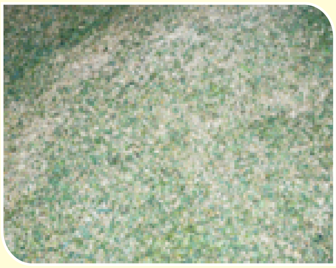
PRACTICAL DAIRY ANIMAL NUTRITION

WHAT EVERY EXTENSION WORKER OUGHT TO KNOW



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Practical Dairy Animal Nutrition -What Every Extension Worker Ought to Know

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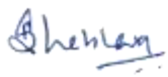
MESSAGE

National Institute of Agricultural Extension Management (MANAGE), Hyderabad is an autonomous organization under the Ministry of Agriculture & Farmers Welfare, Government of India. The policies of liberalization and globalization of the economy and the level of agricultural technology becoming more sophisticated and complex, calls for major initiatives towards reorientation and modernization of the agricultural extension system. Effective ways of managing the extension system needed to be evolved and extension organizations enabled to transform the existing set up through professional guidance and training of critical manpower. MANAGE is the response to this imperative need. Agricultural extension to be effective, demands sound technological knowledge to the extension functionaries and therefore MANAGE has focused on training program on technological aspect in collaboration with ICAR institutions and state agriculture/veterinary universities, having expertise and facilities to organize technical training program for extension functionaries of state department.

Dairy extension ensures steady flow of information and technology to the client system. Its role in future food, nutrition, livelihood and environmental security becomes indispensable in lieu of daunting challenges especially demand for skilled manpower, resource priorities and quality final products. Research, teaching and extension reforms warrant recalibrated strategies in order to realise sustainable and profitable dairying in the years to come. Extension should play crucial role in bringing informal stakeholders who are still outside the purview of development process and suggest integrated sustainable rural approach. Further, its contribution in popularizing the commercialized dairy innovations and their impact analysis would augment the dairy productivity and vibrancy of dairy sector. This e-book covers discusses improvements in pedagogical approaches, demand driven field extension methodologies and data analytics which would yield greater dividends for future dairy stakeholders.

This e-book covers an array of subjects, Practical Dairy Animal Nutrition -What Every Extension Worker Ought to Know. I would like to extend my appreciation to, GADVASU, Ludhiana & EAAS Centre, MANAGE, Hyderabad for the tremendous effort in compiling this ebook. I also thank the authors, editors, and designers who have contributed to this ebook creation.



Dr. P. Chandra Shekara
(Director General, MANAGE)

FOREWORD

Balance nutrition is the key to successful dairy farming. Indian people are doing dairy farming since ancient time. Though the status of dairy farming is changing fast from allied to main occupation owing to different factors like decreasing cultivable land, plateau in agriculture production, increasing input cost and ever-increasing demands of animal-based food, but the way of rearing these animals is still largely the traditional one. There is dire need to upgrade their knowledge with latest recommendations. For this we need to equip the available extension functionaries with latest knowledge.

GADVASU - the leading veterinary university of the country is striving its best to develop new, farmer friendly technologies and, then, to disseminate them to the end users by all possible means. I am delighted that our university is regularly conducting free online training programs for the field functionaries in collaboration with National Institute of Agricultural Extension Management (MANAGE), Hyderabad. A new training course on "Practical Dairy Animal Nutrition: What Every Extension Worker Ought to Know" will organized in the continuity.

This training course will surely expose the participants to various new aspects of practical dairy farming. I hope that the participants from different parts of the country will be immensely benefitted from this online course by interactions with the expert resource persons selected for this training.

The e-book for the above said training program has been designed to provide first-hand knowledge to the participants/readers. I congratulate the entire team of MANAGE, Hyderabad and Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana associated with to publish the e-book on "Practical Dairy Animal Nutrition- What Every Extension Worker Ought to Know". I am sure that extension workers as well as field functionaries from the line departments will benefit immensely from the rich content of this document.

Dr. Parkash Singh Brar
Director Extension Education,
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PREFACE

Animal nutrition is one of the most researched subjects in Animal Science. Great advances have been made in the past on research on nutritional management of dairy animals. However, it has been noticed that knowledge related to animal nutrition is limited among the farmers, especially small and marginal. Dairy farmers often overlook the importance of balanced nutrition to reproduction. Low knowledge about the basic requirements of dairy animals coupled with scarcity of feed and fodder is a serious impediment to reproduction and thereby milk production.

Balance nutrition can pave the way for not only increased milk production, but it is also the foundation for all herd health programs. There is an immediate need for large scale diffusion of good practices related to animal nutrition amongst the farmers so as to enable them to realize the true potential of their animals. Extension workers have to take the lead in educating and motivating the farmers to adopt improved practices and strategies related to nutrition. They must form a strong link between the researchers and the farming community to empower the farmers with knowledge. But extension workers must first enrich themselves with the intricate details of this subject before educating the farmers. This compendium cum e- book will form a ready reference and provide an extensive knowledge base on animal nutrition for the extension workers.

