NUTRITIVE VALUE OF COMMONLY AVAILABLE FEEDS AND FODDERS IN INDIA

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FOREWORD

The demand for milk and milk products would drive growth in milk production, which is expected to increase to more than 200 million tonnes by 2020 from the current level of about 121 million tonnes.

The National Dairy Plan Phase I, which has been recently approved for funding by the World Bank, will focus on improvements in bovine productivity through the promotion of scientific practices in animal breeding and nutrition, as well as improving access for rural milk producers to urban markets.

Milch animals are usually fed one or two locally available concentrate feed ingredients, grasses and crop residues resulting in either deficiency or excess of proteins, energy, minerals and vitamins.

NDP I aims to promote scientific practices in animal nutrition through education of milk producers by trained village based Local Resource Persons (LRPs) so that the nutrients required by a milch animal are fulfilled in an optimum manner thereby improving milk production efficiency and returns from dairying. The project plans to cover about 2.7 million milch animals through some 40,000 LRPs. To train this large number of LRPs, technical officers with a background in animal nutrition would need to equip themselves with the required knowledge, including the nutritive value of commonly available feeds and fodders in India.

I am happy to note that the Animal Nutrition group in NDDB has put in a great deal of effort to prepare a compendium on the nutritive value of feeds and fodders in India based on data generated by NDDB and other authoritative sources to serve as a practical guide on the subject, for those with and without formal training in the area of animal nutrition.

The compendium has been neatly organized on the basis of feed categories, nutrient categories, product categories etc for easy reference. The description for each feed material or ingredient has concise and useful information on scientific and common names, nutritive value, recommended feeding level in terms of inclusion level and any adverse factor that needs to be noted. Wherever relevant, information on the toxic principles presents in feed/ fodder ingredients has also been provided for caution and to improve understanding in the use of such materials.

I am sure that this compendium would serve as a valuable reference tool in the hands of animal nutrition officers as well as others who have a keen interest in the subject.

July, 2012

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Introduction

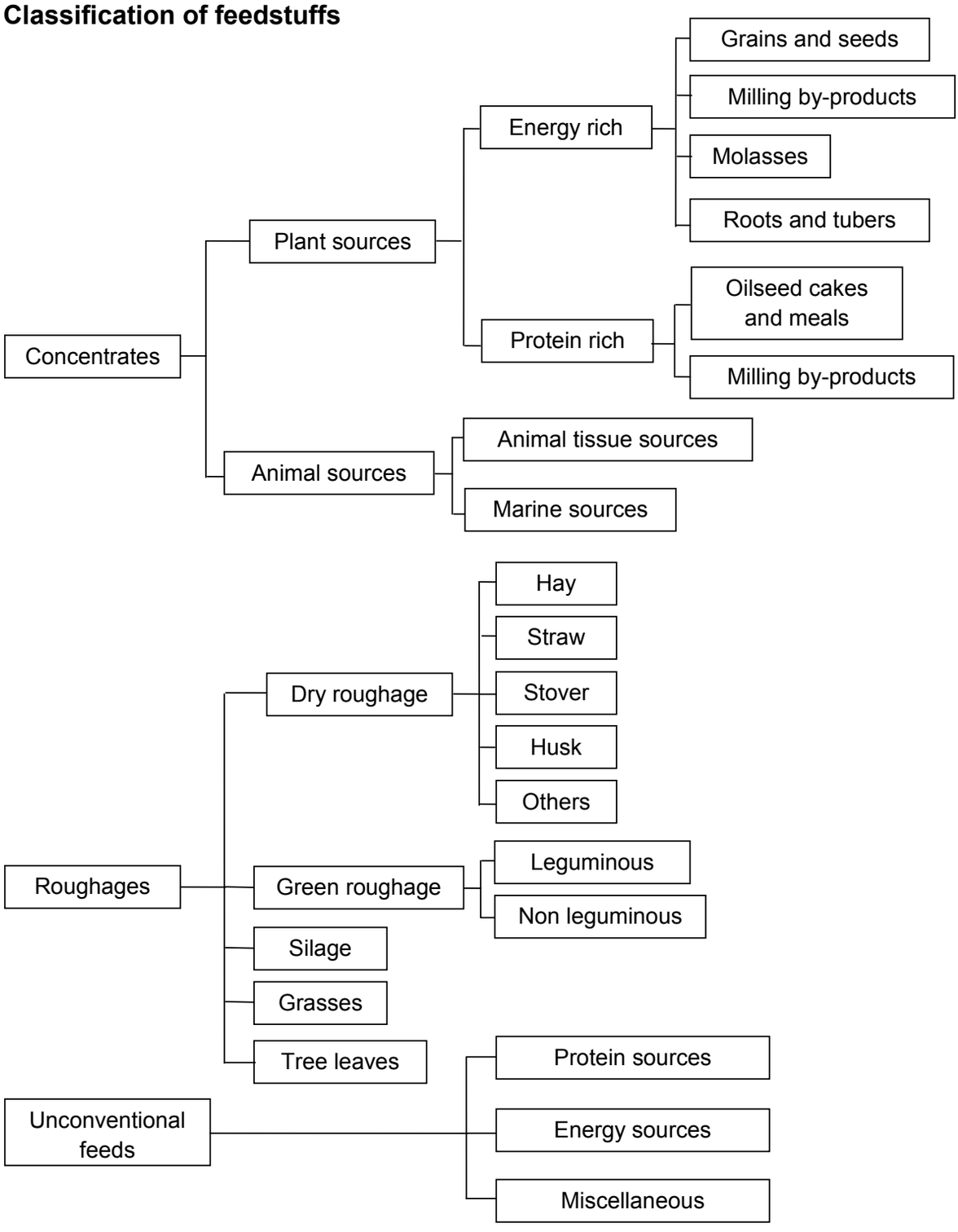
Livestock plays an important role in sustaining livelihood, nutritional and environmental security and growth of Indian Agriculture. The giant strides made in the livestock sector in the past decades are the major reason for positive growth rates recorded in agricultural sector. While we have achieved horizontal growth in terms of animal numbers, there is a need to achieve vertical growth in terms of improving productivity.

Shortage of feed resources in India has been documented by various organizations but several locally available feed resources used for feeding milch animals are not taken into account. These include industrial by-products, horticulture and vegetable wastes, local grasses, tree leaves, weeds and other non-conventional feed resources. The available feed resources are not fed in right proportion as per the requirement of animals, leading to imbalance of nutrients in the ration. The compound cattle feed manufactured by various agencies in different sectors does not usually meet the specific requirement of animals which includes species, breed, stage of lactation, physiological status of animals, quality of basal roughages etc. In view of this, it has not been possible to fully realize the genetic potential of milch animals. Despite shortage, milk production and the productive life of dairy animals can be improved substantially if the available feed resources are utilized judiciously.

National Dairy Development Board of India realized that for productivity enhancement milk producers are advised to feed a balanced ration to their animals with the available feed resources, along with the area specific mineral mixture(s). For this purpose, a user friendly software has been developed, in which entire nutrient requirement of animals is met from the available feed resources, at a least cost.

Officers and field staff of the agencies engaged in implementing ration balancing advisory services at field level should have adequate knowledge of nutritive value of locally available feed resources. All relevant information on the commonly available feed resources along with the photographs, has been compiled in this hand book which may be of immense use for those engaged directly or indirectly in implementing feed related programmes at field level.

Classification of feedstuffs



I. CONCENTRATES

A concentrate is usually described as a feed or feed mixture which supplies primary nutrients (protein, carbohydrate and fat) at higher level but contains less than 18% crude fibre (CF) with low moisture. In general, concentrates are feeds that are high in nitrogen free extract (NFE) and Total Digestible Nutrients (TDN) and low in crude fibre.

On the basis of the crude protein content of air dry concentrates, these are classified as either energy rich concentrates when crude protein (CP) is less than 18% or protein rich concentrates when the CP value exceeds 18%.

1 Energy sources

These are described under the following categories:

1.1. Grains and seeds

1.2. Milling by-products

1.3. Molasses

1.4. Roots and tubers

1.1. Grains and seeds

Grains are seeds from cereal plants, members of the grass family called *Graminaea*. Cereal grains are essentially carbohydrates, the main component of the dry matter being starch, which is concentrated on the endosperm. All cereal crops are annuals (Kharif). By-products of harvested grains as chaff, stover and straw are utilized as low quality forages for ruminant animals. Moreover, many of the grains are milled or processed in some manner thereby creating additional by-products which can be fed to livestock with varying degrees of nutritive values. In India except for poultry, swine and lactating dairy animals, grains are not usually fed for livestock production, because of high cost due to high demand by human beings.

The crude protein content of grains and seeds varies between 8-12%, which again is deficient in lysine and methionine. The oil which is mostly present in the embryo is highest in oats (4-6%) and lowest in wheat (1-2%). Cereal oils are unsaturated, the main fatty acids being linoleic and oleic and because of this, the cereals tend to become rancid quickly and also produces soft body fat in non-ruminants. The crude fibre content of harvested grain is highest in oats and rice, which contain a husk or hull formed from the inner and outer paleae and is lowest in the naked grains like wheat and maize. All cereals are deficient in vitamin D and calcium, but are moderately rich in phosphorus and vitamin E.

Cereal grains and cereal by-products

Nutrient composition of grains

The name cereal is given to those members of the *Gramineae* which are cultivated for their seeds. The dry matter content of grain depends on the method of harvesting and storage conditions but is generally within the range of 80-90%. Protein constitutes 85-90% of the nitrogenous compounds. The protein occurs in all tissues of cereal grains, but higher concentrations are found in the embryo and aleurone layer than in the starchy endosperm pericarp and testa. The protein content of grain though variable, normally ranges from 8-12%. The lipid content of cereal grains also vary with species, normally ranges from 1-6%. Maize and oat contain 4-6% oil, while sorghum 3-4% and wheat, barley and rice

contain 1-3% oil. The embryo or germ contains more oil than the endosperm. Cereal oils are unsaturated, the main acids being linoleic and oleic and because of this, they tend to become rancid quickly.

The crude fibre content of the harvested grains is highest in those such as oats or rice which contain husk and is lowest in grains without husk like wheat and maize. The husk has a diluent effect on the grain as a whole and reduces the energy value of proportionally. Starch occurs in the endosperm of the grain in the form of granules, whose size and shape vary with different species. Cereal starch consists of about 25% amylase and 75% amylopectin, although waxy starches contain greater proportions of amylopectin. The cereals are deficient in calcium and vitamin D. Though phosphorus content is higher, but part of this is present as phytic acid. Cereal phytates have the property of being able to bind dietary calcium and probably magnesium, thus preventing their absorption from the gut. Except yellow maize, all other cereals are low in provitamin A. They are good sources of vitamin E and thiamin, but have a low content of riboflavin. Cereals generally form a lower proportion of the total diet of ruminants.

Following are some of the important inherent problems in the use of grains for ruminant feeding:

1. In ruminant animals, high concentrate ration may cause digestive disturbances, such as acidosis. Ruminants need some roughage, to stimulate the rumen papillae.
2. Some grains must be processed before they can be fed. The need for processing is primarily governed by the type of grain and the particular animal being fed.
3. Grains are deficient in calcium and certain vitamins. Most grains contain less than 0.1% calcium. Adequate amounts of phosphorus are generally present in grain, but the calcium to phosphorus ratio is highly imbalanced. Additionally, grains are also deficient in certain vitamins like vitamin A and vitamin D. However, yellow maize is rich in β carotene, which is a precursor of vitamin A.

Structure of grain

Grain develops from the ovary and its ovule after fertilization by pollen. The flower structures of various cereal plants are different, hence these differences reflect in the structure of the individual grain in kernel. In maize, the male and female structures are found in separate flower structures on the plant. The male flower structure commonly referred to as the tassel, is located at the top of the corn stalk. Pollen is shed from tassels and subsequently comes into contact with the female flower structure thereby producing the grain. The female structure contains a central rachis commonly referred to as cob. The cob contains a series of rows of sessile spikelet and is enclosed by overlapping bracts (husks). The silks which are found on the corncob structure are the stigmas, the pollen receiving organs. Each spikelet contains two flowers one fertile and another sterile.

The grain of barley, oats, wheat, rice and sorghum develops from flowers which contain the ovary, three stamens and two scale like lodicules. These structures are surrounded by a pair of bracts called the lemma and the palea. In rye and wheat, the lemma and palea are loosely attached to the grain. During threshing these particles are separated from grain and constituted what is known as chaff.

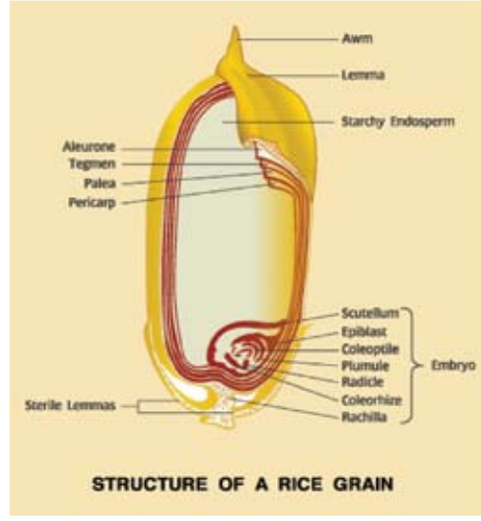


Fig. 1.1 Structure of grain

Barley, rice and oats retain their lemma and palea during threshing, thus giving rise to structures called husks or hulls. In barley, the lemma and palea fuse with the grain. In oats, the lemma and palea do not fuse with the kernel but enclose and adhere tightly to the entire grain. This hull structure can be removed during processing, resulting in dehulled oats called groats. Rice hulls are removed during processing.

Individual kernels of grain are called caryopses. Grains which contain husks (oats, barley and rice) are called covered caryopses; whereas, grain lacking husks (maize, wheat, rye and sorghum) are referred as naked caryopses. Each kernel exclusive of the husk is composed of two main parts - pericarp and seed.

Pericarp

The pericarp consists of two layers. The outer layer contains the epidermis and hydroderm collectively referred to as the beeswing. The inner layer of the pericarp contains cross cells and tube cells. Throughout the ripening process of grain, the inner most layer of pericarp becomes distorted and torn and thus giving a tube like appearance called tube cells.

Seed

The seed portion of grain can be divided into four parts: 1) seed coat 2) hyaline layer (nucellar layer), 3) endosperm and 4) germ (embryo). When grain is processed in such a way that the germ and starch endosperm are removed the composite of the remaining parts of the seed and the pericarp is called the bran. The seed coat is either one or two layers thick. There is very little cellular structure in the region. Likewise, the hyalinase layer lacks any cellular structure, but rather acts as an embryo sac.

Endosperm

The endosperm of grain can be divided into two parts called the aleurone and the starchy endosperm.

Aleurone

The aleurone surrounds the starchy endosperm of grain, but does not encampass the scutellam of the embryo. The cells of aleurone are thick walled, cuboidal, and rich in oil, niacin and mineral matter. Phytic acid is also produced in larger quantities in this region. The number of layers of cells in this region varies according to type of grain. Wheat, rye, oats and sorghum have generally one layer of cells in the aleurone. Depending on the particular variety, maize may contain from 1 to 6, barley 2 to 4 and rice 2 to 6 layers.

Starchy endosperm

The starchy endosperm portion of grains contains thin walled cells that are highly variable in shape, size and contents. Pentosans are found in large amounts in the cell walls of this region, but starch and protein take up most of the cell contents. Starch is found primarily in the form of granules, with protein filling the intergranular spaces. In wheat, the cells adjacent to the aleurone are relatively higher in protein and lower in starch than the rest of the starchy endosperm. The concentration of starch in maize depends on type of the maize and the area of the kernel being analysed. The endosperm of the maize is divided in to two regions - the crown and the horny region. The crown contains loosely packed starch granules with little protein. The protein content of horny region is much higher than crown region.

Germ (Embryo)

Upon germination, food reserves in the endosperm are mobilized and passed on top of the embryo by scutellum. The plumule of the embryo gives rise to the growing bud and the radical to root system.

1.1.1 Maize *(Zea mays)*

Synonym: Corn

Local names: Hindi: Makka, Makai, Bhutta Manipuri: Chujak Marathi: Bhutta Tamil: Makka cholam Malayalam: Makka cholam Telugu: Mokka javanalu Kannada: Makkejola Konkani: Mako Urdu: Makka

Fig. 1.2 Maize grain

Maize is the world's most important feed grain because of its high nutritive value and good agronomic features. Maize can produce more energy per acre than any other cereal grain due to its C4 photosynthetic pathway. The C4 plants have a tropical origin and are inherently more productive than plants with C3 pathway. Maize is also unique among grains in having the male and female flower organs separately on same plant, which allowed development of high yielding maize varieties. There are seven types of maize including dent, flint, flour, pop, sweet, waxy and pod maize. Dent corn is the primary type grown as feed and sweet corn is the major type grown for human consumption. Dent corn is characterized by a dent or indentation at the top of the kernel, formed when the starch shrinks during drying.

Nutritive value

Maize is a high energy grain because it is high in starch and oil and low in fibre. Maize contains about 70% starch, 85-90% TDN, 4% oil and about 8-12% protein. The grains should be ground before feeding to the ruminants, otherwise they will escape digestion. Maize contains starch, which composed of about 25% amylase and 75% amylopectin. The starch in maize is more slowly digested in the rumen than that of the other grains and at high levels of feeding a proportion of starch passes in to the small intestine, where it is digested and absorbed as glucose. This may have advantages in conditions such as ketosis. The maize kernel contains two types of proteins. Zein occurring in the endosperm is quantitatively the more important, but this protein is deficient in the indispensible amino acids lysine and tryptophan. Now new variety of corn (opaque-2) has been evolved which is rich in lysine and protein. A newer variety, Floury-2, has increased contents of both methionine and lysine. A number of different types of maize exist and the grain appears in variety of colours, yellow, white or red. Only yellow variety has a fair amount of cryptoxanthin, a precursor of vitamin A. Yellow maize also contains xanthophylls which are important in poultry production for providing the yellow coloration of the egg yolk and of the skin of the broilers. Maize is a fair source of vitamin E and low in vitamin D and the B complex vitamins. In common with all plants, maize is devoid of vitamin B_{12} activity.

Deleterious factor

Maize does not intrinsically contain any toxic and deleterious compounds. However, it is often contaminated with mycotoxins which are of concern in animal feeding. The major mycotoxin of concern is aflatoxin produced by the mold Aspergillus flavus. The mold infects

maize both in the field and storage. Drought and insect damage promote infection of the developing grain.

1.1.2 Sorghum *(Sorghum bicolor)*

Local names: Hindi: Jowar **Marathi:** Jowari **Tamil:** Cholam

Sorghum resembles in feeding value to that of maize. It is more drought resistant than maize. The kernel of sorghum is very similar to that of maize, although smaller in size. Like maize, sorghum is also a C4 plant accounting for its high productivity and tolerance to high temperatures.

Fig. 1.3 Sorghum grain

Nutritive value

Sorghum grain is very similar to maize in composition. It generally contains more protein but less oil than maize and has no pigmenting xanthophylls. Sorghum contains about 65% starch, 80-85% TDN, 2-3% oil and about 8-12% protein. Grains are slightly less palatable than maize because of the presence of tannins. The grains should be ground before feeding the ruminants, otherwise they will escape digestion. Care is needed in the grinding process as this may produce a fine powder, which is pasty and unpalatable. Tannins in sorghum greatly reduce protein availability both in rumen and small intestine. Lysine, threonine and methionine are the limiting amino acids in sorghum. Grains typically have very low calcium, high phytate phosphorus, no vitamin B_{12} and very little vitamin A activity.

Deleterious factor

The principal deleterious factors in sorghum grain are polyphenolic compounds, known as condensed tannins. Most of the biological effects of tannin are associated with their ability to react with protein. In the digestive tract tannins may react with digestive enzymes reducing nutrient digestibility. They also react with dietary proteins forming indigestible complexes. Various processing methods can be used to overcome the effects of sorghum tannin. Treatment with alkali, such as sodium or ammonium hydroxide or anhydrous ammonia is effective. Polyethelyne glycol which forms complexes with tannins has also been shown to be an effective additive to improve the feeding value of high tannin sorghum.

1.1.3 Wheat *(Triticum aestivum)*

Local names: Hindi: Gehun Kannada: Godhi Manipuri: Gehun Marathi: Gehun Sanskrit: Arupa, Bahudugdha, Godhuma Tamil: Godumai, Godumbaiyarisi Telugu: Godumalu Urdu: Gehun

Wheat is the world`s most important crop. It is grown primarily for human consumption. Wheat belongs to the genus *Triticum*.

Fig. 1.4 Wheat grain

Nutritive value

Though wheat is a good source of energy containing 75-80% TDN, it is rarely used for livestock feeding in India due its higher cost and higher demand for human consumption. Only damaged wheat is used

for feeding animals. Grain of wheat is highly variable in composition. Depending upon the variety, crude protein content ranges from 8-14%. Wheat is superior to maize in protein content and quality. Lysine, threonine and methionine are the major limiting amino acids in wheat grain. Climate, soil fertility and variety influence the protein content. The most important protein present in the endosperm is a prolamin and a glutelin. The mixture of protein present in the endosperm is often referred as gluten. The amino acid composition of these two proteins differs, glutenin containing about three times as much lysine as that present in gliadin. All glutens possess the property of elasticity. Glutens form dough which traps the gases produced during fermentation. Finely ground wheat forms a pasty mass in the mouth and rumen and this may lead to digestive upsets. Newly harvested wheat is apparently more harmful in this respect than wheat which has been stored for some time. When wheat grain is fed in large amounts, because of the rapid fermentation of the grain in rumen, animal is more prone to lactic acidosis.

Deleterious factor

There are no significant toxins in wheat. It is not normally infected with mycotoxin producing fungi, so mycotoxins are not of concern unless the grain is improperly stored. Occasionally it may be infected with ergot.

1.1.4 Barley *(Hordeum vulgare)*

Local names: **Hindi**: Jav, Jau **Kannada**: Javegodhi **Malayalam**: Barli, Yavam **Marathi**: Satu, Jav **Sanskrit**: Aksata, Akshata, Dhanyaraja **Tamil**: Barliarisi **Telugu**: Barlibiyam, Dhanuabhedam **Urdu**: Jao, Jav

Fig. 1.5 Barley grain

Barley is widely grown in Europe and in the cool and dry climates of North America and Asia. It is also one of the very popular grains in feeding livestock.

Nutritive value

Maize, wheat, triticale and sorghum are recognized as high energy grains, whereas, barley and oats are lower in energy content. The lower energy value of barley is due to its lower starch content, a higher content of poorly digested glucans, and higher fiber content. Barley contains water soluble carbohydrates called β-glucans which are poorly digested, especially in non-ruminants. However, the glucans are digested by microbial action in rumen. The crude protein varies from 11-16% and TDN from 78-80%. The lipid content of barley grain is low; usually less than 2.5% of dry matter. Barley is deficient in the amino acid lysine.

In many parts of developed countries barley is used for fattening beef animals. Beef cattle are fattened on concentrate diet consisting of about 85% bruised barley without the use of the roughage. In this process the barley is usually treated so that the husk is kept as one piece and at the same time the endosperm is exposed, the best results being obtained by rolling the grain at a moisture content of 16-18%. Storage of high moisture barley of this type can present a problem because of the possibility of mold growth. Satisfactory preservation of the moist grain can be obtained if it is stored anaerobically. An additional or alternative safeguard is to treat the grain with a mould inhibitor such as propionic acid. Certain hazards such as rumen acidosis and bloat can be encountered with high concentrate diets given to ruminants and it is necessary to introduce this type of feeding gradually over a period of time. There are no significant toxins in barley.

1.1.5 Oat *(Avena sativa)*

Oat is a minor grain and is likely to become less important as a feedstuff for animals. Oat is of low importance simply because the yield per hectare is much lower than other grains. For a farmer it would be economical to produce oat, if the price per ton is higher than that of other grains to compensate for the lower yield; otherwise there is no economic incentive to grow oat. The use of oat as animal feedstuff may decline in future, but it may become more important in human nutrition due to the presence of soluble fibre which has favourable effects to reduce serum cholesterol.

Fig. 1.6 Oat grain

Nutritive value

It is a feed of choice for feeding horses. It can be fed to the ruminants also, but is less suitable for poultry and pigs because of the high fibre content. Oats are a low energy grain because of their low starch and high fibre content. The nutritive value of oats depends to large extent on the proportion of kernel to hull. The proportion of hull in the whole grain depends upon the variety, environment and season and can vary from 23-35%. Oats of high hull content are richer in crude fibre and have a lower metabolisable energy value than low hulled oats. The soft physical nature of the hull and high oil content contribute to the high palatability of oats. The crude protein content ranges from 8-12% and TDN 70-73%. Oats have the highest quality protein of any cereal grain and often have higher protein content and the amino acid distribution is the most favourable of any of the cereal grain. Still oat proteins are deficient in the essential amino acids like methionine, histidine and tryptophan. The lysine content is also low, but is slightly higher than that of the other cereal grains. The oil content of oats is higher than (5% oil) that of most of the cereal grains and about 60% of it is present in endosperm. The oil is rich in unsaturated fatty acids and has a softening effect on the body fat. Oat grain has a higher mineral content than other grains. It should be given crushed to the ruminants and ground to the poultry and pigs.

1.1.6 Rice *(Oryza sativa)*

Local names: Hindi: Chaval **Tamil:** Arisi **Telugu:** Biyyam

Rice is a major foodgrain for millions of people in the tropics especially Asia. It is good source of energy but is seldom used for livestock feeding in Asia. About more than 40,000 types of rice varieties are grown in the world. Its by-products like rice polish and rice bran are extensively used for livestock feeding in India.

Fig. 1.7 Rice grain

Nutritive value

Unprocessed rough rice contains about 8-10% crude protein, 9% crude fibre, 1.9% ether extract and 6.5% ash. The TDN content varies from 78-82%. The unprocessed rice contains about 25% of its weight as hulls. Rice should be ground or cracked before feeding to animals. Rice hulls are high in silica and are abrasive to both feed mill equipment and digestive tract. The hulls are almost totally indigestible and are not recommended for livestock feeding.

1.1.7 Rye *(Secale cereale)*

Rye is the grain most tolerant of adverse growing conditions, like extreme cold and acidic soil conditions. Because of its poor palatability and presence of numerous deleterious factors use of rye in animal feed is very limited.

Nutritive value

Rye grain is very similar to wheat in composition although rye protein has higher lysine and lower tryptophan contents than wheat protein. Protein content of rye varies from 10-14% and TDN 75-80%. It is regarded as the least palatable of the cereal grains. It is also liable to cause digestive upsets and should always be given with care and restricted amounts.

Fig. 1.8 Rye grain

Deleterious factors

Rye has never given favourable results in animal feeding as its nutrient composition suggests that it should. Numerous deleterious factors have been suggested as being responsible for this, including alkyl resorcinols, ergot, pectins, pentosans and water soluble glucan like gums. Rye contaminated with ergot (*Claviceps purpurea*) may be dangerous to animals. This fungus contain a mixture of alkaloids, of which ergotamine and ergometrine are the most important and in view of their action on uterine muscle, have been implicated as a cause of abortion in cattle consuming ergot infested rye. More importantly chronic poisoning by the alkaloids causes injury to the epithelium of the capillaries reducing blood flow and resulting in coldness and insensitivity of the extremities. Subsequently lameness and necrotic lesions occur in the in the feed, tail and ears of mammals. Like wheat, rye should be crushed or coarsely ground for feeding to animals. Studies with cattle suggest that to avoid depressing performance rye should be restricted to 40% or less of diet.

1.1.8 Triticale *(Triticum secale)*

Triticale is a hybrid cereal derived from crossing wheat with rye. The objective in crossing the two cereals was to combine the desirable characteristics of wheat such as grain quality, productivity and disease resistance with the vigour and hardiness of rye.

Fig. 1.9 Triticale grain

Nutritive value

The crude protein content ranges from 8-12% and TDN 75-85%. Protein content is similar to wheat and the quality of protein in hybrid varieties are better than wheat because of high proportion of lysine and sulphur containing amino acids. However, it is deficient in amino acid-tryptophan.

Deleterious factors

As with rye, triticale is subject to ergot infestation. Studies using this hybrid have demonstrated increased liver abscesses in steers when compared with sorghum diets. Triticale contains trypsin inhibitors and alkyl resorcinols and both of these have been implicated in problems

of poor palatability and performance in livestock. Due to its poor performance, it is generally recommended that triticale be limited to 50% of the grain in the diets of farm animals.

1.1.9 Millet

The name millet is frequently applied to several species of cereals which produce small grains and are widely cultivated in tropics. The most important members of this group include *Pennisetum typhoides* (Indian pearl millet or Bajra), *Pennisetum americanum* (pearl millet), *Panicum miliaceum* (broomcorn millet), *Setaria italic* (Italian millet), *Eleusine coracana* (finger millet), *Pspalum scorbiculatum* (ditch millet) and *Echinochloa crusgalli* (Japanese millet). Millet has traditionally been viewed as a poor persons' crop, lacking prestige and appeal but it holds great potential as a food crop adapted to marginal, drought stricken areas. Millet grain is typically is produced in spike like panicle with small round seeds less than half the diameter of sorghum seeds.

Fig. 1.10 Millet grain

Nutritive value

The composition of millet is very variable, the crude protein content being generally within the range 10-12%, the ether extract 2-5% and crude fibre 2-9%. Millet has a nutritive value very similar to that of oats and contains a high proportion of indigestible fibre owing to the presence of hulls which are not removed by ordinary harvesting methods. TDN content varies from 75-85%. Millet is a small seed and is usually ground for feeding to cattle.

1.1.9.1 Pearl millet (*Pennisetum typhoides)*

Local names: **Gujarati, Hindi, Urdu** and **Punjabi**: Bajra, **Rajasthani** and **Marathi**: Bajri, **Telugu**: Sajjalu, **Kannada**: Sajje, **Tamil**: Kambu

Pearl millet is the most widely grown type of millet. Grown in Africa and the Indian subcontinent since prehistoric times, it is generally accepted that pearl millet originated in Africa and was subsequently introduced into India. Pearl millet is well adapted to production systems characterized by drought, low soil fertility, and high temperature. It performs well in soils with high salinity or low pH. Because of its tolerance to difficult growing conditions, it can be grown in areas where other cereal crops, such as maize or wheat, would not survive. Today pearl millet is grown on over 260,000 km^2 worldwide. It accounts for approximately 50% of the total world production of millets. India is the largest producer of pearl millet. It is locally known as *bajra*, and is primarily consumed in the states of Haryana, Rajasthan, Gujarat and Madhya Pradesh.

Fig. 1.11 Pearl millet grain

Nutritive value

It resembles in feeding value to that of sorghum. The crude protein ranges from 12-15% and TDN from 70-75%. It is also rich in tannins. It can be used in place of maize in livestock feeding.

1.2 Milling by-products

1.2.1 Wheat milling by-products

1.2.1.1 Wheat bran

Local names: Hindi: Chokar, **Tamil:** Kodhumai thavidu **Kannada:** Godi bhusa

Wheat bran consists of the outer most layer of the seed along with some flour. It is flaky, reddish brown material. Wheat bran is quite palatable and is well known for its ability to prevent constipation because of its swelling and water holding capacities. Bran has a high capacity to absorb water and swell because of its fiber and nonstarch carbohydrates (β glucans) and so it has a bulk effect in the colon, giving it laxative properties.

Fig. 1.12 Wheat bran

Nutritive value

The crude protein ranges from 13-16% and TDN from 65-70%. The bran has amino acid balance superior to that of wheat. The phosphorus content is high and calcium content is low. Though much of the phosphorus exists as phytate phosphorus, rumen microorganism can digest phytate phosphorus.

1.2.1.2 Wheat middlings

Wheat middlings is a very common ingredient in cattle feeds. Midds are a by-product of the flour milling industry comprising several grades of granular particles containing different proportions of endosperm, bran and germ.

Nutritive value

It has 96% of the energy value of barley and 91% of the energy value of corn. Midds are palatable feedstuffs and can be included in the grain mixture at high levels. Wheat middlings can be maintained in good condition for up to three years if stored in a dry environment.

1.2.2 Rice milling by-products

1.2.2.1 Rice bran de-oiled

Local name: Tamil: Thavidu

In areas where rice is produced, rice bran is a major by-product. It consists of the fibrous outer layer of the grain, some hull, chipped grain and calcium carbonate which is added during milling process. Raw rice bran contains 13-19% oil which is removed by solvent extraction process leading to production of deoiled rice bran.

Fig. 1.13 Rice bran de-oiled

Nutritive value

The crude protein ranges from 13-16% and TDN from 55-65%. It is a good source of proteins,

vitamins and minerals. It also contains better assortment of amino acids, particularly lysine and methionine, compared to other cereal grains, including maize and wheat. The phosphorus content is high (1.30%) and calcium content is low. Though much of the phosphorus exists as phytate phosphorus, rumen microorganism can digest phytate phosphorus.

Deleterious factors

Rice bran contains variable quantities of hulls. Rice hulls are high in silica, which makes them very abrasive. Because of their high silica content they have extremely low digestibility.

1.2.2.2 Rice polish /raw rice bran

Local name: Tamil: Thavidu

Rice polish is a by-product of rice obtained in the milling operation of brushing the grain to polish the kernel.

