttings with or without extraction of part of the fat. Locally 'omena' is used as fish meal, CP 55%. High levels of fish meal or fish meal with high oil content may give an undesirable flavour to meat or milk. There is no special advantage in feeding fish meal to dairy cattle unless it is for by-pass protein. This protein, however, is expensive.

CP – crude protein

It is recommended that not more than 1% of the total nitrogen in concentrates be supplied by urea or any other non-protein nitrogen compound. In total mixed rations, urea should be restricted to not more than 0.5% of the diet (dry matter basis). More than this may make the feed unpalatable and reduce feed intake.

5.2 Minerals

Minerals make up a small portion of the diet but have a major functional contribution. Often their content in the basal diet is inadequate for high-producing dairy cows and supplementation is required. As roughages and concentrates cannot supply all the required minerals, supplementation with a mineral source is recommended.

The level of mineral supplementation depends on the mineral content of the basal diet. The mineral level in plant material in turn depends on the mineral content of the soil. As much as possible, the basal diet should meet the mineral requirements. Individual requirements for minerals depend on age and level of production.

Depending on the amount required, minerals are classified as macrominerals (g/day) or microminerals (mg/day or ppm). Table 5.3 shows some of the most commonly used sources for the macrominerals.

Table 5.3. Typical levels of minerals in commonly used supplements

	Dry matter (%)				
Supplement	Calcium	Magnesium	Phosphorus	Potassium	Sodium
Sodium chloride	—	—	—	—	39.34
Limestone	34.00	2.06	0.02	0.12	0.06
Magnesium oxide	3.07	56.20	—	—	—
Di-calcium phosphate	22.00	0.60	19.30	0.10	0.10

Microminerals are commonly added to the ration as pre-mixes obtained from commercial pre-mix manufacturers or through commercial mineral supplements. The mineral mixes are specific for age and level of production.

5.2.1 Mineral feeding methods

Force-feeding

Force-feeding is recommended for feeding minerals to dairy cows as it eliminates palatability problems, daily and cow-to-cow variation in intake, and over-consumption of minerals. The best method of force-feeding is in a total mixed ration. Another commonly used method is to use a grain carrier. This method is suitable where the requirements can be predicted fairly accurately.

Free choice

The free choice method is not as accurate as force-feeding but is very practical. The mineral supplement, which is usually in powder or block form, is purchased and placed in a mineral box. Construct a mineral box and place it in the housing unit or at a strategic place in the grazing area. The box should be raised from the ground and covered with a roof to protect the mineral from the rains. Animals consume the mineral ad libitum (as much and as often as desired).

Topdressing

The topdressing method is often used for stall-fed cows where individual feeding is practised. The mineral mixture in powder form is sprinkled on the chopped material and the animal consumes it as it feeds. The problem is the minerals may separate and settle at the bottom of the trough.

5.3 Vitamins

Most of the vitamins required by a dairy cow are present in the diet in sufficient amounts. Water-soluble vitamins are synthesized by rumen bacteria. Animals consuming aged grasses or improperly cured hay may require vitamin A supplementation.

5.4 Feed additives

Feed additives are non-nutritive in nature but are used to improve performance through improved feed use or by benefiting in some manner the health or metabolism of the animal. Several additives have been used for dairy cows. Feed additives are, however, neither a requirement nor a guarantee of high productivity or profitability.

An additive should be used only if income is increased over the cost of the additive. If the cost of additive equals the increase in product, there is no financial benefit in using it. The withdrawal period or product discard period should also be considered.

Factors that should be considered to determine whether to use a feed additive include anticipated response, economic return and available information. Response refers to the expected change in performance the user could expect or anticipate when a feed additive is included. Returns reflect the profitability of using a selected additive. One guideline is that an additive should return two shillings or more for each shilling invested to cover non-responsive cows and field conditions that could minimize the anticipated response.

Some of the changes brought about by different additives include

- higher milk yield (peak milk and/or milk persistency)
- increase in milk components (protein and/or fat)
- higher dry matter intake
- stimulated rumen microbial synthesis of protein and/or energy production
- increased digestion of nutrients within the digestive tract

- stabilized rumen environment and pH
- improved growth (gain and/or feed efficiency)
- reduced heat stress effects
- improved health, such as reduced ketosis, reduced acidosis or improved immune response

5.4.1 Bloat control products

Bloat control products are added to feed to prevent bloat, especially when animals are grazing on young grasses or legumes. Examples are Bloat Guard® (poloxalene) and Rumensin®.

5.4.2 Buffers

Buffers are added to dairy cattle rations to mitigate against drastic pH changes in the rumen. High concentrate rations or sudden change from high roughage to high concentrate will result in excessive production of acid in the rumen. The resultant low pH of the rumen changes the microbial populations, favouring acid-producing bacteria. This leads to rumen upsets and reduced fibre digestion, which can be mitigated by buffers through stabilizing the rumen pH. Examples are sodium bicarbonate (baking soda), sodium sesquicarbonate and magnesium oxide.

5.4.3 Probiotics (microbial enhancers)

Probiotics are substances that contain desirable gastrointestinal microbial cultures and/or ingredients that enhance the growth of desirable gastrointestinal microbes, for example, Yea-Sac®, effective microorganisms and Diamond V-XP®.

5.4.4 Ionophores

Ionophores are feed additives that change the metabolism within the rumen by altering the rumen microflora to favour propionic acid production. They are effective in altering the composition of rumen microflora by favouring some types resulting in increased propionic acid production and decreasing production of acetic acid, methane and carbon dioxide. This improves efficiency of feed utilization by reducing gases thus lowering pollution by dairy cattle. Examples are Bovatec® (lasolacid) and Rumensin® (monensin).

5.5 Complete meals vs concentrate mix

Total mixed ration exemplifies a complete meal. It is defined as a mixture of all diet ingredients formulated to a specific nutrient requirement, mixed thoroughly and fed ad libitum to the cow.

Concentrate mix is formulated to supplement a basal diet and thus it is not a balanced feed (see Table 5.4). Animals supplemented include those grazing or fed on a basal diet of roughage.

Table 5.4. Kenya Bureau of Standards specifications for dairy cattle concentrates

Nutrient	Percentage		
	Dairy calves	Heifers	Mature cows
Moisture (max)	12	12	12
Crude protein (min)	18	14–16	14–16
Non-protein N (max)	0	2	2
Crude fibre (max)	8	12	12
Crude fat (max)	3.0–8	3–6	3–6
Calcium (min)	0.7	0.7	0.7
Phosphorus (min)	0.5	0.5	0.5
Common salt	0.5–0.6	0.5–0.6	0.5–0.6

CHAPTER 6: FEEDING CALVES

"Today's calf is tomorrow's cow"

6.1 Calf feeding

6.1.1 Aim of calf feeding

The aim of calf feeding should be to reduce the mortality (death) rate while maintaining a growth rate of at least 400 g/day. For bigger breeds (Friesian and Ayrshire) the aim should be to wean calves at 12 weeks at approximately 80 kg body weight.

The primary concern in rearing the newborn calf is to ensure it remains healthy. Feeding management addresses nutrient requirements and in the initial stages should be primarily directed at encouraging rumen development.

6.1.2 Stages of development of the calf rumen

Calf feeding is divided into four phases, depending on the development stage of the digestive system.

When the calf is born, the rumen is not functional and forms only a small proportion of the stomach. As such the calf cannot digest complex fibrous feeds. The calf is thus fed on liquid feeds and low-fibre solid feeds until the rumen develops. As these feeds are mostly milk or milk by-products, which are expensive, early rumen development to allow feeding of cheap feeds is desirable. Early development is stimulated by feeding solid feeds. Concentrate feeding has been shown to stimulate development faster than fibrous feeds.

Colostrum phase (1–3 days)

The calf is born with low immunity (protection from pathogens found in the environment) and is therefore susceptible to infections. Colostrum is the first milk extracted from the mammary gland of the cow after calving. Colostrum is a source of antibodies that protect the calf from these pathogens. It is therefore imperative for calves to get this milk immediately after birth as the rate of absorption is highest within the first 3 days.

Pre-ruminant phase (4 days to 20–30 days)

During the pre-ruminant phase, the calf rumen is still not functional and the calf can only take in liquids. The calf cannot digest complex carbohydrates or complex protein and thus only milk or milk by-products should be fed. Milk replacers should contain simple proteins. Rumen development starts towards end of this phase.

Transition phase (2 to 3 weeks before weaning)

Rumen development continues. In addition to liquids, the calf should be encouraged to consume dry feeds, especially concentrates, as they are known to accelerate rumen development.

Post-weaning phase

In the post-weaning stage, the rumen is fully functional and the calf can handle fibrous material. However, the calves should be weaned on high-quality pasture and fodder to maintain a high growth rate. Water should be made available ad libitum.

6.1.3 Calf feeds

Colostrum

Colostrum provides both antibodies and nutrients to the calf. Antibodies protect the calf against diseases the mother has been exposed to and their absorption in the digestive tract occurs for an extremely limited period (significantly reduced 12 hours after birth and very low after 24 hours).

If necessary, help the calf consume colostrum from a nipple bottle. If new animals are introduced into the herd just before calving, it may be necessary to vaccinate them against the common diseases so that they can develop antibodies. If for any reason the calf is not able to get colostrum from the mother, make artificial colostrum (see below), use stored (frozen) colostrum or use a contemporary mother.

Where possible, the calf should be allowed to suckle for at least 3 days before separating it from the mother. A supply of high-quality colostrum should be saved and frozen for use by calves from cows that die at birth or have mastitis or milk fever.

Preserved colostrum

Exotic breeds produce colostrum in excess of the calf's requirement. As colostrum has a high nutrient content, do not discard this excess but store it for feeding the calf later.

The colostrum can be preserved by several methods. Freezing is ideal but is not feasible on small-scale farms without electricity. Other methods include natural fermentation (store at room temperature) and use of preservatives (formaldehyde 0.05%, or formic acid 0.1%).

Before feeding the calf, mix the colostrum with warm water at the ratio of 2 parts colostrum to 1 part water.

Artificial colostrum

If the mother does not produce colostrum, artificial colostrum is recommended. Artificial colostrum does not provide antibodies but is rich in nutrients.