We are really grateful to Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, and MANAGE, Hyderabad, for organising and sponsoring the online training course on "Practical Dairy Animal Nutrition: What Every Extension Worker Ought to Know”. We also thank the resource people who provided timely and insightful contributions to this publication. We are confident that the extensive content of this e-book will be extremely beneficial to extension workers as well as field employees from the line departments.

Editors

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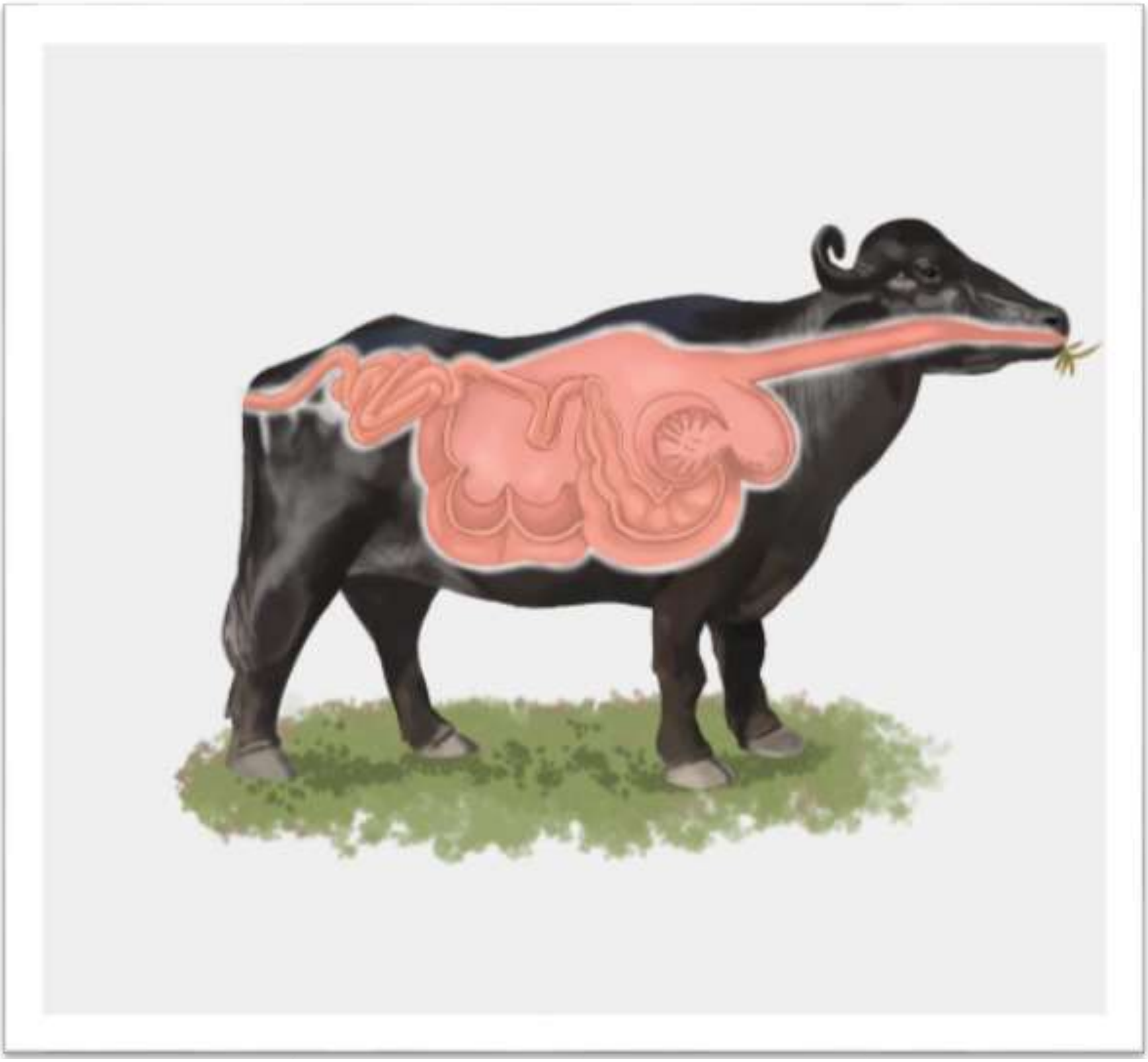
Content

Chapter 1



Roaming in the Ruminant Digestive System: Understanding Digestive Anatomy and Physiology

Devendra Pathak, Opinder Singh and Varinder Uppal
Guru Angad Dev
Veterinary and Animal Sciences University, Ludhiana

Introduction:

Nutrients are required by all animals and are acquired through the digestive system. The digestive system comprises a musculo-membranous tube (digestive tract/ gastrointestinal tract) and accessory organs. The digestive tract consists of the mouth, pharynx, oesophagus, stomach (forestomach and glandular stomach), small intestine, large intestine, and rectum. The accessory organs are the teeth, tongue, salivary glands, liver, pancreas, and gallbladder.