Nutritive value

The oil content of rice polish varies from 13-19%. The crude protein ranges from 13-16% and TDN from 70-90% depending on the oil content. Rice polish supplies as much TDN as maize. It is a good source of proteins, energy, vitamins and minerals. It also contains better assortment of amino acids, particularly lysine and methionine, compared to other cereal grains, including maize and wheat. The phosphorus content is high (1.30%) and calcium content is low. Though much of the phosphorus exists as phytate phosphorus, rumen microorganism can digest phytate phosphorus.

Deleterious factors

Rice polish contains factors which promote rancidity, especially under the warm humid climatic conditions that favour auto-oxidation. These include lipoxidases, which are enzymes that promote oxidation of unsaturated fatty acids. Rancid feeds are unpalatable and potentially toxic. Heat treatment may improve its utilization especially in nonruminants by inactivating lipoxidases and trypsin inhibitors.

1.2.3 Barley by-products

1.2.3.1 Brewer's grain

Fig. 1.14 Brewer's grain

Brewer's grain is the material that is remaining after grains have been fermented during the beer making process. These materials can be fed in the un-dried form (wet brewer's grains) or dried (dried brewer's grains) and fed. The nutritional content of the material will vary from plant to plant and depending upon the type of substrate being used (barley, wheat, corn, etc.), proportions being fermented and fermentative process being used. Some plants will dry the brewer's grain and sell it as dried brewer's grain, while others will have it available as wet brewer's grain. Both types have similar feeding characteristics if the wet brewer's grain is fed shortly after it is produced. Although the rumen degradability of the protein in the dried brewer's grain is lower, that is directly related to the amount of heat subjected during the drying process.

Nutritive value

Dried brewer's grains contain 27-30% protein and 65% TDN. They are an excellent source of high quality bypass protein and digestible fiber. Dried brewer's grains have a good amino acid, mineral and B-vitamin contents. Lysine is normally the most limiting amino acid and it is a good source of water soluble vitamins. Brewer's dried grain usage is limited in monogastric animals, because of its high fiber (24% ADF) content.

Inclusion level

Suggested feeding levels are 30-40% of the ration for dairy cows. The wet brewer's grains are normally fed fresh, but can be ensiled. If ensiled, the quality of the resultant silage can be improved by adding a readily fermentable carbohydrate source (molasses, cereal grain, etc.) that will accelerate the fermentation rate, which results in more acids being produced and a more stable silage. Packing and ensiling characteristics can be improved by blending the wet brewer's grains prior to ensiling with other material that are dryer (forage, bran, hulls, etc.). If wet brewer's grains are ensiled alone then excessive runoff may occur, so it is best to ensile it in a silo with proper drainage. If fed as wet brewer's grains care needs to be taken to assure that it does not deteriorate prior to being fed. Since the wet brewer's grain is an excellent media for microbial growth and has been shown to support the growth of yeast and mold, it is best to feed the material as soon as possible after receiving it.

It is better to not store the material much longer than a week to 10 days prior to feeding it; this is especially true in hot or warm areas. In general, wet brewer's grain could be stored for 10 days in Spring, 5 days in Summer and 30 days in Winter. If storing for longer periods of time the material should be ensiled. Under hot and humid conditions it might not be possible to store the material for a week. Storing in a shaded or cool place will lengthen the time that the wet brewer's grains can be stored. Covering the surface with plastic or some other covering material will minimize surface spoilage and timelength that the material can be stored. Various methods to preserve wet brewer's grain have been evaluated. Feed consumption will be reduced if spoiled brewer's grain is fed. Feed mixtures containing brewer's grain will spoil quite rapidly, so any excess feed that animals have not consumed should be removed and discarded. The palatability of wet brewer's grain will decline with increasing storage time.

When fed to dairy cattle off-flavors in the milk can be avoided by feeding the cows after they have been milked instead of before. It is best to feed wet brewer's grain fresh, since it will sour after being stored for a few days and may upset the acid base balance in the animal. If Sodium bicarbonate is fed twice daily (150 g/animal) along with brewer`s grains, will normally cure this disorder.

1.2.4 Grain distilling by-products

Grains are fermented and distilled to yield ethanol or acetone butanol. The by-products from grain distilleries vary in chemical composition according to the type of grain and the process employed. The most commonly used grains are rye, wheat and maize. The two most important processes are outlined below.

Fig. 1.15 Distiller's grain

The British method

The grains are crushed, and the grain starch is converted into sugars by adding malt. The sugars are extracted and the grains are screened off, either to be dried or used as wet feed for animals. Yeast is added to the wort for fermentation. The alcohol is distilled from the

fermented liquor, after which the alcohol-free effluent (spent wash) containing the yeast may be dried to yield dried distiller's solubles. Alternatively, the spent wash may be centrifuged and the solids dried into distiller's concentrate, which is similar in composition to the solids, or dried dreg, collected from the spent wash by sedimentation.

The American method

The grains are converted by adding malt, and the whole mixture is passed forward to the fermenting vessel, where yeast is added. After fermentation the whole mixture, including the grain, is distilled. The alcohol-free effluent, or whole stillage, from the still is then passed over a screen to separate the grain from the liquid. This liquid, called thin stillage, which contains the yeast, is condensed and may be dried into distiller's solubles. In some plants the thin stillage is centrifuged before being condensed and the solids are added to the grain.

1.2.4.1 Distiller's spent grain

Distiller's spent grain is not as palatable as brewer's spent grain, but it contains more crude protein and less fibre. It can be fed fresh, ensiled or dried by the same method and in the same quantities as brewer's grain. Distiller's spent grain with distiller's solubles has been included up to 15% in diets with no change in performance. The addition of calcium carbonate to the diet (40g for cows and 10g for sheep/day) increases the digestibility of distiller's spent grain.

1.2.4.2 Distiller's solubles

Distiller's solubles are valued for their growth factors and as a source of B-vitamins. It is doubtful whether distiller's solubles promote growth in cattle, but it has been claimed that they contain a rumen-stimulating factor that increases cellulose digestion. The growth-promoting effects in pigs and poultry have been clearly demonstrated. In most cases the addition of 5-10% dried distiller's solubles increased the productivity of both classes of animals. The use of distiller's solubles as the major source of protein has been less successful owing to their poor palatability. Nevertheless, they have been included up to 20% in calf starters.

1.2.5 Chunies

Local names: Churana, Churi, Chunni

The compound consists primarily of the broken pieces of endosperm including germ and a portion of husks obtained as by-product during the processing of pulse grains for human consumption, for example arhar chuni, masoor chuni, mung chuni, gram chuni, tur chuni etc. The compound is valued as a concentrate feed due to being comparatively low in fibre and more in energy and protein content comparison with roughage.

Fig. 1.16 Mung chuni

Nutritive value

Nutritive value of chunies varies depending on the type of pulse grains from which it is originated during processing. Generally they are high in CP and low in TDN value than that of the parent pulse grain. The CP value of different chunies varies from 15-20% and TDN value ranges from 55-65%.

1.3 Molasses

Molasses is highly palatable and an excellent source of energy. In addition to its use as energy feed, is also used in following ways. 1) As appetizer 2) To reduce dustiness of a ration 3) As a binder for pelleting 4) To stimulate rumen microbial activity and 5) To supply unidentified factors. The quality of molasses is measured by its sugar content, which is expressed by the term Brix. Brix is determined by measuring the specific gravity of molasses. After the specific gravity has been obtained the value is applied to a conversion table from which the level of sucrose can be determined. As sugar content increases, degrees brix likewise decreases.

1.3.1 Cane molasses

Cane molasses is a by-product during manufacture of sugar from sugarcane. From each ton of sugarcane approximately 25-50 kg of molasses are produced. Cane molasses must contain atleast 43% sugars and have a density of not less than 79.5° brix.

Nutritive value

The crude protein ranges from 1-2% and TDN from 55-60%. Although low in phosphorus, it is an excellent source of other minerals. Molasses is deficient in thiamin, riboflavin, vitamin A and vitamin D, but it is rich in niacin and pantothenic acid.

Inclusion level

Cane molasses is often included in manufacture of feeds and urea molasses mineral blocks. In ruminant rations molasses is restricted to the level of 10-15% of the ration. Excessive amount of molasses will cause the feed to become messy and unmanageable as well as create digestive disturbance.

Deleterious factors

When molasses is fed in very large quantities molasses toxicity may develop, which is characterized by neurological defects such as incoordination and blindness. The clinical syndrome is identical to polio encephalomalacia or cerebrocortical necrosis associated with induced thiamin deficiency in ruminants. Molasses toxicity has a complicated etiology and involves an inadequate supply of glucose for the brain, induced thiamin deficiency and rumen stasis. Inadequate glucose status occurs because molasses fermentation produces a high ratio of butyrate to propionate as end products. Butyrate is ketogenic and propionate is glucogenic. An excess of butyrate relative to propionate results in inadequate glucose synthesis and a shortage of glucose for brain metabolism. Molasses toxicity occurs when the roughage component of the diet is inadequate. Low fiber intake results in rumen stasis and the proliferation of slow growing microbes that produce thiaminase destroying thiamin. The combined thiamin glucose deficiency results in brain damage. Provision of adequate roughage is effective in preventing molasses toxicity.

1.3.2 Beet molasses

Beet molasses is a by-product during manufacture of sugar from sugar beet. Beet molasses contain about 48-53% sugars and have a density of not less than 79.5° brix.

Nutritive value

The crude protein ranges from 6-10% and TDN from 65-75%. Most of the protein is in the form nonprotein nitrogenous compounds including the amine betaine which is responsible for the fishy aroma associated with the extraction process. It is highly laxative because of its high mineral content.

Inclusion level

Beet molasses is often included in manufacture of feeds and urea molasses mineral blocks. In ruminant rations molasses is restricted to the level of 10-15% of the ration. Excessive amount of molasses will cause the feed to become messy and unmanageable as well as create digestive disturbance. Since beet molasses is a rich and relatively cheap source of soluble sugars it is sometimes used as an additive in silage making.

1.3.3 Citrus molasses

Citrus molasses is produced from the juice of citrus wastes. Citrus molasses contain about 41-43% sugars and have a density not less than 71.0° brix. Moisture content is higher ranging from 27-30%. The crude protein ranges from 10-14% and TDN from 65-75%.

1.4 Roots and tubers

1.4.1 Roots

The most common root crops used in the feeding of farm animals are fodder beet, sugar beet and turnip. The main characteristics of roots are their high moisture content 75-90% and low crude fibre content. The organic matter of roots consists mainly of sugars (50-75%) and is of high digestibility. Roots are generally low in crude protein content and degradability of the protein in the rumen is very high (80-85%). Root crops are generally poor source of vitamins.

1.4.1.1 Turnips *(Brassica rapa)*

The turnip or white turnip is root vegetable commonly grown in temperate climates worldwide for its white, bulbous taproot. Small tender varieties are grown for human consumption, while larger varieties are grown as feed for livestock.

Fig. 1.17 Turnips

Nutritive value

The dry matter, CP and TDN contents of turnip are 8-10%, 12-13%, 75-80%, respectively. Of the two types grown, yellow fleshed cultivars have more dry matter content than the white fleshed cultivars.

Deleterious factors

If given to dairy cows at or just before milking time, may taint milk. The volatile compound responsible for the taint is absorbed from the air by the milk and is not passed through the cow.

1.4.1.2 Fodder beet

Nutritive value

Fodder beet is a poor source of protein less than 7%. Dry matter content ranges from 14-22%. Fodder beet is a popular feed in Denmark and Netherlands for dairy cattle and young ruminants. In India now it is gaining popularity as livestock feed.

Fig. 1.18 Fodder beet

Deleterious factors

Care is required in feeding cattle on high dry matter fodder beet since excessive intake may cause digestive upsets hypocalcemia and even death. The digestive disturbances are probably associated with high sugar content of the root.

1.4.1.3 Sugar beet *(Beta vulgaris)*

Mostly sugar beet is grown for commercial production though it sometimes given for animals. Because of its hardness, the beet should be pulped or chopped before feeding.

Fig. 1.19 Sugar beet

Nutritive value

Protein content varies from 10-15% and TDN 55-65%. Dry matter content ranges from 14-25%.

Deleterious factors

Sugar beet has a reputation for adversely affecting breeding capacity if fed to male stock. Wilted leaves and crowns can be fed to cattle and sheep, which relish them. Caution is necessary, however, as they may cause scouring because of their oxalic acid content and contamination by soil. No more than 10 kg per day should be fed to cattle, and they should be mixed with hay. As oxalic acid binds the calcium in the diet, extra calcium has to be supplemented. The laxative effect of beet tops is not so pronounced in beet-top silage. Beet tops are easily ensiled both in trench silos and in stacks above the ground. The best results are obtained if the beet-top silage is fed together with lucerne hay. The ensiling of beet tops produces large amounts of seepage water (about 200 litres per ton) during the first few weeks; therefore, good drainage has to be provided.

1.4.2 Tubers

Tubers are various types of modified plant structures that are enlarged to store nutrients. These includes both root and stem tubers. Tubers differ from root crops in containing starch.

1.4.2.1 Cassava root (*Manihot esculenta)*

Synonyms: *Jatropha manihot, Jatropha dulcis*

Common names: Tapioca, Manioc, Mandioca, Brazil arrowroot, Para arrowroot, Rio arrowroot, Yucca

Fig. 1.20 Cassava roots

Local names: Hindi: Shakarkand Manipuri Umangra **Marathi:** Prochugaali Chine, Pavde-pharin **Tamil:** Maravallikkilanku, Allvallikizhangu **Malayalam:** Kollikkilannu, Maraccini, Marakkilannu **Telugu:** Karrapendalamu **Kannada:** Kanagale, Mara genasu, Baragaaladagedde **Oriya:** Kaatokonda **Mizo:** Pangbal **Sanskrit:** Tarukandah, Kalpakandah

Cassava is a tall semiwoody perennial shrub or a small tree (4 m height) with large palmately compound leaves. It looks deceptively similar to the castor bean plant. The plant is cultivated widely in

the tropics and subtropics, including India and Sri Lanka for its tuberous edible roots, which are 8-30 cm in long and 1-3 cm in diameter. They grow in outward pointing clusters from the base of the stem just below the soil surface. In India, dried cassava roots are sold in the name of tapioca chips, and the meal in the name of tapioca flour.

Availability

In India, availability of cassava is 6.7 million tones (Srinivas and Anantharaman, 2005). Kerela, ranks 1st in cassava production and is largest producer with 50% of area and Tamil Nadu accounts for 32% of area and 9% area is in Andhra Pradesh.

Nutritive value

It is a very good source of energy and rich in carbohydrates (NFE 92%). The crude protein content is 2.4% and TDN content is 67%.

Deleterious factor

Cassava roots contain a glucoside, linamarin, which when acted up on by enzyme liberates prussic acid. The peeled roots contain much less prussic acid than unpeeled roots because most of the prussic acid is in the skin. There are two varieties of cassava: (1) Bitter varieties with roots containing 0.02-0.03% prussic acid. These have to be processed before being used as feed. (2) Sweet varieties with roots containing less than 0.01% prussic acid. These can be used raw for feeding. Most commercial varieties belong to this group. Usually the bitter varieties have longer and thicker roots than the sweet varieties.

Detoxification

The toxic substances can be removed by cooking or by drying slices of the roots for about two weeks (AFRIS, FAO).

Inclusion

In ruminants, it can be used up to 20-25% level in concentrate mixture with economic advantage provided it is mixed with other palatable feed stuffs. Both fresh and dried cassava roots are consumed by ruminants in different forms (sliced, chopped, ground). Dried cassava roots have given satisfactory, results as the principal energy source for dairy cattle (AFRIS, FAO).

1.4.2.2 Potato *(Solanum tuberosum)*

Local names: Hindi: Alu **Tamil:** Urulai

Surplus and cull potatoes, either raw or after cooking (the water should be discarded), are suitable for most classes of livestock. Raw potatoes are not very palatable and have a laxative effect. They should therefore be introduced gradually. To get the most value from the starch, potatoes should be boiled or steamed. Potatoes may get stuck in the gullet, but this risk can be minimized if the potatoes are fed from low troughs or mashed. In India, potato production was estimated about 34391 thousand tones in 2010 (FAO).

Fig. 1.21 Potato

Nutritive value

The starch content of dry matter is 70%. TDN ranges from 70-80% and crude protein varies from 9-12%

and about half of this in the form of nonprotein nitrogenous compounds. Potatoes are a poor source of minerals except potassium which is very high. The phosphorus content is also higher.

Deleterious factors

Raw potatoes are not very palatable and have a laxative effect. They should therefore be introduced gradually. Potato contains an alkaloid called solanidine which occurs free and also in combination as the glycol-alkaloids chaconine and solanine. Solanidine and its derivatives are toxic to animals causing gastroenteritis. The alkaloid may be high in potatoes exposed to light. Green potatoes should be discarded. Removal of the eye and peel in which the solanidine is concentrated will reduce the toxicity. Young shoots are also likely to be rich in solanidine and these should be removed before feeding. Immature potatoes have been found to contain more solanidine than mature tubers. The risk of toxicity is reduced considerably, if potatoes are steamed or cooked and the water in which potatoes are boiled is discarded. Ensiling also destroys toxins. Ruminants are more resistant to toxicity than non ruminants because of its partial detoxification in the rumen. Frozen or dirty potatoes should never be used as feed.

Inclusion level

Dairy cows can be fed up to 15 kg of raw potato a day and beef animals up to 20 kg a day. Potato tubers can be chopped with forage and ensiled. The heat generated during the fermentation is sufficient to cook the potatoes. The haulm can be ensiled for feeding to cattle. If cattle are given not more than 20 kg a day, it is a good feed that will in no way impair health.

1.4.2.3 Sweet potato *(Ipomoea batatas)*

Local names: **Hindi**: Shakrkand **Manipuri**: Mangra, **Tamil**: Sarkaraivallikizangu **Kannada**: Sihigensu **Gujarati**: Rataru, sakkareo **Telugu**: Genusu **Malayalam**: Madhurakkilannu

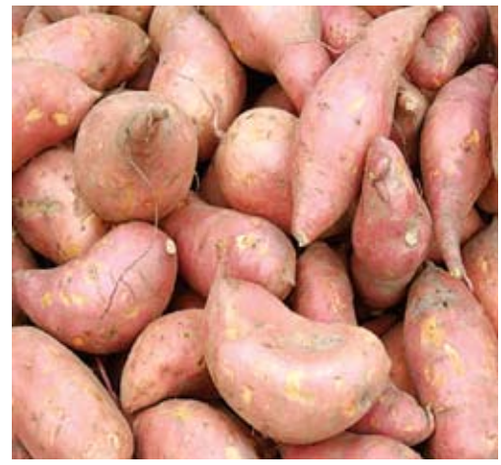


Fig. 1.22 Sweet potato

The sweet potato is a very important tropical plant whose tubers are widely grown for human consumption and as a commercial source of starch. Production of sweet potato was about 1.12 million MT during 2009-10 in India. Sweet potato is a creeping plant with perennial vines and adventitious roots, some of which produce swollen tubers.

Nutritive value

Low protein, fat and fibre were found in the roots, but the high nitrogen-free extract fraction in this tuber is indicative of its potential value, mainly as an energy source. The vines have a lower carbohydrate content but higher in fibre and protein and their principal nutritive value is as a source of vitamins and protein. Carbohydrates generally make up between 80-90% of the dry weight of sweet potato roots, but the uncooked starch of the sweet potato is very resistant to the hydrolisis by amylase. When cooked, their susceptibility to the enzyme increases. Thus, after cooking, the easily hydrolysable starch fraction of sweet potato increases from 4 to 55%. The content of trypsin inhibitors of the raw sweet potato roots could decrease the protein digestibility in mixed feed. The vines will not produce this effect because they do not contain them in great quantities. This trypsin inhibitor could be destroyed or lowered by preheating raw sweet potato roots.

The fresh tubers are palatable for cattle and sweet potato meal was found to be 90% efficient as a feed for lactating cows when compared to corn meal feed.The vines serve as a nutritive and relished green feed for cattle. The feeding value of vines is close to that of alfalfa. Fresh sweet potato vines are palatable to cattle and a cow weighing 400-500 kg can consume 50-70 kg daily. An increased proportion of fresh sweet potato vines produced more milk. The supplementation of sweet potato-forage improves feed intake and weight gain of young bulls fed sugar cane stalks.

1.4.2.4 Carrot *(Daucus carota)*

Carrot is an annual or biennial herb of European origin with a thick orange or yellow root that has long been used as food. Some varieties can be grown at all altitudes in the tropics. Longer maturing, longer rooted varieties are best suited to high altitudes, while those with quick-maturing smaller roots do best at lower altitudes. Carrots have a high vitamin A activity, which makes them valuable when hay and straw are the only other feeds. Carrots may also be dried and ground to a meal for inclusion in compound supplements.

Fig. 1.23 Carrots

Nutritive value

Protein content varies from 10-15% and TDN 75-80%. Dry matter content ranges from 10-20%.

Inclusion level

Cattle may be fed up to 20 kg/day. Carrots may also be dried and ground to a meal for inclusion in compound supplements.

2 Protein sources

Ingredients that contain more than 18% of their total weight in crude protein are generally classified as protein feeds. Protein is one of the critical nutrients particularly for the young rapidly growing animal and high producing adults, although, it may be secondary to energy or other nutrients at times. In addition, protein supplements are usually more expensive than energy feeds, so optimal use is a must for any practical feeding system. Protein supplements may be further categorized according to source of origin as i) plant protein ii) animal protein iii) non protein nitrogen and iv) single cell protein.

Plants provide more than 90% of the protein feeds used in livestock rations. Most protein feeds of plant origin consist of processed oilseeds. Millings by-products generally make up the remainder of the plant protein feeds. Many protein feeds of animal origin are derived from sources that are considered unsuitable for human consumption. Many proteins of mammalian origin are banned for use in feeding of cattle because of the threat of mad cow disease.

2.1 Plant proteins

The bulk of the protein of ruminants comes from plant sources. The protein content of plant varies considerably from one type to another. Even within the same plant, there is considerable variation from one stage of maturity to another or from one part of the plant to another. Proteins in plants are primarily associated with the tissues which are actively metabolizing such as leaves, centers of growth and the seeds. Eventhough they are not

especially high in protein by comparison with other feedstuffs, the vegetative portions of many plants supply an extremely large portion of the protein in the total ration of livestock, simply because these portion of feeds are consumed in large quantities. Needed protein not provided in these feeds is commonly obtained from one or more of the oilseed by-products –soybean meal, cottonseed meal, groundnut meal, safflower meal, sunflower meal, rapeseed meal linseed meal, sesamum meal and coconut meal. The protein content and feeding value of these products vary according to the seed from which they are produced, the amount of hull and/or seed coat included and the method of oil extraction used. Sometimes the unprocessed seed is used to provide both a source of protein and a concentrated source of energy. The oil bearing seeds are especially high in energy because of the oil they contain.

Additional plant proteins are obtained as by-products from grain milling, brewing and distilling and starch production. Most of these industries use the starch from grains and seeds, then dispose of the residue which contains a large portion of the protein of the original plant seed.

2.1.1 Oilseed cakes and meals

Oilseed cakes and meals are the residues remaining after removal of the greater part of the oil from oilseeds. The residues are rich in protein and most are valuable feeds for livestock. According to the method of processing, the cakes are classified into *a) Ghani pressed b) Expeller pressed* and *c) Solvent extracted.* Of these, ghani pressed cakes contain the maximum amount of ether extract, while solvent extracted contain traces of oil. Conversely the protein content is higher in solvent extracted cakes and lowest in the ghani cakes.

Oilseed cakes are in general very good sources of protein and about 95% of the nitrogen is present as true protein. Vegetable proteins are generally poorer compared to animal proteins. Proteins of oil cakes have a low glutamic acid, cystine, methionine and variable but low lysine content. The meals usually have a high phosphorus content which tends to aggravate their low calcium content. They may provide good amount of B vitamins but are poorer sources of carotene and vitamin A.

The high temperature and pressures of the expeller process may result in a lowering of digestibility and in denaturation of the protein with a consequent lowering of its nutritive value. The high temperature and pressure also reduces most of the deleterious substances which might be present in oilcakes such as gossypol and goitrin. Some seeds such as groundnut, cottonseed and sunflower have a thick coat or husk rich in fibre, and of low digestibility which lowers the nutritive value of the material. It may be completely removed by cracking and riddling a process known as decortication.

2.1.1.1 Soybean meal *(Glycine max)*

Soybean is the oilseed crop that is produced in the largest amounts in the world. In South Asian region, India ranks first in the production of soybean seeds. Soybean is an annual legume that grows in wide range of conditions. Soybeans contain from 16-21% of oil and are normally solvent extracted. The residual meal has an oil content of about 1%.

Fig. 1.24 Soybean meal

Nutritive value

Soybean meal is an excellent feed for livestock; it is very palatable, highly digestible and contains a high amount of digestible energy. The CP content

of soybean meal ranges from 45-55% and TDN from 75-84%, depending upon the extent of dehulling and the processing method used. The protein contains all the essential amino acids but the concentration of cystine and methionine are suboptimal. Methionine is the first limiting amino acid and may be particularly important in high energy diets. The CP of soybean meal is highly degradable in rumen and due to this, large amounts have not been fed to dairy or beef cattle. In recent years various methods for processing soybeans to reduce rumen degradation of CP have been developed. Soybean meal is better source of calcium and phosphorus than the cereal grains. Recently feeding of full fat roasted soybeans has emerged as an important ingredient in feeding dairy cattle especially in developed countries. Feeding of full fat soybeans has also been shown as a way of increasing the conjugated linoleic acid levels in the milk which has been shown to be a compound that reduces cancer in humans.

Deleterious factors

Soybean meal contains a number of toxic, stimulatory and inhibitory substances including allergenic, goitrogenic and anticoagulant factors. The anti nutritional factors associated with soybean meal are trypsin inhibitors, saponins, phytoestrogens, glucinins, goitrogens, lectins, mineral binding substances and several additional factors. Of particular importance in nutrition are the protease inhibitors of which six have been identified. Two of these, the kunitz anti trypsin factor and the bowman birk chymotrypsin inhibitor are of practical significance. The trypsin inhibitor has a lesser effect in ruminants as compared to monogastrics, because of their transformation in rumen. The trypsin inhibitor is easily deactivated by heating the soybean prior to feeding. Soybean meal contains about 0.1% of genistein, which has estrogenic properties and a potency of 4.44×10^{-6} times that of diethyl stilbesterol. The effect of this constituent on growth rate has not been elucidated. Soybean flour and isolated soy protein have been used as a partial replacement for milk proteins in the formulation of milk replacers in calves.

2.1.1.2 Groundnut meal *(Arachis hypogaea)*

Local names: Hindi: Moomphly **Marathi:** Bhuemug **Gujarati**: Sing **Tamil:** Kadalai

Groundnut meal is an important source of protein for livestock feeding in India. Three types of oil cakes are available in India, namely *ghani* pressed, expeller pressed and solvent extracted cake.

Fig. 1.25 Groundnut meal

Nutritive value

The content of oil is variable according to the process of extraction of oil. It is 10-12% in ghani pressed, 6-8% in expeller pressed and 0.5-0.7% in the solvent extracted cake. The protein content is variable from 40-50% and TDN 75-85%. The groundnut cake may be decorticated or undecorticated. In undecorticated groundnut cake the fibre content is very high. It is deficient in lysine, methionine, cystine, tryptophan and also low in calcium, carotene and vitamin D.

Deleterious factors

Groundnut cake is fed to the cattle, buffalo, sheep, goats, poultry and swine. It has been reported that both a growth factor and an antitrypsin factor occur in groundnut meal. The latter has antiplasmin activity and so shortens bleeding time, it is destroyed by heating. Feeding more than 25% of the diet with groundnut meal leads to laxative action, which limits its use for lactating cows, for which it otherwise forms an excellent and acceptable protein

source. The cake is liable to contain a toxic factor which is shown to be a metabolite of the fungus *Aspergillus flavus* and is named aflatoxin. This is now known to be a mixture of four compounds designated as Aflatoxin B_1, G_1, B_2 and G_2 of which B_1 is the most toxic. There are considerable species differences in the susceptibility to these toxins. Young animals are more susceptible than adult animals of the same species. There are several reports of death in calves below six months of age when fed on contaminated groundnut meal. Older cattle are more resistant but cases of death in cattle, loss of appetite and reduced milk yield in cows have been reported. A metabolite of aflatoxin known as aflatoxin M_1 has been shown to be present in the milk of cows fed on toxic meals. Aflatoxins are relatively stable to heat.

2.1.1.3 Cottonseed meal *(Gossypium arboreum)*

Common name: Cotton

Local names: **Hindi:** Kapas **Marathi:** Kapus **Tamil:** Parutthi

Cotton, belonging to genus *Gossypium,* is widely distributed in temperate and tropical regions. It is a native of Northwest India and Pakistan. Like groundnut cake ghani pressed, expeller pressed and solvent extracted cotton seed cakes are available for feeding the livestock. In cotton growing belt it is the main source of protein to the livestock.

Fig. 1.26 Cottonseed meal

Nutritive value

Nutritional value of cottonseed meal depends up on method of extraction, proportion of husk and lint and degree of decortication. The protein content of cottonseed meal varies from about 22% in meal made from undecorticated cottonseed to 42% in meal made from decorticated seed. The decorticated cottonseed meal contains 41% CP and 78% TDN. The crude fibre content ranges from 2-2.7% in glandless and 7.9-16.0% in decorticated to 26.9% in undecorticated form. Ether extract content varies from 4.2-11.3% in expeller and 0.9-2.9% in solvent extracted meals. Protein degradability of cottonseed meal is similar to or slightly less than soybeans (57% *vs* 65%). In comparison to other oil seed cakes, cotton seed cake has relatively high phosphorus content. Lysine is the most limiting amino acid in cottonseed meal (Sastry, 2002).

Deleterious factor

Cottonseed and its products contain an anti-nutritional factor, Gossypol ($C_{30}H_{30}O_8$) which is a polyphenolic compound found exclusively in discrete bodies called 'pigment glands' which are distributed in leaves, stems, roots and seeds. Out of 15 gossypol pigments, the yellow pigment gossypol is the predominant naturally occurring which is chemically 1, 1', 6-6', 7-7' hexahydroxy-5-5'-diisopropyl-3-3'-dimethyl (2,2'-binapthalene)-8-8' dicarboxaldehyde. Gossypol content in different products depends on species, variety, location, year of growth, maturity, length or condition of storage and method of processing.

Ruminants are less susceptible to gossypol toxicity because of the detoxification mechanism present in the rumen. In rumen, there is binding of free gossypol with soluble protein (mostly to epsilon amino group of lysine) which is resistant to proteolytic enzymes secreted in lower gut. Ruminants can become susceptible to gossypol toxicity only if either rumen detoxification mechanism is bypassed or if they receive higher gossypol than the capacity of rumen microbes to detoxify it. Gossypol exerts partially reversible anti-fertility effect in male animals. Death from gossypol toxicity is partially attributed to reduced oxygen carrying capacity of blood and haemolytic effect on erythrocytes and exerts its toxic effect

in animals by uncoupling of respiratory linked oxidative phosphorylation. Besides gossypol, contamination of cottonseed meal with aflatoxin can be a problem in some areas.

Detoxification

There are various methods available for detoxification of cottonseed meal. Out of which, hydraulic or expeller processing, cooking or moist heat treatment results in binding and inactivation of gossypol which is in free form in seed, giving rise to 'bound' and 'free' gossypol. During processing free gossypol binds with protein thereby reducing protein quality, especially lysine availability.

Detoxification of cottonseed meal with either metallic ions like Ca and Fe, roasting, cooking, autoclaving or supplementation with lysine and methionine or fermentation with *Aspergillus oryzae* may prove beneficial in reducing the free gossypol content and its toxic effect. Some workers showed that out of various physical (cooking) and chemical (lime, iron) treatments, the detoxification of cottonseed meal with 1% $Ca(OH)_2$ was found to be satisfactory in small ruminants (Agrawal, 2002).

Inclusion

Palatability and availability makes cottonseed meal a very common protein supplement. It can replace 100% soybean meal in ration when economics is to be considered. Cottonseed meal can be safely included up to 15% in total ration of cattle.

2.1.1.4 Rapeseed/ mustard meal *(Brassica juncea)*

Synonyms: *Brassica campestris, Brassica napus, Brassica, Crucifer*

Common names: Mustard, Leaf mustard, Indian mustard

Local names: **Hindi**: Sarson **Marathi**: Mohari **Manipuri**: Hangam **Tamil**: Kadugu

Rapeseed or canola is a member of the cabbage family (Brassicas or Crucifers), which also contains plants such as, mustard, turnips and kale. The name 'mustard' is given to various species, the most common being white mustard (*B. hirta Moench* or *Sinapis alba L*.), black mustard *(B. nigra Koch*) and Indian or leaf mustard (*B. juncea* Coss). Mustard is cultivated for its seeds which yield oils and are used to make a condiment. It is occasionally grown (like rape or green manure) as a cover crop for fodder. Rapeseed is grown extensively in northern India. When processed it yields about 40% oil and 50% oil meal.

Fig. 1.27 Rapeseed meal

Nutritive value

Mustard seeds contain 30-35% oil. The protein content of meal varies from 32-39%. The amino acid profile of rapeseed meal is comparable to that of soybean meal, thus making it a rather high quality plant protein source. However, it is rather unpalatable.