The recommended composition of artificial colostrum is

1 egg (beaten) + 400 ml fresh warm water + 600 ml whole milk +
1 teaspoonful castor oil or cod liver oil.

Feed this mixture 3 times a day for the first 3 days of life. A calf that has not received any maternal colostrum requires much more care.

Milk

Since milk is the saleable product from a dairy farm, it is necessary to switch young calves to cheaper feeds as early as possible. However, the diet must be able to promote health and growth.

Calves should be fed milk at the rate of approximately 10% of their body weight (reducing this as the calf starts to consume other feeds) to achieve good growth rates. Feed at body temperature. The milk can be mixed with other milk products (whey or skim milk) to lower cost. Whey (powder or liquid) can be obtained from creameries making cheese and skim milk (powder or liquid) from butter makers.

Milk replacer

Before using saleable milk or milk replacer, make proper use of stored excess colostrum. Use milk replacer only if it has an economic advantage over milk. Compare on the basis of dry matter. For example, Friesian milk contains about 26% protein and 30% fat on a dry-matter basis while most milk replacers contain about 23% protein and 15% fat.

Example

If the cost of milk replacer is 160 Kenya shillings (KES) per kilogram (KES 85 = USD 1) (23% crude protein, 15% fat, 100% dry milk) and the cost of fresh milk is KES 20/kg (5% crude protein, 4% fat, 13% dry milk), should the farmer buy the replacer or use fresh milk?

1 kg of dry milk costs KES 20 x 100/13 = Ksh 154

1 kg dry milk contains 5 x 1000/13 = 387 g crude protein and 4 x 1000/13 = 308 g fat

1 kg of dry milk replacer = KES 160

1 kg dry milk replacer contains 230 g crude protein and 150 g fat

In this scenario the milk is cheaper and supplies more nutrients. Milk replacers are always inferior to whole milk and should be fed only if they are cheaper.

Calf starter

The starter contains a slightly higher fibre content than does the pre-starter, a highly digestible, highly palatable feed specifically formulated as the first dry feed to allow early intake. At this stage the calf is consuming little milk and its rumen is still not fully developed. The starter should contain 18% crude protein, low fibre, 0.7% calcium, 0.45% phosphorus and vitamins A, D and E.

Roughage

Offer calves only high-quality forages early in life and supplement with concentrates (calf starter). If hay is used, it should be of high quality, fine texture, mixed with legumes and fed ad libitum. If calves are on pasture, it is best to always graze them ahead of adults to avoid calves consuming parasite eggs or larvae that are normally shed through the faeces of adult animals onto pastures.

Common roughages offered to calves include sweet potato vines and freshly harvested, wilted lucerne.

Water

Calves should be offered fresh water in addition to milk. Lack of drinking water slows down the fermentation process of the starter in the developing rumen, which in turn slows down development of the rumen lining and it takes longer before calves can be safely weaned.

It is estimated that efficient conversion of feed into body mass growth requires about 4 kg of water for each kilogram of dry feed calves eat. Lack of water thus lowers feed conversion. Age and stage of development determine how much water calves require:

- From 1 to 6 days of age, calves may drink large quantities of water when it is first presented. This novelty water consumption pattern rarely persists more than a day or two as long as water is offered ad libitum.
- Calves less than 3 weeks old do not need a lot of water but a steady supply of clean, fresh water is recommended.

Between 3 weeks and weaning, calves' water consumption usually increases and water should be offered ad libitum.

6.2 Calf feeding methods

6.2.1 Individual suckling

The natural way for a calf to feed is to suckle the dam after she is milked, the farmer having made sure that the dam is not milked dry. This is the most hygienic way as the calf gets milk direct from mother, clean and at body temperature.

6.2.2 Foster mother or multiple suckling

One milking cow may be assigned a number of calves to suckle, depending on the level of milk production. This is practical only on farms with several cows lactating at the same time.

6.2.3 Nipple suckling

A rubber nipple is fixed on a milk bottle and the calf is trained on how to suckle. The alternative is to put milk into a bucket and insert a flexible plastic hose pipe with one end attached to a nipple.

6.2.4 Bucket feeding

The most commonly used method is bucket feeding. The calf is trained to drink milk placed in a bucket (place your finger in the milk and as calf suckles your finger it imbibes milk). Stainless steel buckets, where available, should be used for hygienic reasons as plastic buckets are difficult to clean. At all times, feed milk at body temperature. This is especially important during the cold season.

Sick calves should always be fed last to minimize cross-infection.

6.3 Nutritional disorders

A calf's health can be affected by disorders resulting from improper feeding. Diligent feeding management is therefore essential to ensure calf health is maintained. Common problems associated with feeding are diarrhoea and pneumonia.

6.3.1 Scours (diarrhoea)

Scours may be caused by nutritional disorders, viruses or bacteria. Digestive upsets leading to scours are a major cause of mortality in young calves.

The problem can however be minimized by

- ensuring calves receive adequate colostrum within 6 hours of birth and therefore acquire some natural immunity
- feeding the correct amount of milk
- recognizing, segregating and treating scouring calves early
- maintaining hygiene and cleanliness of feeding utensils and the environment
- not rearing calves continually in pens, dirty yards or small paddocks that become heavily contaminated; paddock rotation will help prevent disease
- separating sick animals to avoid cross-infection

Closely observing calves at feeding to identify scouring animals as soon as possible for remedial treatment will prevent dehydration and secondary disease leading to chronic illness and mortality.

Incidents of scours can be treated simply by using electrolyte replacers fed several times per day to prevent dehydration. Reduce or omit milk for one or two feeds but provide fresh water, concentrates and forage. Do not use antibiotics to treat scours resulting from overfeeding or digestive upsets.

Blood scours (mostly caused by coccidia) require veterinary treatment and management changes to improve hygiene.

6.3.2 Pneumonia

One cause of pneumonia in young calves is fluid going to the lungs via the windpipe (trachea). The first feeding of colostrum can cause problems if the feeding rate is faster than the swallowing rate.

If colostrum is bottle fed it is important to use a nipple that matches the calf's ability to swallow. Greedy calves swallow large quantities of milk from the bucket, some of which may end up in the windpipe, leading to pneumonia.

6.4 Calf feeding program

The calf feeding program shown in Table 6.1 should result in a growth rate of approximately 400–500 g/day. The liquid feed (milk) should be fed twice daily and more frequently for sick or weak calves.

Table 6.1. Example of a calf feeding schedule with weaning at 12 weeks

Age of calf (days)	Milk (kg/day)	Total cumulative milk (kg)	Calf starter (kg/day)
1 to 7	colostrum	—	—
8 to 21	5	70	handful
22 to 42	6	126	0.5
43 to 56	5	70	0.5
57 to 63	4	28	1.0
64 to 77	3	42	1.0
78 to 84	2	14	1.5
Total		350	4.5

Calves should be given roughage throughout.

6.5 Weaning

Weaning is the withdrawal of milk or milk replacer while the calf becomes fully dependent on other feeds. Traditionally, dairy calves are weaned based on age, 12 weeks being the most common. Early weaning is possible if more milk is fed and calves are introduced to pre-starter and starter early in life.

To minimize stress, wean gradually. Reduce the milk feeding from twice a day to once a day then to once every other day to allow the calf's digestive system to adjust to the new diet.

Criteria that have been used to determine weaning time include when the calf attains twice its birth weight, when the calf can consume 1.5% of its body weight of dry feed and the age of the calf.

6.6 Bull calves

Of the calves born, about 50% will be bull calves, which consume milk and compete with heifers. Farms dispose of the bull calves in different ways, depending on the economics and type of production. These include

- selling after birth
- slaughtering after birth
- rearing as beef steers
- rearing as possible future sires

Base the decision to keep or dispose of bull calves mainly on the cost of rearing them—price of milk vs disposal price—and the genetic value for future sires.

CHAPTER 7: HEIFER FEEDING

After weaning, a female calf becomes a heifer, which will eventually replace the culled animals, increase the herd size or be sold to generate income. After weaning, heifers should be grouped according to size in small, uniform groups that have adequate access to forage and concentrate. Balance the ration and consider feeding a total mixed ration. Heifers should be closely observed and fed correctly to avoid the growth slump that can occur after milk is withdrawn.

7.1 Aim of heifer feeding

Heifers should achieve a growth rate of 500–700 g/day. This ensures that they will come on heat at the right time, as puberty is related to size rather than age. Reduce the interval between weaning and first calving to increase the number of calvings per lifetime (more lactations) and lead to faster genetic improvement. Achieving first calving at 27 or fewer months of age is possible only if the growth rate is high.

7.2 Feeding

On most farms, heifers are normally the most neglected group in terms of feeding, resulting in delayed first calving. When heifers of different ages are fed as a group, aggressiveness varies such that when concentrate is fed to the group, some get little. Heifers should thus be reared in groups of similar age or size—weaners, yearlings, bulling heifers (those that are ready for breeding) and in-calf heifers.

Heifers can be reared on good-quality pasture as their nutrient requirements are low (growth and maintenance). Supplementation with concentrate should be at 1% of body weight with 12–14% crude protein for heifers on legume forage and 15–16% crude protein on grass forage.

Protein is extremely important in the diet of growing heifers to ensure adequate frame size, wither height and growth. Avoid short heifers by balancing the ration and including enough crude protein.

While designing heifer feeding programs, it is important to consider the following:

- Puberty, which is related to calving age, is also related to size (a feeding indicator) rather than the age of the heifer. The consequences of poor feeding are therefore manifested in delayed first calving and commencement of milk production.
- Feeding heifers too much energy leads to fat infiltrating the mammary glands, inhibiting development of secretory tissue, thus reducing milk yield.
- Underfeeding results in small-bodied heifers, which experience difficulty during calving (dystocia).

- The size of the animal is related to milk yield. With twins of the same genetic makeup, every kilogram advantage in weight one has over the other results in extra milk.
- Overfeeding heifers on feed high in energy but low in protein results in short, fat heifers; high protein and low energy feed results in tall, thin heifers.

Underfed, hence slow-growing heifers may reach puberty and ovulate but signs of heat may be masked (silent heat), while those in good condition will show signs of heat and have higher conception rates. Over-conditioned or fat heifers have been reported to require more services per conception than heifers of normal size and weight.