The digestive tract functions include ingestion of feed into the oral cavity (prehension), propulsion of ingested feed by swallowing and peristalsis, mechanical processing (mastication), digestion, secretion (of Water, mucus, acids, enzymes, buffers, and salts), absorption of nutrients, and elimination of solid wastes and immunity (a physical barrier and an innate immune system).

Mouth/ Oral Cavity/ cavumoris:

The mouth, or oral cavity, or buccal cavity extends from the lips to the pharynx, where food first enters the digestive tract. The mouth is lined with stratified squamous epithelium, which protects against friction. For further protection, the epithelium of the gums, hard palate, and dorsum of the tongue are slightly keratinized. The mouth is bound anteriorly by lips and laterally by cheeks; the roof is formed by a hard palate, while the floor is formed by the tongue. The anterior opening bounded by the mouth is Rima oris, and the posterior opening into pharynx is called Isthmus faucium. The mouth cavity is subdivided into two parts by teeth and alveolar processes as mouth cavity proper and Oral Vestibule (Space bounded by lips and cheek external to teeth and alveolarprocesses).

Function:

The mouth cavity is responsible for prehension of feed, food selection, mastication, salivation of food to form bolus, taste (taste buds), vocalization, and providing an alternate or supplemental airway.

Labia oris (Lips):

The lips are two-upper and lower and are thick, wide, and comparatively immobile musculo-membranous folds. The angles of the union of the lips- the commissures. The middle part of the external surface of the upper lip and the surface between the nostrils is bare and is termed the muzzle or nasolabial plate. The muzzle is smooth and shows irregular lines mapping out small polygonal areas on which the duct of the naso-labial glands opens.

Cheeks:

The cheeks form the lateral wall of the mouth cavity and are continuous with the lips in front. The buccal glands are well-developed and arranged in three rows: dorsal, middle and ventral. The ducts of these glands open into the mouth between the papillae of the cheek. A large papilla the papilla salivalis is seen about the level of the upper fifth cheek tooth and it shows on its summit the opening of the *Stenson's duct* (duct of the parotid salivary gland).

Gums (Gingivae):

The gums comprise dense fibrous tissue intimately blended with the alveolar processes' periosteum and surround the teeth' neck. They are covered with mucous membrane, destitute of glands and of a low degree of sensibility. In ruminants, the gums are modified to form the dental Pad, which takes the place of the upper incisor.

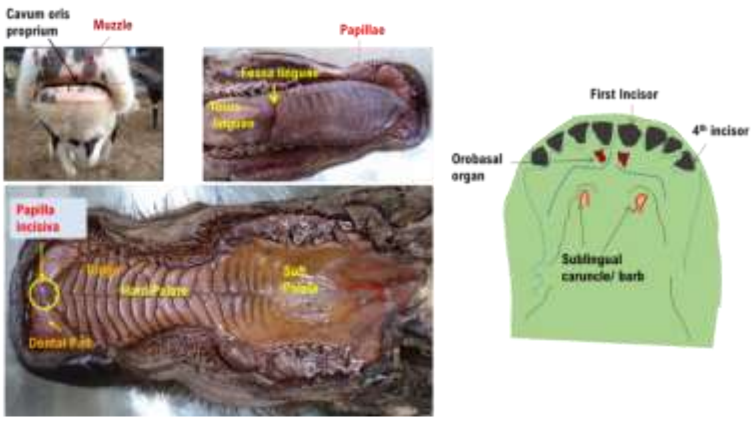
Palate:

The palate is partly osseous and partly soft tissue partition that separates the digestive and respiratory passages of the head. The bony hard palate lies rostral to the membranous soft palate. Formed by the palatine processes of the maxilla and incisive bones and the horizontal plate of the palatine bone. Forms roof of the oral cavity. Oral side is covered by a thick cornified mucosa which is crossed by a series of transverse ridges (15-19) (palatine ridges) and a shallow median palatine raphe. In ruminants, the palatine ridges carry papillae which are directed caudally to guide food backwards.

Upper incisors are absent and are replaced by dental pad. Between the dental pad and first palatine ridge, a small median swelling, the incisive papilla/ Papilla inciciva, is located. On either side of the incisive papilla, the orifices of the incisive ducts perforate the palate. Incisive ducts lead to the nasal cavity and the vomeronasal organ, a blind-ending canal lined by the nasal mucosa.

Soft Palate (PalatumMolle):

It is a caudal continuation of the hard palate. It is a musculo-membranous part that separates the mouth from that of the pharynx except during deglutition. It separates the respiratory portion of the pharynx (nasopharynx) dorsally from the pharynx's digestive portion (oropharynx) ventrally.