Deleterious factor

Rapeseed contains several anti nutritional factors like glucosinolates, tannins, erucic acid, sinapine, phytic acid, mucilage etc. Their presence is not serious for ruminant animals although there is some evidence of reduced intake, minor liver damage and reduced volatile fatty acid production, when the toxins have been administered orally. Rapeseed

meal frequently contains tannins. These are polyphenolic compounds which complex with proteins and carbohydrates to form enzyme resistant substrates with a consequent lowering of digestibility. This may result also from the combination of tannins with digestive enzymes with a consequent loss of activity. Tannins may cause damage to the intestinal mucosa and are known to interfere with iron absorption.

Glucosinolate

Rapeseed contains glucosinolate (5-10 mg/g) that inhibit thyroid gland metabolism, which causes the thyroid gland to enlarge, causing goiter (enlargement of the thyroid gland). Glucosinolates are very unpalatable, which cause animal to reduce their feed intake which results in a reduction in their performance. Therefore, low glucosinolate variety of rapeseed (0-rapessed and 00-rapeseed) has been developed and is called as 'canola' (AFRIS, FAO). Often rapeseed and canola can be identified visually, because the rapeseed meal is darker in color than the canola meal, which has more of a golden yellow color. Another simple method is to taste the meal, if it has a 'hot' stringent taste which is an indication of high glucosinolate content. This stringent taste of mustard makes it quite unpalatable to animals.

Myrosinase

In black mustard the enzyme myrosinase acts on a glucoside - sinigrin - to produce volatile, very irritat oil. In white mustard the same enzyme acts on a different glucoside - sinalbin - to produce less irritat oil than that of black mustard. These glucosides (sinigrin and sinalbin) are considered to be toxic to livestock (AFRIS, FAO).

Sinapine

It is a methylated substance that is converted into trimethylamine which is then absorbed by the animal. Most animals have the ability to convert the trimethylamine to trimethylamine oxide, which can then be easily excreted in the urine by animals. Presence of sinapine reduces palatability of feed and thus it has depressing effect on feed consumption. Besides these, erucic acid (toxic to animals) and tannins present in mustard cake act as anti-nutritional factors.

Detoxification

Sinigrin is a water soluble glucoside which can be removed by heating the rapeseed cake with 5 parts of water at 85^0C for one hour and then filtered, after that the residue is washed five times with water (AFRIS, FAO). Similarly, ethyl alcohol treatment, ammoniation or Sodium carbonate treatment can be followed for detoxification of mustard cake. Prolong steam treatment (2 hours) destroys enzyme and glucosinolates (AFRIS, FAO).

Inclusion

Feeding trials have shown that ruminants are less susceptible than other classes of livestock to the toxic effects of rapeseed meal. Adult cattle can be given from 1-1.5 kg a day without detrimental effects on feed consumption, growth or milk flavor (AFRIS, FAO). Detoxified mustard cake can be used up to 10% in the ration of cattle provided it is mixed with other palatable feed ingredients. Low glucosinolate variety i.e. Canola can be used for feeding of livestock.

2.1.1.5 Sunflower meal *(Helianthus annuus)*

Common name: Common sunflower

Local names: Hindi: Surajmukhi, **Marathi:** Suryaphul **Manipuri:** Numitlei, **Malayalam:** Sooryakanthi, **Tamil:** Suryakaanti

Sunflower is an annual or perennial plant that grows up to 6 m height. The seeds of the cultivated sunflower species are used in the manufacture of oil and its by-product, sunflower meal. Sunflower meal is generated when the black oil seeds are crushed. The seeds consist

of 25-40% shell. The availability of sunflower meal in India for the year 2009-10 was about 0.67 million tones.

Fig. 1.28 Sunflower meal

Nutritive value

TDN and CP contents of sunflower meal are around 65 and 30%, respectively. The composition of the sunflower meal varies with the quality of the original seed and the method of processing. Good quality sunflower meal contains about 35-44% high grade protein especially rich in methionine. Pre-press solvent extraction of whole seeds with no dehulling produces meal with a crude protein content of 25-28%, partial dehulling yields 34-38% crude protein content, and completely dehulled sunflower meal commonly yields >40% crude protein, but up to 50% crude protein has been observed. The expeller variety of sunflower meal makes the butter soft if fed in large amounts to cows because of the character of oil it contains. It contains chlorogenic acid and tannins as deleterious factors. Supplementing with methyl donors (methionine and choline) can help in increasing the availability of protein to animals.

Inclusion

Sunflower meal can be safely included up to 20% level in cattle ration. The use of high fibre sunflower cakes (undecorticated) is restricted to the feeding of adult ruminants, whereas, the decorticated cake is a digestible high-protein feed that can be used freely for all livestock. As the cakes are hard, they are best fed ground and incorporated in compound cattle feeds. Sunflower meal can be used as the sole source of protein to feed animals.

2.1.1.6 Safflower meal *(Carthamus tinctorius)*

Common names: Safflower, Dyers' saffron, False saffron

Local names: Hindi: Kusum **Marathi**: Kardai **Manipuri**: Kusumlei **Tamil**: Kusumba **Urdu**: Gul rang

The safflower plant, 0.6-1.5 m high, produces many branches with heads at the ends. Each head may produce from 20-100 seeds, which are shaped like small sunflower seeds. The seed is composed of a kernel surrounded by a thick fibrous hull so difficult to remove that much safflower meal is made from unhulled seed. The undecorticated oil meal is also called whole pressed seed meal, whereas the decorticated meal is referred to as safflower meal. It is produced after removal of most of the hull and oil from safflower seed. It is available to the tune of 0.45 million tones in Asia.

Fig. 1.29 Safflower oil cake

Nutritive value

In decorticated form (mechanically extracted) it has about 49.7% CP (AFRIS, FAO) while the value goes down to 18-24%, if not decorticated. Undecorticated safflower meal contains about 60% hulls, which limits its energy value and utilization in non-ruminants. TDN content is 55-65%. Safflower meal is low in lysine and methionine.

Deleterious factor

Safflower meal contains phenolic glucosides which are reported to be associated with bitterness and cathartic activity.

Detoxification

Deleterious glucosides in safflower meal can be removed by extraction with either water at the iso-electric point or with methanol, enzymatic treatment with β-glucosidase, dialysis, or by processing to prepare protein isolates.

Inclusion

The undecorticated cake or meal is fed only to ruminants. Though not very palatable, it is readily eaten when mixed with other feeds. Use of safflower meal is restricted to 20% in the concentrate mixture of cattle.

2.1.1.7 Sesame meal *(Sesamum indicum)*

Common name: Sesame/ gingelly

Local names: Hindi: Thil **Marathi:** Til **Tamil:** El

Sesame is mainly grown for oil production. The seeds are produced in capsules or pods that split open readily at maturity, so most of the harvesting is done by hand.

Fig. 1.30 Sesame meal

Nutritive value

TDN and CP contents of sesame meal are 70-75% and 40-50%, respectively. The composition of the sesame meal varies with the quality of the original seed and the method of processing. Good quality meal contains about 40-50% high grade protein especially rich in leucine, arginine and methionine but low in lysine. For ruminants the protein has degradability of 65-75% depending on the passage rate of the rumen. Sesame meal is mildly laxative. Feeding large quantities to dairy cattle may lead to production of soft butter.

2.1.1.8 Coconut meal *(Cocos nucifera)*

Common name: Copra

Local names: Hindi: Nariyal **Marathi:** Naral **Malayalam:** Kopparai **Tamil:** Thenghai

Coconut meal or copra is the meal remaining after extraction of oil from the dried endosperm of the coconut. Coconut meal is an important protein supplement for livestock in many tropical countries.

Nutritive value

It contains about 70-75% TDN, 25-30% crude protein and approximately 10% crude fibre. The oil content of coconut meal varies from 2.5-6.5%. Meals of higher oil content are being very useful in the preparation of high energy diets. However, they suffer the disadvantage of being susceptible to rancidity on storage. The protein is low in lysine and histidine and this together with the generally high fiber content limits the usage of the meal for simple stomached animals. Neither protein quality nor fibre content is limiting for ruminant animals.

Coconut meal provides an acceptable and very useful protein supplement. In diets for dairy cows it is claimed to increase milk fat content. The milk fats produced on diets containing considerable amounts of coconut meal are firm and excellent for butter making.

2.1.1.9 Palm kernel meal *(Elaeis guineensis)*

Synonyms: *Elaeis melanococca, Elaeis madagascariensis*

Common names: African oil palm, Macaw fat

African oil palm is native to the rain-forests of West Africa. It is a tall tree, 8.3-20 m in height, erect, heavy with ringed trunk. Palm flour of good quality is obtained when the trees are cut before flowering (at the age of 60 years). The pith of tree is cut into small pieces, dried and powdered to get the palm flour. The fruit of palm grows in bunches and consists of a soft outer skin, which is reddish orange when ripe, and a fibrous layer covering the nut, composed of a shell and a kernel containing the palm oil.

Fig. 1.31 Palm kernel meal

Nutritive value

It contains 20% CP and 60% TDN. The fibre content is about 8%. This is low in protein but very rich in NFE. Therefore, it can be used as source of energy. Palm kernel meal is rich in sulphur containing amino acids.

Inclusion

Palm kernel cake is dry and gritty and is not readily accepted by all types of stock. It is largely used for feeding cattle and tends to produce a firm butter when fed to dairy cattle. A ration of 2-5 kg/day has been found satisfactory for adult cattle (AFRIS, FAO). Solvent-extracted meal is particularly unpalatable and must therefore be mixed with well-liked feeds, such as molasses, and fed in gradually increasing proportions. It is, however, a safe and wholesome material, and if reasonable care is taken in the arrangement of the feeding, it is readily eaten. No much study in India has been done with palm flour feeding in cattle, but the proximate composition suggests that this can be used in cattle for growth and production with economic gains.

2.1.1.10 Linseed meal *(Linum usitatissimum)*

Synonyms: *Linum rubrum, Linum grandiflorum var rubrum*

Common name: Flax seed

Linseed meal is the residue remaining after extraction of linseed oil from linseed/flaxseed.

Nutritive value

Linseed meal contains 32-37% CP and 70-85% TDN. It is unique among the oilseed residues in that it contains from 3-10% of mucilage. This is almost completely indigestible by nonruminant animals but can be broken down by rumen microbes. It is readily dispersible in water forming a viscous slime. It is fed mostly to horses and young calves.

Fig. 1.32 Linseed meal

Linseed meal has a fairly low protein content of approximately 35% and is severely deficient in lysine. For this reason it is a good source of protein for cattle, buffalo, sheep and swine but is not a good source of protein in the poultry rations. Linseed meal is also low in carotene and vitamin D. Linseed has the highest omega-3 fatty acids content of any oilseed and research has shown that feeding linseed in the ration of animal increases the omega-3 fatty acid content of milk and meat.

Deleterious factors

Linseed meal is laxative when fed in large amounts. It contains two types of toxic factors. One is adipeptide called linatine composed of glutamic acid and l- amino-D -proline. The latter amino acid is an antagonist of pyridoxine (vitamin B_6). Thus, in nonruminants linseed meal may produce pyridoxine toxicity. Immature linseed contains a small amount of cyanogenetic glycoside, linamarin and an associated enzyme linase which is capable of hydrolyzing it with the evolution of hydrogen cyanide which is extremely toxic. Death results from combination of the cyanide with cytochrome oxidase leading to immediate cessation of cellular respiration and anorexia. Low temperature removal of oil may produce a meal in which unchanged linamarin and linase persist. The cyanogenetic glycosides in linseed meal have protective effects against selenium toxicity.

II. ROUGHAGES

Roughages are bulky feeds containing relatively less digestible material i.e., crude fibre more than 18% and low (about 60%) in TDN on air dry basis. Most of roughages have a high content of cell wall material. The cell wall fraction may have highly variable hemicellulose, pectin, polyuronides, silica and other components. In contrast to cereal grains, roughages generally are low in readily available carbohydrates. The amount of lignin is a critical factor with respect to digestibility. Lignin is an amorphous material which is associated closely with the fibrous carbohydrates of the cell wall of plant tissue. It limits fibre digestibility, probably because of the physical barrier between digestive enzymes and the carbohydrate in question.

The protein, mineral and vitamin contents of roughages are highly variable. Legumes may have 20% or more crude protein content, although a most of may be in the form of non protein nitrogen (NPN). Other roughages, such as straw may have only 3-4% crude protein, most others fall between these two extremes. Mineral content may be exceedingly variable; some roughages are relatively good sources of calcium and magnesium, particularly legumes. Phosphorus content is apt to be moderate to low and potassium content high; the trace minerals vary greatly depending on plant species, soil and fertilization practices.

Roughages are sub-divided into two major groups; dry and green or succulent roughages based upon the moisture content. Green roughages usually contain moisture from 60-90%, whereas, dry roughages contain only 10-15% moisture. For the sake of convenience, succulent feeds are again classified into various types such as pasture, cultivated fodder crops, tree leaves, roots and crops. Dry roughages have been further classified as hay and straw, based on the nutritive values and methods of preparation.

1. Dry Roughages

1.1 Hay

A method of conserving green crops is that of hay making. The aim in hay making is to reduce the moisture content of the green crop up to 15-20%, to inhibit the action of plant and microbial enzymes. Thus, a green crop in a mature stage is preserved for a long time.

Fig. 2.1 Legume hay

Indian hay is seldom taken in the same in which this term is understood in the western countries. It consists of dry grass on which the seed has ripened and leaves have usually been shed. In feeding value, it mostly corresponds to the straw of cereals rather than to hay made before the seed has ripened. During the later part of the monsoon season, when grass is ready to be cut for hay (the only time when grass is available for hay making), the weather is often so wet that hay making cannot be attempted. At the end of the monsoon season when there is still some chance of making hay from some good quality grasses that may be left, cultivators are too busy in making preparation for rabi sowing. According to the type of forages which are dried, hays are categorized as leguminous, non leguminous and mixed.

1.1.1 Leguminous hay

Fig. 2.2 Lucerne hay

Good legume hay has many characteristics that make it of special value to the dairy cattle. It has a higher percentage of digestible nutrients. It has more of digestible proteins because of the high protein content. Furthermore, the proteins of legumes are of superior quality, as compared to proteins from other plants. Well cured legume hays are higher in vitamin contents. They are particularly rich in carotene and may even contain vitamin D. They are also a rich source of vitamin E. The legume hays are particularly rich in calcium and generally palatable. Among various leguminous fodder crops lucerne, berseem, cowpea and soybean hays are considered first.

1.1.1 Non-leguminous hay

Non-legume hays made from grasses are inferior to legume hays. They are, as a rule, less palatable and contain less proteins, minerals and vitamins than the legume hays. Non-legume hays have the advantage over legume hays because their outturn per hectare is more than that of legume hays and the former can be grown easily. Hays made from green crops like oat and barley, compare very favorably with the other grass hays. For making good quality hay, these crops should be harvested in the milk stage. They are low in proteins and minerals, but rich in carbohydrates.

1.1.3 Mixed hay

Hay prepared from mixed crops of legumes and non-legumes is known as mixed hay. The composition of such kind of hay will depend on the proportion of the different species grown as a mixed crop. Such a crop is generally cut earlier because of the variation in the seeding time of the mixed crops. If harvested early, cereals are generally richer in proteins.

1.2 Straw

Fig. 2.3 Wheat straw

Inadequate production of green fodder in the country compelled the farmers to utilize dry roughages as livestock feed particularly for the ruminants. In one estimate, it has been found that in the country, there are about 310 million tones of these dry roughages produced annually. Among these straw, bhusa, karbi and hay are noteworthy. In all developed countries, feeding of high quality hay is in practice. Due to unavailability of high quality dry roughages, straw, bhusa and karbi form the major bulk of livestock feed in India. Obviously, feeding of inferior quality dry roughage is reflected in low productivity of animals.

Farmers utilize these poor quality dry roughages as energy feed, which unfortunately varies between 40-50% in digestible energy. Voluntary intake of animals is so low that it is barely sufficient to yield adequate energy to meet their maintenance needs. For some roughages, more energy are spent by the animal in chewing and digesting the roughages than what the animal derives from the dry roughages.

The poor nutritive value of these roughages may be attributed to the following facts:

- The digestibility of straw is limited due to the formation of strong physical and/ or chemical bonds between lignin and the structural polysaccharides (hemicellulose and cellulose). Although cellulose by itself has a highly ordered crystalline structure, it has very strong association with lignin with the result that even most the potent cellulosic enzymes can not have easy access to the cellulose unless the bondage between lignin and cellulose is broken. The lignin thus acts as a barrier in the efficient utilization of cellulosic plant materials even as a source of energy. Whether, the inhibitory mechanism involves the presence of ligno-cellulosic or ligno-hemicellulosic chemical bonds or the three dimensional macromolecular lignin network by itself acts as a protective barrier in the efficient utilization of cellulose as a source of energy is yet fully understood and established
- Crystalline structure of cellulose is also responsible for low digestibility of cellulose
- Highly deficient in other nutrients like minerals, vitamins, fatty acids and in proteins. The minimum crude protein requirement for efficient lignocellulose breakdown of roughages fed as the sole diet is claimed to be from 3.8-5.0%
- High silica content of straws known to depress organic matter digestibility
- Due to dustiness of straw, the total intake is markedly affected

1.2.1 Cereal straw

Paddy and wheat straw are by-products available after harvesting the grains, form the main bulk of roughages in tropical region, including India. They form the staple feed for cattle and buffaloes throughout the region. Though they are poor in nutritive value, containing about 3% protein and 40-45% TDN, these straws can maintain adult non-producing cattle as a sole feed along with small quantities of protein supplements. However, certain factors like high lignin content, reduced palatability, dustiness, high oxalic acid content in straw which limits calcium absorption, limit their extensive use as cattle feed.

1.2.2 Pulse straw

Most common pulses are (1) Urad/blackgram *(Vigna mungo)*, (2) Moong/greengram *(Vigna radiata)*, (3) Moth *(Phaseolus aconitifolius)*, (4) Cowpea *(Vigna unguiculata)*, (5) Masoor *(Lens culinaris)*, and (6) Arhar/redgram/pigeon pea *(Cajanus cajan)*. After harvesting, seeds of pulses are threshed out of the pods to split to form dals used extensively as a protein adjunct to an otherwise starchy diet of the human population. The husks of the pods with leaves and tender stems are left behind as by-products and can be utilized as fairly nutritious cattle feeds.

Among the above mentioned straws, those of urad, moong and moth are highly palatable and nutritious, straws of arhar and masoor, although of comparable nutritive value, are not as palatable as the other three straws. The energy value of these straws is comparable with those of cereal straws but they are a fairly good source of digestible protein.

Cereal straws like wheat bhoosa and paddy straws contain 3% digestible protein and 40% TDN and can meet the maintenance requirements of adult cattle and buffaloes. Since these by-products (pulse straws) contain from 40-100% more of DCP, they can as well meet the production requirements of the animals to certain extent. Supplementation with energy rich feeds like cereal grains will, however, be necessary in the case of high milk producing cattle.

1.2.3 Other Straws

Groundnut straw

Groundnut is the major oilseed produced in India. At the time of harvesting, large quantities of leaves and stem become available for feeding of livestock. Extensive studies were conducted on the groundnut bhoosa as a partial substitute for concentrates in the ration of milk cows. It is understood that in large parts of India, groundnut straw is commonly fed to livestock.

Nutritive value

The DCP value of groundnut straw is superior to that of non-leguminous hays and is comparable to that of leguminous hay of cowpea. In energy value, as represented by TDN, groundnut straw is superior to most of the grass hays. It can be safely fed along with wheat bran and wheat straw to meet entire nutritional requirements of milch cows producing up to 5 kg milk daily.

Rape straw

Being quite fibrous and good in nutritive value than pulse straws and groundnut straw, it should be fed in limited quantities in conjunction with cereal straws to non-productive animals.

Nutritive value

It contains 4-6% crude protein, 51% crude fiber, 77% NDF and 62% ADF.

1.3 Husks

1.3.1 Rice husk

Rice husk is the dry outer covering of rice grain, which is always removed during the milling of rice. It is of no direct nutritional value to man and in most mills it is often discarded or allowed to rot away. In some areas however, it may be collected and used as litter material or used in fire making. In spite of rice husk abundance, nutritionists have neglected the use of it in animals feed production because of its fibre content, roughness poor nutritive value and induced irritation in digestive tract.

Fig. 2.4 Rice husk

Nutritive value

Rice husk contains 2.9-3.6% crude protein, 0.8-1.2% ether extract, 39-42% crude fibre and 15-22% ash. Attempts at increasing the utilization of fibrous feed ingredients like rice husk include adequate fortification with micro nutrients, supplementation with high quality protein and amino acids, physical and chemical pre-treatments and the use of microbial enzymes and antibiotics.

1.3.2 Coffee husk

Coffee husk is not palatable to cattle, and they can form only a small portion of rations fed to unproductive animals. Under acute scarcity or famine conditions, the cattle may be able to consume this feed, if they are fed after mixing them with cereal straws. Even for

maintaining animals, when this feed forms a part of the ration, the requirement of energy rich feeds will be more in order to make up the poor energy content of this husk.

Nutritive value

Coffee husk contains 7-8% crude protein. NDF and ADF contents are 60 and 49%, respectively. However, calcium and phosphorus content is 0.51 and 0.25%, respectively.

1.3.3 Groundnut husk

Grounfnut husk is also unpalatable to cattle and poorer in nutritive value than rice husk and coffee husk. Milling of this by-product, and adding molasses and one percent urea to this ground product may improve its palatability.

1.3.4 Maize husk

Maize husk is superior to even gram husk in its nutritive value. About 50% of the dry roughage portion in the rations of adult non-producing cattle can be replaced by this by-product.

1.4 Stover

Crop residues are important feed resources and increased ruminant production can be accomplished through improved utilization of the crop residues. Stovers are the mature cured stalks from grain crops, typically maize or sorghum, with the grain or corn removed. Cereal stovers are relatively poor in nutritive value, which is concentrated in the harvested grain, but are widely used for feeding ruminants, often when other feeds are inadequate or unavailable towards the end of the dry season. The total value of these crops therefore lies in their grain yield as well as the use of the stovers for livestock feed.

1.4.1 Sorghum stover

Cereal stovers are widely used for feeding ruminant livestock, and in semi-arid areas. Sorghum stover may be an important part of livestock diets during the dry season, helping to maintain condition and increase survival.

1.4.2 Maize stover

Harvesting maize at grain milk stage for human food (roasting and boiling) is also popular. Stovers harvested at grain milk stage are greener and more appealing to ruminants, hence generally have high palatability. More importantly, they have been shown to have higher nutritive quality due to lower fibre content as compared to stovers harvested at later maturity stage. Given that maize stover is potentially an important source of roughage for dairy cattle production, improvement in their utilization is expected to result into considerable positive impact on the overall productivity.

2 Green roughages

2.1 Cultivated fodders

2.1.1 Summer forages

2.1.1.1 Cowpea, lobia *(Vigna unguiculata)*

Local names: **Hindi**: Lobia, Barbati, Alsande **Marathi**: Chavli **Tamil**: Karamani **Telugu**: Bobbarelu, Alasandulu **Kannada**: Avadai **Malyalam**: Kottapayaru

Fig. 2.5 Cowpea fodder

Cowpea is important quick growing legume, which fits well in crop rotation. It is adapted to warm summer climate and can be grown on all types of soils, ranging from sandy loams to heavy loams, if they are well drained. It is susceptible to water logging conditions. It can be sown alone or with non-legumes like sorghum and maize.

If irrigation is available, this crop can be grown in the months of February and March in India, and then the green fodder can be made available during the critical period of May/ June. As a rainfed crop it is sown in July. The crop is generally ready in three months. When sown alone, it gives a yield of 200-300 quintals fodder per hectare of land. It has great potential as a mixed crop when sown with maize, sorghum and millets to produce an ideal legume and cereal fodder mixture. It has been observed that the yield of green pods is about 20 quintals per hectare.

Nutritive value

Cowpea is used as fodder crop for green feeding, hay making, grazing and also for ensiling in mixtures with sorghum or maize. The grains are used as human food as well as animal feed. Cowpea is also used as green manure crop and as cover crop in plantations. The feeding value of cowpea forage is high. It is superior to other legumes like soybean because of its low fibre content and minimum wastage in feeding livestock.

The crop can support a 6-7 kg milk yield/ cow/ day without any concentrate supplement. It can be used as a dual purpose crop; that is the green mature pods are removed for human consumption and the residual fodder is used as a cattle feed. When so used, the residual crop forms an excellent fodder which is comparable with any legumes and can support growth and milk production up to 5 kg daily, without any concentrate supplement.

The early fresh leaves and stalks contained 18.0% crude protein, 3.0% ether extract and 26.7% crude fibre. The total digestible nutrient is 59.0% in early and 58.0% in mature cowpea fodder. The calcium and phosphorus content is 1.40 and 0.35%, respectively.

Deleterious factors

The cowpea fodder has low level of anti nutritional and flatulence producing factors than common beans. However, seeds of cowpea contain antinutritional factors such as trypsin inhibitors, lectins and tannins.

Important varieties

EC-4216, UPC-287, UPC-5286, GFC-1, GFC-2 and GFC-4.

2.1.1.2 Sorghum or Chari *(Sorghum bicolor)*

Local names: Hindi: Jowar **Tamil:** Cholam **Telugu:** Jonnalu **Kannada:** Jola **Marathi:** Jwari

Sorghum as green foliage is very popular in most parts of north India and nearly 2.5 million hactare area is planted during *kharif.* In summer, under irrigated conditions, multicut sorghum is very popular. It does well under hot and dry climate. It requires well-drained soil and appears susceptible to water logging conditions. Though it can be grown in any type of soil but loam soils have proved to give more yield. The sowing is done in April and August for fodder and June and July for grains in India. When sown for fodder, the seed rate varies from 55-60 kg per hectare and for taking grains from 15-20 kg. It is generally sown mixed with legumes like cowpea and moth in a ratio 2:1. Mostly the sorghum seeds are broadcasted which are then mixed with the soil by various means such as by a cultivator or harrow. Finally the operation is completed by planking.

Fig. 2.6 Sorghum fodder

Sorghum is generally grown as a rainfed crop. If the rainfall is 25-30 cm during the season, no irrigation is required. If it is desired to sow the fodder earlier during the months of April or May, four irrigations are required depending upon the climatic conditions. The fodder is ready for harvest within 70-90 days. The average yield of the fodder varies between 250-450 quintals per hectare. Some varieties show a yield of about 500 quintals per hectare.

Nutritive value

Sorghums are generally non-maintenance type of roughages, containing about 4-5% of protein. Some varieties, however, contain 8-10% of protein like *S. almum* and *Sirsa 20.* The total digestible nutrients are 58.0%. However, calcium and phosphorus content is 0.5 and 0.2%, respectively. These varieties constitute a maintenance ration and are thus more profitable to a farmer than the other varieties. *Sirsa 20* and *Sorghum almum* are maintenance type of fodder and proved very useful in the western tract of Uttar Pradesh. Other useful varieties are Rio, Vidisha 68-1 and IGFRI-5.

Deleterious factors

Sorghum (less than 50 cm high) contains cynogenic glycosides. Ruminant animals (cattle and sheep) are more susceptible to prussic acid poisoning than monogastric animals (horses and pigs). The lower pH in the stomach of the monogastric helps to destroy the enzymes that convert cyanogenic glycosides to prussic acid. For prussic acid poisoning to occur, high levels of cyanogenic glycosides and enzymes necessary to metabolise them need to be present. The action of rumen microbes will also metabolise cyanogenic glycosides. Therefore, poisoning is more likely in ruminant animals. Sheep are more resistant to poisoning than cattle due to the different enzyme systems in their fore-stomachs. Hungry animals are also at greater risk as they will normally consume a larger amount of toxic material in a short time.

Signs of poisoning usually occur 15–20 minutes after the toxin is consumed. Death occurs very quickly, approximately 2–3 minutes after the onset of clinical signs in peracute cases, and within 1–2 hours in acute cases. Usually, animals are found dead with no signs observed. The brain and heart are the first to be affected by lack of oxygen, and so the resulting

clinical signs prior to death include: breathing difficulties, rapid, weak, irregular pulse, anxiety and restlessness followed by depression, stumbling/staggering, muscle tremors, moaning, dilated pupils, recumbency, bloat, terminal convulsions and bright red mucous membranes. Sorghum grain contains low levels of tannins and α- amylase.

M.P. Chari *(Sorghum bicolor)*

M.P. Chari is the most important cereal fodder crop grown in summer/ rainy season and gaining more popularity in India because of its high yield. Covering the maximum cultivated area among fodder crops, sorghum is grown in all parts of the country except the cool hilly areas. It has high tolerance to drought and excessive rain fall. There are single, two multicut varieties/ hybrids of sorghum giving one to six cuts per crop producing 50-100 tonnes of green fodder/ hectare. To avoid prussic acid or cyanide toxicity to livestock, the crop should be harvested at about 50% flowering or after irrigation at the preflowering stage. The crop is also useful for hay and silage making.

Important varieties

PC-1, PC-6, PC-23, HC-136, HC-171, PSC-1, Pant Chari-5, Pant Chari-6 and Sorghum Sudan hybrid.

2.1.1.3 Maize *(Zea mays)*

Local names: Hindi: Makka **Tamil**: Makka cholam **Telugu**: Mokka Jonnalu **Kannada**: Makkjola

Fig. 2.7 Maize fodder

Maize is one of the most important *kharif* crop of Asian countries, including India. Maize is also one of the best cereal fodder crop grown during summer, rainy and/or early winter season. It requires warm and temperate climate and grows well on alluvial soils. The crop grows well in slightly acidic to neutral soils (pH 5.5-7.5).

Sowing is done from the middle of March to middle of September for fodder and in July for grains in the plains and May to June in the hills. The fodder is ready between 60-70 days but for grain production it takes about 90-110 days. The yield of fodder is between 350-450 quintals/ hectare. It is a maintenance type of fodder containing 8-10% of protein like *Sirsa 20,* M. P. chari and *S. almum* but the yield of maize is generally lower than the improved varieties of sorghums. It can, however, be used as a dual purpose crop like cowpea. When the cobs in milk stage are removed the residual plant constitutes a maintenance ration. When the crop is allowed to mature, the stalk becomes very hard and is not even comparable with straw.

Nutritive value

Maize produces rich and nutritious green fodder which is a good source of carbohydrates. The green fodder is particularly suitable for silage making. It contains 8-10% protein and 60.0% total digestible nutrients. Maize grains contain trypsin inhibitor. The important varieties are African tall, JS-1006 and Vijaya composite.

2.1.1.4 Mak Chari or Teosinte *(Euchlaena mexicana)*

Local name: Hindi: Makiya

Mak Chari is a close relative of cultivated Maize. It is a *kharif* crop and requires hot and temperate climate. It has high tolerance to flooding and excessive soil moisture. It is highly valued as silage, hay and for soiling. It requires rich and well drained soils for good growth. The plants tiller profusely and give rise to a number of shoots forming thick clumps. The fodder is ready between 90-100 days. The yield of fodder is about 350 to 500 quintals per hectare. When fed as a sole feed in the form of green, it can meet the maintenance requirements of animals. It also makes good silage and hay. Important varieties include Sirsa, Rah, Maizente-1, Maizente- 2, etc.

2.1.1.5 Soybean *(Glycine max)*

Local name: Soybean

Though soybean has not yet become popular in Asia as fodder crop, now it is gaining popularity not only as a fodder but also as an oil-bearing seed. It requires well drained loam to sandy loam soils and hot temperate climate for good growth. It is a productive ration and can support a cow yielding 6 kg of milk per day when fed exclusively on this fodder. The yield is comparable with that of cowpea under favorable conditions. It contains 13.0% crude protein and 31.3% crude fibre.

Fig. 2.8 Soybean fodder

Deleterious factors

Antinutritional factor in soybean includes urease, trypsin inhibitor, lectin and globin.

2.1.1.6 Guar *(Cyamopsis tetragonoloba)*

Local name: Guar

Guar is an important drought resistant legume most suitable for dry areas. It is generally sown mixed with sorghum and pearl millet. It cannot withstand water logging otherwise, does well in all kinds of soils. The crop is generally ready for harvesting after 80-90 days of its sowing.

The crop is sown either alone or in a mixture with non-legume like jowar and bajra from the end of March to the middle of July. One ploughing will prepare the land cultivation. Average green yield is about 250-400 quintals per hectare.

Fig. 2.9 Guar fodder

Nutritive value

It is better to harvest before flowering or else the stem gets hard and fibrous which cattle do not seem to relish. However, even during the early stages it is not highly palatable. The average protein content is about 10-15% which can be considered as a productive fodder.

2.1.1.7 Pearl millet, Bajra *(Pennisetum typhoides)*

Local names: **Hindi**: Bajara **Telugu**: Sajja **Tamil**: Cumbu **Kannada**: Sajje **Marathi**: Bajri

Pearl millet is the fourth most important grain crop next to rice, wheat and sorghum. The crop is cultivated for grain as well as fodder in the semi arid tropical regions of Africa and Asia including India. It is quick growing, disease resistant, high tillering fodder crop, suitable for sowing in arid and semi arid regions. It can be sown early in spring under irrigated conditions and in *kharif* under rainfed condition. It is not suitable in high rainfall areas. It does well even on light soils. It is sown alone or in mixture with guar or cowpea. Its cultivation and other particulars are like sorghum.