7.3 Growth rate (weight and height) vs age

To monitor the performance of heifers, measure the body weight and the height at withers and plot on a chart. Growth of the heifer should be such that any increase in weight should be accompanied by a proportionate change in height.

Standard charts have been developed for different breeds with the expected weight and height at different ages for different breeds. Where weighing facilities are unavailable, the weight may be estimated based on the heart girth in centimetres. Measure the heart girth using a tape measure and use a weight conversion table (see Appendix 3) to get an estimate of the weight based on the heart girth. The height can be measured by a graduated piece of timber as shown in Figure 7.1.

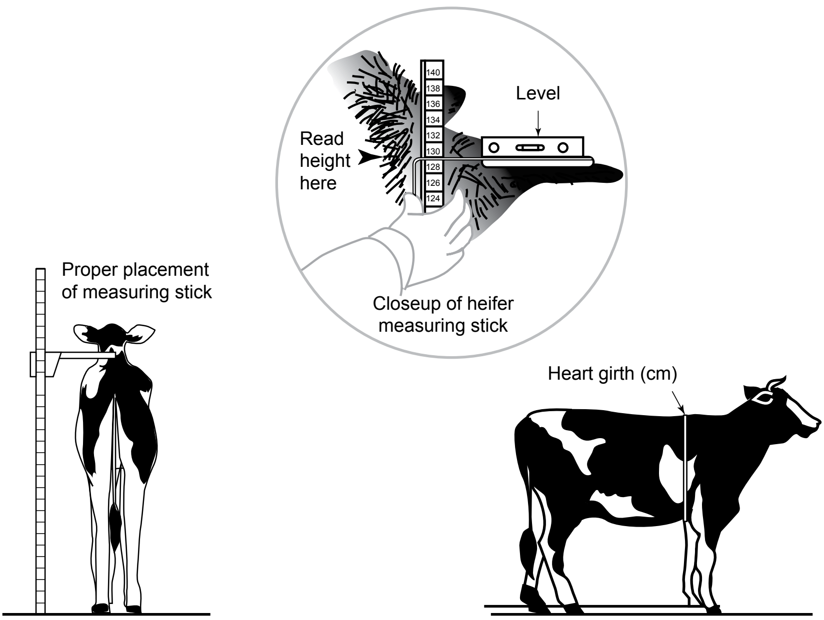

Figure 7.1. Measuring the height of the heifer and estimating the weight based on heart girth (see Appendix 3).

Measurements taken are plotted on a chart (Figure 7.2) that shows the expected weight and height at a particular age for a particular breed. If the weight falls below what is expected, the heifer is underweight thus underfed and vice versa. Short heifers indicate low protein in the diet.

Fat, over-conditioned heifers, at the same weight as leaner heifers, are normally younger with less skeletal growth. The pelvic opening is therefore narrow. Due to overfeeding, the calf is normally bigger, leading to dystocia. Underfed heifers will also require assistance and have a higher death rate at calving than normal-sized heifers.

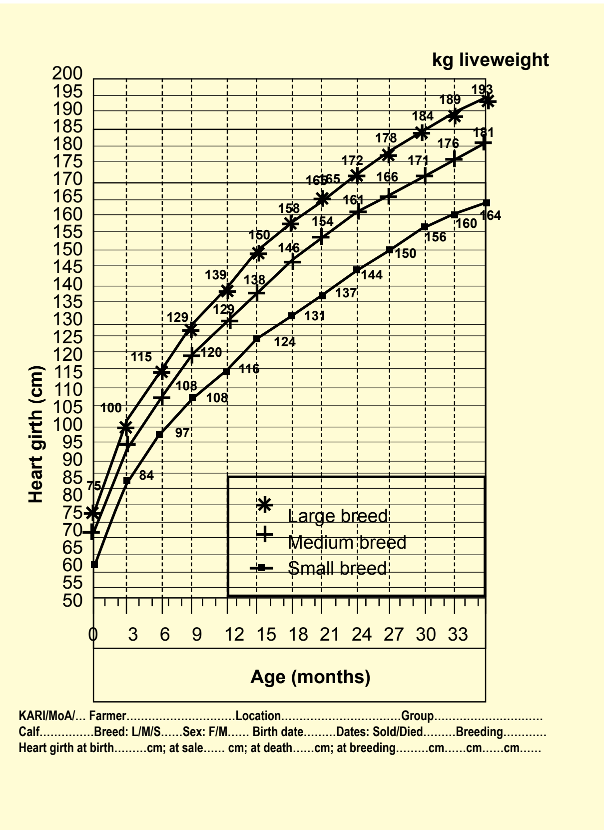

Figure 7.2. Chart of heifer growth.

7.4 Steaming up

Steaming up refers to providing extra concentrate to a pregnant heifer in the last 4 weeks of pregnancy. This extra concentrate should be fed in the milking parlour if possible, to accustom the heifer to the parlour. This feeding is also intended to allow the rumen bacteria to get accustomed to high levels of concentrate. It provides extra nutrients for the animal and the growing foetus.

Steaming up also allows the heifer to put on extra weight (reserve energy) to promote maximum milk production from the very beginning of the lactation.

7.4.1 Stages of heifer development and expected weight for age

Table 7.1 indicates the tremendous increase in weight during the 9 months of gestation (100–150 kg), which is due to heifer growth and foetal weight. Table 7.2 summarizes the stages in heifer growth and development.

Table 7.1. Expected weight of different breeds of heifer at breeding and calving

Breed	Breeding		Calving	
	Age (months)	Weight (kg)	Age (months)	Weight (kg)
Jersey	15–16	230–275	24	350–375
Guernsey	15–16	275–300	24	375–400
Ayrshire	18	300–320	27	420–450
Friesian	18	300–320	27	420–450

Table 7.2. Expected weight for age at different stages of heifer development

Stage	Common name	Age (mo.)	Weight (kg)
Weaning	weaner	3–4	70–80
Puberty	bulling heifer	12	220–240
Insemination	in-calf heifer	15–18	275–300
First calving	milking heifer	24–27	400–450
Drying		36	

CHAPTER 8: FEEDING THE DAIRY COW

8.1 Feeding the lactating cow

8.1.1 Aim of feeding the dairy cow

Maximizing milk yield by meeting the cow's nutrient requirements is the aim of a feeding program. The nutrient requirements will largely depend on the amount of milk produced, which in turn depends on the stage of lactation—the period from calving. Other factors affecting nutrient requirements are pregnancy and maintenance. The amount required for maintenance is largely affected by the cow's weight, environmental temperature and activity.

Milk production follows a curve (lactation curve), hence the amount of nutrients required will depend on the point on the curve. During the dry period, the aim should be to feed a diet that provides for the fast-growing foetus, deposition of an energy reserve and regeneration of the mammary gland.

8.1.2 Nutrient requirements of a lactating cow

Energy

Quantitatively, energy is the most important nutrient considered during the formulation of dairy cow rations. Energy requirements of a lactating cow depend on

- maintenance—keeping the cow alive—which depends on body size (bigger cows require more), activity (walking long distances to graze increases the requirement) and environmental temperature (too cold or too hot increases the requirement)
- amount of milk the cow produces
- the energy content of milk, indicated by butter fat content—the higher the fat content, the more energy required
- reproductive condition—pregnant cows require more energy to cater for the growth of the calf

Protein

Like energy, the protein requirement is dependent on milk yield, maintenance (replaces the amounts lost in urine, faeces and skin), growth and pregnancy. Protein is not stored in the body and any excess is removed.

Protein is an expensive component and overfeeding should be avoided to minimize the cost. In addition, extra energy, which would otherwise be used for milk production, is used to remove the extra protein (nitrogen) from the body in form of urea in the urine.

At the same time, protein deficiency leads to reduced growth and milk yield. See Table 8.1 for recommended levels of dietary crude protein at different levels of milk yield.

Table 8.1. Recommended levels of dietary crude protein for dairy cows at different levels of milk yield

Milk yield (kg/day)	Crude protein in whole ration (%)
10	13
15	15
20	16
25	17
30	18

Minerals

Dairy cattle require all minerals in their diet for optimal milk production, reproductive performance and health. Although classical mineral deficiency symptoms are rare, in many cases under- and overfeeding of certain minerals does occur.

Even small imbalances or deficiencies can develop into reproductive, health and milk production problems. As herd milk production increases, it will become more critical to balance and fine-tune the dairy cow's mineral and vitamin feeding program. Generally, the two sources of minerals include natural (organic) feeds (forages and grains) and inorganic mineral supplements to balance the minerals present in the forages and grains.

Vitamins

The dairy cow, like all ruminants, depends on rumen microorganisms to synthesize the water-soluble vitamins and vitamin K. Requirements for vitamins A, D and E must be satisfied from the diet.

Water

Although water is not a nutrient as such, it is essential for life. Water can be obtained from feed, from drinking or from within the body processes. Lactating cows need larger proportions of water relative to body weight than do most livestock species since 87% of milk is water. The amount required depends mainly on milk yield, moisture content of feed, amount of feed consumed and the environmental temperature.

Cows will drink more water if it is available at all times and when warm water is offered on cold days. Dairy cows suffer from a limited intake of water more quickly and severely than from a deficiency of any dietary nutrient. Lack of water has a big effect on feed intake, especially if the feed is low in moisture.

8.1.3 Lactation period

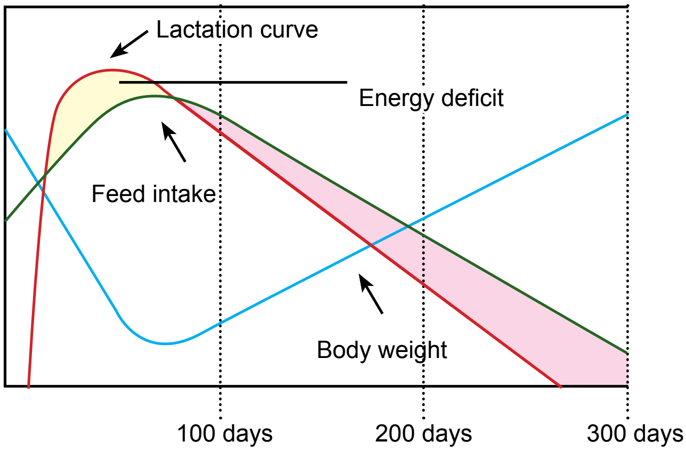

Figure 8.1. Typical lactation pattern of a dairy cow.