Floor of Mouth Cavity:

The floor is visible when the tongue is raised. Two prominent structures are visible i.e.Sublingual fold and Sublingual caruncle. About opposite to the corner tooth at the level of the lateral incisor on each side is *–the sublingual caruncleor barb* through which the ducts of the mandibular and ventral part of sublingual salivary glands open into the mouth. A median fold of mucous membrane passes from the floor to the ventral surface of the tongue and is called frenulum linguae.

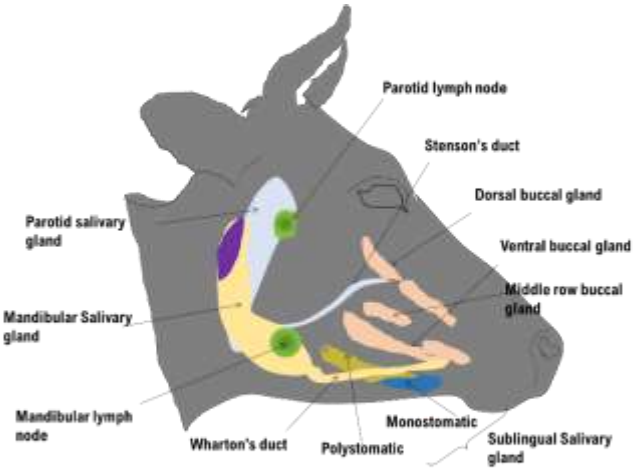
Teeth:

Dentition of the domestic mammals consists of two dental arches. The functions of teeth are prehension, mastication, and sometimes defence. According to position and specialized function, teeth are classified as incisors or cutting teeth, Canine teeth, premolars, and molars (Grinding or shearing teeth).

The dental formula of ruminants (permanent teeth): 2 (I 0/4 C 0/0 PM 3/3, M 3/3)

Tongue:
Tongue is the chief organ of ruminants' prehension and largely fills the oral cavity.It consists of apex, body and root. The surface of tongue opposite the palate is called dorsum linguae. Which is raised in its caudal part to form an elliptical prominence called torus linguae. Depression in front of torus linguae called fossa linguae. The gustatory papillae present in ruminants are fungiform and circumvallate (8-17 in number) and mechanical papillae are filiform, conical and lenticular.

Salivary Glands:
Salivary glands are extramural glands, emptying into the digestive system via ducts. Numerous salivary glands drain into oral cavity and their secretion, the saliva, keeps the interior of mouth moist, when mixed with food, saliva facilitates mastication. There are three major salivary glands (parotid, mandibular and sublingual glands and minor salivary glands (labial salivary glands on lips, buccal salivary glands: on Cheeks, Buccal salivary glands form large aggregates in three rows; dorsal middle and ventral rows, lingual salivary glands: on tongue, palatine salivary glands: on palate, sublingual oral floor and Oesophageal: oesophageal wall) and they produce mucous.



The parotid duct opens into the buccal vestibule. It produces a predominantly serous secretion. The mandibular (submandibular, submaxillary) salivary gland is located caudal to the angle of the jaw and is a mixed gland. The mandibular duct runs rostrally along with the sublingual duct, medial to the mandible, and opens near the sublingual caruncle. The sublingual salivary gland is under the tongue and secretes mostly mucus. Ruminants produce enormous quantities of saliva. An adult cow is estimated to produce saliva in the range of 100 to 150 liters of saliva per day.Saliva is hypoosmotic and consists of water (97–99.5%), electrolytes (sodium, potassium, chloride, bicarbonate, and phosphate). It tends to be slightly acidic (pH 6.75–7.00). Apart from its normal lubricating function, saliva provides fluid for the fermentation vat and alkaline buffering. It is rich in bicarbonate, which buffers the large quantity of acid produced in the rumen and is probably critical for the maintenance of rumen pH.

Pharynx:

The pharynx is a musculo-membranous passage common to both the digestive and respiratory systems. It directs food and air into proper channels. The pharyngeal cavity is divided into the nasopharynx, Oropharynx, and laryngopharynx.