Fig. 2.10 Pearl millet fodder

Nutritive value

A1/3 and new hybrid varieties are good for fodder as well as for grain production. Fresh and mature pearl millet contains 2.3% crude protein and 36% crude fibre.

Varieties

Giant Bajara, APFB-2, Rajco, HB 3, 4, 5 are grain hybrids suitable for fodder production.

2.1.2 Winter forages

2.1.2.1 Berseem *(Trifolium alexandrinum)*

Local name: Egyptian clover

Berseem is one of the most important fodder crops and has been rightly described as the king of fodders. It is highly esteemed fodder which has a special place in animal husbandry programmes throughout the country. Though a migrant from Egypt, it has established in this region for the last 60 years and may well be considered as a native of India. It has many desirable qualities. Ten to fifteen kg of fodder alone with straw constitutes a maintenance ration. It can support growth and milk production on *ad lib* feeding, balanced by straws.

Fig. 2.11 Berseem fodder

It does not tolerate acidic soils but grows in other kinds of soils except usar lands. The crop is sown from middle of September to end of October in plains and from middle of August to first week of September in hills. This crop requires a thorough preparation of land. Berseem is now available in another form called Giant berseem. The advantage of giant berseem is that lesser irrigation is required. While the seed rate of ordinary diploid berseem is 20-25 kg that of giant berseem is 30-35 kg per hectare.

The crop is ready in 55-60 days after sowing for the first cutting. Subsequent cuttings are taken at 30 days interval during winter and spring. In all 5-6 cuttings can be obtained up to middle of May. The total yield obtained may vary between 500-600 quintals/ hectare. For taking the seeds, plots are left uncut after February and in that case 4-5 quintals seeds per hectare may be obtained. Tetraploid berseem has been considered as high yielding variety.

Ordinary diploid and tetraploid or giant berseem are the varieties of the berseem. Amongst the various strains of giant berseem, strain 526 has shown the better result.

Nutritive value

Berseem is highly palatable fodder and it contains 17% crude protein and 25.9% crude fibre. The total digestible nutrients content is 60-65%. Berseem contains saponins, if fed in high quantity to ruminants leads to bloat.

Varieties

Mescawi, Varda, JB-1, 2 and 3, UPB 103, Pusa giant, Khadarvi, Chindwara

2.1.2.2 Lucerne (*Medicago sativa)*

Local name: Lucerne

Lucerne is a valuable leguminous forage and hay crop which is generally grown in areas, where water supply is inadequate for berseem. Its deeper root system makes it very well adaptable to dry areas with irrigation facility. It continues to supply nutritious fodder for 3-4 years. It is sown both as an annual and perennial crop. The crop is generally grown in irrigated areas to dry tracts and gives yield in well drained sandy loam soils.

Fig. 2.12 Lucerne fodder

The best time of sowing is between early October to end of November. First cutting is ready after 2-2.5 months of sowing. During rainy season its growth is affected by other monsoon grasses. After rains when soil is dried up, it is harvested or else there are chances of roots coming out while harvesting. If taken as a perennial crop it may yield up to 1000-1200 quintals per hectare, when taken as an annual (up to June), the yield is 700-900 quintals per hectare.

Nutritive value

Lucerne is a productive fodder which can support not only growth but also milk production up to 8 kg when fed *ad lib*. There are many varieties but types 8 and 9 developed at the fodder research station at Sirsa are recommended for adoption in Uttar Pradesh. It contains 18-22% crude protein and 25-35% crude fibre according to the maturity.

Deleterious factors

Lucerne contains saponins. Continuous feeding with early morning dew on, may lead to the risk of bloat or tympanitis in ruminants, mainly due to the foaming, hemicelluloses, higher quantity of soluble leaf cytoplasmic proteins, saponins and pectins. Ruminal tympanitis is overdistention of rumen and reticulum with the gases of fermentation either in the persistent form mixed with rumen contents or in the free gas form separated from the ingesta. Due to feeding of large quantity of lucerne, it results in primary ruminal tympany or frothing bloat.

2.1.2.3 Oat *(Avena sativa)*

Local names: Oat, Jai, Ganer, Ganerji, Togi koddi

Oat is one of the most important cereal fodder crops of rabi season in North, Central and West Zone of the country. The introduction of oat hay in India is of recent origin. The hay can be baled easily with least transport difficulties. It is highly palatable to each type of livestock including sheep.

It is generally sown at the end of September but some verieties can be sown in December. It can be sown alone or in a mixture with berseem.

Oat can be harvested at various stages for fodder purposes. The early varieties are generally sown by the end of September and the fodder is ready for harvest by the end of January. There are some varieties that can be sown in October/ November to get the harvest by the end of February. The late varieties are generally sown in November/ December to supply green fodder right to the end of April. Thus from January onwards oat fodders are available till the end of April not only for feeding as a green feed but also for conservation in the form of hay. The weather during these periods is most suitable for hay making. The average yield of grains obtained from these varieties is about 20-30 quintals/ hectare.

Fig. 2.13 Oat fodder

Nutritive value

The chemical composition of green fodder varies with the stage of harvest. Oat is a highly esteemed fodder specifically for conservation in the form of hay throughout the world. Oat may be considered as maintenance quality fodder containing about 7-9% crude protein, can be increased up to 11% by nitrogen fertilizers in which case it may be considered as a productive fodder. The grains are very much relished by horses, sheep, poultry and equines. It is an ideal fodder as a green chop, silage and hay mostly covering the lean periods of year. Oat contains protease inhibitor as antinutritional factor. Oat 17, Craigs afterlee, N.P. I, N.P. 3, Wild oats, Sativa kent, Filmingold etc are some of the important varieties.

2.1.2.4 Senji or Indian sweet Clover *(Melilotus indica)*

Synonyms: *Trifolium indicum, Melilotus parviflorus*

Senji appears to be a drought resistant clover. It is because of this quality; sometimes this fodder crop is preferred. Though a number of species are available, mostly the yellow and white varieties are used for fodder purposes. Under dry and cold climate, it requires loams to heavy soils for its propagation.

The sowing time of the crop is between September to the end of October. Since the fodder can be grown in unirrigated areas, it is better to sow the crop immediately after the harvest of *kharif* crop, so that the residual moisture present in the soil can be utilized for the germination of seeds. Under irrigated conditions it gives about 300-350 quintals of fodder/ hectare. Under unirrigated conditions the yield is about 200-250 quintals.

Fig. 2.14 Indian sweet clover fodder

Nutritive value

Indian clover contains 16.57% crude protein and 60% total digestible nutrients. Since it is legume, it is productive ration.

2.1.2.5 Chicory (*Cichorium intybus*)

Local Name: Chicory

Synoname: Coffeeweed, blue sailors

Chicory is a perennial forage herb characterized by high nutritional quality and the potential to produce good dry matter yields from autumn to late spring. Although it is best known for the traditional coffee additive, it has proven to be an excellent source of livestock forage.

Chicory has exhibited tolerance to acidity and for this reason it has been successfully grown in low pH soils. In addition to this, chicory has good disease resistance and insect tolerance and with appropriate grazing management can provide viable stands for five or more years.

Fig. 2.15 Chicory fodder

Nutritive value

Chicory produces leafy top growth and has a thick, deep tap-root giving it excellent drought tolerance and mineral extraction. It has a nutritional quality comparable to lucerne as it contains similar proportions of protein, lipid, minerals and other nutrients. It generally contains 22-24% CP and 50-55% TDN on dry matter basis. It is also a good source of Ca (1.70%) and P (0.50%). Chicory does not cause bloat in cattle as it contains condensed tannins (0.04%).

2.2 Grasses

2.2.1 Napier grass *(Pennisetum purpureum)*

Local names: Pusa giant napier grass, Elephant grass

Napier grass requires warm and moist climate, clay to clay loam soil for good growth. It is a prolific yielder and has recently acquired a great popularity. The crop is sown from end of February to end of August in the northern India. But for getting the maximum return in terms of yield, the crop should be sown by the end of February, since late sowing may give only one cut till the end of November after which it remains in a dormant stage.

The first cut is ready after three months of plantation and thereafter every 50-60 days. The objective of green fodder is to at least provide a maintenance ration. A fodder which does not satisfy this condition cannot be recommended for adoption under any circumstances regardless of its yield. The Pusa giant napier has a fabulous yield, but the yield depends on the height of the plant at which it is harvested.

Fig. 2.16 Napier grass

Nutritive value

For instance, if napier grass is harvested at 3.5 m height, the yield may be a little more but the fodder may be of little value to an animal nutrition because it does not constitute a maintenance ration and thus the very purpose of green fodder production is defated. To obtain satisfactory results this grass should not be fed alone but with legumes, concentrate or oil cakes. It contains 8-12% crude protein and 26-28% crude fiber. The total digestible nutrient ranges from 55-58%.

2.2.2 Anjan grass *(Cenchrus ciliaris)*

Local names: Buffel grass, African foxtail

Anjan grass is a most important perennial grass with a marked tussocky habit of growth. It is leafy prostrate and rhizomatous grass of the tropics up to an altitude of 1500 meters. It shows best growth in monsoon. It can withstand drought and is an excellent grazing grass for hot dry areas in tropics and sub-tropics. It is a good soil binder and hence used as a cover crop on bunds for soil and water conservation. Depending on rainfall, the yield varies greatly and in arid tract with less than 300 mm rainfall, a well established pasture produces 90-110 tonnes/ha green matter.

Fig. 2.17 Anjan grass

Nutritive value

Anjan grass is relished by all classes of livestock. It is an excellent type maintenance quality fodder and can support milk yield without concentrate up to a limited extent. It contains 11% crude protein at young stage with suitable ratio of calcium and phosphorus. Neutral detergent fibre and acid detergent fibre content is 72.0 and 38.0%, respectively. It provides vary good hay since it retains its nutritive value even when ripe fully.

2.2.3 Blue panic *(Panicum antidotale)*

Local name: Blue panic, **Hindi**: Ghamari

Blue panic is a grass which can be grown on any type of soil and under various climatic conditions. The yield of the grass depends on the soil conditions but it is ideally suited to well drain light soils. It is a maintenance quality fodder, containing 8-10% protein at the flowering stage. Apart from being a maintenance ration, it is an excellent for soil conservation. Under irrigated conditions, 5-6 cuttings are available and the total yield of the fodder is about 40-50 MT per hectare.

Fig. 2.18 Blue panic grass

Nutritive value

As a pasture grass, blue panic shows remarkable regrowth after cutting of the crop. It is the earliest pasture to get ready in the spring season and is well relished by the cattle when young. It contains 10.0-12.0% crude protein and 32.0-34.0% crude fibre. Calcium and phosphorus content is 0.39 and 0.09%, respectively.

2.2.4 Jerga grass *(Dichanthium annulatum)*

Fig. 2.19 Jerga grass

Local Name: Jerga grass, Blue stem, Marvel grass

Jerga grass is a perennial tufted grass and is very common in the natural pasture lands in the western tract of Uttar Pradesh. It grows to a height of 70-90 cm during monsoon when it covers all types of weeds. The average yield of the grass is 500-600 quintals per hectare in 4-5 cuttings. The grass is normally propagated by root stumps.

Nutritive value

Jerga grass is maintenance quality roughage containing 7-9% protein and 35% crude fibre at the flowering stage. After the well known doob, this grass is very much relished by the horses.

2.2.5 Choti jergi *(Bothriochloa pertusa)*

Local name: Choti jergi

Choti jergi is a beautiful grass with erect clums. Nodes are boarded with spreading hairs and internodes are smooth and shining. It is quite common in the pasture and of western tract of Uttar Pradesh.

Fig. 2.20 Choti jergi grass

Nutritive value

The protein and crude fibre content is 6-8% and 32-34%, respectively at flowering stage.

2.2.6 Rhodes grass *(Chloris gayana)*

Local name: Rhodes grass

Rhodes grass is an excellent perennial grass and is native of South Africa. It grows luxuriantly and covers large areas and thus helps in checking soil erosion. This grass is reported to useful in reclaiming saline tracts.

Fig. 2.21 Rhodes grass

The seeds of Rhodes grass are light and difficult to sow evenly. It may be mixed with about double its weight of saw dust and sown through a grain seed drill. It should not be sown deeply. Broadcasting into a prepared surface and rolling in May gives best results. It gives yields about 450-600 quintals of fodder in 5-6 cuttings per year. The grass also spreads by means of running branches which root and produce tuft at every node.

Nutritive value

The grass is leafy and palatable and fairly nutritious. It is also used as soiling (grazing) crop. In combination with lucerne, it helps in improvement of soil fertility. It contains 8-10% crude protein and 32% crude fibre at fresh late vegetative stage. The total digestible nutrient is 55.0%.

2.2.7 Doob grass *(Cynodon dactylon)*

Common names: Bahama grass (because of its introduction to U.S. by way of Bahama Islands) Doob grass, Dhub grass

Local names: Sanskrit: Durva Haritali **Hindi:** Dhub, Hariali **Tamil:** Arugam pillu, Hariali **Telugu:** Garicha gaddi, Harvali **Kannada:** Garikahullu, Kudigarike

Doob grass is one of the best fodder and is a good soil binder. It is perennial with creeping habit. It contains about 10-12% protein and is propagated by stem and root cuttings. The best sowing time is monsoon but can be planted in spring and summer when water is available. In some of the strains of *doob* grass the content of protein may be as high as 20%, which with progressive maturity is lowered nearly to half. It is a turf grass for lawns and golf courses.

Fig. 2.22 Doob grass

Studies on this grass have revealed that its protein content is never lowered below 8-10% under any circumstances, even during the months of May and June in the western tracts of UP. It is, therefore, always a maintenance ration but according to the season and stage of growth it can provide a good production ration as well. It has been observed that although some of the leaves of doob grass dry up; simultaneously new growth springs up which probably maintains its content of protein. From these desirable qualities it has been highly respected through ages. The only disadvantage seems to be its low yield, but not all the strains are low yielder. Some of these form a thick mat and are much softer than the common *doob* grass available. The average yield of the grass is about 300-350 quintals of fodder/ hectare. It is an excellent pasture grass and is always found in natural pastures mixed with legumes. There are other strains of *Cynodon* dactylon. One of the strains is giant star grass.

Nutritive value

Doob grass is palatable, nutritious, cheap and it is a dependable winter feed for cattle. It is a turf grass for cattle. Leafy perennial with numerous and stolens used for vegetative propagation. Readily eaten by all types of livestock and also used as a soil binder for the control of soil erosion. Better weight gain is possible in cattle fed with the grass than with any other grass species due to higher values of protein and low crude fibre and proved to be equal to timothy hay in supporting the milk production. It contains 10% crude protein and 28% crude fibre.

2.2.8 Para grass *(Brachiaria mutica)*

Local names: Para grass, Buffalo grass, Water grass, *Pani wali ghas*

Para grass is a rapid summer growing perennial. It produces runners and throws a broad hairy flag. It is propagated by roots and stem cuttings as seeds are not viable. It is ideally suited for heavy rainfall areas. It grows well in water logging conditions on ponds, river and canal banks and can withstand prolonged flooding. There are other species of Brachiaria-like *B. brezentha*, which does well under well drained soil.

Fig. 2.23 Para grass

Nutritive value

This grass is highly palatable and nutritious. It contains 10.2% crude protein and 23.6% crude fibre in fresh grass. The grass is used as green fodder, soiling and even for dry hay.

2.2.9 Dallis grass *(Paspalum dilatatum)*

Local name: Dallis grass

It is perennial grass which does well in deep rich soil and provides abundant fodder during summer. It is maintenance quality roughage, containing good protein and yields about 300-400 quintals/ hectare under irrigated conditions.

Nutritive value

Dallis grass contains 10-15% crude perotein and 57-63% total digestible nutrients.

Fig. 2.24 Dallis grass

2.2.10 Kikuya grass *(Pennisetum clandestinum)*

Local name: Kikuya grass

Kikuya grass grows on all types of soils. It is a drought resistant grass and grows very well under irrigated condition. It is a grass which normally grows at high altitude. It is a perennial with strong system of underground runners which quickly root at the joints. The propagation is by root and stem cuttings. The normal yield of the grass is 300-350 quintals per hectare.

Nutritive value

Kikuya grass is more than a maintenance quality fodder (protein 10-12%) and is thus suitable for limited milk production.

Fig. 2.25 Kikuya grass

2.2.11 Cocks foot *(Dactylis glomerata)*

Local name: Cocks foot

Cocks foot grows in dense perennial tussocks to 20-140 centimeters tall, with leaves 20-50 cm long and up to 1.5 cm broad, and a distinctive tufted triangular flowerhead 10-15 cm long, which may be either green or red to purple-tinged (usually green in shade, redder in full sun), turning pale grey-brown at seed maturity. The spikelet's are 5–9 mm long, typically containing two to five flowers. It has a characteristic flattened stem base which distinguishes it from many other grasses.

Nutritive value

It is a perennial grass containing 7-9% protein at the flowering stage and is thus a maintenance ration.

Fig. 2.26 Cocks foot grass

2.2.12 Reed canary grass *(Phalaris arundinacea)*

Local name: Reed canary grass

It is a summer quick perennial grass which may form large tussocks and stands water logging. It is a maintenance quality fodder which gives a yield of 300 quintals per hectare. The yield of this species is 450 quintals per hectare in 4-5 cuttings.

Fig. 2.27 Reed canary grass

Nutritive value

Reed canary grass is highly palatable. There is another species known as phalaris tuberosa, which is very nutritious. It contains 3% crude protein and 37% crude fibre.

2.2.13 Rompha grass

It is a summer quick perennial grass. Phalaris arundinacea and P. tuberose have been crossed and a new strain evolved is named as Rompha grass. It is more nutritious than either of its parents. At the prime stage it appears to contain over 20% crude protein is thus comparable with any legume.

2.2.14 Perennial rye grass *(Lolium perenne)*

Local name: Perennial rye grass

Perennial rye grass is important in forage/livestock systems. High palatability and digestibility make this species highly valued for dairy and sheep forage systems. As a result, it is the preferred as forage grass in temperate regions of the world. The perennial rye grass is one of the finest grasses which grow well in rich alluvial soil in a cooler climate. It does not seem to grow in the plains under Indian climatic conditions. In the Hilly areas it seems to thrive well.

Fig. 2.28 Perennial rye grass

Nutritive value

Perennial rye grass is noted for high levels of quality, palatability, digestible energy, protein and minerals. Rye grass accumulates high levels of total usable carbohydrates in spring and fall. Composition, however, depends largely on maturity, stage at harvest and on fertility. It contains 10.4% crude protein and 50-60% total digestible nutrients. Calcium and phosphorus content is 0.57 and 0.27%, respectively.

2.2.15 Sewan grass *(Lasiurus scindicus)*

Local name: Sewan grass

Sewan is the primary grass of extremely arid parts of Jaisalmer, Barmer and Bikaner districts of western Rajasthan in the Indian Thar desert. It thrives well under moisture stress on sandy plains, low dunes and hummocks of this region, receiving annual rainfall below 200 mm. Until the last decade, about 80% of the total geographical area of Jaisalmer covering Nachana, West Puggal, Mohangarh, Sultana and Binjewala with 100-150 mm annual rainfall

supported Sewan grasslands. For decades, these grasslands in turn supported an ever-increasing livestock population in the Indian desert, where animal husbandry remained the predominant occupation of the inhabitants. During years of normal rainfall, the available forage from farming, cultivable wastes, fallow and pasturelands meet only about two–thirds of the requirement of the existing livestock. The situation becomes serious during years of subnormal rainfall. The yield of this grass is about 10 tonnes of fodder per hectare in 4-5 cuttings a year.

Nutritive value

It is one of the most productive and suitable grass for arid and semi arid zones. It contains 8-10% protein during early growth. It becomes woody and fibrous unless grazed after every 20-30 days.

2.2.16 Dhaman grass *(Cenchrus setigerus)*

Local name: Kala dhaman

Dhaman grass is indigenous to India and is adapted to arid and semi arid tropical climates with long dry season. It is very tolerant of drought and grows in areas of annual rainfall as low as 200 mm, making it excellent for improvement of low rainfall grazing land. It is more tolerant than C. ciliaris. It is a leafy fodder having a tender stem which provides abundant foliage. It is adapted to arid and semi arid tropical climates with long dry season. About 8-10 tonnes of forage may be obtained in 3-4 cuttings per hectare. Sow just before the usual rainy periods in summer at the rate of 1.5-3.0 kg per hactare depending on seed supplies, cost and rapidity of cover desired.

Fig. 2.29 Dhaman grass

Nutritive value

Dhaman grass contains 4.5% crude protein and 38% crude fibre. Neutral detergent fibre and acid detergent fibre content is 72.0 and 33.0%, respectively.

2.2.17 Guinea grass *(Panicum maximum)*

Local name: Guinea grass, Green panic

It is a well known perennial grass adapted to tropical regions and is high yielding. The grass is a tall, densely tuffed perennial with numerous shoots arising from short, rhizomes. A full grown plant attains a height of 1.8-2.7 m under favourable conditions. The yield is about 120-150 tonnes of green forage in 4-5 cuttings. It is maintenance quality roughage containing 8-10% protein under ideal conditions and is propagated by roots.

Fig. 2.30 Guinea grass

Nutritive value

Guinea grass can be grown along water channels where the grass besides giving additional fodder. It normally contains 8-12% crude protein and 31% crude fibre.

Toxicity

Most of the panicum varieties contain hepatotoxins which may cause secondary photosensitization. In that case, the affected animals may be fed on chlorophyll free diet and kept in darkness for a few days till recovery.

2.2.18 Jaragua grass *(Hyparrhenia rufa)*

Local name: Jaragua grass, Faragua grass, Yaragua grass, Puntero, Veyale, Senbelet, Yellow spike thatching grass, Thatching grass.

Fig. 2.31 Jaragua grass

Tufted grass with culms up to 60-240 cm tall. Panicles are loose and narrow up to 50 cm long. Jaragua is a fast-growing perennial and mostly grown in spring to autumn. Jaragua grass is common on seasonally flooded grassland and open woodlands. Dry matter yields up to 19 ton per hactare have been recorded. It is a coarse tropical tall growing grass which requires well drained sandy loam soils.

Nutritive value

Jaragua grass is used for fodder and silage and is highly palatable, mainly used for beef production. When it becomes tall, it is not highly palatable to the livestock. It recovers quickly from grazing and must be cut frequently to control flowering. Also used for pulp for paper. The average content of protein is 7-9% at flowering stage.

2.2.19 Tall fescue *(Festuca arundinacea)*

Local name: Tall fescue

Fig. 2.32 Tall fescue grass

The fescues (Festuca spp.) compose a large genus of about 100 species of grasses. Tall fescue is a deep rooted, cool season perennial grass. The plant produces vigorous growth in the spring and fall and its extensive root system helps it withstand drought conditions. Tall fescue does produce short rhizomes but has a bunch-type growth habit; it spreads primarily by erect tillers. Individual tillers, or stems, terminate in an inflorescence, reach 3-4 feet in height, and have broad, dark green basal leaves. Leaf blades are glossy on the underside and serrated on the margins. The leaf sheath is smooth and the ligule is a short membrane. The inflorescence is a compact panicle, 3-4 inches long with lanceolate spikelets one-half inch or longer. The grass flowers in the spring and seed mature in early summer. Seed are 4-7 mm long, elliptic and awned. It is a high yielding perennial grass which grows very well on rich moist soil.

Nutritive value

It stands high alkalinity but is not palatable to livestock when it grows tall. It is grown for forage, hay and silage and soil improvement and conservation. It is also used as an ornamental grass. It contains about 9% crude protein and 28% crude fibre.

2.2.20 Sudan grass *(Sorghum vulgare)*

Local name: Sudan grass

Sudab grass is near relative of Sorghums and Baru grass. It grows 120-240 cm in height and is adapted to the same conditions as the sorghums.

Fig. 2.33 Sudan grass

Nutritive value

Sorghum-Sudan grass hybrids fit best in summer feeding programs. They are thick stemmed and hard to dry for hay but they can supply ample yields of silage, green chop and pasture when perennial grasses are slowing down or going dormant. Once Sorghum-Sudan grass begins to head out, the quality and feeding value drop drastically. It is difficult to meet nutrient requirements of high production or early lactating milking cows when Sorghum-Sudan grass is a large part of the forage intake. It is more suited to rations for dry cows, replacement heifers over 12 months of age, beef cows and calves. It contains about 6-8% crude protein and 50-60% total digestible nutrients.

2.3 Legumes

2.3.1 *Atylosia scarabaeoides*

Common name: Wild kulthi

Wild kulthi is fairly common in the grass lands of peninsular India and thrives in the semi arid regions in the summer. It is palatable to the animals. It produces abundant leafy growth and seeds, and shows good regeneration from self sown seeds. It is a productive type of fodder containing 15-16% protein at flowering stage.

2.3.2 *Clitoria ternatea*

Local names: Butterfly pea, Aparjita

The butterfly pea *(C. ternatea)* is a deep-rooted, tall slender, climbing legume with five leaflets and a deep blue flower. It is well adapted to a variety of soil types (pH 5.5-8.9) including calcareous soils. It is surviving in both the extended rainfall regions and prolonged periods of drought. Propagation is through seed; the plants may be grown with support crops (or) staked with bamboo to facilitate hand picking of the pods.

Fig. 2.34 Clitoria ternatea

It is a tall, slender climber and once established it becomes difficult to eradicate because of its deep root system and heavy self seeding habits. It does very well under irrigation. Under favorable condition, butterfly pea yields up to 30 tons dry matter per hectare per year.

Nutritive value

Butterfly pea is productive type of fodder and may be grown with other grasses in the pasture. The levels of crude protein and crude fibre in the leaves are 20-22% and 21-29%,

respectively. Total plant protein ranges from 14-20%. Dry matter digestibility levels vary between 60-75%. Good quality hay can be made from *Clitoria*. It is well accepted by livestock.

Varietities

IGFRI-S-23-1 and IGFRI-S-12 are the famous high yielding varieties available for forage cultivation in India.

2.3.3 *Dolichos lablab var. lignosis*

Dolichos lablab is a vigorously growing annual legume. Its vines attain a length of 3-5 m, the leaves are trifoliate with large ovate leaflets. The flowers are white. It may be grown under rainfed conditions and requires hot and humid climate for its preliminary growth. It grows in every type of soil even under neglected conditions. There are many varieties of *D. lablab*. One of these is an Australian strain Rongai which is a prolific yielder.

Fig. 2.35 Dolichos lablab

Nutritive value

Besides its high yielding capacity *D. lablab var. D. lignosis* is more palatable and a productive type of fodder likes other legumes. It contains 16% crude protein and 26% crude fibre. It can also be converted into excellent quality hay.

Toxicity

Lectins are cell agglutinating sugar specific proteins that are widely distributed in leguminous plants. Seeds of *D. lablab* contain lectins.

2.3.4 Kudzu *(Pueraria thunbergiana)*

Local name: Kudzu

Kudzu is a rapidly growing perennial legume when once established it is difficult to remove from land. Normally it is being used by soil conservation department to prevent soil erosion in the hilly regions. It has an excellent coverage. Best adapted to a warm, moist climate but, because of the stored plant food in the roots, can withstand protracted drought when once established. Kudzu is a fast-growing plant and produces long, prostrate branches which root at many of the joints if the soil is moist and contact good. New plants are established in this manner. It takes one year to establish. Quite a useful forage, retaining its palatability throughout the growing season, but new pasture legumes are likely to replace it for grazing purposes. Two cuttings can be taken in a year. It contains 20-22% protein. Observations showed that it is not highly palatable to livestock.

Fig. 2.36 Kudzu

2.3.5 *Centrosema pubescens*

Fig. 2.37 Centrosema pubescens

Local Name: Centro

Centrosema pubescens has been developed mainly as a tropical cover crop in recent years. It is perennial which grows aggressively and has a tendency to climb. It covers the ground quickly and forms seeds.

Nutritive value

Centrosema pubescens is important forage legume as protein and mineral sources for ruminant livestock in the tropics. It contains 12% crude protein and 33% crude fibre.

2.3.6 *Leucaena leucocephala*

Fig. 2.38 Leucaena leucocephala

Local names: Hindi: Shoo babool **English:** Black wood **Kannada:** Chiguru **Marathi:** Su-babul **Philippines:** Ipil-Ipil

Leucaena leucocephala is a perennial shrub. The young foliage is very palatable, rich in protein and its seed can be used as a concentrate. The fodder is suitable only for ruminants but is toxic to pigs and horses on account of mimosine, a toxic amino acid. When grown for fodder purposes, the first cut (5-10 cm above ground) can be taken within 6-9 months of sowing and the subsequent cuts may be obtained at intervals of about 4 months. It has extensively propagated in India and other Asian countries. This is most widely used forage tree legume in a two or three or multitier system of fodder production and in various agroforestry models. Due to presence of *Rhizobium* bacteria, it can fix more than 500 kg nitrogen per hectare per year by the act of symbiosis. It is considered as a miracle tree because of its worldwide success as a long lived and highly nutritious forage tree.

Nutritive value

The fodder is a rich source of carotene and vitamin A. The leaf meal also contain good amount of riboflavin, vitamin K and xanthophyll pigments which can enhance the egg hatchability, color of egg yolk and broiler skin. It contains 22% and 11.84% crude protein and crude fibre, respectively.

Toxicity

Mimosine is a toxic amino acid found in leaves, stems and seeds of Leucaena species of plants at a concentration of up to 100 g per kg dry matter. Mimosine is distributed in all parts of plants and is more concentrated in young growing leaves (9.1%) than roots (0.1%) and wood (0.4%). Heifers fed excessively with leucaena after mating have been shown to have decreased rate of conception, even those conceived gave birth to calves having goiter. The embryonic death due to feeding excess mimosine may be due to amniotic activity or goitrogenic activity of metabolite, 3-hydroxy-4-pyridone.

2.3.7 Moth *(Phaseolus aconitifolius)*

Local name: Moth

Moth is a creeping annual which can be used as a green manure and as a fodder. It forms excellent hay. It is sown in the kharif season by broadcasting. The yield is about 250 quintals per hectare.

2.3.8 *Rhynchosia minima*

It grows wild in the western tract of Uttar Pradesh. It is a strong, creeping perennial with small yellow flowers. The leaves are shed in winter but again during the spring they come up. It grows vigorously and is a good fodder. It can be sown in mixed pasture, but yield of fodder per hectare will not be very encouraging. It is a productive fodder.

Fig. 2.39 Rhynchosia minima

Nutritive value

Palatability of *R. minima* appears to vary widely from place to place. It is probable that it varies with the wide range of different ecotypes that exist. It contains crude protein 15%, crude fibre 45.9% and 60% digestibility of dry matter. There are no known toxicities.

2.3.9 Dhaincha *(Sesbania aculeata)*

Dhaincha is generally grown as a green manuring crop in India. It is a tall branching annual herb adapted to wet areas and heavy soils. This species has long been used for feeding livestock and for soil improvement in India.

Fig. 2.40 Dhaincha

Nutritive value

The crude protein content of seeds of *Sesbania* species is 33.0% and 10.9% crude fibre. It can also be used as fodder during the scarcity period. *Sesbania* species contain lectins.

2.3.10 Stylo *(Stylosanthes hamata)*

Stylo is a vigorous summer growing perennial which grows to the height of 60-90 cm and tend to root at the nodes. It is found generally adjuscent the costal regions of North and South America and introduced in many tropical regions of India. It is adapted to wide range of soil types and is drought resistant.

Though not very palatable at the initial stages, once the animals are accustomed to it, they graze the plant readily. Seeds can be sown at the rate of 3-4 kg per hectare. The green forage production ranges from 20-30 ton per hectare, while dry forage is 6-10 ton per hectare. It contains about 10-11% CP, 0.61-1.72% calcium, 0.10-0.12% phosphorus and 7.0-14.2% ash.

2.3.11 *Cassia* spp.

Cassia tora is a common herbaceous annual occurring as a weed throughout India and belongs to the family of *leguminosae*. It is a small attractive shrub grows during the monsoon period. It contains pod. Cassia tolerates a wide range of climates and temperatures, though it tends towards loving warmth. Their showy flowers make them desirable ornamental plants for parks and gardens. Arid land species are well-suited for reforestation purposes and to provide sources of natural goods and improving soil quality and stemming desertification also.

Fig. 2.41 Cassia

Nutritive value

Studies have shown that methanolic extracts of *Cassia tora* improved microbiological safety by detoxifying aflatoxin B1. The seeds of *Cassia tora* have been shown to contain high amounts of protein and essential amino acids. Currently *Cassia tora* seeds are being used as a source of galactomannan gums in the food industry. In India, *Cassia tora* is the common species which is not very much relished in the green stage. However after conservation in the form of hay and silage, it is consumed by the ruminants. Its seeds are used as a concentrate, although they are rich in tannins.

Deleterious factors

Because of the presence of various antinutritional factors like trypsin inhibitors, polyphenols, saponins and haemagglutinins, their utilization as a protein source particularly in animal feed, has not been explored so far. Various detoxification procedures attempted such as autoclaving, acid treatment, alcohol extraction showed limited success in removing these factors.

2.3.12 *Desmodium* spp.

It is a woody leguminous plant and has many species. *Desmodium capitatum, D. ovalifolium* and *D. gyroides* are common species in India. *D. gyroides* grows to a height of 1-2.5 m and cattle browse the leaves. It is rich in protein.