The lactation period is divided into four phases based on the cow's physiological cycle and nutrient requirements. Feeding should be based on these phases.

Phase 1: 1–70 days

The first phase lasts from calving to peak milk production, which occurs at about 70 days. During this phase of lactation, milk production increases rapidly such that the voluntary feed intake cannot meet the energy demand. This results in an energy deficit leading to use of body reserves and to weight loss (negative energy).

The health status and feeding of the cow during this phase are critical to its entire lactation performance. The cow should be fed so as to achieve peak production. If it does not peak, feeding later in the lactation period will not result in any appreciable increase in lactation yield.

In an attempt to maximize milk production while maintaining good health, the tendency is to feed high levels of concentrates in this phase. However, if excessive concentrates are added too rapidly to the rations of non-accustomed cows, they may lead to digestive disturbances (e.g. rumen acidosis, loss of appetite, reduced milk production and low milk fat content). It is therefore recommended that concentrates be limited to 50–60% of diet dry matter, the rest being forage to ensure rumination (proper function of the rumen).

During this phase, buffers can be helpful for cows fed high levels of concentrates.

For very high-yielding cows, the necessary energy increase cannot be achieved through cereal-based rations—excess leads to digestive problems. Other ingredients with higher energy density (e.g. fat) can be used. However, not more than 7% should be included as high fat reduces fibre digestibility by affecting cellulolytic bacteria. By-pass fat (rumen-protected fat) is available commercially.

During this phase, a high-protein diet is important since the body cannot mobilize all the needed protein from itself, and microbial protein, which is synthesized in the rumen by microbes, can only partially meet requirements. A protein content of 18% crude protein is recommended in rations for high-yielding cows.

Animals that are well fed during this phase come on heat and achieve a 365-day calving interval—a calf every year.

> It is therefore important to ensure that the cow receives adequate nutrients when they are required and not later.

Phase 2: 71–150 days

The second phase lasts from peak lactation to mid-lactation. The voluntary dry matter intake is adequate to support milk production and either maintain or slightly increase body weight. The aim should be to maintain peak milk production for as long as possible with milk yield declining at the rate of 8–10% per month.

The forage quality should be high. A 15–18% whole ration crude protein content is recommended. Concentrates high in digestible fibre (e.g. wheat or maize bran rather than starch) can be used as an energy source.

Phase 3: 151–305 days

The third phase lasts from mid- to end-lactation, during which the decline in milk production continues. The voluntary feed intake meets energy requirements for milk production and body weight increase. The increase is because body reserves are being replenished, and towards the end of lactation, it is because of increased growth of the foetus. It is more efficient to replenish body weight during late lactation than during the dry period. Animals can be fed on lower-quality roughage and more limited amounts of concentrate than during the earlier two phases.

Phase 4: Dry period (306–365 days)

This phase lasts from the time cow is dried to the start of the next lactation. The cow continues to gain weight primarily due to the weight of the foetus. Proper feeding of the cow during this stage will help realize the cow's potential during the next lactation and minimize health problems at calving time (e.g. ketosis, milk fever and dehydration, dystocia).

Drying a cow

To minimize stress on the drying cow, consider the following options.

- Reduce feed intake to maintenance level (withdraw concentrates).
- If the cow is a low yielder, just stop milking. Pressure builds up in the udder and cuts off milk production.

- If the cow is a high yielder, practise intermittent milking, skipping some milking times (milk only in mornings) so as to reduce milk synthesis caused by pressure building up in the udder.
- Temporarily withdraw water or reduce the amount for very high yielders to reduce milk synthesis.
- After milking is stopped, treat (infuse) all the quarters with long-acting antibiotics to prevent mastitis from developing.

The aims of drying a cow are to

- build up body reserves in time for the next lactation period—if a cow is not dried in time, milk production will be reduced during the next lactation period.
- allow the cow to regenerate alveolar tissue (milk-synthesizing tissue) that might have degenerated during the lactation period.
- save nutrients for the fast-growing foetus. During the last phase of pregnancy, the calf grows rapidly and the cow's drying saves nutrients for the calf's growth.

At the time of drying, the cow should be fed a ration that caters for maintenance and pregnancy, but 2 weeks before calving the cow should be fed on high-level concentrates in preparation for the next lactation. This extra concentrate (steaming) enables the cow to store reserves to be used in early lactation.

To avoid over-conditioning, cows should not be fed large amounts of concentrate. The aim is to achieve a body condition score of 3.5–4.0 (see Table 8.2). If the diet is rich in energy, limit the intake of concentrates. Feeding bulky roughages can help increase rumen size to accommodate more feed at parturition (birth).

Before calving, feed concentrate progressively to adapt the rumen microbial population. This will minimize digestive disturbances in early lactation when the diet changes to high concentrate.

The amount of calcium fed during the dry period should be restricted to minimize incidents of milk fever in early lactation. A ration providing 15 g of calcium per day for the last 10 days of the dry period or an intake of 30–40 g/day over the whole dry period should reduce the number of incidents.

This extra concentrate (steaming) enables the cow to store reserves to be used in early lactation. During this phase the cow may be fed good-quality forage or poor-quality supplemented with concentrate to provide 12% crude protein.

Transitional feeding (3 weeks before and after calving)

During the 3 weeks immediately before and after calving, the cow should be given high-energy, highly palatable and digestible feed (e.g. commercial dairy meal and maize germ) or starchy feeds and molasses (this is also referred to as close-up feeding). This is to prepare the cow to consume large amounts of feed (for high milk production), accustom the rumen bacteria to high concentrate levels and prevent nutritional disorders (e.g. milk fever and ketosis) that are common in early lactation without over-fattening the cow.

This period is important because there is rapid growth of the unborn calf, regeneration of the mammary tissue and colostrum production.

8.1.4 Milk from pasture and fodder

Dairy cattle can be fed on forage or on pasture with no supplementation and milk production will depend on the quality and quantity of the pasture. However, it is difficult to realize the full genetic potential of a cow fed in this manner.

On Napier grass only, the expected milk production is 7 kg/day; it is 9–12 kg/day when the cow is fed on a Napier–legume (desmodium) mixture. On grass alone (e.g. Rhodes grass or Nandi setaria), an average milk yield of 5–7 kg/day has been obtained and 7–10 kg/day on a grass–legume mixture. Oats harvested at milk stage and fed to a dairy animal can enable it to produce up to 12 kg/day.

8.1.5 Challenge feeding

Lactating cows may be challenged with increasing amounts of concentrate until there is no corresponding increase in milk production. This method of feeding is recommended only if the extra milk produced offsets the added cost of the concentrate.

Challenge feeding should take place in the early lactation, when there is a risk of underfeeding. Feed each cow the maximum amount of concentrates that it can consume, without reducing its roughage intake. Continue this until the cow reaches peak milk production, 4 to 10 weeks after calving. By using this strategy, each cow is given the possibility to show its production potential.

8.2 Use of body conditioning to assess feeding

Body conditioning can assess the appropriateness of a feeding regime for lactating dairy cows. Dairy cattle deposit their energy reserves around the pelvic area and by scoring the amount of deposit using a standard score, their condition can be assessed. Condition scores are normally on a scale of 1–5 with 1 being too thin and 5 too fat. Animals prior to calving should be in good condition (3.75–4). Table 8.2 shows body-conditioning scores and indications.

Overweight cows (over-conditioned) have been shown to be more susceptible to metabolic problems (ketosis) and to both infectious (mastitis) and non-infectious (retained placenta and lameness) health problems. They are also more likely to have difficulties at calving. Under-conditioning can lower milk production as there are insufficient energy and protein reserves for mobilization in early lactation.

Important areas assessed when scoring are short ribs, thurl, tail head, hook and pin bones (Figure 8.2). An ideal cow has a body condition score of about 3.5, but the system is designed to have cows at certain stages of lactation at certain body conditions.

After calving, cows should lose less than one point before they begin to gain weight; those losing more than one point are more vulnerable to reproductive problems.

Table 8.2. Body-conditioning scores and indications

Score	Indications
1	Skin and bones
2–2.4	Severe negative energy balance in cow in early lactation; risk of production loss
2.5–2.9	High producer in early lactation
3.0–3.4	Milking cow in good nutrient balance
3.5–3.9	Late lactation and dry cow in good condition
4	Over-conditioned; potential calving problems if dry
5	Severely over-conditioned; risk of fat cow syndrome

Source: Heinrichs AJ, Ishler VA and Adams RS. 1989. *Feeding and managing dry cows*. Pennsylvania State University, USA.

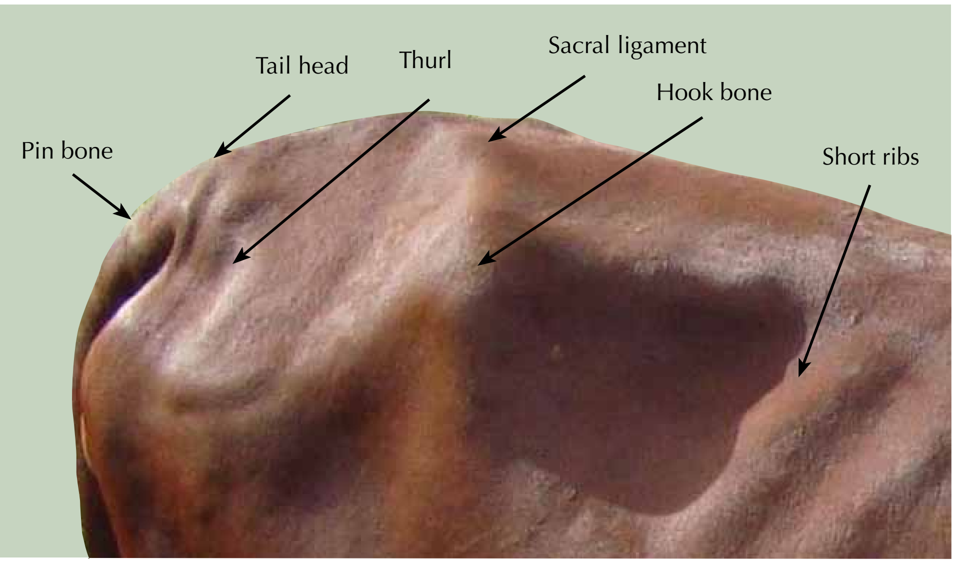

Figure 8.2. Areas assessed in scoring body condition.