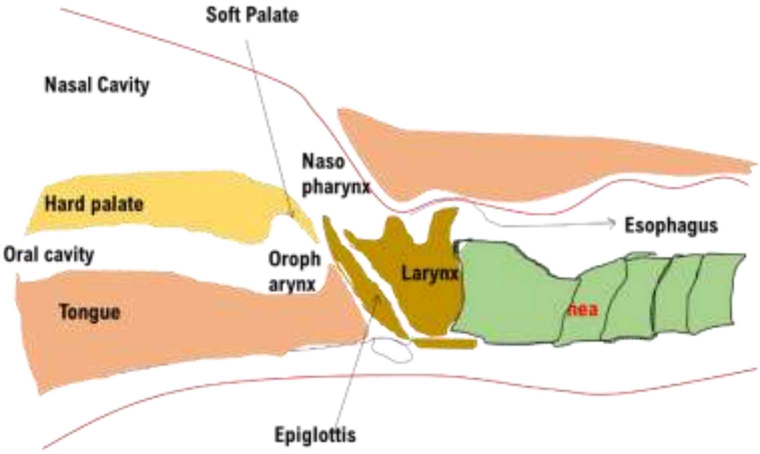


Fig. 2. Sagittal section of Pharynx, Larynx, Trachea and Esophagus

Oesophagus:

Musculo-membranous tube, which extends from the pharynx to the stomach. It is divided into cervical and thoracic parts. The *cervical part* begins at median line above the anterior border of the cricoid cartilage of larynx. At the level of the fourth cervical vertebra, it crosses to the left of the trachea and continues this relation on the left side of the neck and enters the thoracic cavity. The *thoracic part* begins at the level of the first rib. It continues its course in between the lungs, inclines to the left, and reaches the hiatus oesophagi of the diaphragm. It passes through it and immediately terminates on the dome-like rumino-reticular wall -the atrium ventriculi.

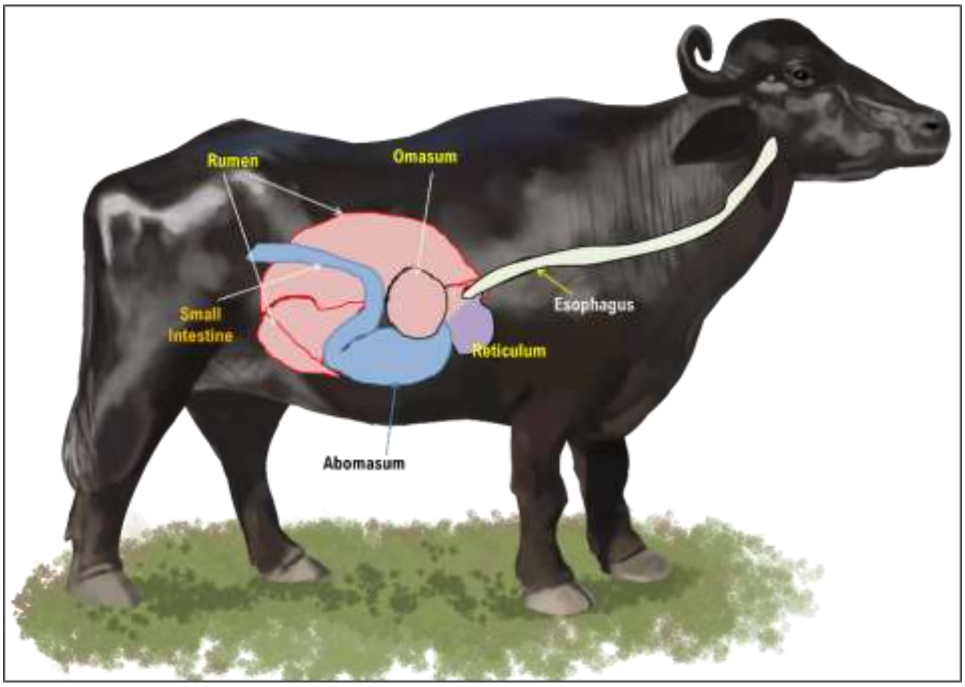
Stomach:

The stomach of ruminants has been modified to allow bacteria and protozoa to ferment the food that has been consumed. Fermentation produces energy that would not otherwise be available. Since the cellulose in growing, mature, or dried grass cannot be digested by mammalian digestive enzymes, ruminants primarily consume these elements in their diet. The fermentation process, however, allows microbial enzymes to digest the plant cells. The ruminant stomach is very large and occupies nearly three-fourths of the abdominal cavity. It completely fills up the left of the abdomen except for a small space for the spleen and extends considerably into the right half.

It has four compartments,

1. Rumen (*paunch*)
2. Reticulum (*honeycomb*)
3. Omasum (*many folds, many plies*)
4. Abomasum (*rennet or true stomach*).