Nutritive value

In contrast to the remarkable agronomic performance of *D. ovalifolium* in high rainfall areas, the nutritive value of the species falls behind other tropical pasture legumes such as *Centrosema spp.* or *Arachis pintoi.* In vitro dry matter digestibility value ranges from 29-56%, which is below the mean value for tropical legumes (56%). Crude protein contents ranges from 12-20%, phosphorus and calcium concentrations from 0.10-0.16% and 0.27-0.57%, respectively. Fibre contents (acid and neutral detergent fibre) are in the range of 40-50% in *D. Ovalifolium*.

Deleterious factor

This is mainly attributed to the high condensed tannin (CT) content of the legume with subsequently reduced *in vitro digestibility* (IVDMD), low palatability and animal intake. Data on CT contents of *D. ovalifolium*, however, are limited. The CT content is ranged from 19-43%. Leaf tissue analysis revealed CT contents, which varies within and between seasons (16-25%).

2.3.13 *Prosopis cineraria*

Fig. 2.42 Prosopis

Prosopis cineraria, locally known as khejri, has an important place in the economy of the Indian desert. In the arid zone of Rajasthan, camels, goats, donkeys and mules, which make up about 40% of the 19 million head of livestock in the region, depend on browsing to meet their nutrient requirements.

Khejri is well adapted to the very dry conditions in India and is found in zones with annual rainfall ranging from 150-500 mm; the optimum density is seen between 350-400 mm range. This plant produces leaves, flowers and fruit during the extreme dry months (March-June) when all other species adapted to arid zones are leafless and dormant. It is the characteristic which deserves greatest attention as the tree offers a new forage resource for extreme arid zones. Khejri is a slow growing tree in its early stages, requiring 10-15 yrs to develop a height of 6 m, compared to 12-15 m in 4-5 yrs for *Prosopis juliflora* (Vilayti babool). An average tree yields 25-30 kg of dry leaf forage per year.

Nutritional value

Khejri trees are ready to provide animal feed from the 10th year onwards and, if properly managed, may be kept in production for 2 centuries. Leaves contain 15% crude protein and 15-20% crude fibre. Calcium and phosphorus contents are 1.92% and 0.18%, respectively. Total digestible nutrients are 40%.

2.3.14 *Sesbania* spp.

Fig. 2.43 Sesbania grandiflora

Local names: **Bengali**: Agate, Bake **Hindi**: Basma, Hatiya, Agasti **Sanskrit**: Anari **Tamil**: Peragati, agate

There are many species of *Sesbania* ranging from small shrub/ tree to a long tree. *Sesbania aegyptiaca* and *S. grandiflora* are common in western and southern parts of India.

Nutritive value

It contains 25-30% crude protein. Supplementation with *S. grandiflora* to goats fed guinea grass hay increased intake by 25% and supported a positive nitrogen balance. *In sacco* digestibility was 75% in 12 hours. Other *in vitro* and in sacco studies reported the very high forage quality of *S. grandiflora.* It is highly palatable to ruminants and well accepted by monogastrics also.

Deleterious factor

Seeds contain a toxin poisonous to fish. It contains low quantities of condensed tannins. Also contains canavanine, the nutritional implications of which are unknown.

3 Tree leaves

Large varieties of plant materials which are conventionally not included in the feeds for livestock are used for feeding of cattle and other ruminants during periods of scarcity. Some varieties of tree leaves are conventional feeds for sheep and goats. Certain varieties are also fed to cattle and buffaloes. Leaves of different species have different nutritional characteristics. In general, in the early stages of growth the leaves contain fairly high percentage of crude protein and comparatively low fibre content. As the vegetation advances in age, there is progressive decrease in the protein content and increase in the crude fibre. Tree leaves are generally rich in calcium, but have low phosphorus. The ratio of calcium and phosphorus is generally wide. Due to presence of tannic acid, the digestibility of protein in the leaves is low.

3.1 Pipal leaves *(Ficus religiosa)*

Local name: Pipal tree

Pipal trees grow throughout India. The trees remain green throughout the year. Considerable research has been conducted on the use of pipal leaves as livestock feed.

Fig. 2.44 Pipal leaves

Nutritive value

The palatability and nutritive value of pipal leaves is not very good. Leaves when fed alone could form a maintenance ration. On an average, the leaves contain 5.47% DCP, and 39.22% TDN. The DCP content is fairly high as compared to conventional fodders. The TDN value is lower as compared to poor type roughages. Studies revealed that various nutrients in the leaves varied during different months and seasons. The leaves along with other sources of TDN could form a ration during scarcity periods.

3.2 Bamboo leaves *(Dendrocalamus strictus)*

Local name: Bamboo

Bamboo trees grow in large parts of India. Large quantities of leaves become available during harvesting for paper manufacture. It is estimated that about 90-150 tonnes of leaves can be obtained from one hectare of bamboo forests.

Fig. 2.45 Bamboo leaves

Nutritive value

Bamboo leaves are rich in protein. The leaves in tender stages are relished by the animals and can form a part of the ration. Several studies shown that bamboo leaves are important source of roughage for feeding of livestock.

3.3 Neem *(Azadirachta indica)*

Local name: Neem

Neem trees grow all over India. The plant remains green throughout the year and is drought resistant. Large quantities of leaves become available if judiciously collected.

Neem is a large and evergreen tree with edible fruits and aromatic leaves found throughout southern Asia. A mature tree can produce 350 kg of leaves a year, which may be used for feeding cattle during famines.

Fig. 2.46 Neem leaves

Nutritive value

The neem leaves are not relished by the animals. Buffaloes consume about four to six kilogram. The nutritive value is 6.19% DCP and 50% TDN. After the oil has been pressed from the seeds, the cake is used as fertilizer, but it can also be used as feed. Up to 10% neem cake may be included in concentrates for cattle and up to 5% for poultry. The oilcake has a very bitter taste. Leaves and cakes are used as anthelmintic for goats and is said to give healthy looking animals when fed.

Deleterious factor

The terpenoids azadirachtin and limonin impart a bitter taste and the leaves of A. indica are therefore not relished by cattle.

3.4 Mulberry leaves (*Morus alba*)

Local name: Kalambi

Mulberry tree is grown in the sub-Himalayan track up to 1500 m.

Fig. 2.47 Mulberry leaves

Nutritive value

The leaves are highly palatable. The left over leaves and stalks contain 11.4% crude protein, 2.7% ether extract and 3.4% crude fibre. These are highly palatable and the digestible crude protein is 7.8% and total digestible nutrients are 48.4%.

3.5 Ber leaves *(Zizyphus jujuba)*

Local name: Beri

Zizyphus jujuba is a commonly grown shrub, whose leaves are used as a conventional fodder for sheep and goats. In arid zones, it is an important fodder for these two species of animals. Ground leaves used in combinations with other feeds in dry season in Rajasthan. Entire shrub can be cut, leaves allowed to dry and beaten off with sticks. Dried product called pala (a generic term for dried leaves collected as livestock feed) and yielding at 1.0-1.6 kg dry matter per tree.

Fig. 2.48 Ber leaves

Nutritive value

In a comparative study on the palatability of different varieties of tree leaves; it was observed that beri leaves are comparatively more palatable than pipal or pakar leaves. The beri leaves have high crude protein content (18.6%) but the digestibility coefficient is only 36%.

3.6 Tapioca leaves (*Manihot esculenta)*

Fig. 2.49 Tapioca leaves

Local name: Tapioca

Tapioca is a tuber crop extensively grown in Kerala State and parts of Tamil Nadu. Out of three species *M. esculenta* is most commonly cultivated in India. Annual production of tapioca in India is estimated at 4.5 million tonnes. At the time of harvest, generally the tuber is harvested and the leaves are thrown away.

Nutritive value

Tapioca leaves are a rich source of protein having a DCP value of 8.3% and TDN value of 45.5% of dry leaves. When fed to growing calves 2.27 kg of partially dried tapioca leaves could replace 0.68 kg of groundnut cake. Tapioca leaf meal also gives good results in feeding of lactating cows.

Deleterious factors

So far, tapioca leaves were not fed to cattle due to presence of hydrocyanic acid (HCN). The HCN content is the minimum when the plants are five months of age. The tapioca leaf meal contains 7.58 mg of HCN per 100 g of material. At an intake level of 0.5-0.8% of body weight, it does not bring about any adverse effect.

3.7 Ardu leaves *(Ailanthus excelsa Roxb)*

Local name: Ardu

Fig. 2.50 Ardu leaves

Ailanthus excelsa Roxb belongs to the genus *Ailanthus*, in which two other species *A. grandis* and *A. grandulosa* are also found in India. All these species grow into enormous trees and a full grown tree gives 6-7 quintals of edible leaves twice a year.

Nutritive value

Crude protein and total digestible nutrients contents are 19 and 64%, respectively. Acid detergent fibre and neutral detergent fibre are 42 and 48%, respectively. Ardu leaves regarded as a good fodder by farmers. Mature leaves highly palatable and nutritious, usually fed to sheep and goats. Adult animals can be maintained on ardu leaves.

3.8 Bhimal *(Grewia optiva, Grewia oppositifolia)*

Local name: Biul

Bhimal tree grows from plains to a height of 2000 metre. It is most commonly grown in the mountains region. It gives about 10-20 kg of green leaves per year per plant. It has been successively adopted in plains (Mathura and Izatnagar). It can be propagated both by seeds and vegetative cuttings.

Nutritive value

Bhimal leaves contain about 20-23% crude protein. The digestibility is very high (about 75%). There is practically no tannin in its leaves. It is commonly used as a supplemental feed for cattle, sheep, goats, etc. in the Kumaon and Himachal regions of India.

3.9 Kachnar *(Bauhinia variegata)*

Local name: Kachnar

Kachnar is very common fodder tree cultivated in India. The flower buds are used as vegetable. It is generally propagated by seeds.

Nutritive value

Kachnar is palatable to cattle, sheep, goats, etc. Leaves contain about 7.0% DCP, 1.5 Mcal of ME per kg dry matter. The tannin content is about 1.5%.

Fig. 2.51 Kachnar

3.10 Robinia *(Robinia pseudoacacia)*

Local name: Robinia

Robinia is very good fodder tree which yields about 15 kg of green leaves per year. It can be propagated by seeds.

Nutritive value

Due to presence of higher tannins (1.9%), the digestibility of crude protein is low (50%). It contains about 10% DCP and 1.5 Mcal of ME per kg of dry matter. It is a palatable fodder for the farm animals.

Fig. 2.52 Robinia

III. UNCONVENTIONAL FEEDS

Increase in livestock and human population and decrease in land under cultivation has resulted in acute shortage of feeds and fodder for livestock which further increases due to natural calamities like droughts and flood. The feeds which are traditionally not used for feeding animals are called unconventional feeds. Their use in livestock ration is increasing day by day due to shortage of animal feeds. The main source of such feeds is agricultural and forest by-products. Such feeds are not used either because of traditional beliefs of livestock owners or due to less palatability and presence of incriminating factors in them. It also happens that certain un-conventional feeds are being traditionally fed to animals in particular region but the same may be neglected in other regions. Recent studies indicated that quite a large number of agricultural by-products and industrial waste materials could be used for livestock feeding.

Unconventional feeds are described under the following categories:

1. Protein sources
2. Energy sources
3. Miscellaneous unconventional feeds

1 Protein sources

1.1 Guar meal *(Cyamopsis tetragonoloba)*

Common names: Guar, Cluster Bean, Calcutta lucerne, guar bean, gum bean, Siam bean

Local names: **Hindi**: Gawar, Guwar, Guaar, Goaar **Bengali**: Jharsim **Gujarati**: Gavar **Kannada**: Gorikaayi **Konkani**: Midkisaang **Malayalam**: Kothavara **Marathi**: Bavachi, Citaki, Gavar, Gavari, Govari **Mizo**: Kaurakasaila, Phali guar, Safaid moth **Oriya**: Guanrachhuim, Shimba Tamil: Kottavarai **Telugu**: Goru-chikkudu-kaya

Fig. 3.1 Guar meal

Guar is an erect annual herb 1-2 m high with trifoliate leaves and rose-coloured flowers. It is cultivated as grain, fodder or vegetable and is drought resistant. It is poor for grazing because of its hairy, nettle leaves. It can be cut for fodder as soon as the pods begin to develop. It is palatable to stock if cut and wilted. The seeds are used for extraction of gum (mannogalactan). Guar meal is the by-product of guar gum industry consisting of guar germ material. India is producing around 0.6 million tones guar annually.

Nutritive value

Guar meal contains 75-80% TDN and 50-55% CP. It is a good source of amino acids as it is richer in lysine (2.55%), cysteine (1.16%) and glycine (4.61%) than groundnut cake but comparable in respect of methionine content. It is also rich in trace minerals.

Deleterious factor

Guar meal contains two anti-nutritional factors: anti-trypsin and residual guar gum. Residual guar gum is a polysaccharide (galactomannan) and it may be as high as 18% of the guar meal which is neither digested nor absorbed. Toasting can be followed to inhibit anti-trypsin factor.

Inclusion

Guar meal is not palatable to cattle since its inclusion at only 5% level was refused at the initial phase by cows, although if accustomed, cows can accept rations containing as high as 15% raw guar meal. Toasted guar meal, however, has not that acute palatability problem. Further, trypsin inhibitor factor is depressed. Higher level of guar meal may cause diarrhea (watery and sticky faeces), particularly in young calves. It is therefore, always advisable to incorporate guar meal in the ration very gradually and once accustomed may be used as high as 10-15% level in cows and 5-10% level in calves (Banerjee, 2000).

1.2 Niger seed cake *(Guizotia abyssinica)*

Synonym: *Guizotia oleifera, Polymnia abyssinica*

Common names: Ramtil, Niger, Blackseed

Local name: Hindi: Ramtil, Kalatil, Surguja, Jagni **Marathi:** Karal, Kalitil, Rantil **Tamil:** Payellu, Uchellu, Kattel **Telugu:** Valesulu, Vulisi, Adavinvvulu **Kannada:** Huchchellu, Ramtil, Gurellu, **Bengali:** Sorguja **Oriya:** Ramtila, Alashi **Konkani:** Jhusetil, Krishhna guru **Assamese:** Sarguja Gujarati: Ramtil

Guizitia abyssinica is an annual herbaceous plant with softly hairy stems reaching a height of 15 m. Cultivated in India and tropical Africa for the edible oil obtainable from the small black seeds.

Fig. 3.2 Niger seed cake

Availability

Approximately 0.1 million tone cake is available annually in India. It is chiefly produced in Andhra Pradesh, Madhya Pradesh, Maharashtra and Odisha.

Nutritive value

Niger seed cake is a very good source of protein (CP 34%) and a moderate source of energy (TDN 50%). Its protein digestibility is about 80%. It is richer in available lysine (400 mg/100 g) and methionine content than groundnut cake. Niger seed cake does not contain any toxic factor and is quite palatable.

Inclusion

It can be incorporated up to 57% in the concentrate mixtures of crossbred calves (daily gain 632 g), (Punj, 1988; Talpada et al., 2002). Singh et al. (1983) found that replacement of 50 or 100% of linseed cake (57 parts in concentrate mixture) with niger cake had no effect (comparable) on weight gain, utilization of diet, nutrient digestibility and balances of nitrogen, calcium and phosphorus in growing calves.

1.3 Rubber seed cake *(Hevea brasiliensis)*

Synonyms: *Ficus cordata, Ficus decora*

Common names: Rubber, Para rubber

Rubber tree is a large spreading evergreen tree native to north-east India, the eastern Himalayas, and south-east Asia. The tree can yield milky white latex, which has been used to make rubber. The young rubber leaves are poisonous to most animals, causing profuse sweating, paralysis and ultimately death. The potential availability of rubber-seed cake is

0.15 million tones annually in India (Banerjee, 2000). A good quality rubber seed cake contains about 35% CP and 55% TDN.

Fig. 3.3 Rubber seed cake

Deleterious factor

Rubber seed cake contains hydrocyanic acid but its level is too low (0.009% or 9 mg/100g) to produce any toxic symptoms. Roasting, toasting and water soaking can be followed for detoxification of rubber seed cake.

Inclusion

Rubber seed cake can be incorporated up to 30 and 25%, respectively, in the concentrate mixture of crossbred calves (daily gain 500 g) and milch cattle (daily yield 7-9 kg), (Punj, 1988).

1.4 Sun hemp seeds *(Crotalaria juncea)*

Common names: Sun hemp, Indian hemp, Madras hemp

Local names: Hindi: San, Sonai **Manipuri:** Chingenjhin **Bengali:** Shon, Sanpat **Malayalam:** Chanaka, Vakku **Marathi:** Tag **Oriya:** Sanpat **Telgu:** Gilaka, Shanama, Janumu **Kannada:** Pundi, Saab **Tamil:** Vakkunnar

Fig. 3.4 Sun hemp seeds

Sun hemp is a rapid growing crop that is used for fibre production in Indo-Pakistan. Sun hemp originated in India, where it has been grown since the dawn of agriculture. It is also good for use as a green manure in many tropical and subtropical areas in the world as an organic and nitrogen source. It suppresses weeds, slows soil erosion, and reduces root-knot nematode population. The pods are small and inflated, having stiff hairs. It is commonly grown in India as fodder. Sun hemp seeds after crushing can be fed to cattle but feeding as such is not palatable. This can, however be mixed with other palatable feedstuffs in concentrate mixture for feeding of cattle.

Nutritive value

Sun hemp seed contains 71% TDN and 40.3% CP. The lysine and methionine content is 4.7 and 1.7% (on protein basis), respectively.

Deleterious factor

Sun hemp contains pyrrolizidine alkaloids, which are converted by oxidases or cytochrome P450 system of the liver into potent toxins (Mannetje, 2004). Seeds also contain trypsin inhibitor and 'Retusamine-N-oxide' - an alkaloid (Chaudhury et al., 2005).

Inclusion

Intake of sun hemp hay by cattle should be restricted to about 10% of their diet (Reddy et al. 1999).

1.5 Dhaincha seeds *(Sesbania bispinosa)*

Synonyms: *Sesbania aculeata, Aeschynomene aculeata*

Common name: Prickly Sesban

Local names: Hindi: Dhaincha, Lkad, Dadon, Daden **Kannada:** Dhaincha, Mullujeenangi **Malayalam:** Kedangu **Marathi:** Bhuiavali, Chinchani, Kansevari, Ran-Shevri **Tamil:** Mutcempai, Uravi

Dhaincha is an erect, somewhat woody, low annual subshrub, growing up to 7 m tall. Usually it is seen only 2 m tall and found especially in dry regions.

Fig. 3.5 Dhaincha seeds

Nutritive value

This leguminous seed is excellent in protein quality. It contains 32.7% CP. It is a good source of lysine and methionine.

Deleterious factor

The seed cannot be used as such, as it contains deleterious factor like gum, trypsin inhibitor and tannin.

Detoxification

Enzymatic treatment as in case of guar meal can improve feeding value of this material. Even deleterious factor can be removed by microbial fermentation. Fermentation by fungi can decrease the gum content and trypsin inhibitory activity appreciably and increase the crude protein content of the seed (Banerjee, 2000).

Inclusion

Studies with dhaincha seed in cattle are limited. However, autoclaved dhaincha seed may be used in cattle in limited quantities.

1.6 Corn gluten meal *(Zea mays)*

Common names: Maize, Corn

Local names: Hindi: Makka, Makai, Bhutta **Manipuri:** Chujak **Marathi:** Bhutta **Tamil:** Makkacholam **Malayalam:** Makkacholam **Telugu:** Mokkajavanalu **Kannada:** Makkejola **Konkani:** Mako **Urdu:** Makka

Maize is a cereal grain domesticated in the American continent. After European contact with the Americas in the late 15th century and early 16th century, corn spread to the rest of the world. Maize is widely cultivated in the tropics and sub-tropics, including India. Maize gluten meal consist chiefly dried residue from maize after the removal of the larger part of the starch and bran by the process employed in the wet milling manufacture of maize starch. Occasionally it may include maize oil meal. It contains about 58% CP and 80% TDN.

1.7 Ambadi cake *(Hibiscus cannabinus)*

Common names: Deccan Hemp, Wild stockrose Kenaf, Brown Indian Hemp, Ambadi, Mesta

Local names: Hindi: Patsan, San **Manipuri:** Sougri **Marathi:** Ambadi **Tamil:** Palungu, Pulimanji **Malayalam:** Kanjaru **Telugu:** Pimdikura, Gonkura **Kannada:** Dirin da rani **Bengali:** Patsan, Ambari **Oriya:** Kanuriya **Konkani:** Ambadi **Gujarati:** Sheria **Sanskrit:** Machika, Maryurika, Ambika, Sahasravatamulika

Ambadi or deccan hemp is a species of Hibiscus, probably native to southern Asia, though its exact natural origin is unknown. The name also applies to the fibre obtained from this plant. It is an annual or biennial herbaceous plant (rarely a short-lived perennial) growing to 1.5-3.5 m tall with a woody base. The fruit is a capsule 2 cm diameter, containing several seeds. New varieties used as a raw material in the paper industry may become important as cattle feeds. The cake is available in very large quantity, particularly in western Maharashtra and Marathwada regions of India.

Fig. 3.6 Ambadi plant

Nutritive value

Ambadi cake is a very good source of energy and protein (TDN 60% and CP 23.4%), (Arora *et. al*., 1983). The cake does not contain any toxic factor and is quite palatable.

Inclusion

It can be incorporated at 20% level in the concentrate mixture of crossbred calves (daily gain 418 g) and lactating cows yielding daily 12.9 kg milk (Punj, 1988).

1.8 Subabul seeds *(Leucaena leucocephala)*

Common names: Wild tamarind, White babool, Lead tree, Ipil-Ipil, White popinac, Koa haole, Shack shack

Local names: Hindi: Safed babool **Bengali:** Subabul

Subabul is cultivated widely in the tropics as a fodder plant, especially on dry waste lands. It produces white flowers tinged with yellow resembling mimosa and long flattened pods. Subabul (kubabul) trees are grown all over India. Subabul leaves are fed to animals as green fodder.

Fig. 3.7 Subabul seeds

Nutritive value

Subabul seeds contain 65% TDN and 29% CP. Thus it is a good source of energy and protein.

Deleterious factor

Subabul seeds contain toxic principle 'Mimosine' (a glucoside) which has adverse effect on growth, reproduction and health of animals. Mimosine may cause loss of hairs in young cattle. So it should be used as per recommended levels.

Detoxification

The addition of iron salts decreases mimosin toxicity, and if the treated material is allowed to stand for a week before being mixed with feeds, little toxicity remains (FAO, AFRIS). The mimosine content can also be reduced by soaking the seeds in water and drying.

Inclusion

When subabul seeds are used in feed, it is advisable to add iron and iodine containing mineral mixture. Subabul as green fodder should not be used more than 33% of total ration. Subabul seeds can be safely used up to 10 and 30% level in concentrate mixture for lactating and growing animals, respectively. They can be used up to 30% level in the ration of adult bullocks (Talpada et al., 2002).

1.9 Jowar cake and gluten *(Sorghum bicolor)*

Fig. 3.8 Jowar

Common name: Jowar

Local names: Hindi: Jowar **Marathi:** Jowari

Jowar is mostly cultivated for grain for human consumption and for animal feed. The species originated in Northern Africa and can grow in arid soils and withstand prolonged droughts. Jowar is usually an annual, but some cultivars are perennial. It grows in clumps which may reach upto 4 meters high.

Nutritive value

Jowar cake contains about 10% CP and 67.2% TDN. It is a good source of energy. Jowar gluten contains 39% CP and 65% TDN and is a good source of energy and protein (Talpada et al., 2002).

Deleterious factor

Jowar cake contains tannin (2.88%). Jowar cake and gluten can be used as animal feed. Both are cheaper than maize cake and maize gluten. But jowar cake is unpalatable to animals so should be fed along with other palatable ingredients. Due to its low CP content, it should be supplemented with other protein rich feeds.

1.10 Corn steep liquor

Fig. 3.9 Corn steep liquor

Corn steep liquor is a by-product of corn starch manufacturing industry. It is available to the extent of 0.01 million tone in India.

Nutritive value

It contains 40% CP and 75% TDN. Thus, it is an excellent source of energy, protein and phosphorus.

Inclusion

The moisture content is about 50%. Because of high moisture content, it requires special care for its storage. However, by mixing wheat bran, rice bran or rice polish at 40% level, it can be stored and transported easily in gunny bags. Due to its low pH (4-5) it cannot be used more than recommended levels. Due to its high phosphorus content, care should be taken to maintain proper Ca: P ratio by supplementing calcium. It can be incorporated up to 15% and 10% level in the ration of growing calves and lactating cows (Talpada *et al.*, 2002).

1.11 Isabgol gola and Isabgol lali *(Plantago ovata)*

Common names: Psyllium husk, Psyllium seeds, Plantago, Ispaghula, Fleam.

Local names: Hindi: Isabgol **Sanskrit:** Isabgulam, Snigdhbijam **Bangla:** Isabgol **Gujarati:** Udhamjeru **Marathi:** Isabgol

Isabgol *(Plantago ovata)* is an annual herb that grows to a height of 12 to 18 in. It is indigenous to the Mediterranean region and West Asia. It has been introduced in India

and cultivated specially in Gujarat and some parts of Rajasthan and Madhya Pradesh. Psyllium mucilage is also used as a natural dietary fibre for animals. The dehusked seed that remains after the seed coat is milled off is rich in starch and fatty acids and is used in India as cattle feed. The Psyllium husk recovered after dehusking process is also used as cattle feed.

Fig. 3.10 Isabgol husk

Nutritive value

Isabgol lali contains 30-40% CP and 21.3% EE, 1.0% CF, 28.1% NFE, 1.4% P and 0.9% Ca on dry matter basis. Thus, it is good source of protein and energy. Isabgol gola contain about 18-20% CP.

Inclusion

Isabgol lali and gola can be used up to 25% and 50% level, respectively in concentrate mixture for cattle (Talpada *et al*., 2002).

2 Energy sources

2.1 Tamarind seed powder *(Tamarindus indica)*

Common name: Tamarind

Local names: **Hindi**: Imli **Bengali**: Tentul **Manipuri**: Mange **Tamil**: Puli **Telugu**: Chinta **Marathi**: Chinch

Fig. 3.11 Tamarind seeds

Tamarind is a very common large tree with a short massive trunk, ferny pinnate leaves, small yellow flowers and fat reddish brown pods.

Availability

Tamarind seeds are available to the extent of 11 million tones annually in India (Talpada *et al*., 2002).

Nutritive value

Tamarind seeds contain 30-40% red hulls and 55-70% white kernels. Tamarind seed kernels are good source of energy (TDN 64%). It contains 12% CP.

Deleterious factor

Tamarind seed contains tannin (13-14%) as an anti-nutritional factor. *Tamarindus indica* proteins were poorly digested and utilized by cattle. The seeds contained low levels of lectins which agglutinated cattle erythrocytes which had been pre-treated with suitable proteases (FAO, AFRIS). Overnight soaking in cold water reduces the tannin content.

Inclusion

Tamarind seeds can be fed after grinding during scarcity period. It is not very much palatable. To make the seeds palatable to cattle, they should be ground and soaked in water for an hour before feeding (FAO, AFRIS).

2.2 Mango seed kernel *(Mangifera indica)*

Common name: Mango

Local names: Hindi: Aam **Manipuri:** Heinou **Tamil:** Ma **Telugu:** Mamidi **Malayalam:** Mangga **Kannada:** Mavinamara **Marathi:** Amba **Konkani:** Ambo

It is a large spreading tree that is native to tropical Asia but cultivated in most tropical countries. The round or oval fruit is somewhat flattened and can weigh up to 0.5 kg. In the centre of fruit, there is large fibrous flat seed containing a kernel. The kernels constitute about 15% of the weight of the fruit and may well be used for livestock. Mango seed kernel is a waste product of mango fruit canning industry. It is available after extraction of juices from mangoes or from the leftover of fruits after the same has been consumed by human beings. Mango seed kernels are available to the tune of 1 million tones annually in India (Punj, 1988).

Fig. 3.12 Mango seed kernels

Nutritive value

Mango seed kernel is a poor source of protein (6% CP).The TDN content is 55%.

Deleterious factor

Mango seed kernels contain high level of tannins (5-6%). Therefore, its more use in animal feed may affect growth and health of animals.

Inclusion

Mango seed kernel is palatable to the animals. The kernels can be incorporated up to 10% level in the concentrate mixtures of milch cattle (daily milk yield 8 kg), (Punj, 1988). Mango seed kernels can be safely used up to 20 and 40% level in the ration of growing calves and bullocks, respectively (Talpada et al., 2002). Ruminants can tolerate concentrates with up to 50% mango kernels without adverse effects (FAO, AFRIS).

2.3 Rain tree pods *(Samanea saman)*

Common names: Rain tree, Monkey pod, Pithecellobium, Samanea.

Rain tree pod or monkey pod is a fast-growing tree that has been introduced to many tropical countries throughout the world from its native habitats in Central America and northern South America. Although it is generally planted as a shade tree and ornamental, it has been naturalized in many countries and is greatly valued in pastures as shade for cattle. It is found in Assam, West Bengal, Orissa, Mumbai, and Southern India as shade tree. Rain trees are grown on roadsides. The most widely used common name for the species is rain tree is from the belief that the tree produces rain at night. The pulp of the rain tree pods is also sweet like pulp of *Prosopis juliflora* pods. These pods are palatable to animals.

Fig. 3.13 Rain tree pods

Nutritive value

It provides 16.7% CP and about 64% TDN. The pods contain a sweet edible pulp that supplies nutritious food for animals. The pods are palatable. Rain tree pods after grinding can be included in the concentrate mixture of cattle.

2.4 Kusum cake *(Schleichera oleosa)*

Common names: Ceylon oak, Lac tree, Gum lac tree, Indian timber

Local names: **Hindi**: Kusum, **Telgu**: Posku, **Marathi**: Kusumb, **Gujarati**: Kosumb, **Tamil**: Kumbadiri, **Malayalam**: Cottilai, **Kannada**: Cakota.

Kusum tree has a broad, shady crown, found widespread in tropical Himalayas (Punjab to Nepal), India, Ceylon, Burma, Thailand, Indo-China, Malaysia. The fruit is about the size of a small plum. It is a rich source of energy (TDN 79.62%) and a good source of protein (CP 20.9%).

Fig. 3.14 Kusum

Deleterious factor

The expeller processed cake contains cynogenic glycosides at a level of 6.12 mg HCN per 100 g. The solvent extracted cake contains only 2.14 mg HCN per 100 g of the cake (Punj, 1988).

2.5 Cocoa pods *(Theobroma cacao)*

Common names: Cocoa, Cacao, Chocolate

Local names: **Tamil**: Kakkavo, **Malayalam**: Kokkoo

It is a tropical rain forest crop cultivated for its beans, which are contained in large red or yellow pods. The plant is "cauliflorous" with flowers (and later fruits) protruding directly from the woody branches and trunk. The fruit, or "pod", reaches to one foot long and 2-4 inches in diameter. The beans are embedded in white mucilage (together about one third the total weight of the pod). Approximately 0.030 million tone of the material is annually available in the country. It contains 63.5% TDN and 6.3% DCP. The pods are rich in potassium.

Fig. 3.15 Cocoa pods

Deleterious factor

Cocoa beans contain theobromine, an alkaloid poisonous to animals, which limits their use for feeding. The level of theobromine is very low in the pods.

Inclusion

Fresh pods are sometimes consumed by livestock, but to ensure that the animals consume sufficient quantities, the pods must be sun dried (to 60% moisture content) and then chopped, ground and pelletized. Pod meal has been fed without toxic effects to cattle in quantities of up to 7 kg per day (FAO, AFRIS). For dairy cows, pod meal seems to be comparable in value to corn-on-cob meal.

2.6 Vilayati babul pods *(Prosopis juliflora)*

Common names: Algaroba, Mesquite

Local names: **Hindi**: Junglee kikar, Vilayati babul

Prosopis juliflora is native to Peru, Chile and Argentina. It has been introduced in Asia and Africa and is now wide spread in the semi arid areas of the world. In many areas, it is considered a weed. It is a drought resistant deciduous thorny shrub or small tree up to 12 m tall and has been planted in dry areas of the country.

Fig. 3.16 Vilayati babul pods

Availability

About 1 million tones *vilayati* babul is available annually in India and about 0.2 million tones pods are available per annum for animal feeding.

Nutritive value

Babul pods are very good source of energy (TDN 65%). It contains about 12% CP.

Deleterious factor

The pods contain about 0.74 to 1.5% tannins which is very low and does not produce any harmful effect on animal. The material is not known to contain any other toxic substance.

Inclusion

The pulp of the pods contains about 20-30% water soluble sugars, most of which is sucrose; hence the pods are greatly relished by the livestock. High soluble carbohydrate content of pods also acts as binding agent in pellet making. Livestock poisonings has been reported from pods eaten after exposure to rain (FAO, AFRIS). Only ripe pods should be fed, as the green pods are bitter and have little feed value. Vilayati babul pods should not be used as such as its seeds are very hard so animal cannot digest it and comes out as such with faeces. Therefore, it should be fed after grinding. The ground pods can be incorporated at 20% level in the concentrate mixture of crossbred calves (Punj, 1988). These can be included at 30% level in the concentrate mixture of lactating cows and 45% level in the ration of adult bullocks (Talpada *et al*., 2002). Studies indicated that *P. juliflora* pod flour can replace up to 60% of wheat flour in rations for lactating cows and the DM intake, weight gain and milk production increases with increasing proportion of pod flour (Habit and Saavedra, 1988).