From peak milk production to dry-off, cows should gain back the body condition that was lost before they reached the peak. Ideally, the body condition score of a cow should be taken whenever it is handled. At the very minimum, scores should be taken at freshening, breeding and dry-off. If evaluation indicates over- or under-conditioning, the feeding strategy for an individual cow or group has to be evaluated. Feed rations may have to be recalculated and corrected to satisfy the cow's demand.

8.3 Nutritional diseases

8.3.1 Milk fever

Milk fever is a common metabolic disorder in dairy cattle. It generally affects older, high-producing cows. It may also be referred to as parturient paresis or hypocalcaemia.

At the beginning of lactation, high-yielding cows experience a sudden rise in demand for calcium to replace the large amount lost through milk. This may result in a great decrease in blood calcium if the cow is not able to replenish the calcium fast enough, causing a disease called milk fever.

Most milk fever cases occur within 48 to 72 hours of calving when demand for calcium for milk production exceeds the body's ability to mobilize calcium reserves. Fever is a misnomer as body temperature is usually below normal. Low blood calcium interferes with muscle function throughout the body causing general weakness, loss of appetite and eventually heart failure.

Signs

At first, the cow experiences muscle tremors, lack of appetite and unsteadiness. Eventually, the cow is unable to rise, body temperature falls, and constipation occurs. Cows go down to a sitting position often with a kink in the neck. Death may occur if the cow is not treated promptly.

Causes

The onset of milk production drains the animal's blood calcium levels. If the cow is unable to replace this calcium quickly, due to loss of its ability to mobilize reserves of calcium in bone and absorb calcium from the gastrointestinal tract, milk fever occurs.

Older cows are more susceptible as they produce more milk and are unable to replenish calcium quickly enough.

Prevention

Managing the diet can be a valuable aid in preventing milk fever. The key to prevention is managing a dry (close-up) cow nearing parturition, which should be kept on a low calcium diet. Such a diet stimulates the calcium regulatory system to keep the blood levels normal by mobilizing the body stores from the bone. Lucerne, a feed high in calcium and potassium, should thus not be a major ingredient in close-up dry cow diets to avoid too high calcium levels before calving.

When the demand for calcium increases at calving, calcium can be mobilized much more rapidly thus preventing milk fever. In early lactation, high-yielding cows should receive as much calcium as possible. High-risk cows can be injected with vitamin D3 2–8 days before calving.

Diets providing less than 15 g of calcium per day per cow and fed for at least 10 days before calving will reduce the incidence of milk fever.

8.3.2 Ketosis

Ketosis is a disorder that occurs when energy intake fails to meet the high glucose requirement necessary for maintenance and for producing milk lactose. Ketosis affects high-producing cows during the first 6–8 weeks of lactation when cows are in negative energy balance. The excessive ketone bodies in the bloodstream come from the breakdown of fat when the animal is forced to draw on its bodily reserves for energy.

Predisposing factors

Cows of any age may be affected but the disease appears more common in later lactations, peaking at about the fourth lactation. Over-conditioning at calving has been associated with increased incidence of ketosis.

Clinical signs

Many cases of ketosis are subclinical. The cow's performance and health are compromised but there are no obvious clinical signs. Some of the signs include lack of appetite (refusal to eat even concentrates) and a sudden drop in milk output.

The urine, breath and milk carry a sweet smell of acetone. Cows have raised blood ketone levels and may excrete ketones in urine and milk. Body condition is gradually lost over several days or even weeks.

Prevention

Ketosis causes financial loss through lost production and treatment. It may be prevented by management strategies that maintain a good appetite and supply adequate feed to meet this appetite during the late dry period and immediately after calving.

These strategies include

- feeding transition rations to close-up cows
- ensuring cows are in body condition of 4.0 or less before calving
- ensuring that any health problems that might cause reduced feed intake are treated as early as possible

8.3.3 Acidosis

Acidosis is a syndrome related to a fermentative disorder of the rumen resulting in overproduction of acid, which lowers rumen pH below pH 5.5. The problem is related to feeding management, where the ration has high levels of digestible carbohydrates and low effective fibre.

Causes

Acidosis may be caused by

- diets high in readily fermentable carbohydrates and low in roughage
- fast switch from high forage to high concentrate
- excessive particle size reduction by feeding finely chopped forage

Signs

Watery milk: Acetate, one of the end products of fibre digestion, is a precursor of milk fat synthesis. A diet that is low in fibre will lead to low levels of acetate in milk and thus low levels of milk fat. As a result, the milk appears watery.

- Diarrhoea—Accumulation of acid causes an influx of water from the tissues into the gut resulting in diarrhoea. Faeces are foamy with gas bubbles and have mucin or fibrin casts.

- Sore hooves (laminitis)—Endotoxins resulting from high acid production in the rumen also affect blood capillaries in the hoof, causing hooves to constrict, resulting in laminitis.

- Ulcers, liver abscesses—High levels of acid in the rumen also cause ulcers, allowing bacteria to infiltrate the blood and causing liver abscesses, which are seen at post-mortem.

- Prevention—Good management practices are needed to prevent predisposing situations from occurring. The root problem must be found and corrected.

- Buffers can also be used to prevent a drop in rumen pH when high-concentrate diets are fed. Ensuring the presence of effective fibre in the diet promotes production of saliva, which is a buffer.

8.3.4 Bloat

Bloat is the abnormal accumulation of gas in the rumen. There are three categories:

- frothy bloat that occurs when diets lead to formation of a stable froth or foam in the rumen
- free gas bloat caused by diets that lead to excessive gas production
- free gas bloat caused by failure to belch rumen gases, leading to accumulation of gas (e.g. oesophageal obstruction)

Bloat occurs when gases cannot escape but continue to build up causing severe distension of the abdomen, compression of the heart and lungs, and eventually death.

Predisposing factors

Bloat is a risk when animals are grazing young lush pasture, particularly if the pasture has a high legume content (e.g. clover or lucerne). Ruminant animals produce large volumes of gas during the normal process of digestion, which either is belched or passes through the gastrointestinal tract. If anything interferes with the gas escape from the rumen, bloat occurs.

Natural foaming agents in legumes and some rapidly growing grasses cause a stable foam to form in the rumen. Gas is trapped in small bubbles in this foam and the animal cannot belch it up. Pressure builds up in the rumen causing obvious swelling on the left side of the body.

Signs

- The animal stops grazing and is reluctant to walk.
- The left side of the abdomen is distended.
- The animal strains to urinate and defecate.
- Rapid breathing—the mouth may be open with the tongue protruding.
- The animal staggers.

Prevention

Pasture management: Legumes should be introduced into the diet gradually over several days. Avoid cows gorging on new pastures by feeding them on other feeds before letting them out to graze. Silage, hay or mature pasture can be used to reduce the cow's appetite.

Initially, cows should be allowed access to the pasture only for short periods (an hour or so) and monitored closely during grazing and immediately after removal. Cutting and wilting the pasture for 2–3 hours before feeding reduces the risk of bloat.

Preventive medication: Drench with detergents and anti-foaming agents before letting animals graze.

Treatment

Insert a stomach tube through the oesophagus to release the gas. In an emergency on the farm, puncture the rumen on the left side of the animal with a sharp knife. Puncturing the rumen with the standard trocar and cannula is the quickest way to release the gas that cannot be expelled with a stomach tube.

8.4 Ration formulation

To formulate rations, knowledge of nutrients, feedstuffs (ingredients) and the animal to be fed is required. The ration formulated must be nutritionally adequate and be consumed in sufficient amounts to provide for the level of production desired at a reasonable cost.

8.4.1 Balanced rations

A ration is balanced when all the nutrients an animal requires are present in the feed the animal consumes during a 24-hour period. When an animal consumes nutrients in excess or in insufficient amounts, the ration is imbalanced.

Some imbalances have drastic consequences and if not corrected may lead to the death of the animal (e.g. milk fever due to calcium imbalance in dairy cows). However, most imbalances are difficult to identify as they result in some degree of loss of production, which causes animals not to realize their genetic potential.

8.4.2 Formulation

Ration formulation is the recipe, that is, the list and amounts of feed ingredients to be included in a ration. Before formulating a ration, the following information is needed.

Nutrients required

Obtain information on nutrients from feed requirement tables developed by various bodies.

Feedstuffs (ingredients)

Prepare an inventory of all available feedstuffs. For home-made rations, use materials available at home as much as possible; commercial feeds may use a wider range.

The *nutrient composition* of each feedstuff should be known. Analysis of the ingredients is most desirable but if not possible, obtain estimates from textbooks. Book values, however, can at times be misleading, especially for by-products. Also consider the *palatability* of the ingredient and any limitations such as toxicity.

Always consider the *cost* of the ingredients. Least-cost formulations should be made to obtain the cheapest ration.

Type of ration

Ration type may be complete (total mixed ration), concentrate mix or a nutrient supplement of protein, vitamin or mineral.

Expected feed consumption

Rations should be formulated to ensure that the animal consumes the desired amount of nutrients in a day. For example, if a heifer requires 500 g of crude protein per day and consumes 5 kg of feed, the crude protein content should be 10%. If it consumes 4 kg per day the crude protein content should be 12.5%.

Calculations

The simplest formulation is when two ingredients are being mixed to balance one nutrient. Using a Pearson's square method allows blending of two feedstuffs or two mixtures. Figure 8.3 illustrates how to make a ration with 18% crude protein using cottonseed cake (40% crude protein) and maize (10% crude protein).