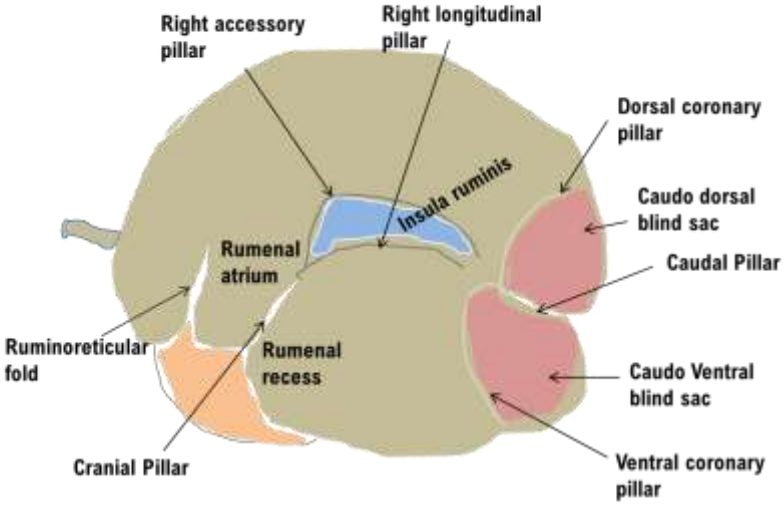
The capacity of the stomach varies according to age, size, and breed. In the newborn, the rumen and reticulum are about half of the abomasum, and the ratio is reversed at 10 to 12 weeks. At four months rumen and reticulum are 4 times as large as the other two compartments. Omasum equals abomasum, rumen 80%, reticulum 5%, Omasum 7 to 8%, abomasum 8 or 7% in adult.



Rumen

Large sac laterally compressed and occupies the major part of the abdominal cavity, which extends from the diaphragm to the pelvic cavity. It occupies most of the left half of the abdomen and extends considerably over the median plane to the right. It extends from the lower part of the 7th or 8th intercostal space to the pelvic inlet. The two surfaces are marked by right and left longitudinal grooves dividing them into dorsal and ventral sacs. Rumen is divided into several parts by a number of grooves of varying depths. Shallow left and right longitudinal grooves on the parietal and visceral surfaces are connected cranially and caudally by two deep, transverse grooves, the cranial and caudal grooves. These four grooves form a nearly horizontal constriction, which divides the rumen into dorsal and ventral sacs.

The *cranial extremity* is divided by a cranial transverse groove into two sacs - *dorsal and ventral,* of which the dorsal one becomes continuous with the reticulum. The junction of the dorsal sac and reticulum is marked by a groove, the *rumino-reticular groove*; the two compartments form a sort of dome - the atrium ventriculi on which the oesophagus terminates. The *caudal extremity* extends to the pubis and is divided by the deep caudal transverse groove into dorsal and ventral blind sacs. The grooves lodge the vessels and nerves of the rumen.The cavity of the rumen is divided into two sacs (Dorsal and Ventral) by the *pillars of the rumen*, which are muscular folds and correspond to the grooves on the exterior. They project like shelves into the cavity of the organ. The *rumino-reticular fold* corresponds to the rumino-reticular groove. The mucous membrane is thickly studded with papillae which are however not present on the pillars and in the dorsal sac.The ruminoreticular fold forms a U-shaped partition between the reticulum and cranial sac (also known as the ruminal atrium) of the rumen. The cranial pillar runs obliquely between the ruminal atrium and the ventral sac of the rumen. The cranial part of the ventral sac is called ruminal recess. The *reticular or oesophageal groove* is formed by two muscular ridges or lips extending from the cardia to the reticulo - omasal opening. The two lips meet dorsal to the cardiac opening and pass ventrally along the right wall of the reticulum, the right lip twisting around the left lip.



The pH of the rumen is 5.9 to 6.5 and rumen contraction occurs every 20-40 seconds. The feed passage rate varies from 6-9 % per hour.
Functions of rumen

- Bulky, fibrous food can be soaked and fermented in the rumen, and because of its motility, the contents are constantly mixed.
- The rumen is the largest compartment, and it contains billions of bacteria, protozoa, moulds, and yeasts.These microorganisms live in a symbiotic manner with the bovine, which is why cattle can eat and digest large amounts of roughage.
- The bacteria and protozoa do most of the digestion of feeds for the cow and produce volatile fatty acids [Acetic acid (65% energy), Propionic acid (20% energy), and Butyric acid (15% energy)]. The type of acid production might vary with the diet. These fatty acids are absorbed directly through the rumen wall and supply 60 to 80 % of the energy needed by the cow.
- In addition to energy, the microorganisms produce protein, including essential amino acids from the protein and nitrogen the cow ingests.
- Because the microbes can use nitrogen to make protein, cows can eat urea and other sources of non-protein nitrogen that would kill non-ruminants.
- The microbes also make vitamins B and C.

Reticulum

The *reticulum* is the most cranial and smallest of the four compartments. It is spherical but slightly flattened craniocaudally. It lies between the diaphragm and the rumen at the sixth to ninth intercostal spaces level, about equal to the right and left of the median plane.Dorsally, it is continued without demarcation by the cranial sac of the rumen, while ventrally and to the sides, it is sharply separated from the rumen by the deep rumino-reticular groove. Its diaphragmatic surface is convex in adaptation to the curvature of the diaphragm. Its visceral surface is applied against the rumen.