2.7 Coconut pith *(Cocos nucifera)*

Synonyms: Coco peat, coir fibre pith, coir dust

Common name: Coconut

Local names: **Hindi**: Nariyal **Manipuri**: Yubi **Tamil**: Tennai **Malayalam**: Thengu **Telugu**: Kobbari chettu, Kobbari kaya **Konkani**: Narlu **Marathi**: Naral, Shriphal

The Coconut palm is a member of the palm family. The origin of this plant is claimed to be south-east Asia and northwestern South America. The term coconut refers to the fruit of the coconut palm. Coir fibre and fibre pith are extracted from the coconut husk. Coconut fibre is extracted by soaking the husks

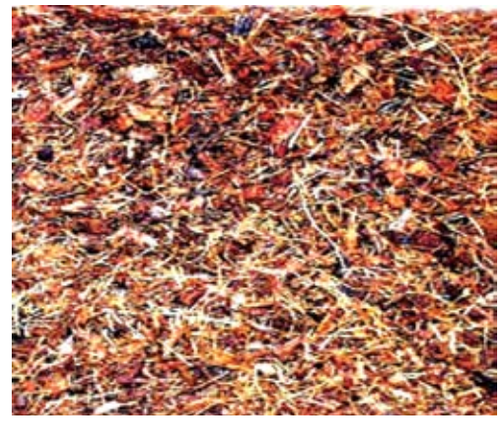


Fig. 3.17 Coconut pith

in water for 6 weeks. This loosens out the fibre and makes extraction possible by mechanical means. Coco pith is a by-product obtained in this process (when coconut husks are processed for the extraction of the long fibres from the husk). The availability of the coconut pith is approximately 0.15 million tones in India. It contains about 62.7% TDN.

2.8 Apple waste *(Malus domestica)*

Fig. 3.18 Damaged apple

Availability

The damaged apples (broken or injured during plucking and unfit for packing) are available in plenty during the apple season.

Nutritive value

It is a good source of energy (TDN 60%). The protein content is 12%.

Inclusion

After slicing, drying and grinding these can be incorporated as energy source up to 30% level in the concentrate mixture of crossbred calves replacing 100% maize (Punj, 1988). The material is quite palatable.

2.9 By-products of tapioca (*Manihot esculenta*)

2.9.1 Tapioca starch waste

Tapioca starch waste is a by-product obtained during manufacturing of starch from tapioca roots. It is also called as cassava pomace. Cassava roots yield approximately equal amounts of starch and pomace, which have less feed value than cassava root meal but can be included in rations for cattle.

Fig. 3.19 Tapioca roots

Availability

The availability of the tapioca starch waste is estimated at 0.065 million tones. Most of it is used as animal feed.

Nutritive value

It contains about 8-12% CP. It is a good source of energy (TDN 60-65%). It contains hydrocyanic acid (HCN) hence it should be fed after HCN testing.

Inclusion

For adult cows it can be safely used up to 30% level in the concentrate mixture with a considerable economy for maintaining body weight, milk yield and butterfat production (Banerjee, 2000).

2.9.2 Tapioca thippi

During manufacture of sago, first the tapioca roots/tubers are deskinned and soaked in water. The tubers are then fed into the crusher adding equal amount of water for extraction of milk. The milk thus obtained is allowed to pass through a sieve to remove the fibrous material. This fibrous material in pulp form when dried is known as Tapioca thippi.

Nutritive value

It is low in protein and fat, but fibre content is 8-9%. The ME content is 2450 kcal/kg.

Inclusion

Cassava flour and thippi mixed in equal proportions (1:1). Then, this mixture is steam treated for 30 minutes and dried in sunlight. After grinding and mixing with groundnut meal and vitamin mineral premix, it can be used in concentrate mixture of cattle ration up to 25% in calves and 30% in adult cows.

Cassava waste (thippi and peel) is used relatively in less quantity as most of the cattle feed preparations in India contain 5-10% of cassava waste. Sand and silica content to the tune of 6% is the most limiting factor in the usage of cassava waste as cattle feed. Cassava thippi and peel flour find a good market in Maharashtra, Andhra Pradesh and Tamil Nadu where small dairy farm units are using this flour in the compound feed preparations (Srinivas and Anantharaman, 2005).

2.9.3 Tapioca milk residue

Tapioca milk residue is a by-product of tapioca root in preparation of sago. Tapioca tubers after deskinning and soaking in water are fed into the crusher and milk is obtained. The heavier starch particles are collected for sago preparation while the lighter starch particles which cannot get together to form the crystals of sago are collected by a different process and dried. The dried second grade starch is known as tapioca milk residue.

Nutritive value

It contains about 3-4% protein and 60-70% starch. It can be used up to 20-25% in ration of cattle (Banerjee, 2000).

3 Miscellaneous unconventional feeds

3.1 Seaweed meal *(Sargassum spp.)*

Fig. 3.20 Seaweed meal

India has got a long coastal belt, where different varieties of seaweeds are available in plenty. Seaweeds are primitive type of plants growing in the intertidal or sub-tidal regions of the sea. Depending upon the type of pigment present and other morphological and anatomical structures, the seaweeds are broadly grouped into green, brown, red and blue-green algae. Seaweeds contain more than 60 trace elements in a concentration much higher than in land plants. They also contain protein, iodine, bromine, vitamin and certain antibiotic substances (Chennubhotla et al., 1991).

Seaweeds are used as human food, livestock feed and fertilizer for land crops in many countries. Phytochemicals obtained from seaweeds are used in food, confectionary, pharmaceutical, dairy, textile, paper, paint and varnish industries as gelling, stabilizing and thickening agents. The availability of seaweeds in India is about 0.6 million tones.

Nutritive value

There is wide variation in the nutritive value of seaweeds. The CP content ranges from 9-19.93% and the total ash content is 23-44.62%. Extracted variety of seaweed contains more protein and fewer minerals.

Inclusion

Dried seaweeds can be utilized up to 20% level in ration of growing calves and up to 15% level in ration of milch animals without any adverse effect on animal performance (Talpada *et al.*, 2002). Dry seaweeds as such are less palatable. But if they are fed with some more palatable feeds or molasses, they become palatable.

3.2 Babul pods, seeds and babul seed chuni *(Acacia nilotica)*

Common name: Gum Arabic

Local names: **Hindi**: Babool, Kikar **Marathi**: Babul **Telugu**: Nallatumma, **Kannada**: Babli, **Malayalam**: Karivelam, **Tamil**: Karuvelai **Gujarati**: Babaria

Babul is a medium to large tree, native to West Asia, can reach a height of 10 m, with an average of 4-7 m in height. This tree grows in dry regions like Haryana, Punjab, Uttaranchal, Uttar Pradesh, Rajasthan, Madhya Pradesh, Maharashtra, Gujarat and many more states of India. Babul seeds contain gum. Large quantities of extracted (degummed) babul seeds are available for feeding livestock. Babul seed extraction (meal) is available after extraction of oil from babul seeds. Babul seeds are separated from pods and are ground and available as babul seed chuni.

Fig. 3.21 Babul pods

Availability

Babul pods are available in plenty. Approximately 6 lakh tones babul pods (Feedstuffs, 2005) and 60,000 tones babul seeds are annually available in India.

Nutritive value

Babul pod contains 12% CP and 55% TDN. Pod contains 56.50% RDP and 43.50% RUP or bypass protein (Feedstuffs, 2005). In terms of bypass protein, it is comparable to cottonseed meal and is highly beneficial for high-producing dairy cows. Babul seeds are moderate source of energy (TDN 59%). Babul seed chuni contains 16% CP and 55% TDN.

Deleterious factor

The extracted seeds contain about 5% tannins. Babul seed chuni contain 3% tannins which reduces the digestibility of CP in feed.

Inclusion

Due to its particular smell, babul seeds are not palatable as such to animals. But it is consumed by animals when mixed with more palatable conventional feeds. Babul seeds and babul pods chuni can be used up to 15% level in the concentrate mixture of lactating cows. These can be included at 39% level in the concentrate mixture of crossbred calves (Punj, 1988). Babul seed chuni can be used up to 30, 45 and 15% level in the ration of growing calves, adult bullocks and lactating cows, respectively (Talpada *et al*., 2002). Patel et al. (1982) found that incorporation of processed babul seeds at 15, 30 and 45% level in ration of kankrej bullocks resulted in lower CP digestibility and lower retention of nitrogen, calcium and phosphorus as compared to control. In scarcity period, babul pods and babul pods chuni can be used for feeding of animals to save the livestock. Babul pods must be ground before feeding to cattle, otherwise the seeds pass undigested with faeces.

3.3 Jackfruit waste *(Artocarpus heterophyllus)*

Synonyms: *Artocarpus integer, Artocarpus integrifolia, Artocarpus jaca*

Common name: Jackfruit

Local names: Hindi: Katahal, Kathal **Manipuri:** Theibong **Marathi:** Phanas **Tamil:** Palaa **Malayalam:** Chakka **Telugu:** Panas **Kannada:** Halasinahannu **Bengali:** Kathal **Oriya:** Panas **Sanskrit:** Panasam **Kuki:** Lamphong

Jackfruit is a tree which is unique in the fact that it produced huge fruits directly from its stem. Jackfruit is most probably native of the rain-forests of the Western Ghats. In fact, the name Jackfruit is derived from the Malayalam name *chakka*. It is cultivated at low elevations throughout India.

Fig. 3.22 Jackfruit waste

Nutritive value

The waste from ripe fruits is more palatable than waste from raw fruits. It contains 7.9% CP, 14.1% crude fibre, 0.80% calcium and 0.10% phosphorus. This is rich source of energy, having 65.3 % NFE (Banerjee, 2000). The rind of the ripe fruit is relished by cattle.

3.4 Sugarcane bagasse

Sugarcane bagasse (the fibrous portion which leaves the last processing stage of the sugar mill) is the residue of sugar cane stalks after the juice has been pressed out in the factories and mainly two varieties are available viz. (i) fine bagasse and (ii) coarse bagasse. The fibre which leaves the last processing stage of the sugar mill contains roughly 50% moisture and 1.5-4% sucrose. It is passed through rotary sieves to remove fine particles (bagasse pith or bagacillo) which may be used as a filter aid later in the process.

Nutritive value

The chemical composition of fine and coarse varieties depend on the place of production. The nutritive value of fine and course varieties being, CF 36.52-42.1% and 40.49-43.22%, EE 0.52-1.68% and 0.53-0.87%, ash 2.60-3.49% and 1.81-2.58%, NFE 51.95-54.8% and 50.39-54.54% respectively. It contains 3.5% CP and 35% TDN.

Deleterious factor

The low digestibility, high lignin (>20%) and very low nitrogen content of raw bagasse limit its inclusion in feeds.

Detoxification

Nutritive value of bagasse and bagasse pith can be improved by various ways like pre-digestion by chemical and physical methods and mixing readily available sources of carbohydrate (molasses) and nitrogen or protein.

Chemical treatments include alkali (sodium hydroxide) and ammonia (gas) or urea treatment. In order to convert urea to ammonia, a source of urease may be necessary for this more inert fibrous residue. The ground seed of jack-bean *(Canavalia ensiformis)* is being used commercially for this purpose (AFRIS, FAO). In NaOH treatment, 12% NaOH solution is mixed for 5 minutes with the pith before adding 10% molasses-urea. It improves digestibility from 20 to 50% (AFRIS, FAO).

Physical treatment to increase digestibility which appears to have application on an industrial scale is the use of steam at high pressure. Treatment of bagasse with high pressure steam

(14 kg/cm) for 5 minutes raised dry matter digestibility from 28 to 60% (rumen nylon bag method, 48 hr incubation), (AFRIS, FAO).

Inclusion

Bagasse and bagasse pith are often used as fillers in compound diets and as carriers for molasses or molasses-urea mixture.

3.5 Sugarcane tops (*Saccharum officinarum)*

Common name: Sugarcane

Local names: **Hindi**: Eekh, Ganna **Manipuri**: Chu **Marathi**: wade **Tamil**: Karumbu, Pundaram **Malayalam**: Karibpu **Telugu**: Cheruku **Kannada**: Petta patti kabbu, Khabbu **Urdu**: Ganna **Sanskrit**: Ikshu, Pundrakah

Sugarcane is a plant which is actually a giant grass. The stem is jointed, 3–5 m tall, 2–3 cm thick, solid juicy, the lower internodes short, swollen; sheaths greatly overlapping, the lower usually falling from the culms. Tops include growing point of the cane, a few of the upper nodes and accompanying leaves. On large farms the tops and dry leaves are burned off before the cane is processed for disposal, while on small farms the tops are cut for livestock feed.

Fig. 3.23 Sugarcane tops

Nutritive value

The feeding value of fresh cane tops is not very promising. It contains 3% CP and 45% TDN. It contains oxalate as a deleterious factor.

Inclusionv

The material serves as roughage in conjugation with concentrates. Sugar cane tops can be very well ensiled alone as well as with 0.5% urea. The silage is well acceptable to crossbred cattle and contains 47.8% TDN (Banerjee, 2000).

3.6 Panewar seed *(Cassia tora)*

Common names: Kuvadia seeds, Stinking Cassia, Chinese senna, Foetid cassia, Java bean, Low senna, Peanut weed, Sickle senna, Sicklepod

Local names: **Assamese**: Bon medelua, Dari diga, Medeluwa **Bengali**: Panevar, Chakunda Hindi: Panwar, Chakunda, Chakvat **Kannada**: Sogata **Malayalam**: Sakramardakam **Manipuri**: Thaunum namthibi **Marathi**: Takla, Tankala **Mizo**: Kelbe-on **Oriya**: Chakunda **Tamil**: Senavu **Urdu**: Panwar, Panevar, Tarota

Cassia is a small erect hairlesss shrub, about 1 m tall, commonly found growing wild on roadsides. According to rough estimate about 0.030 million tones seeds are available annually, but the collection is hardly 30-35% in India. It is good source of energy and protein (TDN 55% and CP 16%) for cattle.

Fig. 3.24 Panewar seeds

Deleterious factor

The seeds contain 0.083% crysophanic acid which is considered to be anti-nutritional factor. Kuvadia seeds have some odour that animals do not like which makes them unpalatable. The tannic acid content is very low i.e. 0.8%.

Detoxification

Most of the toxic factor is removed during fresh water treatment. Soaking the seeds in cold or hot water removes 28.3% and 37.5% chrysophanic acid, respectively.

Inclusion

As such they are not palatable but if seeds are boiled and mixed with other concentrates, animals very well consume it. The seeds after grinding can be incorporated at 15% level in the concentrate mixtures of bullocks and lactating cows (Punj, 1988). Unboiled panewar seeds can be incorporated up to the level of 10% in the concentrate mixture of cows without affecting milk yield and composition.

3.7 Palm male tree *(Borassus flabellifer)*

Common names: Palmyra palm, African fan palm, Borassus palm, Doub palm, Great fan palm, Lontar palm, Ron palm, Tala palm, Tal-palm, Toddy palm, Wine palm

Local names: Hindi: Taad, Tal, Trinaraaj **Marathi:** Taad **Tamil:** Talam **Malayalam:** Karimpana **Telugu:** Tatichettu **Kannada:** Olegari, Taalegari, Taatinimgu **Bengali:** Taala **Konkani:** Eroal **Urdu:** Taad **Gujarati:** Taad

Fig. 3.25 Palm male tree

Palm is a native of tropical Africa but cultivated and naturalized throughout India. India is one of the most palm tree rich countries in the world. Palm is mostly cultivated for its edible fruits and for its sap, which can be fermented into palm wine (toddy). Male palm tree bears flowers called 'Spadix' during two times in a year (September and January). One male palm tree yields 30 kg dry spadix per year. The flowers are produced in big clusters of long, white string-like inflorescence. The palm male flowers as green are fed to cattle. Dry male flowers become hard so can be used after grinding. It contains 10.4% CP and provides 40% TDN (Talpada et al., 2002). The main incriminating factor is its high content of tannin (8.7%). The dry male flowers are not palatable as such so they should be mixed with other palatable ingredients.

3.8 Warai bran *(Panicum miliaceum)*

It is a quick-maturing annual cereal whose grains are used for human consumption. Approximately 0.020 million tones of warai bran is annually available for animal feeding (Talpada *et al*., 2002).

Fig. 3.26 Warai

Nutritive value

Warai bran contains about 57.4% TDN and 6.24% CP. So it is average source of energy and protein. It has not been reported to contain any toxic effect and is quite palatable.

Inclusion

Warai bran can be incorporated up to 30% level in the concentrate mixture of crossbred calves and lactating cows (Punj, 1988). The bran can replace wheat bran/rice bran by suitably adjusting the protein contents in the ration.

3.9 Tea waste *(Camellia assamica)*

Fig. 3.27 Tea waste

Every year about 0.015 million tone of tea waste is available. The decaffeinated tea waste is available in plenty at the tea processing industry, particularly in Assam and West Bengal.

Nutritive value

The decaffeinated tea waste is a moderate source of energy and protein i.e. 58% TDN and 17.94% CP. Tea waste contains about 1.9% tannic acid.

Inclusion

The level of incorporation should not exceed to 10-15% because of its low TDN value. It is not very palatable and should therefore be mixed with more palatable ingredients for efficient use.

3.10 Tomato waste *(Lycopersicon esculentum)*

Common name: Tomato

Local names: Hindi: Tamatar **Tamil:** Takkali **Manipuri:** Khamen asinba

Fig. 3.28 Tomato waste

Tomatoes are one of the most common vegetables in India, with a production of 11.15 million tones (2009). Tomato waste is a product from canning industry available during preparation of Tomato sauces and catchup.

Nutritive value

The TDN and CP content is 55 and 15%, respectively.

Inclusion

It can be used up to 50% and 16% level, respectively in the ration of adult bullocks and milch cows without any adverse effect (Talpada *et al.*, 2002).

3.11 Banana root bulbs *(Musa paradisiaca)*

Common name: Banana

Local names: Hindi: Kela **Manipuri:** Laphoo tharo **Tamil:** Vaazha **Malayalam:** Vaazha

Fig. 3.29 Banana root bulbs

Banana is a tropical tree-like herb, with large leaves of which the overlapping bases form the so-called false trunk. India ranks first for banana production about 26.7 million tones (2009) in South Asian countries.

Nutritive value

It contains less protein but is a good source of carbohydrates. It provides about 50% TDN and 12% CP. Thus it is a good source of energy. It contains tannins.

Inclusion

After cleaning, it can be fed @ 20-25 kg daily to adult cattle (Talpada *et al*., 2002).

3.12 Potato waste

India is the third largest potato producer after China and Russian Federation, in the world. In India, potato production was estimated about 34391 thousand tones in 2010 (FAO). The amount of waste and by-product of potato industry is estimated to be around 12-20% of their total production. Potato processing generates waste in the form of peels, pulp and rejects. Potato peels, pulp and unpmarketable potatoes can be processed and incorporated into animal feed formulations. Thus the attempts to utilize the industrial wastes (potato peels, pulps and starch) and waste potatoes for animal feeding will provide additional feed options for the livestock and make potato growing and processing more economical.

Fig. 3.30 Potato waste

Nutritional value

Potato waste is an excellent energy source for feedlot cattle. It has energy value similar to corn and barley while being low in protein and calcium. Potato waste meal produced by drying and grinding whole potatoes, potato pulp and peelings and discarded potato chips contain 7.6% CP, 7.0% EE, 4% CF and 4% ash (Hulfan *et al*. 1982).

Inclusion

Large amounts of discarded potato can be fed to beef cattle after cattle have been adapted to such rations. The biggest problem that has managed with potato waste is the water, as raw potatoes contain about 80% water. Animal feed pellets can be prepared from unmarketable potato, barley and maize. Feed pellets were prepared by incorporating 10-20% unmarketable potatoes as an ingredient.

3.13 Citrus by-products (*Citrus spp*)

The term 'citrus by-product' includes numerous by-product feedstuffs, which vary according to the originating crop and method of production, that are an important component of ruminant feeding systems in many areas of the world. The genus *Citrus* includes several important fruits with the most important on a worldwide basis being sweet orange *(C. sinensis)*, lemon *(C. limon)* and grapefruit *(C. paradisi)*.

Fig. 3.31 Citrus peel waste

Citrus fruits are principally consumed by humans as fresh fruit or processed juice. After juice is extracted from the fruit, there remains a residue comprised of peel (flavedo and albedo), pulp (juice sac residue), rag (membranes and cores) and seeds. These components, either individually or in various combinations, are the source materials

from which citrus by-product feedstuffs (BPF) are produced. In India total availability of grape and orange waste is about 2.20 million tones.

Nutritive value

The nutrient content of citrus BPF is influenced by factors that include the source of the fruit and type of processing (Ammerman and Henry, 1991). The nutrient composition of citrus wastes varies depending on the type of waste and type of fruit. The selected values for total ash, crude fat, crude fibre, crude protein, NFE, total sugar, lignin and pectin ranges from 1.7-7%, 1.2-2.1%, 5.7-8.6%, 2.2-4.2%, 65-75%, 10.2-16.5%, 1.3-6.5% and 4.4-12.8% respectively, for different types of wastes (Javed Ali *et al*., 2010).

Inclusion

The fresh citrus pulp waste is palatable to cattle, when they are accustomed to the feed and a mature cow can consume about 10 kg per day. Dried citrus pulp has been used as the main energy source for beef cattle and heifers, and up to 45 percent has been used in rations. However, the pulp should not be used at high levels for milking cows as milk production tends to decrease. Digestibility trials with sheep show that its digestibility decreases when citrus pulp is included at levels in excess of 30 percent of the ration (Gohl, 1978). It is more advantageous to mix the fresh pulp with partially dried grass or with legumes which cannot be successfully ensiled on their own.

3.14 Azolla *(Azolla pinnata X Anabaena azollae)*

Local Name: Azolla

Azolla is a floating fern mostly utilized as bio-fertilizer for wetland paddy. It belongs to the family of *Azollaceae*. The fern Azolla, hosts a symbiotic blue green algae *Anabaena azollae*, which is responsible for the fixation and assimilation of atmospheric nitrogen. Azolla was found to be a very nutritive and cheap organic feed substitute for dairy cattle.

Fig. 3.32 Azolla fern

Nutritive Value

Azolla is rich in protein, almost 20-25% CP on dry weight basis. It is also found to contain essential minerals like Iron, calcium, magnesium, phosphorus, copper, manganese etc. apart from appreciable quantities of vitamin A and vitamin B12. It is also found to contain almost all the essential amino acids, many probiotics, bio-polymers and beta carotene.

Inclusion

The above mentioned bio-chemical constitution along with the rapid multiplication rate makes azolla an ideal organic feed substitute for livestock. Livestock can easily digest azolla due to its high protein content and low lignin content. Fresh azolla can be mixed with commercial feed in the ratio 1:1 or given directly to livestock. It was found that the milk production in cattle increased by 10-12% when they were fed with azolla. It is also found that azolla feeding improve the quality of milk.

Table 1: Proximate composition of concentrates (on dry matter basis)

Ingredient	CP (%)	EE (%)	CF (%)	NFE (%)	Ash (%)	NDF (%)	ADF (%)	Lignin (%)	ME (Mcal/kg)
Grains and seeds									
Maize	9.0	4.2	2.0	81.6	2.0	15.6	3.5	1.0	3.1
Sorghum	8.7	2.5	3.0	81.6	2.8	10.9	5.9	1.1	3.0
Wheat	11	2.6	2.0	81.5	2.4	16.0	4.0	1.2	2.9
Barley	12	2.5	5.9	79.0	2.5	20.0	7.0	2.0	2.8
Oats	11	4.4	15.5	63.3	5.0	13.8	5.0	2.9	2.6
Rice	9	1.5	10.1	72.5	8.4	12.5	4.3	1.5	2.8
Bajra	12	3.5	2.0	78.4	4.9	15.3	5.3	2.5	2.2
Black gram	29.0	1.0	5.3	62.1	5.6	17.0	2.0	7.0	2.5
Whole Cottonseed	22.0	17.3	18.0	40.0	3.7	48.0	42.7	17.45	3.3
Milling by-products									
Wheat bran	16.0	2.2	15.0	59.9	8.4	64.0	14.5	3.6	2.7
Rice bran (de-oiled)	17.0	1.5	18.0	48.1	18.2	38.2	11.9	4.3	2.1
Rice polish	14.0	14.0	12.0	49.2	11.8	19.4	15.0	3.0	2.7
Brewer's grain	25.4	6.5	14.9	48.4	4.8	44.0	23.0	5.5	2.4
Molasses									
Cane molasses	2.0	8.5	-	84.2	3.5	-	-	-	2.6
Plant protein concentrates									
Soybean meal	53.0	1.4	7.0	36.0	8.6	18.6	8.8	1.5	2.5
Groundnut oil cake	40.0	8.2	7.4	35.9	7.5	23.3	18.2	3.6	2.8
Groundnut meal	44.0	1.0	13.2	35.4	6.1	31.2	22.1	3.0	2.7
Cottonseed meal (decorticated)	41.0	9.2	6.3	37.8	8.2	28.0	20.0	6.0	2.8
Cottonseed meal (undecorticated)	22.8	9.2	24.1	36.6	7.3	53.9	41.2	11.5	2.5
Rapeseed meal	42.0	1.0	8.5	48.2	4.7	23.8	15.4	2.4	2.5
Rape seed cake	38.0	7.5	7.9	45.1	4.3	25.6	18.6	6.3	2.9
Sunflower meal (undecorticated)	31.0	6.7	25.3	27.2	14.0	39.9	26.9	8.2	1.9
Sesame oil cake	30.0	10.0	8.0	39.2	8.6	14.3	8.2	1.3	2.3
Coconut meal	30.0	0.5	9.0	54.5	9.0	37.6	22.2	3.1	2.3

Table 2: Proximate composition of roughages (on dry matter basis)

Ingredient	CP (%)	EE (%)	CF (%)	NFE (%)	Ash (%)	NDF (%)	ADF (%)	ME (Mcal/kg)
Hay (sun-cured)								
Sorghum *(Soghum bicolor)*	7.0	1.2	38.9	47.1	8.5	56.5	40.3	1.9
Wheat *(Triticum aestivum)*	3.5	1.0	41.5	43.0	11.0	72.3	43.5	1.9
Maize *(Zea mays)*	3.6	0.8	33.2	51.9	10.5	62.2	37.4	2.1
Oats *(Avena sativa)*	5.6	1.7	35.9	48.5	8.3	58.0	36.4	2.0
Cowpea *(Vigna sinensis)*	15.0	1.1	34.8	35.5	13.3	54.0	48.0	1.8
Peanut *(Arachis hypogaea)*	10.8	3.4	33.2	44.0	8.6	45.0	36.0	2.0
Rice *(Oryza sativa)*	8.2	1.0	32.0	43.1	15.7	71.7	48.7	1.9
Soybean *(Glycine max)*	15.0	1.3	29.1	42.6	12.0	59.0	42.8	1.9
Cassava *(Manihot esculenta)*	15.4	12.2	22.8	41.1	8.5	40.2	30.7	2.5
Lucerne *(Medicago sativa)*	16	1.4	29.4	35.2	12.7	43.6	35.8	2.0
Guar *(Cyamopsis tetragonoloba)*	25.2	0.9	13.8	43.6	16.5	48.9	33.3	1.8
Moth bean *(Phaseolus aconitifolius)*	15.0	1.2	29.1	42.7	12.0	61.6	45.0	2.1
Chickpea *(Cicer arietinum)*	12.2	2.3	33.0	42.3	10.2	55.1	40.5	1.8
Berseem *(Trifolium alexandrinum)*	15	6.6	30.6	36.0	12.1	49.6	50.4	2.4
Cogon grass *(Imperata cylindrica)*	4.7	1.7	38.1	49.2	6.3	63.3	43.6	1.1
Para grass *(Brachiaria mutica)*	5.3	2.0	34.6	45.8	12.3	64.4	30.4	1.7
Guinea grass *(Panicum maximum)*	7.6	1.2	38.1	37.1	16.0	60.5	39.7	1.7
Rhodes grass *(Chloris gayana)*	9.4	1.2	36.2	42.1	11.1	72.0	39.8	2.1
Pigeon pea *(Cajanus cajan)*	9.3	2.5	29.7	49.2	9.3	78.6	60.2	2.2
Garden pea *(Pisum sativum)*	10.9	1.9	29.2	50.3	7.7	67.2	45.9	1.8
Lemon grass *(Cymbopogon citratus)*	6.6	1.0	34.3	51.9	6.2	72.6	44.1	1.9
Marvel grass *(Dichanthium annulatum)*	4.6	0.9	38.9	46.1	9.5	63.8	41.1	2.1

Ingredient	CP (%)	EE (%)	CF (%)	NFE (%)	Ash (%)	NDF (%)	ADF (%)	ME (Mcal/kg)
Rice grass *(Leersia hexandra)*	6.3	1.5	31.4	45.9	14.9	66.2	36.2	2.2
Ulla grass *(Themeda arundinacea)*	1.9	1.0	49.0	43.5	4.6	-	-	1.7
Molasses grass *(Melinis minutiflora)*	4.4	1.1	37.8	46.6	10.1	69.8	40.4	1.9
Natal grass *(Rhynchelytrum roseum)*	5.6	1.4	41.6	43.4	8.0	66.8	36.9	1.9
Bermuda grass *(Cynodon dactylon)*	8.4	1.4	20.2	58.4	11.6	71.1	38.2	1.8
Plume grass *(Erianthus ravennae)*	1.9	1.6	43.9	45.7	6.9	78.5	50.7	1.6
Pili grass *(Heteropogon contortus)*	7.0	1.4	34.5	47.9	9.2	72.1	43.1	2.0
Dal grass *(Hymenachne interrupta)*	7.5	1.4	29.3	52.6	9.2	64.7	34.4	2.0
Sain grass *(Sehima nervosum)*	4.5	1.0	24.5	61.1	8.9	73.7	44.9	1.9
Mauritian *(Apluda mutica)*	5.5	1.0	34.8	51.0	7.7	-	-	1.3
Giant reed *(Arundo donax)*	8.8	1.1	33.0	44.7	12.4	68.3	38.6	1.9
Atylosia scarabaeoides	10.0	2.0	36.0	44.5	7.5	-	-	-
Musal grass *(Iseilema laxum)*	6.4	0.6	35.6	50.6	6.8	71.1	41.9	2.0
Baib grass *(Eulaliopsis binata)*	4.1	1.6	38.3	48.3	7.7	-	-	-
Chloris polydactyla	6.0	1.4	30.9	49.8	11.9	-	-	1.7
Chrysopogon lancearius	4.7	1.2	27.6	50.2	16.3	70.4	41.1	1.7
Anjan Grass *(Cenchrus ciliaris)*	4.9	0.8	32.9	51.2	10.2	-	-	1.9
East African stargrass *(Cynodon plectostachyus*)	5.4	0.9	37.6	45.3	10.8	-	-	1.8
Dolichos biflorus	10.6	1.8	16.2	58.3	13.1	69.8	45.2	1.7
Shama Millet *(Echinochloa colona)*	7.3	2.0	40.5	42.2	8.0	72.6	43.6	1.7
Ghiabati *(Ipomea pes trigis)*	13.6	3.5	27.0	44.0	11.9	-	-	1.8
Dropseed *(Marginatus sporobolus)*	6.1	1.0	34.3	49.8	8.8	66.4	40.6	1.4

Ingredient	CP (%)	EE (%)	CF (%)	NFE (%)	Ash (%)	NDF (%)	ADF (%)	ME (Mcal/kg)
Straws								
Wheat *(Triticum aestivum)*	3.0	1.0	35.2	50.8	10.0	74.2	49.6	1.4
Millet *(Setaria spp.)*	4.0	1.0	34.0	52.3	8.7	78.0	56.0	1.7
Proso millet *(Panicum miliaceum)*	4.5	1.2	33.1	45.9	15.3	65.8	39.9	1.5
Koda millet *(Paspalum scrobiculatum)*	2.3	1.4	34.3	49.4	12.6	69.1	41.2	1.9
Oats *(Avena sativa)*	3.4	0.9	34.9	53.3	7.5	74.2	49.6	1.6
Barley *(Hordeum vulgare)*	4.0	0.9	47.4	40.4	9.1	65.8	39.9	1.7
Rice *(Oryza sativa)*	4.6	1.5	42.2	32.1	20.6	66.2	51.6	1.4
Ragi *(Eleusine coracana)*	3.4	1.1	33.0	51.2	11.0	61.5	49.5	2.0
Peanut *(Arachis hypogaea)*	15.0	2.9	27.6	43.7	10.8	64.4	54.3	1.9
Pigeon pea *(Cajanus cajan)*	10.7	2.0	36.2	39.1	12.0	57.5	41.4	1.5
Chickpea *(Cicer arietinum)*	10.1	0.4	28.8	46.5	14.2	64.8	41.4	1.7
Dolichos biflorus	10.5	1.2	44.8	38.2	5.3	-	-	-
Pili grass *(Heteropogon contortus)*	3.2	1.5	37.4	48.2	9.7	73.7	45.0	1.8
Reed-grass *(Phragmites karka)*	3.8	1.0	29.8	49.6	15.8	-	-	-
Rottboellia exaltata	5.3	0.8	31.1	52.0	10.8	-	-	-
Schizachyrium brevifolium	4.7	1.0	26.1	56.1	12.1	-	-	-
Pasture, Range Plants and Forages Fed Fresh								
Maize *(Zea Mays)*								
Early vegetative	12.1	1.1	29.6	44.2	13.0	52.47	32.8	2.2
Late vegetative	8.2	0.9	27.2	51.9	11.8	-	-	-
Milk stage	6.4	0.9	29.9	51.2	11.6	-	-	-
Silage, milk stage	7.9	1.1	24.6	55.1	11.3	-	-	-