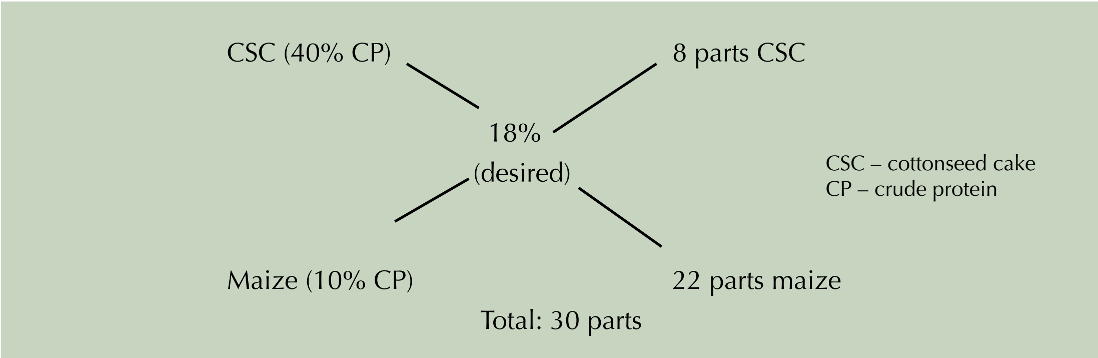

Figure 8.3. Calculating feedstuff proportions.

Steps

- Subtract the lesser value from the larger diagonally. (Hence from the figure: 40 minus 18 = 22 and 18 minus 10 = 8.)
- One ingredient must have a higher nutrient content than the desired and the other must have a lower value.
- No ration can be formulated with a higher nutrient content than the highest of the ingredients or vice versa. (You cannot make a ration of 15% crude protein if both ingredients are higher than 15% or lower than 15%.)
- Therefore: If 8 parts of cottonseed cake are mixed with 22 parts of maize, the mixture will have 18% crude protein.

If expressed as percentage (100 kg feed) then

8/30 x 100 = 26.7% cottonseed cake

22/30 x 100 = 73.3% maize

Confirm crude protein content

The cottonseed cake content in the ration is 26.7%, crude protein 40%; therefore it contributes 26.7 x 40/100 = 10.7. The maize contributes 73.3% of the mixture, crude protein 10%; therefore it contributes 73.3 x 10/100 = 7.3.

8.5 Feed budgeting, planning and costs

Feeding high-yielding dairy cows is a challenge to both farmers and nutritionists. Profit margins in the dairy enterprise vary and are dependent on milk prices and feed cost. Feed represents the largest input cost to produce milk (estimated to be 35–50% depending on the production system).

The cheapest way to produce milk is by using farm-grown forages. However, forages are bulky and low in nutrient content and cannot support optimal milk production.

Feed costs for a dairy herd can be budgeted to determine ingredients to be purchased or grown on farm. Following is an example of how to budget for feed requirements:

Consider the size of the cow, for example 450 kg. The dry matter requirement is estimated at 3% of the body weight (3/100 x 450 = 13.5 kg).

Dry matter requirement per year is 13.5 x 365 = 4928 kg.

To obtain 4928 kg dry matter from fresh young Napier grass (contains 15 kg dry matter per 100 kg fresh Napier grass) will require 32,850 kg of fresh material. This amount of Napier grass can be harvested from about 0.65 ha of land (Napier yield is estimated at 8000 kg dry matter/ha per year under smallholder farmer conditions).

Assume a farmer has 0.4 ha under Napier grass, dry matter production per year = 3200 kg giving a deficit of 1728 kg dry matter.

If the deficit is to be covered using a commercial concentrate, the farmer will have to buy 1919 kg of concentrate (concentrate 90 kg dry matter per 100 kg fresh weight).

If the cost of concentrate is KES 21 (USD 0.25) per kg, the farmer will spend approximately KES 40,800 (USD 480) per year on it.

8.5.1 Costs of acquisition (consider dry matter and cost of nutrients)

When purchasing feeds off farm, the cost comparison between feedstuffs should be based on nutrients purchased rather than weight of the feedstuff. Thus the nutrient and dry matter contents of the material to be purchased should be known (Table 8.3).

Table 8.3. Costs of various feedstuffs

Feedstuff	Cost per kg (KES)	DM per kg feed (g)	CP content (DM basis)	CP per kg DM (g)	Cost per kg DM (KES)	Cost per kg CP (KES)
Rhodes hay	6	850	7	59.5	7.0	101
Napier grass	2	150	8	12.0	13.0	166
Lucerne hay	10	850	18	153.0	11.7	65
Commercial dairy concentrate	18	900	16	144.0	20.0	125

KES – Kenya shilling, DM – dry matter, CP – crude protein

Kenya shilling valued at Ksh 85 to USD 1

According to Table 8.3, Napier grass may appear cheap when being purchased but the nutrient cost is high. The cheapest source of protein is lucerne but it is low in energy.

8.5.2 Maximum production vs maximum profit

As already mentioned, feed costs and farm gate price of milk determine the profitability of a dairy enterprise. An enterprise may opt to produce the maximum amount of milk irrespective of the profit margin. This is termed maximum production. If the milk price is high, this method may coincide with maximum profit.

On the other hand, an enterprise using home-grown forage may or may not produce the maximum amount of milk but makes a profit. This happens when the cost of concentrate is too high. Farm gate price of milk also depends on location, with peri-urban farmers getting better prices.

A true maximum profit ration program includes a least-cost function, incorporates milk price information, and uses maximum profit (income over feed cost) as one of the constraints or specifications on which to formulate. To maximize profit the computer selects feeds and a milk production level to obtain a maximum profit; but for least-cost or balanced rations the computer selects only feeds to meet the nutrient requirements specified for a given level of milk production.

8.6 Feeding systems

8.6.1 Total mixed rations

Total mixed ration is a blend of all of the constituents of a ration fed to a confined animal, mixed to prevent separation to a specific nutrient concentration and fed at free will to the cow. In the total mixed ration feeding system, the concentrates and roughage are mixed either by hand, in small-scale operations, or in a mixer wagon. Where a mixer wagon is used, the mix is often dispensed to the cow directly from the wagon.

Before a total mixed ration is formulated, the following information is needed:

Feedstuffs (ingredients)

- available feedstuffs
- moisture and nutrient content of feedstuffs
- cost
- attributes of feed (e.g. maximum allowed in feed mix, presence of undesirable substances)
- degree of processing required before mixing

Cow to be fed:

- body weight (to allow estimation of maintenance requirements and voluntary dry matter intake)
- expected milk yield

Total mixed ration feeding

A total mixed ration can be fed to cows using either the same ration to the whole herd (no grouping) or different rations to different groups. In a non-grouping system one mix is usually formulated to suit the high-yielding cows, the risk being overweight cows.

Grouping the cows improves the precision of the feeding. The cows can be grouped according to many criteria: yield, stage of lactation, first-calf heifers etc. The main drawback of grouping is the time spent moving the cows from one group to another as production changes. These group changes can result in reduced milk yield due to social adjustment. In addition, several mixes have to be prepared and dispensed to suit each group.

The total mixed ration feeding regime has several advantages over feeding ingredients separately:

- It is possible to use a wide range of feedstuffs.
- Total mixed ration allows greater accuracy in ration formulation.
- Cows are able to consume large amounts of feed, especially in early lactation when high intake is helpful.
- Total mixed ration allows energy and protein to be used more efficiently by microorganisms in the rumen. This also results in good rumen health with few metabolic disturbances.
- By mixing roughage and concentrates and feeding the mix at free will, the total nutrient intake for a group of cows can be regulated by the degree of concentration of nutrient in the feed.
- Total mixed ration allows use of ingredients that singly are not very palatable.

The main disadvantage of total mixed ration is the high initial investment in equipment.

8.6.2 Partly mixed rations

The partly mixed ration regime combines total mixed ration and individual feeding of concentrates. Roughage is mixed with some of the concentrates manually or with a mixer. The concentrate level in the mix is adjusted to fit the lower-yielding cows.

The high-yielding cows are fed extra concentrates in the parlour. The PMR system makes possible combining the advantages of a group total mixed ration with individual feeding.

8.6.3 Guidelines for concentrate feeding

Locally available concentrates for feeding dairy cows are of several types. The most common is the commercial dairy concentrate (referred to locally as Dairy Meal®). Concentrates can also be home made using locally available ingredients with the help of a nutritionist.

For home-made concentrates, the general rule is energy sources should form 70%, protein sources 29% and minerals/vitamins 1%.

The maximum amount of milk that can be produced without concentrate supplementation will depend on the quality of the pasture or forage, which has been reported to vary from 7 to 20 kg milk per day.

Guidelines on the amount of concentrate that should be fed to a cow have been suggested. The only accurate one is as calculated by a nutritionist and based on the cow's nutrient requirements. Examples in Box 8.1 show some of these guidelines.

Box 8.1. Examples of guidelines on the amount of concentrate to be fed to a dairy cow

Guideline 1
Up to 7 kg of milk, no concentrate
For every extra 1.5 kg of milk above 7 kg, give 1 kg concentrate

Guideline 2
Forage : concentrate ratio
Pasture or fodder – 70%
Concentrates – 30%
For high yielders, concentrate portion may go up to 60%

CHAPTER 9: CHALLENGES

9.1 Major forage diseases

In the past, forage diseases of major economic importance were rare in Kenya. The situation has recently changed with reports of smut and stunting diseases affecting Napier grass, one of the most important forages in the country. Outbreaks of smut were reported by Kungu and Waller in 1992 in an unpublished report and of stunting by Jones et al. (2004).[1] The diseases reduce Napier grass yields by almost 100% for the affected stools.

9.1.1 Napier grass head smut disease

The disease is caused by a fungus, *Ustilago kameruniensis*. Affected Napier grass flowers early and the head is characterized by a loose black soot-like powder, which is the disease-causing spores.

Affected Napier grass changes in appearance, the leaves become short and narrow, the internodes short, and the plant appears seriously dwarfed. In a stool, it starts with a few stems that when pulled, uproot easily and appear like a parasitic plant. The roots also appear shortened and dwarfed.

The disease is spread by

- planting diseased Napier grass
- transporting disease-causing spores to clean Napier grass by wind or water or through farm tools
- manure from cattle fed on diseased Napier grass (with the spores)

In Kenya, the occurrence of disease has been reported in

- central Kenya in the districts of Kiambu, Kirinyaga, Maragua, Murang'a, Nyeri, and Thika
- eastern Kenya; Meru Central and Meru South
- the Rift Valley: Londiani and Molo

Control

- Uproot the diseased stems or stools and burn; do not feed to cows.
- Apply enough farmyard manure on the Napier grass to increase the yield, although it does not eradicate the disease.
- Avoid applying manure from cows fed on diseased Napier grass.
- Plant disease-resistant Napier grass cultivars such as Kakamega 1 or Kakamega 2, which are available from the Kenya Agricultural Research Institute.