The interior of the reticulum is raised into folds about 1/2 inch high, enclosing 4 to 6-sided spaces or cells (honeycomb).Smaller folds subdivide these cells, and bottoms are studded with pointed horny papillae. The reticulum joins with the omasum at the reticulo-omasal orifice.

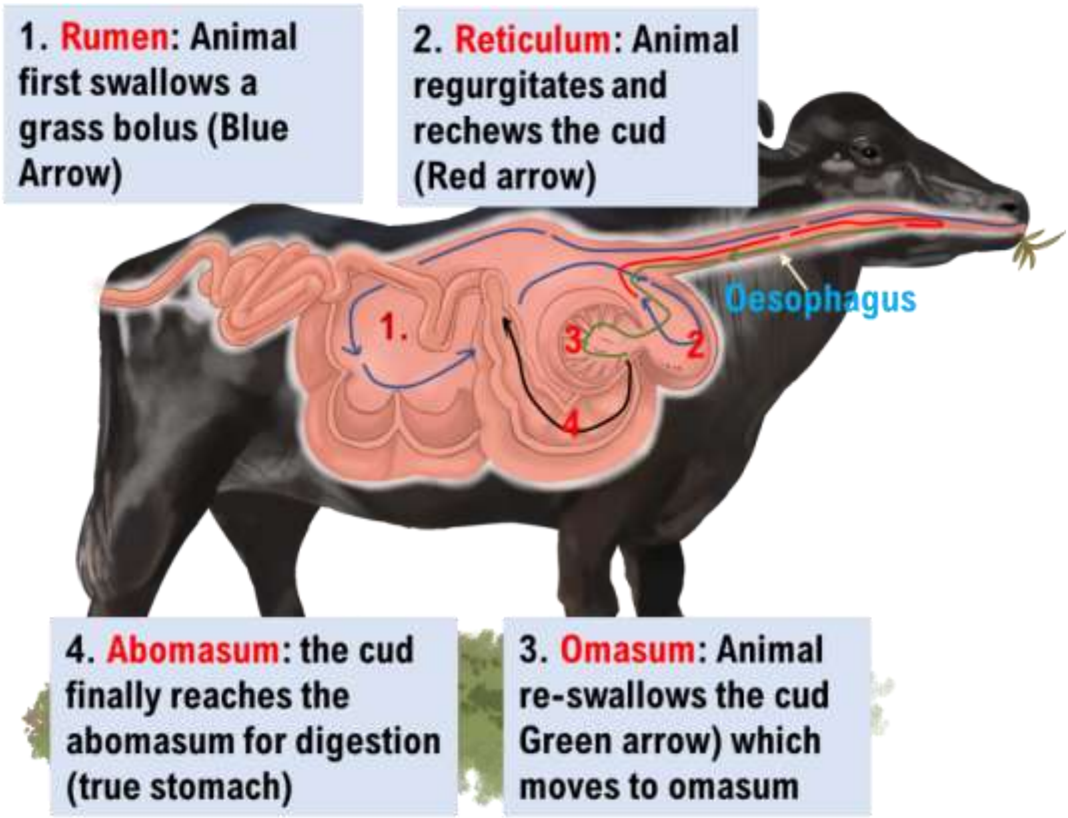
Functional aspects of the Reticulum:

The reticulum is involved with rumination. It controls how ingesta travels from the rumen to the omasum, moistens the contents of the rumen, and floods the cardia before regurgitation.

Hardware Disease:

It also acts as a trap for foreign objects ingested by the cow. As swallowed, foreign materials like wire or nails usually land in the reticulum and stay there. However, as the reticulum contracts, it may push sharp things through the stomach wall and cause traumatic peritonitis or hardware disease. Because the muscular diaphragm is the only structure between the reticulum and the heart, these pointed items can also be propelled into the pleural and pericardial compartments. The reticulum frequently retains dense metal items. Reticular contractions may cause pointed items to pierce the heart or lungs and cause inflammation if they are pointed. Traumatic pericarditis (heart involvement) or, more popularly, hardware disease are the terms used to describe this ailment.

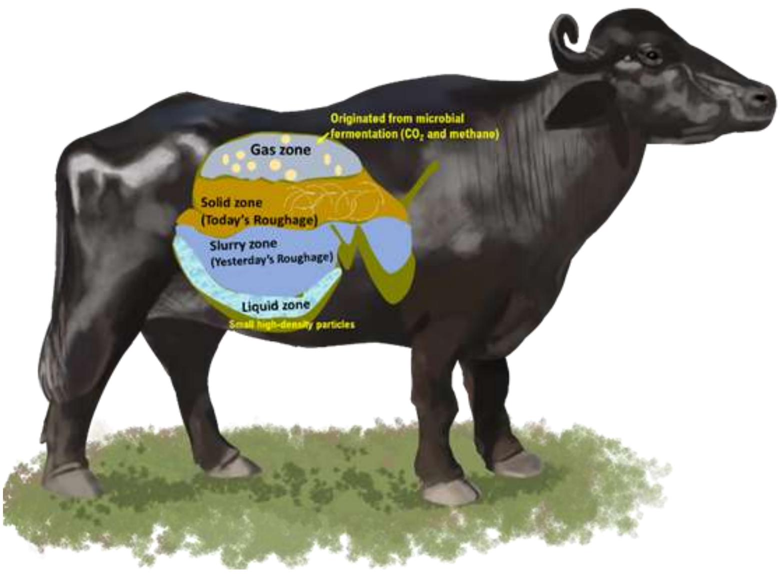
It is hard to treat but can be prevented by keeping metal trash out of pastures. Specially shaped magnets can be administered to cows to decrease the possibility that ingested metal will pierce the digestive tract. These magnets stay in the reticulum for the life of the animal.