Ingredient	CP (%)	EE (%)	CF (%)	NFE (%)	Ash (%)	NDF (%)	ADF (%)	ME (Mcal/kg)
Oats *(Avena sativa)*								
Early vegetative	18.8	3.6	18.0	37.5	22.1	53.4	30.2	2.3
Late vegetative	14.6	2.1	32.9	36.5	13.9	-	-	-
Early bloom	10.8	1.8	31.0	46.0	10.4	-	-	-
Late bloom	9.2	1.8	34.8	44.8	9.4	-	-	-
Milk stage	6.4	2.3	28.7	53.3	9.3	-	-	-
Ripe	5.3	2.5	34.2	47.1	10.9	-	-	-
Silage, late bloom	7.3	1.6	40.8	40.6	9.7	-	-	-
Wheat (Non-irrigated)								
Early vegetative	11.2	2.6	25.2	50.4	10.6	-	-	-
Milk stage	9.3	2.3	15.3	65.4	7.4	-	-	-
Dough stage	7.3	1.3	34.7	48.0	8.7	-	-	-
Wheat (Irrigated)								
Early vegetative	23.3	3.4	21.5	40.2	11.6	58.1	29.8	2.6
Milk stage	11.8	2.0	31.6	41.7	12.9	-	-	-
Dough stage	6.4	1.4	26.3	56.2	9.7	-	-	-
Wheat straw silage	3.5	0.5	39.4	42.0	14.6		-	1.7
Pearl millet *(Pennisetum typhoides)*								
Full bloom	2.4	1.3	37.1	48.7	10.5	64.8	34.5	2.2
Mature	2.3	1.1	36.7	49.8	10.1	-	-	
Rice *(Oryza sativa)*								
Early vegetative	7.0	1.8	25.9	47.3	18.0	-	-	1.9
Dough stage	5.8	2.2	29.5	44.2	18.3	-	-	-
Rice straw silage	5.9	1.7	30	51.0	11.4	-	-	-

Ingredient	CP (%)	EE (%)	CF (%)	NFE (%)	Ash (%)	NDF (%)	ADF (%)	ME (Mcal/kg)
Sweet clover *(Melilotus indica)*								
Early vegetative	25.3	3.0	21.2	35.9	14.6	-	-	-
Late vegetative	23.3	2.7	19.3	40.3	14.4	-	-	-
Early bloom	23.0	2.5	27.4	33.5	13.6	-	-	-
Mature	16.0	1.9	35.2	38.0	8.9	-	-	2.1
Soybean *(Glycine max),* early vegetative	13.0	1.7	31.3	45.2	8.8	-	-	2.1
Sunflower (*Helianthus annuus)*, late vegetative	11.0	3.4	24.0	46.2	15.4	-	-	2.3
Barley *(Hordeum vulgare)*	8.4	1.9	31.8	43.4	11.4	47.7	29.3	2.2
Bluestem *(Dichanthium annulatum)*								
Early vegetative	8.8	1.2	35.0	45.1	9.9	-	-	-
Late vegetative	4.8	0.8	36.3	48.3	9.8	-	-	-
Early bloom	4.7	1.3	41.1	43.8	9.1	-	-	-
Late bloom	4.7	1.3	40.7	42.4	10.9	-	-	-
Milk stage	3.8	1.2	35.0	50.9	9.9	-	-	-
Mature stage	3.1	1.1	35.2	50.6	10.0	76.1	47.8	1.8
Guar *(Cyamopsis tetragonoloba*)								
Early vegetative	18.1	1.9	31.9	37.7	10.4	42.3	37.3	2.1
Late vegetative	12.8	1.5	29.5	49.3	6.9	48.4	42.5	-
Mature	8.6	1.7	30.0	47.0	12.7	55	47.7	-
Chick pea *(Cicer arietinum)*								
Late vegetative	11.3	2.2	27.2	47.9	11.4	-	-	2.2
Mid bloom	10.9	2.1	33.1	44.8	9.1	-	-	-
Milk stage	8.6	0.8	36.8	43.0	10.8	-	-	-
Safflower *(Carthamus tinctorius)*								

Ingredient	CP (%)	EE (%)	CF (%)	NFE (%)	Ash (%)	NDF (%)	ADF (%)	ME (Mcal/kg)
Early vegetative	17.0	1.6	10.9	58.3	12.2	-	-	-
Late vegetative	15.1	1.7	16.4	55.3	11.5	-	-	2.2
Milk stage	15.6	1.9	23.6	47.7	11.2	-	-	-
Mid bloom	12.2	2.1	25	50.4	10.3	-	-	-
Peanut *(Arachis hypogaea)*	9.8	0.7	34.1	48.1	7.3	-	-	2.4
Bluestem, Pitted *(Andropogon pertussis)*								
Late vegetative	5.4	1.2	36.5	44.6	12.3	-	-	-
Late bloom	3.9	1.1	35.7	48.0	11.3	-	-	-
Mature	3.2	1.3	36.5	47.7	11.3	-	-	-
Bluestem, Eastindies *(Andropogon ischaemum)*, mature	3.9	1.5	38.5	46.0	10.1	-	-	-
Beet root *(Beta vulgaris)*, early vegetative	13.6	2.8	6.3	60.3	17.0	-	-	2.8
Tickclover *(Desmodium gyroides)*, late vegetative	11.5	0.7	45.2	34.1	8.5	-	-	-
Tickclover, silver lead *(Desmodium uncinatum)*	12.8	3.4	29.6	45.1	9.1	-	-	-
Hyacinth bean (*Dolichos lablab)*, early vegetative	16.5	13.1	25.9	34.5	10.0	44.6	34.0	2.2
Water hyacinth *(Eichhorna crassipes)*								
Early vegetative	9.8	1.5	21.6	51.2	15.9	-	-	-
Whole silage	7.3	1.2	25.4	45.8	20.3	-	-	-
Koda millet *(Paspalum scrobiculatum)*								
Early vegetative	11.4	1.4	28.8	44.1	14.3	68.8	39.2	2.0
Early bloom	6.7	1.2	36.5	43.7	11.9	-	-	-
Dough stage	5.7	1.5	31.6	49.1	12.1	-	-	-
Sorghum *(Sorghum bicolor)* Silage	5.9	1.8	37.3	44.4	10.6	65.9	42.3	2.1
Fenugreek (*Trigonella foenum graecum),* early vegetative	15.7	2.1	13.1	60.3	8.8	-	-	2.1

Ingredient	CP (%)	EE (%)	CF (%)	NFE (%)	Ash (%)	NDF (%)	ADF (%)	ME (Mcal/kg)
Berseem (*Trifolium alexandrinum)*	17.4	1.9	25.9	40.6	14.2	42.4	30.5	2.3
Cowpea *(Vigna sinensis)*, mature	25.5	2.6	25.3	32.4	14.2	46.3	31.2	2.3
Fresh	15.4	1.2	32.3	49.9	1.2	64.4	30.6	-
Early vegetative	12.0	2.9	28.2	45.1	11.2	-	-	-
Early bloom	6.9	0.8	35.4	46.1	10.8	-	-	-
Rhodes grass *(Chloris gayana)*								
Early vegetative	11.9	1.5	33.5	43.0	10.1	-	-	-
Late vegetative	8.5	1.7	34.7	45.1	10.0	65.2	32.2	1.9
Signal grass *(Brachiaria eruci formis, B. erucaeformis)*	6.4	1.0	32.0	47.0	13.6	67.7	38.0	2.1
Ginger grass *(Cymbopogon caesius)*	5.9	5.2	37.1	42.4	9.4	-	-	-
Bermuda grass *(Cynodon dactylon)*								
Fresh	10.5	1.8	28.2	47.7	11.8	71.1	38.1	2.1
Early vegetative	21.9	2.7	18.0	44.8	12.6	-	-	-
Late vegetative	10.0	1.4	31.9	44.1	12.6	-	-	-
Mature	4.9	1.2	39.7	46.1	8.1	-	-	-
Stargrass *(Cynodon plectostachyus)*								
Early vegetative	9.4	0.9	30.4	48.1	11.2	72.0	43.0	2.0
Milk stage	7.2	0.9	32.7	51.0	8.2	-	-	-
Late bloom	5.4	0.9	37.6	45.3	10.8	-	-	-
Nut grass *(Cyperus rotundus)*	8.9	2.4	26.7	49.0	13.0	-	-	-
Crowfoot grass *(Dactyloctenium aegyptium)*								
Early vegetative	8.3	2.5	35.2	40.5	13.5	-	-	-
Milk stage	7.2	1.2	33.7	45.4	12.5	-	-	-
Mature	5.7	1.2	27.7	49.8	15.6	69.3	39.8	2.0

Ingredient	CP (%)	EE (%)	CF (%)	NFE (%)	Ash (%)	NDF (%)	ADF (%)	ME (Mcal/kg)
Kikiuyu grass (*Pennisetum clandestinum),* early vegetative	15.7	1.7	27.6	40.2	14.8	65.3	35.1	2.3
Pennisetum orientale, early vegetative	8.2	3.2	27.9	44.6	16.1	71.6	42.5	2.0
Pennisetum pedicellatum, late vegetative	2.9	1.6	35.8	49.6	10.1	75.8	47.4	1.8
Napier grass *(Pennisetum purpureum)*								
Early vegetative	15.6	1.2	27.4	36.7	19.1	-	-	-
Late vegetative	14.5	2.2	27.9	38.3	17.1	-	-	-
Mature	9.2	1.9	29.2	43.1	16.6	71.7	42.6	1.9
Post ripe	6.2	2.3	28.1	47.4	16.0	71.0	31.8	-
Mission grass *(Pennisetum polystachion)*								
Early vegetative	17.4	1.4	23	42.3	15.9	72.7	43.8	1.9
Late vegetative	12.2	1.7	31.4	44.3	10.4	-	-	-
Early bloom	6.4	1.1	28.6	46.3	17.6	-	-	-
Late bloom	5.4	0.8	33.0	47.3	13.5	-	-	-
Milk stage	4.9	0.9	29.9	49.7	14.6	-	-	-
Mature	2.8	1.1	34.5	49.8	11.8	-	-	-
Canary grass *(Phalaris minor)*								
Early vegetative	13.9	5.2	9.9	51.3	19.7	57.2	25.6	2.2
Mid bloom	10	3.7	21.2	47.6	17.5	-	-	-
Napier grass (*Pennisetum purpureum x Pennisetum glaucum)*, mature	2.9	1.8	37.2	51.1	7.0	-	-	-
Cabbage (*Brassica oleracea capitata)* Outside leaves	20	3.5	10.3	39.0	27.2	-	-	-
Cauliflower (*Brassica oleracea botrytis)*, Leaves	18.8	3.6	10.8	52.9	13.9	-	-	-

Ingredient	CP (%)	EE (%)	CF (%)	NFE (%)	Ash (%)	NDF (%)	ADF (%)	ME (Mcal/kg)
Crabgrass (*Digitaria longiflora)*, Longiflora, late vegetative	6.0	0.8	24.6	46.2	22.4	-	-	-
Crabgrass *(Digitaria sanguinalis)*, hairy, early vegetative	7.1	1.2	33.6	44.9	13.2	-	-	-
Pili grass *(Heteropogon contortus)*, mature	5.2	1.8	33.8	50.1	9.1	72.1	43.1	1.9
Dal grass *(Hymenachne pseudointerrupta),* early bloom	9.4	2.3	22.1	54.0	12.2	63.9	33.5	2.2
Tropical cupgrass (*Eriochloa procera)*, mature	5.8	0.6	25.3	50.9	17.4	-	-	-
Lovegrass, boer *(Eragrostis chloromelas)*, late vegetative	6.8	1.4	37	48.8	6.0	64.5	34.2	2.3
Stink grass *(Eragrostis cilianensis)*, late vegetative	11.6	2.5	31.7	43.7	10.5	68.4	36.5	2.2
Lovegrass (*Eragrostis superba),* late vegetative	5.3	1.1	39.4	47.3	6.9	65.2	35.2	2.2
Weeping lovegrass *(Eragrostis curvula)*, late vegetative	5.2	1.7	36.4	45.6	11.1	74	41.6	-
Early vegetative	5.1	3.0	30.7	51.0	10.2	-	-	-
Late vegetative	5.1	2.9	32.8	47.0	12.2	-	-	-
Early bloom	4.7	2.8	33.2	44.1	15.2	-	-	-
Mature	3.7	2.5	35.8	45.2	12.8	-	-	-
Aerial, fresh	10.2	2.2	23.6	47.3	16.7	-	-	-
Brachiaria decumbens	6.8	1.1	31.5	48.1	12.5	61.8	28.9	2.1
Calopo *(Calopogonium mucunoides)*	15.0	1.5	35.2	41.2	7.1	54.3	44.7	2.0
Early vegetative	7.5	2.5	31.5	41.4	17.1	-	-	-
Mid bloom	8.2	2.4	33.0	43.0	13.4	-	-	-
Mature	5.5	2.3	35.0	43.5	13.7	-	-	-
Bird-woodgrass (*Cenchrus setigerus)*, full bloom	4.4	1.1	34.1	43.6	16.8	72.0	33.6	1.9
Butterfly pea (*Centrosema pubescens)*	11.8	0.7	33.8	44.7	9.0	56.0	39.2	2.2

Ingredient	CP (%)	EE (%)	CF (%)	NFE (%)	Ash (%)	NDF (%)	ADF (%)	ME (Mcal/kg)
Chloris virgata	6.4	1.6	32.1	42.5	17.4	-	-	2.0
Convolvulus arvensis	13.2	2.5	29.7	46.8	7.8	-	-	-
Sunhemp *(Crotalaria juncea)*, midbloom	14.2	2.5	33.3	42.0	8.0	-	-	-
Early vegetative	4.5	2.2	33.3	51.0	9.0	-	-	2.3
Late vegetative	4.2	2.2	30.9	51.0	11.7	-	-	-
Midbloom	3.2	2.0	30.4	53.5	10.9	-	-	-
Jungle-rice *(Echinochloa colonum)*, midbloom	5.2	1.8	34.8	45.8	12.4	69.6	40.2	1.9
Eleusine compressa, full bloom	5.6	1.7	29.2	51.5	12.0	-	-	-
Late vegetative	7.6	1.1	33.6	42.6	15.1	-	-	-
Dough stage	6.4	2.1	28.8	50.3	12.4	-	-	-
Early vegetative	8.0	2.3	35.0	45.5	9.2	-	-	-
Late vegetative	7.5	3.4	32.2	47.7	9.2	-	-	-
Teosinte (*Euchlaena mexicana)*, mature	4.5	1.2	32.2	51.3	10.8	60.9	30.0	2.4
Meadow fescue *(Festuca spp.)*	8.9	4.2	24.0	53.7	9.2	-	-	-
Indigo (*Indigofera spicata)*, early vegetative	12.3	9.8	38.4	27.8	11.7	-	-	1.8
Early vegetative	7.0	3.3	34	47.4	8.3	-	-	-
Midbloom	5.5	3.2	32.4	50.7	8.2	-	-	-
Mature	3.5	1.6	39.4	48.7	6.8	-	-	-
Early vegetative	12.3	3.0	26.2	48.2	10.3	-	-	-
Late vegetative	10.5	3.3	25.6	47.5	13.1	-	-	-
Ischaemum rugosum, early bloom	7.1	2.5	29.8	50.5	10.1	-	-	-
Iseilema anthephoroides, mature	2.6	2.1	34.1	51.0	10.2	-	-	-
Early vegetative	12.2	1.7	31.4	44.3	10.4	-	-	-
Late vegetative	6.4	1.1	28.6	46.3	17.6	-	-	-

Ingredient	CP (%)	EE (%)	CF (%)	NFE (%)	Ash (%)	NDF (%)	ADF (%)	ME (Mcal/kg)
Early bloom	5.4	0.8	33.0	47.3	13.5	-	-	-
Full bloom	5.1	1.4	34.2	47.7	11.6	-	-	-
Milk stage	4.9	0.9	29.9	49.7	14.6	-	-	-
Mature	3.7	1.0	38.8	46.7	9.8	-	-	-
Early vegetative	6.0	1.4	36.6	45.8	10.2	-	-	-
Late vegetative	4.2	1.0	38.9	45.6	10.3	-	-	-
Mid bloom	4.1	1.1	41.1	44.3	9.4	-	-	-
Mature	3.2	1.1	37.4	47.7	10.6	68.0	35.4	-
Lasiurus sindicus, early vegetative	10.2	1.5	32.5	46.6	9.2	75.9	47.5	1.9
Grass pea *(Lathyrus sativus)*, milk stage	20.9	1.3	21.2	39.9	16.7	-	-	2.2
Rice grass *(Leersia hexandra)*, late bloom	5.8	2.1	28.4	47.0	16.7	-	-	-
Perennial rye grass *(Lolium perenne)*, early vegetative	12.2	3.6	13.3	63.1	7.8	-	-	-
Early vegetative	25.8	3.1	35.2	24.1	11.8	-	-	-
Late vegetative	20.3	3.1	25.7	36.1	14.8	-	-	-
Early bloom	18.1	2.6	24.9	43.5	10.9	-	-	-
Late bloom	16.9	3.5	29.0	41.8	8.8	-	-	-
Microstegium ciliatum, early bloom	6.0	1.8	37.3	45.2	9.7	-	-	-
Lyon bean (*Mucuna cochinchinensis)*, early vegetative	15.1	2.1	19.3	48.6	14.9	27.9	32.0	2.3
Broomrape *(Oroban haceae spp.),* early bloom	8.6	1.7	11.3	68.5	9.9	-	-	-
Panicum blue *(Panicum antidotale)*	13.9	2.7	34.6	36.6	12.2	71.7	42.6	1.9
Witchgrass *(Panicum spp*.), late vegetative	8.0	1.4	34.8	42.7	13.1	68.8	40.5	2.1
Panicum sweet (*Panicum laevifolium)*, late bloom	5.4	1.5	40.2	42.4	10.5	65.7	39.8	2.2

Ingredient	CP (%)	EE (%)	CF (%)	NFE (%)	Ash (%)	NDF (%)	ADF (%)	ME (Mcal/kg)
Early vegetative	14.0	2.7	41.8	25.4	16.1	-	-	-
Early bloom	7.7	1.7	37.3	39.4	13.9	-	-	-
Mature	4.7	0.7	31.6	51.6	11.4	-	-	-
Paspalum flavidum Fresh, aerial	9.1	1.2	35.4	43.0	11.3	62.3	38.5	2.0
Perotis indica, aerial	2.5	1.6	35.8	50.0	10.1	-	-	-
Polytoca digitata, late vegetative	8.0	1.0	33.8	44.2	13.0	-	-	-
Kudzu Tropical (*Pueraria phaseoloides),* late vegetative	9.2	1.1	42.3	40.3	7.1	55.4	32.4	2.1
Early vegetative	14.5	1.1	32.2	41.4	10.8	-	-	-
Late vegetative	13.0	1.1	32.8	43.0	10.1	-	-	-
Early bloom	11.0	1.5	31.3	43.6	12.6	-	-	-
Jhanii (*Scirpus articulatus)*, early vegetative	15.0	1.6	27.1	36.3	20.0	-	-	-
Saingrass (*Sehima nervosum)*, early bloom	5.6	1.6	35.9	42.1	14.8	73.7	44.9	1.9
Early vegetative	14.5	2.0	28.1	40.1	15.3	-	-	-
Late vegetative	13.6	2.0	24.5	40.9	19.0	-	-	-
Early bloom	12.0	2.2	33.4	37.6	14.8	-	-	-
Late vegetative	5.8	1.4	33.3	46.3	13.2	-	-	-
Vetiver *(Vetiveria zizanioides)*, mid bloom	12.7	1.5	30.5	42.3	13.0	68.4	41.3	2.2
Sissoo leave silage *(Dalbergia sissoo)*	3.2	3.3	27.5	51.6	14.4	-	-	2.7
Finger millet straw silage *(Eleusine coracana)*	3.6	1.5	38.8	46.5	9.6	78.9	46.8	2.1
Teonsinte silage *(Euchlaena mexicana)*	5.6	4.6	31.4	48.2	10.2	-	-	-
Spear grass whole silage *(Heteropogon contortus)*	4.5	1.9	33.8	50.3	9.5	72.0	42.9	1.8
Silage, late vegetative	6.9	1.9	27.8	45.5	17.9	-	-	-
Silage, early bloom	6.6	1.3	36.8	43.1	12.2	-	-	-

Ingredient	CP (%)	EE (%)	CF (%)	NFE (%)	Ash (%)	NDF (%)	ADF (%)	ME (Mcal/kg)
Silage, mature	6.6	1.6	32.6	43.7	15.5	-	-	-
Guinea grass silage *(Panicum maximum)*	5.2	1.5	38.7	44.7	9.9	-	-	-
Acacia leucophloea, Arini	15.3	2.8	18.8	55.8	7.3	-	-	-
Aeluropus lagopoides	5.7	2.3	33.2	44.4	14.4	66.9	42.8	2.0
Amaranthus spp., Amaranth	11.8	4.5	22.7	49.5	11.5	-	-	-
Anabasis multiflora	2.3	2.6	35.4	49.4	10.3	-	-	-
Andropogen taniger	6.1	1.8	30.5	49.3	12.3	61.2	36.9	2.0
Alysicarpus rugosus, Chainpea	14.7	1.8	39.1	34.6	9.8	51.4	38.1	1.9
Apluda Aristata	6.0	0.9	36.2	47.2	9.7	-	-	-
Apluda varia	8.1	2.4	32.6	42.2	14.7	-	-	-
Aristida depressa	5.0	1.5	37.1	44.4	12.0	62.5	39.5	2.0
Aristida funiculata (full bloom)	2.4	1.1	33.2	53.8	9.5	61.2	38.4	2.0
Arundo donax, Giant reed (full bloom)	13.2	1.9	28.2	41.6	15.1	65.6	35.5	2.1
Basella alba, Spinach	20.9	0.3	0.6	71.2	7.0	60.4	36.4	2.1
Palisade grass (*Brachiaria brizantha)*, late bloom	36.5	40.7	10.5	11.2	7.1	12.5	64.0	2.0

Table 3: Proximate composition of unconventional feeds (on dry matter basis)

Unconventional feeds	CP (%)	EE (%)	CF (%)	NFE (%)	Ash (%)	ME (Mcal/kg)
Niger seed cake (*Guizotia abyssinica*)	34.0	1.2	22.3	30.4	12.0	1.8
Rubber seed cake (*Hevea brasiliensis*)	35.0	12.1	7.1	34.8	10.5	2.4
Sun hemp seeds (*Crotalaria juncea*)	40.3	1.4	10.0	42.7	5.6	2.5
Dhaincha seeds (*Sesbania bispinosa*)	32.7	2.9	10.7	48.7	5.0	-
Corn gluten meal (*Zea mays*)	58.0	2.0	4.6	43.1	2.3	2.9
Ambadi cake (*Hibiscus cannabinus*)	23.4	4.2	22.6	38.3	9.9	2.2
Guar meal (*Cyamopsis tetragonoloba*)	50.0	5.2	7.2	35.9	8.8	2.9
Castor bean meal (*Ricinus communis*)	30.0	-	-	-	-	2.0
Pilludi cake (*Salvadora oleoides)*	24.0	-	-	50	-	1.9
Subabul seeds (*Leucaena leucocephala)*	29.0	7.5	11.4	40.9	4.4	2.3
Jowar gluten (*Sorghum vulgare)*	39.0	-	-	-	--	2.3
Jowar cake	10.0	6.6	12.1	69.5	-	2.4
Corn steep liquor	52.0	2.7		26.0	-	2.7
Isabgol lali (*Plantago ovata)*	32.2	21.3	1.0	28.1	-	-
Tamarind seed powder (*Tamarindus indica)*	12.0	7.4	26.4	44.4	3.5	2.3
Mango seed kernels (*Mangifera indica*)	6.0	8.9	2.8	74.4	5.4	2.0
Rain tree pods (*Samanea saman*)	16.7	0.7	14.5	69.6	2.4	2.3
Kusum cake (*Schleichera oleosa*)	20.9	7.4	9.0	56.9	5.8	2.8
Cocoa pods (*Theobroma cacao*)	6.3	0.5	24.0	61.4	7.8	2.2

Unconventional feeds	CP (%)	EE (%)	CF (%)	NFE (%)	Ash (%)	ME (Mcal/kg)
Vilayati Babul pods (*Prosopis juliflora*)	12.0	3.0	27.7	50.6	4.8	2.3
Damaged apple waste (*Malus domestica*)	12.0	-	-	-	-	2.2
Tapioca starch waste	12.0	0.6	26.9	66.9	3.4	2.2
Tapioca milk residue	3.5	3.5	2.5	-	-	-
Seaweed meal (*Sargassum* spp.)	10.0	0.8	10.3	48.0	-	-
Babul pods (*Acacia nilotica*)	12.0	2.3	12.3	67.0	5.3	2.0
Babul seed chuni	16.0	-	-	39.5	-	2.0
Jack fruit waste (*Artocarpus heterophyllus)*	7.7	-	14.1	65.3	-	0.72
Sugarcane bagasse (*Saccharum officinarum)*	3.5	0.3	50.1	46.1	2.5	1.3
Sugarcane bagasse pith	1.7	1.5	45.1	49.2	2.5	-
Sugarcane tops	3.2	1.7	33.5	50.3	8.5	1.6
Panewar seeds (*Cassia tora*)	16.0	7.4	4.6	60.7	9.1	2.0
Warai bran (*Panicum miliaceum*)	6.2	4.8	18.7	-	-	2.0
Tea waste (*Camellia assamica*)	17.9	-	-	-	-	2.0
Tomato waste (*Lycopersicon esculentum)*	15.0	18.0	-	40.0	-	2.0
Banana root bulbs (*Musa paradisiaca)*	12.0	2.8	47.2	42.2	-	1.8
Potato waste (*Solanum tuberosum*)	7.6	7.0	4.0	-	4.0	-
Citrus by-product (*Citrus Spp.)*	4.2	1.5	7.0	65.0	4.0	-

Table 4: Mineral contents of concentrates (on dry matter basis)

Ingredient	Ca (%)	P (%)	Mg (%)	K (%)	Na (%)	Cl (%)	S (%)	Co (ppm)	Cu (ppm)	I (ppm)	Fe (ppm)	Mn (ppm)	Se (ppm)	Zn (ppm)	Mo (ppm)
Grains and seeds															
Maize	0.02	0.35	0.12	0.42	0.02	0.08	0.10	-	1.00	-	59	7	0.07	21	0.7
Sorghum	0.03	0.25	0.17	0.47	0.01	0.06	0.11	-	10.00	-	284	44	-	34	2.3
Wheat	0.03	0.28	0.15	0.50	0.01	0.01	0.15	-	5.00	-	72	42	0.28	40	1.3
Barley	0.05	0.38	0.14	0.56	0.02	0.13	0.12	0.35	6.00	-	70	22	0.11	38	1.1
Oats	0.07	0.30	0.16	0.52	0.03	-	0.19	0.06	8.00	-	106	43	0.48	41	1.7
Rice	0.02	0.28	0.1	0.25	0.01	-	0.1	0.13	13.79	-	655.8	39.45	0.07	24.46	0.41
Rye	0.07	0.37	0.14	0.52	0.03	0.03	0.17		8.00	-	69.0	66.0	0.44	36.0	-
Bajra	0.08	0.38	0.59	0.97	0.10	-	0.19	0.31	6.07	-	234.7	33.35	0.19	28.78	0.54
Milling by-products															
Wheat bran	0.17	0.93	0.53	1.32	0.04	0.16	0.21	-	11	-	157	122	0.50	85	2.5
Wheat middlings	0.16	1.02	0.42	1.38	0.03	0.10	0.18	-	10	-	158	125	0.46	91	2.5
Rice bran	0.07	1.33	0.81	1.57	0.03	0.09	0.19	-	10	-	239	186	0.17	71	2.8
Rice polish	0.07	1.58	0.42	0.81	0.01	-	0.13	0.52	10.68	-	543.7	118.46	0.28	38.26	0.47
Brewer's grain	0.30	0.67	0.26	0.50	0.04	0.07	0.38	-	11	-	224	45	1.06	85	3.2
Distiller's grain	0.11	0.43	0.07	0.18	0.10	0.08	0.10	0.46	0.09	48.0	0.05	223.0	23.0	0.48	35.0
Distiller's soluble	0.22	0.83	0.33	1.10	0.30	0.26	0.44	-	8	-	178	27	0.39	65	1.9
Molasses															
Cane molasses	0.40	0.23	0.42	4.01	0.22	-	0.47	-	66	-	263	59	-	21	1.6

Ingredient	Ca (%)	P (%)	Mg (%)	K (%)	Na (%)	Cl (%)	S (%)	Co (ppm)	Cu (ppm)	I (ppm)	Fe (ppm)	Mn (ppm)	Se (ppm)	Zn (ppm)	Mo (ppm)
Beet molasses	0.15	0.03	0.29	6.06	1.48	-	0.60	-	22	-	87	66	-	18	0.5
Citrus molasses	1.92	0.12	0.12	1.10	0.06	0.08	0.10	-	8	-	151	9	-	11	0.9
Roots															
Turnip	0.59	0.26	0.22	2.99	1.05	0.65	0.43	-	21.0	-	118.0	43.0	-	-	-
Sugar beet	0.91	0.09	0.23	0.96	0.31	0.18	0.30	-	11	-	642	62	0.14	22	1.5
Tubers															
Cassava	0.28	0.19	-	0.26	-	-	-	-	-	-	9.0	20.0	-	-	-
Potato	0.49	0.29	0.11	1.04	0.26	0.19	0.11	-	11	-	1006	26	-	25	1.6
Carrot	0.27	0.27	0.20	2.80	1.04	0.50	0.17	-	10.0	-	120.0	31.0	-	-	-
Plant protein concentrates															
Soybean meal	0.22	0.63	0.30	2.12	0.04	0.10	0.34	-	17	0.12	169	39	-	72	3.8
Groundnut meal	0.18	0.60	0.32	1.32	0.03	0.10	0.32	-	13	0.07	302	33	0.21	54	3.8
Cottonseed cake (Decorticated)	0.17	0.60	0.37	1.13	0.02	0.06	0.23	-	7	-	94	18	0.14	37	1.3
Cottonseed cake (undecorticated)	0.12	0.30	0.29	1.1	0.03	-	0.22	0.42	9.97	-	450.6	0.29	0.11	31.22	0.35
Rapeseed meal	0.73	0.85	0.54	0.90	0.50	-	-	-	7.0	-	190.0	60.0	1.04	47.0	-
Sunflower meal	0.33	0.93	0.63	1.50	0.04	0.12	0.39	-	32	-	298	45	0.50	88	2.7
Safflower meal	0.20	0.60	0.39	1.21	0.04	-	0.32	-	22	-	319	30	-	77	2.3
Sesame meal	1.33	0.90	0.50	1.35	0.04	0.07	0.35	-	-	-	100.0	52.0	-	32.0	-
Coconut meal	0.15	0.50	0.33	1.62	0.04	-	0.36	0.14	15.0	-	1651.	71.0	-	-	-
Linseed meal	0.40	1.20	0.55	1.22	0.09	-	0.37	-	19	-	369	39	1.05	69	2.0

Table 5: Mineral contents of roughages (on dry matter basis)

Ingredient	Ca (%)	P (%)	Mg (%)	K (%)	Na (%)	Cl (%)	S (%)	Co (ppm)	Cu (ppm)	I (ppm)	Fe (ppm)	Mn (ppm)	Se (ppm)	Zn (ppm)	Mo (ppm)
Hay (sun-cured)															
Jowar hay	0.83	0.75	0.28	0.97	0.01	-	0.09	0.19	5.96	-	472.19	30.54	0.08	33.77	0.39
Grass hay	0.42	0.25	0.18	0.16	0.01	-	0.12	0.36	4.23	-	571.37	62.23	0.14	23.31	0.17
Apluda mutica	0.20	0.034	0.003	0.72		-	-	0.042	10.0	-		7.5	--	14.0	-
Peanut *(Arachis hypogaea)*	1.24	0.65	0.21	0.51	0.69	-	-	-	-	-	-	-	-	-	-
Oats *(Avena sativa)*	0.30	0.35	0.26	1.51	0.18	0.52	0.25	0.07	15.0	-	155.0	64.0	0.17	39.0	-
Bermuda grass *(Cynodon dactylon)*	0.47	0.17	017	1.53	0.08	-	0.21	0.12	-	0.12	290.0	-	-	-	-
Soybean *(Glycine max)*	1.29	0.28	0.79	1.07	0.09	0.15	0.24	0.09	9.0	0.24	292.0	106.0	-	24.0	-
Lucerne *(Medicago sativa)*	2.00	0.40	0.30	2.26	0.17	0.37	0.30	0.23	11.0	-	195.0	31.0	0.54	24.0	-
Berseem *(Trifolium alexandrinum)*	2.00	0.38	0.43	1.62	0.19	0.32	0.17	0.16	11.0	0.25	184.0	73.0	-	17.0	-
Wheat *(Triticum aestivum)*	0.15	0.20	0.12	1.00	0.21	0.22	-	-	-	200.0	-	-	-	-	-
Cowpea *(Vigna sinensis)*	2.33	0.88	0.45	2.26	0.27	0.17	0.35	0.07	-	-	300.0	-	-	-	-
Maize *(Zea mays)*	0.42	0.14	0.37	1.13	0.01	-	0.13	0.38	9.35	-	616.56	53.41	0.08	39.55	0.35
Straws															
Peanut *(Arachis hypogaea)*	1.29	0.12	0.58	1.12	0.03	-	0.13	0.75	10.93	-	1345.22	71.0	0.09	18.72	0.19
Oats *(Avena sativa)*	0.24	0.06	0.18	2.57	0.42	0.78	0.23	-	10.0	-	175.0	37.0	-	6.0	-
Barley *(Hordeum vulgare)*	0.30	0.30	0.23	2.37	0.14	0.67	0.17	0.07	5.0	-	201.0	17.0	-	7.0	-
Bean, mung *(Phaseolus aureus)*	0.81	0.13	0.09	0.3	-	0.07	0.7	3.01	-	117.9	10.42	0.38	20.4	0.39	-
Wheat *(Triticum aestivum)*	0.30	0.10	0.15	1.23	0.04	-	0.14	0.45	3.96	-	812.03	63.24	0.15	11.89	-

GLOSSARY

Acid Detergent Fibre (ADF)

Acid detergent fiber is the fibrous, least-digestible portion of roughage. ADF consists of the highly indigestible parts of the forage, including lignin, cellulose, silica and insoluble forms of nitrogen. Roughages high in ADF are lower in digestible energy than roughages that contain low levels of ADF. As ADF levels increase, digestible energy levels decrease.