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1 Jones P, Devonshire BJ, Holman TJ and Ajanga S. 2004. Napier grass stunt: a new disease associated with a 16SrXI group phytoplasma in Kenya. *Plant Pathology* 53:519.

9.1.2 Napier grass stunting disease

Napier grass stunting disease is caused by tiny bacterium-like organisms called *Phytoplasma*. The affected Napier grass appears pale yellow-green, leaf size is seriously dwarfed and internodes are shortened. There is normally a proliferation of tillers from the affected stool. The affected and stunted clumps will later die.

The disease is spread by planting diseased stems and splits and by leafhoppers and planthoppers. The diseased grass is safe for livestock to eat and the disease cannot be spread through manure.

Occurrence of disease

- Bungoma, Butere, Kakamega and Mumias in western Kenya
- Kiambu and Murang'a in central Kenya
- Uganda, in areas bordering western Kenya
- Ethiopia

Solution

- Inspect Napier grass fields regularly, remove diseased stools and burn them.
- Use clean planting material from clean areas.
- Avoid harvesting the same area frequently before the grass is at the recommended height, as early cutting exposes the stools to sap-sucking planthoppers that transmit the disease.
- In areas that are seriously affected, use alternative fodders such as giant panicum, Guatemala grass and fodder sorghum.

No Napier grass cultivars presently known resist the disease.

9.2 Cost and quality of commercial concentrates

Commercial concentrates are key to increased milk production as most pastures and forages are of low quality and cannot meet the nutrient demand of high-yielding cows.

The main limitations in using these concentrates are affordability and quality. The farm gate price of milk, which is dictated by the processors, also determines affordability.

Price is dictated by the availability of raw materials, which in some cases are also used for other purposes, especially human food. When there is competition for the use of raw materials as human food, the price increases. Currently, grain-surplus countries are using grains to produce biofuels, leading to an increase in world prices of cereals and cereal by-products.

The quality of these commercial concentrates is also of major concern to the dairy farmer. Though standards exist in different countries to check on quality they are not always enforced. Currently, several laboratories can analyse these concentrates and advise the farmer accordingly.

Farmers should also note that concentrates are supplements and their effectiveness depends on the quality of the basal ration. If the basal ration is very poor, high levels of concentrates will be required to achieve the desired level of production.

9.3 Effect of feed contamination on milk quality

Several factors can affect both milk quality and flavour. Off-flavours in milk have been attributed to feed-related causes (80% of cases), oxidation (5%), rancidity (5%), chemical residues (3%), poor hygiene (3%) and other causes (4%). Some feed-related flavours are not objectionable, while others are usually offensive. Table 9.1 indicates examples of feedstuffs that could cause off-flavour in milk.

Table 9.1. Various feedstuffs and their effect on milk flavour

Little or no feed flavour at normal feeding levels	Off-flavour if fed within 5 hr of next milking	Common weeds causing off-flavour milk
Napier grass	Lucerne (green, hay or silage)	Wild garlic and onions
Most grasses and hay	Silage	Wild lettuce and carrot
Beet tops and pulp	Turnips, cabbage, kale	
Carrots and green peas	Fish meal	
Maize, barley and oats		
Soybean and cottonseed		
Safflower and sunflower		
Fish meal, 3–4% of ration		

To reduce feed off-flavours in milk, eliminate mouldy feeds and ensure that feeds likely to impart off-flavours are fed either soon after milking or at least 4 to 5 hours before the next milking time. Objectionable flavours from some feeds pass from the rumen and digestive tract, via blood, into the udder and milk. Controlling intake of feeds that impart off-flavours is not always easy, and the amount of time between feeding and milking varies.

Oxidized flavour is characterized by a metallic or cardboard-carton taste and can be prevented by using stainless steel or glass equipment. Plastic and rubber are acceptable but are hard to keep clean. Prolonged exposure of milk to light may also result in oxidation.

Rancidity is characterized by a bitter, soap-like taste. Maintaining the milk at cool temperature helps reduce the problem. High levels of bacteria in milk, as from cows with mastitis, can aggravate the problem.

Chemical flavours: Milk may acquire a medicinal, sometimes minty, taste from disinfectants and cleaning agents used in disinfecting the milking equipment and milking area. Care should be taken to use the correct amount of disinfectant for the appropriate length of time. Also, care must be taken to properly clean and rinse equipment and to avoid the chemical agent coming in contact with milking equipment during milking.

General hygiene in the milking area can affect the flavour and quality of the milk. Contamination of milk, hence objectionable flavour, can occur through contact with the udder and from milking equipment. Also, tests have shown that flavours can be transmitted from the environment to the udder within 15 minutes, by way of the cow's respiratory tract.

Another common cause of undesirable milk flavour is mastitis. This is mainly from the effect mastitis has on increasing the salt and decreasing the sugar content of milk. Sometimes a flat or watery taste occurs, or both salty and watery tastes occur at the same time.

GLOSSARY

Abomasum: The fourth chamber of the stomach in ruminant animals, and the only one having glands that secrete digestive acids and enzymes. It can be compared with the simple stomach of other mammals.

Acidosis: An abnormally high level of acidity of the body's fluids, In ruminants it may be caused by accumulation of acids or by depletion of bicarbonates as it happens by ingestion of high amounts of grain hence poor stimulation of saliva production.

Bulling heifer: A heifer unbred but of an age suitable for breeding.

Challenge feeding: A system of feeding where dairy cows are given more concentrate feed than is justified by the level of the individual cow's milk production as a way of stimulating the cow to produce more. In the early part of the lactation the cow in many instances does so. This is done until the cow no longer responds to the increased level of feeding. Challenge feeding is also called lead feeding because the cow is led to produce more heavily.

Dystocia: Difficult calving.

Endotoxin: A toxin present inside a bacterial cell produced and released upon destruction of the bacterial cell.

Fermentation inhibitor: An additive used to retard or prevent undesirable fermentation action in a product.

Hypocalcaemia: Low calcium level in the blood.

Hypoglycaemia: Low glucose level in the blood.

Ketone bodies: Chemicals produced in the body when there is low blood sugar and the animal is forced to break down fat to generate energy. Ketone bodies are toxic acidic chemicals and may build up in the blood and then spill over into the urine or lungs, giving the breath a fruity odour.

Ketosis: The presence of ketone bodies in the blood.

Laminitis: Inflammation of sensitive layers of tissue (laminae) inside the hoof.

Omasum: The third chamber of the stomach of a ruminant animal located between the reticulum and the abomasum.

Milk fever (post-parturient paresis): A disease of pregnant and lactating cows characterized by low calcium levels in the blood. It leads to generalized paralysis and death. The disease commonly occurs around calving in cows and a few weeks before or after lambing in ewes.

Pollard: Wheat by-product.

Probiotics: Live microorganisms (in most cases, bacteria) that are similar to beneficial microorganisms in the animals' digestive system. They are also called 'friendly bacteria' or 'good bacteria' and are fed to ruminants as feed additives to enhance growth of rumen microorganisms.

Propionic acid: One of the end products of carbohydrate digestion in ruminants.

Reticulum: The second chamber of the ruminant stomach.

Rumen: The first and largest chamber of the ruminant stomach.

Steaming up: Putting a pregnant animal on a high plane of nutrition a few weeks before it gives birth.

Stool: Group of Napier grass tillers that have established from one initially planted cane or split.

Appendix 1. Recommended domains of major forages

Agroecological zone	Suitable fodder
LH1 Lower Highland 1	*Brachiaria ruziziensis* *Calliandra calothyrsus* Giant setaria *Leucaena leucocephala* Napier grass Vetch
LH2 Lower Highland 2	*Brachiaria ruziziensis* *Calliandra calothyrsus* *Chloris gayana* Giant setaria *Leucaena leucocephala* Lucerne Nandi setaria Oat *Zea mays*
LH3 Lower Highland 3	Maize Nandi setaria Oat Rhodes grass var Mbarara or Masaba Silverleaf desmodium
LH4 Lower Highland 4	Elmba Rhodes Fodder barley *Leucaena leucocephala* Napier grass
UM2 Upper Midland 2	*Chloris gayana* *Leucaena leucocephala* Maize Napier grass Silverleaf desmodium
UM3 Upper Midland 3	*Andropogon gayanus* *Chloris gayana* *Leucaena leucocephala* Maize Napier grass Silverleaf desmodium

Agroecological zone	Suitable fodder
UM4 Upper Midland 4	*Calliandra calothyrsus* *Chloris gayana* Desmodium *Hyparrhenia rufa* (zebra grass) *Leucaena leucocephala* Maize Napier grass Sorghum Sweet potato vines *Themeda triandra* (red oats grass)
UH2 Upper Highland 2	Kikuyu grass *Leucaena leucocephala* Lucerne Rye grass White clover
UH3 Upper Highland 3	*Brachiaria ruziziensis* Maize—high-altitude composite Oat Rye grass Vetch White clover

Appendix 2. Nutritive value of common feed resources

Feed	Class	DM*	Ash**	CP**
Banana leaves	Crop residue	12.20	8.80	9.90
Banana pseudostem	Crop residue	5.10	14.30	2.40
Banana thinnings	Crop residue	13.00	13.10	6.40
Bone meal	Concentrate	75.00	49.00	6.00
Calliandra leaves	Tree fodder	25.00	4.30	26.30
Couch grass	Grass	30.20	7.40	8.80
Cottonseed cake	Concentrate	92.00	7.00	33.0
Fish meal	Concentrate	92.00	21.40	64.30
Grazing	Grass	28.00	7.00	10.00
Hay	Grass	90.00	5.60	4.30
Maize (green thinnings)	Crop residue	25.00	4.50	6.20
Maize (whole)	Concentrate	90.00	1.70	11.20
Maize bran	Concentrate	85.40	2.20	9.40
Maize germ	Concentrate	88.00	4.20	22.60
Maize stover (dry)	Crop residue	85.00	7.00	3.70
Maize stover (green at harvest)	Crop residue	13.00	8.50	7.70
Napier grass	Grass	15.00	13.00	6.00
Napier grass (30 cm)	Grass	12.10	12.10	9.20
Napier grass (60 cm)	Grass	12.60	12.40	7.40
Napier grass (1 m)	Grass	13.40	12.60	7.00
Napier grass (1.3 m)	Grass	14.40	13.10	6.50
Napier grass (1.6 m)	Grass	15.50	13.00	6.20
Napier grass (2 m)	Grass	18.70	12.90	6.00
Napier grass (> 2 m)	Grass	24.00	13.00	5.00
Rhodes grass	Grass	90.00	9.10	6.30
Sesbania leaves	Tree fodder	28.00	4.50	28.20
Star grass	Grass	30.00	11.60	11.00
Sugar cane tops	Crop residue	30.50	9.10	5.90
Sweet potato vines	Other	25.00	9.40	19.20
Wheat bran	Concentrate	88.00	2.40	17.80
Wheat straw	Crop residue	86.00	9.40	3.80