Acid Detergent Insoluble Nitrogen (ADIN)

Acid detergent insoluble nitrogen is a measure of the nitrogen remaining in the acid detergent fibre residue of a feed sample. While some ADIN occurs naturally in all plant material, it is usually considered to be an indicator of heat damage that can occur during storage or processing. Excessive heating of forages and grains causes some of the nitrogen to become irreversibly bound in the fibre. Nitrogen in excessively heated samples is usually indigestible or poorly digested by rumen microbes. It has been estimated that as much as 70% of the protein bound with the fibre is unavailable to the animal. Feed labs may report acid detergent fibre protein (ADF-P%) or acid detergent insoluble protein (ADIP% or ADICP%), which can be expressed as a percentage of total dry matter or as a percentage of total nitrogen/protein.

The concentration of ADIN is used to determine protein availability in heated feeds. Estimates of crude protein (CP) available to the animal can be adjusted by using the following guideline. If ADIN levels are below or equal to 10%, the crude protein level does not require adjustment, as these levels represent naturally occurring ADIN: for example, CP% = 10% and ADIN = 10%, then CP% = 10%. If reported ADIN is above 10%, then subtract 10% from the ADIN value and use the difference to adjust the crude protein available: for example, if ADIN = 20%, then 20 - 10= 10% ADIN; 10% CP *(10/100)= 1, so 10% CP - 1% = 9% CP available.

Acid Detergent Insoluble Protein (ADIP) or acid detergent insoluble crude protein (ADICP)

It is the insoluble protein fraction, which is unavailable to the animal due to heat damage. It is expressed as a per cent (%) of total protein. ADIP% may be reported as acid detergent insoluble nitrogen (ADIN%) or acid detergent fibre protein (ADF-P%).

As-fed Basis

It represents the sample's moisture level before drying. Most feed reports will have results stated on a wet and a dry basis. The wet basis may be referred to by the terms: As fed, As is or As received.

Bypass Protein

Bypass protein refers to the portion of intake protein in a feed that is not broken down in the rumen but is digested directly in the small intestine. Bypass protein is another name for undegradable intake protein (UIP), rumen undegradable protein (RUP) or escape protein.

Carbohydrates

Chemical compounds containing carbon, hydrogen and oxygen. Carbohydrates in plants can be divided into those that serve as storage and energy reserves in plants and are available for metabolism (sugars, starch, pectin and some cellulose, for example barley grain) and those that are structural (for example, fibrous cellulose, hemi-cellulose and lignin, for example, straw). Carbohydrates are a major source of energy in livestock feeds.

Cellulose
Cellulose is one of the major structural materials in the plant cell walls that can be utilized by microorganisms in the rumen.

Chelated Minerals
Chelated minerals are a group of organic minerals that are actually classified as proteinates, chelates and other complexes, depending on the mineral's molecular structure. A chelated mineral is a mineral such as copper or zinc that is bonded by two or more chemical bonds with peptides (small protein molecules) or amino acids. Each has a varying level of absorption and efficacy.

Concentrates
Concentrate feeds high in energy and low in fibre, for example, barley, oats, wheat, canola meal, soybean meal and molasses.

Conventional Chemical "Wet Chemistry" Analysis
Traditional laboratory methods used to analyze feed samples involve various chemical, drying and burning procedures to determine the major chemical components with the feed sample. Wet chemistry procedures are based on sound chemical and biochemical principles and take considerably more time to complete than the newer electronic methods. The analysis results in the sample being destroyed. The wet chemistry analysis is the most exact and the standard that other analyses are compared to. Accurate results depend on good sampling techniques when the samples are gathered, proper handling of samples after collection and good analytical procedures in the laboratory conducting the evaluation.

Crude Fibre
A chemical method used to describe the indigestible portion of plant material. However, some of these substances can be partially digested by microorganisms in the rumen of cattle. The higher the fibre, the lower the energy content of the feed. It is not a very useful value. The practice of analyzing for it in feeds for ruminants is declining, but it is still commonly used for monogastrics.

Crude Protein
The total amount of protein present as calculated from the total nitrogen present. Unless otherwise stated, protein values given in lab reports, feed tables and feed tags are crude protein. Laboratory analysis measures the total amount of nitrogen present in a feed. The % nitrogen is converted to % protein by multiplying by 6.25.

Degradable Intake Protein (DIP)
It is a portion of intake protein that is digested or degraded in the rumen by microbes to ammonia and amino acids. DIP is expressed as a percentage of CP. DIP consists of rumen soluble nitrogen, non-protein nitrogen, plus soluble true protein. It may be referred as rumen degradable protein (RDP).

Digestible Dry Matter (DDM)
Digestible dry matter is an estimate of digestible fibre in a forage sample. Different laboratories may use different formulas to calculate this value, one common formula is: %DDM = 88.9-(0.779 x %ADF (dry basis)).

Digestible Energy (DE)
Digestible energy is the gross intake energy minus the fecal energy (DE = GE - fecal energy). Digestible energy gives an indication of the actual amount of energy the animal

has available for use. However, it only partially accounts for energy losses in the process of the utilization of nutrients. It also tends to over-value low quality feeds relative to high quality feeds.

Digestible Protein (DCP)

The amount of crude protein actually absorbed by the animal (crude protein minus the protein lost in feces).

Digestion

Digestion refers to all changes that feed undergoes within the digestive tract, with the end result being that the broken down products are absorbed from the digestive tract for use by the animal.

Dry Matter (DM)

Dry matter is the total weight of feed minus the weight of water in the feed, expressed as a percentage. This also referred to as: dry, dry basis, dry result or moisture-free basis. You can convert from As-fed basis or dry matter basis by using the following formulas:

DM basis = (As-fed basis x Dry Matter %) / 100 or
As fed basis = (DM basis x 100) / Dry Matter%.

Dry Matter Intake (DMI)

All the nutrients contained in the dry portion of the feed consumed by animals. Dry matter intake can be measured in feeding studies by weighing the total ration fed and the amount of feed left by the animal. Feeding studies have shown that as the per cent of neutral detergent fibre (NDF) increases in forages, animals consume less. Therefore, the per cent NDF can be used to estimate dry matter intake (DMI (as a per cent of body weight) equals relative feed value as % of body weight divided by % NDF).

DMI (% of body weight) = 120/NDF (% of DM)

Equivalent Crude Protein from Non-protein Sources (ECP from NPS)

The theoretical amount of crude protein value from NPN compounds. For example, urea containing 45 % nitrogen contains 281 % equivalent crude protein (i.e., 45% x 6.25 = 281%).

Feed Efficiency

The amount of feed required to produce one unit of product, such as pounds (kg) of feed to produce one pound (kg) body weight gain, or one pound (kg) of milk or one dozen eggs.

Gross Energy (GE)

Gross energy is the total energy in a feed. It is determined by measuring the amount of heat produced when a feed is completely oxidized in a bomb calorimeter. It is not a very useful measure since the gross energy in most common feeds is about the same, for example, GE in oat grain = GE in oat straw.

Heat Damage

The result of heating in feeds that essentially binds nitrogen to the fibre portion of the feed making it partially or wholly unavailable. The digestible energy of the feed may also be reduced; the net effect is reduced feed quality or feeding value. See Acid Detergent Insoluble Nitrogen.

Hemi-cellulose
Hemi-cellulose is the polysaccharide fraction existing in the cell wall of the plant. It is similar to cellulose but only partially digestible in the rumen.

In Vitro
This technique refers to a feed sample that is digested in test tubes or tested outside the animal. An *in vitro* digestion study occurs in the laboratory, not in the animal.

In Vivo
This refers to a digestion study of a feed that is tested inside the animal's rumen or stomach.

Lignin
Lignin is a complex indigestible substance that is a major structural component of mature plants. It is contained in the fibrous portion of stems, leaves, cobs and hulls of plants.

Macro-minerals
Macro-minerals, also called major minerals, are required in gram (g) quantities if the animal is to live and function. Macro-minerals perform specific roles in the body's structure and functions. The following seven macro-minerals are essential to animals (the mineral names are followed by their chemical symbols): calcium (Ca), phosphorus (P), sodium (Na), magnesium (Mg), potassium (K), sulphur (S), chlorine (Cl).

Megacalorie (Mcal)
Units used to describe quantities of energy. The energy content of feed can be calculated and expressed in a number of different forms. It is most often calculated for cattle as a unit of heat expressed in megacalories. 1 Megacalorie (Mcal) = 1,000 Kilocalories (Kcal).

Metabolizable Energy (ME)
Metabolizable energy is the digestible energy intake minus the energy in the urine minus the energy in the gaseous product of digestion:

ME = DE - (energy in urine) - (energy in gaseous product of digestion).

The ME value of individual feeds is rarely measured. Measuring the amounts of energy lost in gaseous form and in the urine is more difficult than measuring digestible energy. Therefore, conversions formulas are often used by nutritionists when ME values are needed. The common formula used to estimate ME in beef feedstuffs is ME = 0.82 x DE.

Metabolizable Protein (MP)
Metabolizable protein is protein (amino acids) that is actually absorbed from the gut. MP consists of protein in the rumen microorganisms, feed protein and any protein that bypasses digestion in the rumen (undegradable intake protein (UIP). The concept of protein degradability has led to a new protein system called the metabolizable protein (MP) system. In this system, you balance to meet the requirements of the microbes and the animal, paying attention to the DIP and UIP fractions of the feed.

mg/kg
This is the units of concentration, for example, milligrams in a kilogram. This measure is the same as parts per million (ppm) because 1 kilogram is 1 million milligrams. For example 10 mg/kg = 10 ppm.

Micro-minerals
This is also called trace minerals, are required in milligram (mg) or microgram (μg) amounts. They are found in animal tissues and feeds in very low concentrations. They often serve as components of enzyme cofactors or hormones. Examples of micro or trace minerals are cobalt, iodine, zinc, copper, manganese and selenium.

Moisture-free Basis
This is the concentration of a nutrient in the completely dry portion of the feed. Expressing the nutrient content in this way allows you to make comparisons between feeds that have different moisture contents. This also referred as dry, dry basis, dry result or dry matter basis. To convert moisture-free (dry basis) values to as fed values, use the following formula:

Analyzed value (as fed) = Analyzed value (dry) x 100% moisture /100.

National Research Council (NRC) Tables
Sets of tables published by the National Research Council/ National Academy of Sciences (U.S.) giving the amounts of each nutrient required by an animal for body maintenance, growth and production.

Near Infrared Reflectance Spectroscopy (NIRS) Analysis
Near infrared reflectance spectroscopy is a rapid and low-cost computerized method to analyze forage and grain crops for their nutritive value. NIRS uses near infrared light, instead of chemicals as in conventional "wet chemistry" methods, to determine protein, fibre, energy and mineral content. The NIRS method of determining forage nutritional content is about 25 times faster than conventional wet chemistry procedures and less expensive. Accuracy still depends on good sample collection and storage and the consistent drying, grinding and mixing of samples before analysis. The calibration set used must be developed from an adequate number of wet chemistry samples, similar to those being analyzed. Without proper calibration, the NIRS analysis can have serious errors.

Net Energy (NE)
Net energy is metabolizable energy minus the heat increment of feeding: NE = ME - heat increment of feeding. The heat increment of feeding is the heat produced when feed is ingested and utilized. The net energy system divides energy requirements into net energy for maintenance (NEm) and net energy for growth (NEg) or net energy for lactation (NE_l) in milking cows.

The NE system is more accurate than other energy systems because it gives the net value of each feed after accounting for all the energy losses in the process of feed and nutrient utilization. However, most published NE values for feeds are not measured values but values converted from the DE system, so they are subject to the same errors in estimation of digestibility as the DE system. The NE system is becoming increasingly popular for ration formulation.

Net Energy for Maintenance (NE_m)
An estimate of the energy value of a feed used to keep an animal in energy equilibrium, neither gaining weight nor losing weight.

Net Energy for Growth (NE_g)
An estimate of the energy value of a feed used for body tissue gain (weight gain) above that required for maintenance.

Net Energy for Lactation (NE_l)
An estimate of the energy value of a feed used for maintenance plus milk production during lactation and for maintenance plus the last two months of gestation for dry, pregnant cows.

Neutral Detergent Fibre (NDF)
Neutral detergent fiber is commonly called “cell walls.” NDF gives a close estimate of fibre constituents of feedstuffs as it measures cellulose, hemi-cellulose, lignin, silica, tannins and cutins. Neutral detergent fibre has been shown to be negatively correlated with dry matter intake. As the NDF in forages increases, animals will be able to consume less forage. NDF is used in formulas to predict the dry matter intake of cattle (see Dry Matter Intake).

Nitrogen-free extract
Nitrogen-free extract was determined on dry matter basis as:

% NFE = 100 - (%CP + %CF + %EE + %ash)

Nitrate % (NO_3%)
Nitrate is also part of the nitrogen-containing feed fraction; however, it contributes very little to the crude protein percentage. Nitrates can accumulate in a crop that has been subjected to drought, hail, frost or high levels of nitrogen fertilization. Feeds containing high levels of nitrate (greater than 1 %) can be toxic to ruminants.

Non-protein Nitrogen (NPN)
Non-protein nitrogen is the nitrogen comes from other than organic protein sources (e.g. plant or animal) that can be used by ruminants to make animal protein. NPN sources are compounds like urea and ammonia.

Nutrient

Nutrient is an element, compound or group of compounds that can be used as nourishment by an animal.

Organic Matter
The total weight of the feed minus the weight of the mineral matter (or ash) in the feed.

Palatability
Taste appeal, the degree of acceptability of a feed to livestock.

Parts per Million (ppm)
1 milligram per kilogram = 1 ppm = 1 pound per million pounds.

% Moisture (% H_20)
This indicates the proportion of water in the sample, calculated by weighing the sample before and after complete drying. For example, if a sample of silage weights 100 grams before drying and 35 grams after, it is assumed that 65 grams of water were lost. The original sample was therefore 65% moisture. Conversely, the dry matter % of the sample was 35%.

pH
The degree of acidity or alkalinity of a solution: pH levels below 7 are acidic and above 7 are alkaline. The more fermentation that has occurred in silage, the lower the pH will be. The lower the pH, greater will be the acidity. The proper preservation of silage depends

largely on the moisture content and pH. With high moisture silage (60 to 75%), the pH should be below 4.5. With low moisture silage (50%), the pH may be higher.

Probiotics

Probiotic can be a live (viable) culture of microbial species, a dead (non-viable) product of microbial fermentation or an extract of plant origin. The function of a probiotic is to improve the growth and development of the normal, desirable microbial population in the gut, allowing them to maintain domination over the undesirable organisms. There is evidence, however, that probiotics do form beneficial temporary colonies that may assist the body in the same functions as the natural flora, while allowing the natural flora time to recover from depletion. The probiotic strains are then progressively replaced by naturally developed gut flora.

Protein

Complex compounds containing carbon, hydrogen, oxygen, nitrogen and usually sulphur are composed of one or more chains of amino acids. Proteins are essential in the diet of animals for growth, lactation and reproduction. In ruminants (for example, cattle), the rumen microbes break down about 80 % of the protein in the feed to ammonia, carbon dioxide, volatile fatty acids and other carbon compounds. The microbes then use the ammonia to synthesize their own body protein. As feed is passed through the rumen into the rest of the digestive tract, the micro-organisms containing about 65 % high quality protein are washed along too. The ruminant obtains most of its required protein by digesting these micro-organisms.

Relative Feed Value (RFV)

Relative feed value has no units but is a way to compare the potential of two or more like forages for energy intake. Relative feed value is an index of forage quality calculated from ADF% and NDF%. Forages with NDF values of 53% and ADF values of 41% represent the value of 100. Forages with values greater than 100 are of higher quality, and forages with a value lower than 100 are of lower quality. Dry matter intake (DMI) and digestible dry matter (DDM) values of forages can be used to calculate RFV or use the formula with ADF and NDF values.

- RFV=(%DDM x %DMI)/1.29 or
- RFV = [(88.9 - 0.78 x ADF%)) x (120/NDF%)]/ 1.29

Rumen

Rumen is also called the forestomach or paunch. It is the first compartment of four compartments of a ruminant animal's stomach. The rumen serves as the primary site of food fermentation in the entire digestive tract. Protein, non-structural carbohydrates (including starch, sugar and pectin) and structural carbohydrates (including hemi-cellulose and cellulose) are fermented and digested by ruminal microbes for the duration of their time in the rumen.

Rumen Degradable Protein (RDP)

Rumen degradable protein is that portion of the consumed protein digested in the rumen. It may also as be referred to as degradable intake protein (DIP).

Rumen Undegradable Protein (RUP)

See undegradable intake protein or bypass protein.

Starch

Starch is the main carbohydrate component of the dry matter in grain. It contains long chains of glucose molecules, which are easily broken down by rumen microbes.

Soluble Protein
This estimates the amount of crude protein that will readily dissolve when the feed enters the rumen. This protein fraction represents the portion of crude protein that is rapidly degraded or digested by rumen microbes. Higher soluble protein levels are often found in silages that are put up very wet (less than 30% dry matter).

Supplement
A product that contains high levels of one or more nutrients and that is fed to correct or prevent deficiencies of these nutrients.

Total Digestible Nutrients (TDN)
The concept of total digestible nutrients comes from the old system of measuring available energy of feeds and energy requirements of animals involving a complex formula of measured nutrients. It is very hard to measure, but is used widely in some parts of the U.S. and Canada. TDN values are usually quoted as percentages for feeds and as amounts per day for requirements. The values are usually calculated on feed analysis reports. The simplest and most commonly used formula for estimating TDN is TDN = DE/0.044. One kilogram of TDN is equivalent to 4.4 megacalories of DE.

Total Mixed Ration (TMR)
Consists of all the feed ingredients mixed together to form the ration allowance for the animal.

Undegradable Intake Protein (UIP)
This is the portion of intake protein that escapes rumen degradation and is digested directly in the small intestine. About 80 to 85 % of the microbial bacterial protein and UIP or true protein that flows out of the rumen is digested in the small intestine. UIP is expressed as a percentage of CP. It is also called bypass protein or escaped protein or rumen undegradable protein since it is the amount of feed protein that escapes the rumen to the small intestine.

ABBREVIATIONS

ADF	....	Acid Detergent Fibre
ADICP	....	Acid Detergent Insoluble Crude Protein
ADIN	....	Acid Detergent Insoluble Nitrogen
ADIP	....	Acid Detergent Insoluble Protein
CF	....	Crude Fibre
CP	....	Crude Protein
CT	....	Condensed Tannins
DCP	....	Digestible Crude Protein
DDM	....	Digestible Dry Matter
DE	....	Digestible Energy
DIP	....	Degradable Intake Protein
DM	....	Dry Matter
DMI	....	Dry Matter Intake
ECP	....	Equivalent Crude Protein
EE	....	Ether Extract
GE	....	Gross Energy
HCN	....	Hydrocyanic Acid
IFN	....	International Feed Number
IVDMD	....	*In vitro* Dry Matter Digestibility
Mcal	....	Megacalorie
ME	....	Metabolizable Energy
MMT	....	Million Metric Tonne
MP	....	Metabolizable Protein
MT	....	Metric Tonne
NDF	....	Neutral Detergent Fibre
NE	....	Net Energy
NE_g	....	Net Energy for Growth
NE_l	....	Net Energy for Lactation
NE_m	....	Net Energy for Maintenance
NFE	....	Nitrogen Free Extract
NIRS	....	Near Infrared Reflectance Spectroscopy
NPN	....	Non-Protein Nitrogen
NPS	....	Non-Protein Sources
NRC	....	National Research Council
ppb	....	Parts Per Billion
ppm	....	Parts Per Million
RDP	....	Rumen Degradable Protein
RFV	....	Relative Feed Value
RH	....	Rice Husk
RUP	....	Rumen Undegradable Protein
TDN	....	Total Digestible Nutrients
TMR	....	Total Mixed Ration
UIP	....	Undegradable Intake Protein

BIBLIOGRAPHY

Agrawal, D.K. 2002. Scope of unconventional feeds in livestock production. In: *Role of Unconventional Feeds in Future Livestock Production*. CAS in Animal Nutrition, IVRI, Izatnagar. p: 1-8.

Ammerman, C.B., Henry, P.R., 1991. Citrus and vegetable products for ruminant animals. In: Proceedings of the Alternative Feeds for Dairy and Beef Cattle Symposium, St. Louis, MO, USA, pp. 103–110.

Arora, S.P., Jaikishan and Chopra, R.C. 1983. Nutritive value of mesta cake for ruminants. *Indian J. Dairy Sci*., 36: 430-431.

Banerjee, G.C. 2000. Use of unconventional livestock feeds in India. In: *Feeds and principles of Animal Nutrition*. Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi.

Chaudhury, J., Singh, D.P. and Hazara, S.K. 2005. Sun hemp (*Crotalaria juncea L*) Website: www.assamagribusiness.nic.in/Sunnhemp.pdf

Chennubhotla, V.S.K., Kaliaperumal, N., Kalimuthu, S. and Ramalingam, J.R. 1991. Commercially important seaweeds of India, their occurrence, chemical products and uses. In: *Marine Fisheries Information Service*, No. 107, ICAR. Website: www.eprints.cmfri.org.in/4341/1/Article_04.pdf

FAO. Selected Indicators of food and agricultural development in the Asia-Pacific Region 2000-2010.

FAO (AFRIS). Animal Feed Resources Information System – Food and Agriculture Organization of the United Nations. Website: http://www.fao.org/ag/aga/agap/frg/afris/default.htm

Feedstuffs 2005. Acacia pods have used as feed for ruminants. Website: http://goliath.ecnext.com/coms2/gi_0199-4696036/Acacia-pods-have-use-as.html

Gohl B 1.1978. Citrus by-products for animal feed. In: Ruminant nutrition: *Selected articles from the World Animal Review*. FAO Animal Production and Health Paper 12. FAO (Food and Agriculture Organization of the United Nations), Rome, Italy. pp. 41-44.

Habit, M.A. and Saavedra, J.C. (Eds.), 1988. The Current State of Knowledge on *Prosopis juliflora*. Plant Production and Protection Division, FAO, Rome.

Hulfan, H. W.,Proudfoot, F. G. and Zarkadas C. G. 1982. Potato Waste Meal. Compositional Analysis Can. J. Anim. Sci. 62, pp. 116l-1169

Javed Ali, Hamida Abid and Arshad Hussain, 2010. Study on some micronutrient composition in peels of different citrus fruits grown in NWFP. J. Chem. Soc. Pak., Vol. 32, No. 1, pp. 83-86.

Mannetje, L. 2004. *Crotalaria juncea L.* Website: http://www.fao.org/ag/AGP/AGPC/doc/GBASE/data/pf000475.htm

Patel, M.B., Talpada, P.M., Patel, Z.N., Patel, B.H. and Shukla, P.C. 1982. Utilization of processed Babul seed in the ration of Kankrej bullocks for maintenance. *Indian J. Dairy Sci.* 35: 613-615.

Prayukth, K.V. 2005. The potential of seaweeds. Website: http://www.indiatogether.org/2005/oct/eco-seaweed.htm

Punj, M.L. 1988. Utilization of agricultural byproducts and industrial waste materials for evolving economic rations for livestock and poultry. In: *Major recommendations of the All-India Co-ordinated Research Project*, ICAR, New Delhi.

Reddy, V.R., Reddy, R.R., Rao, D.S., Reddy, D.V. and Rao Z.P. 1999. Nutritional evaluation of sunn hemp (*Crotalaria juncea*) hay as sole roughage and their use in complete ration for sheep. *Indian J. Anim. Nutr.* 16: p. 38-43.

Sastry, V.R.B., 2002. Detoxification and utilization of Mahua (*Bassialatifolia*) seed cake as animal feed. In: *Role of Unconventional Feeds in Future Livestock Production*. CAS in Animal Nutrition, IVRI, Izatnagar. p:41-44.

Singh, T.N., Srivastava, J.P., Verma, A.K. and Gupta, B.S. 1983. Utilization of niger-cake (*Guizotia abyssinica*) as a nitrogen supplement in growing calf rations. *Indian J. Anim. Sci.* 53: p. 887-889.

Srinivas, T. and Anantharaman, M. 2005. Cassava Marketing System in India. Technical bulletin series: 43, Central Tuber Crop Research Institute, ICAR. Website: www.ctcri.org/pdfs/cassava.pdf

Talpada, P.M., Pandya, P.R. and Pande, M.B. 2002. Unconventional feed resources for animals. Gujarat Agriculture University, Anand.

Sources for figures:

Fig. No.	Figure Name	Sources
1.1	Structure of grain.....	www.teksengricemill.com
1.2	Maize grain.....	www.worldofstock.com
1.3	Sorghum grain.....	www.purcellmountainfarms.com
1.4	Wheat grain.....	http://mbp.generationcp.org
1.5	Barley grain.....	www.purcellmountainfarms.com
1.6	Oat grain.....	www.agricultural-land.com
1.7	Rice grain.....	www.shivashellac.com
1.8	Rye grain.....	www.brewpublic.com
1.9	Triticale grain.....	www.gourmetsleuth.com
1.10	Millet grain.....	www.purcellmountainfarms.com
1.11	Pearl millet grain.....	www.alibaba.com
1.12	Wheat bran.....	www.theshop.co.nz
1.13	Rice bran de-oiled.....	www.indiamart.com
1.14	Brewer's grain.....	AN group, NDDB
1.15	Distiller's grain.....	www.indianagrain.com
1.16	Mung chuni.....	AN group, NDDB
1.17	Turnips.....	www.ifood.tv
1.18	Fodder beet.....	www.actionfarm.co.uk
1.19	Sugar beet.....	www.montanakids.com
1.20	Cassava roots.....	www.gonepie.com
1.21	Potato.....	www.cropandsoil.oregonstate.edu
1.22	Sweet potato.....	www.ifood.tv
1.23	Carrots.....	www.worldcommunitycookbook.org
1.24	Soybean meal.....	www.pixfr.eu
1.25	Groundnut meal.....	www.indiamart.com
1.26	Cottonseed meal.....	www.balajicottonlinter.com
1.27	Rapeseed meal.....	AN group, NDDB
1.28	Sunflower meal.....	AN group, NDDB
1.29	Safflower oil cake.....	www.topnetintl.cn
1.30	Sesame meal.....	www.ecvv.com
1.31	Palm kernel meal.....	www.manufacturer.com
1.32	Linseed meal.....	www.buketrade.com
2.1	Legume hay.....	www.atascaderofeed.com
2.2	Lucerne hay.....	www.aswatama.com
2.3	Wheat straw.....	AN group, NDDB
2.4	Rice husk.....	www.mk-group.co.in
2.5	Cowpea fodder.....	AN group, NDDB
2.6	Sorghum fodder.....	www.agroatlas.ru

2.7	Maize fodder.....	http://biodiversity.georgetown.edu
2.8	Soybean fodder.....	http://media.web.britannica.com
2.9	Guar fodder.....	http://www.flickr.com
2.10	Pearl millet fodder.....	http://informedfarmers.com
2.11	Berseem fodder.....	www.igfri.ernet.in
2.12	Lucerne fodder.....	AN group, NDDB
2.13	Oat fodder.....	http://informedfarmers.com
2.14	Indian clover fodder.....	http://i.pbase.com
2.15	Chicory fodder.....	AN group, NDDB
2.16	Napier grass.....	www.plantdelights.com
2.17	Anjan grass.....	http://www.fao.org
2.18	Blue panic grass.....	http://www.hear.org
2.19	Jerga grass.....	www.texasinvasives.org
2.20	Choti jergi grass.....	http://luirig.altervista.org
2.21	Rhodes grass.....	www.enhg.org
2.22	Doob grass.....	http://img.tradeindia.com
2.23	Para grass.....	http://indonesia.tropicalforages.info
2.24	Dallis grass.....	http://pics.davesgarden.com
2.25	Kikuya grass.....	http://www.calflora.net
2.26	Cocks foot grass.....	http://www.agroatlas.ru
2.27	Reed canary grass.....	www.plant-identification.co.uk
2.28	Perennial rye grass.....	http://www.habitas.org.uk
2.29	Dhaman grass.....	AN group, NDDB
2.30	Guinea grass.....	www.fao.org
2.31	Jaragua grass.....	http://tanisiaina.com
2.32	Tall fescue grass.....	www.calflora.net
2.33	Sudan grass.....	www.outsidepride.com
2.34	*Clitoria ternatea*.....	www.tropicalforages.info
2.35	*Dolichos lablab*.....	www.dirtdoctor.com
2.36	Kudzu.....	http://herbal099.files.wordpress.com
2.37	*Centrosema pubescens*.....	http://en.academic.ru
2.38	*Leucaena leucocephala*.....	www.ruffordsmallgrants.org
2.39	*Rhynchosia minima*.....	www.dld.go.th
2.40	Dhaincha.....	http://agritech.tnau.ac.in
2.41	*Cassia*.....	www.mytho-fleurs.com
2.42	*Prosopis*.....	http://farm6.static.flickr.com
2.43	*Sesbania grandiflora*.....	http://academic.uprm.edu
2.44	Pipal leaves.....	http://1.bp.blogspot.com
2.45	Bamboo leaves.....	http://upload.wikimedia.org
2.46	Neem leaves.....	http://upload.wikimedia.org
2.47	Mulberry leaves.....	http://1.bp.blogspot.com
2.48	Ber leaves.....	www.tamilnet.com

2.49	Tapioca leaves.....	www.bustaniplantfarm.com
2.50	Ardu leaves.....	www.naturamediterraneo.com
2.51	Kachnar.....	http://farm4.static.flickr.com
2.52	Robinia.....	www.shirleydenton.com
3.1	Guar meal.....	AN group, NDDB
3.2	Niger seed cake.....	www.alibaba.com
3.3	Rubber seed cake.....	Talpada *et al*. (2002)
3.4	Sun hemp seeds.....	www.visionfiber.com
3.5	Dhaincha seeds.....	www.flickr.com
3.6	Ambadi plant.....	www.forestryimages.org
3.7	Subabul seeds.....	Talpada *et al*. (2002)
3.8	Jowar.....	www.skystarexports.com
3.9	Corn steep liquor.....	www.ecplaza.net
3.10	Isabgol husk.....	AN group, NDDB
3.11	Tamarind seeds.....	www.plantcultures.org
3.12	Mango seed kernels.....	Talpada *et al*. (2002)
3.13	Rain tree pods.....	Talpada *et al*. (2002)
3.14	Kusum.....	www.azerbaijanrugs.com
3.15	Cocoa pods.....	http://bettercancersolutions.com
3.16	Vilayati babul pods.....	Talpada *et al*. (2002)
3.17	Coconut pith.....	www.indiamart.com
3.18	Damaged apple.....	www.extension.umn.edu
3.19	Tapioca roots.....	http://au.alibaba.com
3.20	Seaweed meal.....	www.pure4green.com
3.21	Babul pods.....	www.treeaid.org.uk
3.22	Jackfruit waste.....	www.khmerkromrecipes.com
3.23	Sugarcane tops.....	www.genomeindia.org
3.24	Panewar seeds.....	http://bharatagroind.tradeindia.com
3.25	Palm male tree.....	www.theroadtothehorizon.org
3.26	Warai bran.....	http://en.academic.ru
3.27	Tea waste.....	www.molon.de
3.28	Tomato waste.....	Talpada *et al*. (2002)
3.29	Banana root bulbs.....	www.metafro.be
3.30	Potato waste.....	http://cpric.ernet.in/CaseStudy.pdf
3.31	Citrus peel waste.....	http://green.myninjaplease.com
3.32	Azolla fern.....	AN group, NDDB

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