DM – dry matter, CP – crude protein
* dry matter (%), ** % dry matter

Appendix 3. Weight conversion table (heart girth to live weight)

Heart girth (cm)	Live weight (kg)	Heart girth (cm)	Live weight (kg)	Heart girth (cm)	Live weight (kg)	Heart girth (cm)	Live weight (kg)
60	30	87	63	114	130	141	235
61	31	88	65	115	134	142	240
62	32	89	67	116	137	143	244
63	33	90	69	117	140	144	248
64	34	91	71	118	143	145	252
65	35	92	73	119	146	146	256
66	36	93	75	120	150	147	260
67	37	94	77	121	154	148	264
68	38	95	79	122	158	149	268
69	39	96	81	123	162	150	272
70	40	97	83	124	166	151	276
71	41	98	85	125	170	152	280
72	42	99	87	126	174	153	285
73	43	100	89	127	178	154	290
74	44	101	92	128	182	155	295
75	45	102	95	129	186	156	301
76	46	103	98	130	190	157	307
77	47	104	100	131	194	158	313
78	48	105	103	132	198	159	319
79	49	106	106	133	202	160	325
80	50	107	109	134	206	161	345
81	51	108	112	135	210	162	353
82	53	109	115	136	214	163	360
83	55	110	118	137	218	164	366
84	57	111	121	138	222	165	372
85	59	112	124	139	226	166	378
86	61	113	127	140	230	167	385

Heart girth (cm)	Live weight (kg)
168	392
169	399
170	406
171	413
172	420
173	427
174	435

Heart girth (cm)	Live weight (kg)
175	443
176	451
177	459
178	467
179	475
180	483
181	491

Heart girth (cm)	Live weight (kg)
182	500
183	508
184	516
185	525
186	534
187	543
188	552

Heart girth (cm)	Live weight (kg)
189	561
190	570
191	580
192	590
193	600

Appendix 4. Fodder crop conversion table

Fodder type	Unit	Average weight (kg)
Napier grass	Bunch	30
Napier grass	Woman's load	75
Napier grass	Man's load	43
Napier grass	Standard sack (chopped)	36
Napier grass	Wheelbarrow load	124
Napier grass	Bicycle load	84
Napier grass	Pick-up load (1095 tare)	962
Napier grass	Pick-up load (475 tare)	560
Napier grass	Donkey cart load	210
Banana pseudo stems	Count (items)	39
Banana pseudo stems	Standard sack (chopped)	90
Maize stover dry	Standard sack (chopped)	25
Maize stover dry	Donkey cart load	120
Maize stover green	Standard sack (chopped)	35
Maize stover green	Wheelbarrow load	162
Maize stover green	Man's load	35
Maize stover green	Bicycle load	54
Maize stover green	Donkey cart load	172
Maize stover green	Pick-up load (1095 tare)	800
Sweet potato vines	Donkey cart load	90
Sweet potato vines	Standard sack	35
Cut grass	Standard sack	32
Cut grass	Woman's load	37
Cut grass	Wheelbarrow load	88
Cut grass	Bicycle load	43
Cut grass	Donkey cart load	75
Weeds	Standard sack	40
Weeds	Woman's load	40

Fodder type	Unit	Average weight (kg)
Weeds	Man’s load	25
Weeds	Wheelbarrow load	69
Weeds	Donkey cart load	80
Oats	Standard sack	60
Oats fodder	Standard sack	30
Oats fodder	Pick-up load	250
Oats fodder	Man’s load	20

Appendix 5. Ruminant feed conversion table

Feed type	Application unit	Average weight (kg)
Dairy meal	Sack (20 kg)	20
Wheat bran	Standard sack (70 kg)	39
Wheat bran	Sack (50 kg)	28
Maize bran	Standard sack (70 kg)	40
Maize bran	Sack (50 kg)	29
Maize germ	Standard sack (70 kg)	59
Cottonseed cake	Sack (20 kg)	20
Pyrethrum marc	Standard sack (70 kg)	70
Brewers waste	Debe	25
Wheat straw	Bale	15
Grass hay	Bale	20
Molasses	20-kg jerry can	25

Appendix 6. Organic and inorganic fertilizer conversion table

Fertilizer type	Application unit	Average table (kg)
Slurry	20-kg bucket / debe	22
Slurry	Wheelbarrow load	86
Wet manure	Standard sack	57
Wet manure	Donkey-cart load	400
Wet manure	Ox-cart load	200
Wet manure	Hand-cart load	250
Wet manure	Pick-up load	600
Wet manure	Wheelbarrow load	55
Wet manure	20-kg bucket / debe	14
Dry manure	Standard sack	45
Dry manure	Donkey-cart load	280
Dry manure	Hand-cart load	150
Dry manure	Pick-up load	450
Dry manure	Wheelbarrow load	45
Dry manure	Standard kiondo	25
Dry manure	Kasuku	1.5
Dry manure	20-kg bucket / debe	12
Dry manure	50-kg debe	30
Compost manure	Standard sack	50
Inorganic fertilizer	Kimbo or Kasuku tin (2 kg)	2
Inorganic fertilizer	20-kg bucket / debe	20
Inorganic fertilizer	Standard sack CAN	20
Inorganic fertilizer	Standard sack MAP	50
Inorganic fertilizer	Standard sack NPK	20
Poultry manure (unsieved)	Standard sack (70 kg)	72
Poultry manure (unsieved)	Sack (50 kg)	46
Poultry manure (unsieved)	20-kg bucket / debe	7
Poultry manure (unsieved)	Wheelbarrow load	25
Poultry manure (unsieved)	Donkey-cart load	300
Poultry manure (unsieved)	Lorry	6500
Coffee husks	Wheelbarrow load	20

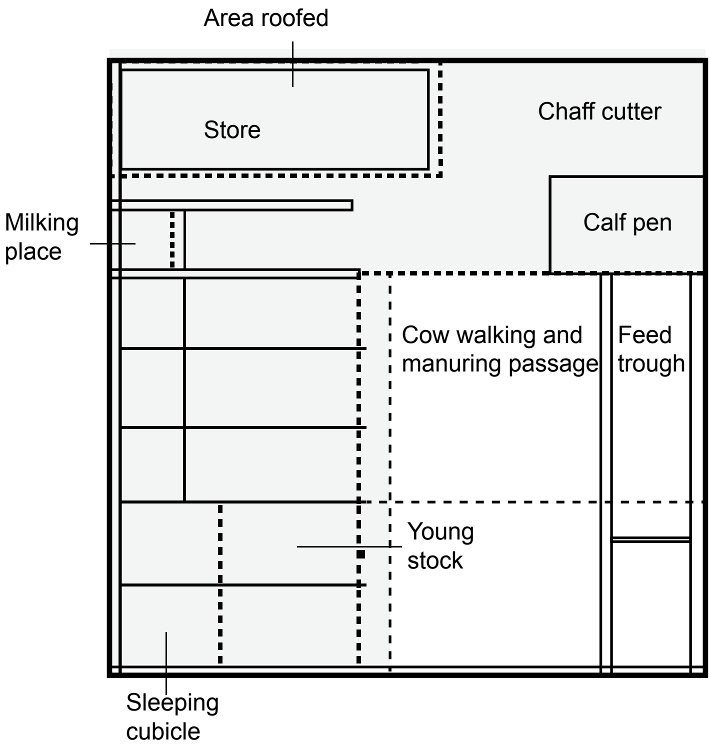
Appendix 7. Volume and weight measures of a Kasuku can

Meal	Volume measure—standard 2-kg plastic Kasuku cooking oil can	Meal weight	
		(g)	(kg)
Dairy meal	Kasuku top level compacted	1287	1.3
	Kasuku top level loose	1179	1.2
Maize bran	Kasuku top level compacted	1252	1.3
	Kasuku top level loose	1124	1.1
Maize germ	Kasuku top level compacted	1438	1.4
	Kasuku top level loose	1287	1.3
Wheat bran	Kasuku top level compacted	841	0.8
	Kasuku top level loose	719	0.7

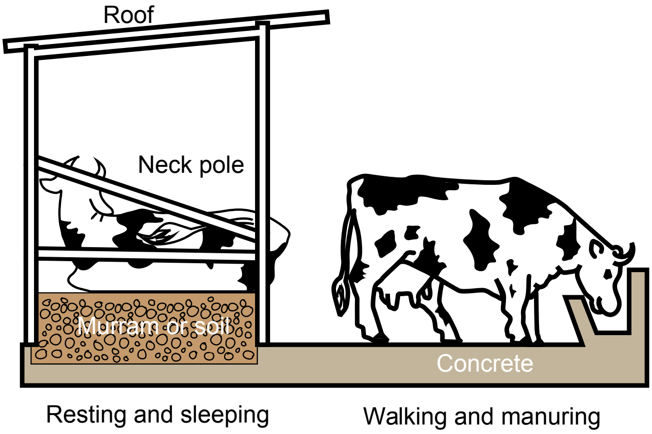
Compiled by J Nyangaga, June 2005 Information based on 48 samples, weighted using 3 replicates, from 12 manufacturers in 7 shop outlets in Nairobi and Limuru

Appendix 8. Diagram of a zero-grazing unit

Cubicle cow shed design 2
Top view B



Side elevation of a cubicle dairy cattle shed



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