Flow of Feed:

The ruminoreticular fold separates the rumen from the much smaller reticulum. Feed, water, and salivafrom the oesophagus enter the rumen and are deposited at the junction of the rumen and reticulum.Heavy stuff like grain, metals, and wires fall into the reticulum, while lighter stuff like grass, hay, etc., enters the rumen proper. Added to this mixture are voluminous quantities of gas produced during fermentation. The contraction of the cranial sac transfers the contents into the reticulum, from where they can be “pumped” by contractions of the reticulum to (1) the cardiac opening for regurgitation, (2) the omasum through the reticulo-omasal orifice for transfer to the abomasum or for further digestion and absorption by the many plies of the omasum, or (3) more caudal parts of the rumen.

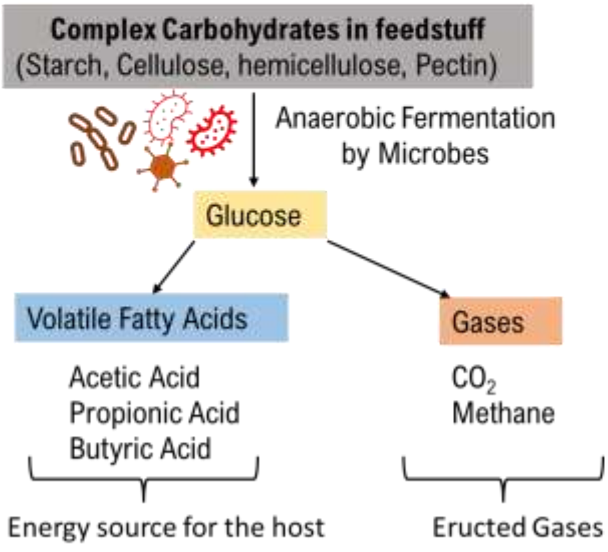
Feed materials within the rumen are subdivided into fourmain zones based on their specific gravity. The gas rises to remain in the upper regions, and freshly landed roughage floats in a second layer, grain and fluid-saturated roughage ("yesterday's roughage") settle in the third layer, and the liquid zone settles in the bottom over a small high-density particles zone.The size and density of the solid material determine the speed with which it moves through the rumen. Feedstuffs are reduced to smaller and smaller sizes during fermentation, and microorganisms are continuously multiplied. Lighter solids are continually being flushed back into the rumen by ruminal contractions. The smaller and more solid material is forced into the reticulum and cranial sac of the rumen, where it is discharged together with fluids with microbes into the omasum.



Regurgitation and remastication help the fermentation process by increasing the surface area for microbial digestion and allowing salivation for the second time. The mixing sequence spreads across the reticulorumen in a “Z” pattern and provides extensive mixing of the rumen contents. The eructation sequence moves gas from the rumen toward the oral cavity, thus allowing the formation of a gas bubble which is eventually forcibly ejected into the esophagus by contraction of the ventral rumen. Feed is then returned to the oral cavity for further mastication through a process called rumination.Rumination occurs in four steps: re-gurgitation, re-mastication, re-salivation, and re-deglutition. It is a reflex initiated by the mechanical stimulus of receptors in the mucosa of the reticulum and rumen in the cardia.

Rumenal microbial fermentation

The microbes in the rumen break down larger carbohydrate molecules found in plant cells by a process called fermentation. The microbes use some of these sugars to grow and multiply; the animals use the rest. Fermentation also produces gases, heat, and volatile fatty acids. The gases produced are carbon dioxide (CO2) and methane (CH4), which are belched out by the cow. The anaerobic action of bacteria and protozoa is responsible for fermentation. Products of fermentation of carbohydrate digestion include short-chainvolatile fatty acids (VFAs), carbon dioxide, and methane. The major VFAs are acetic, propionic, and butyric acids. Microbes hydrolyze dietary proteins into peptides and amino acids and can make amino acids from nonprotein nitrogen sources such as uric acid, urea, and ammonia. Triglycerides are hydrolyzed to glycerol and fatty acids, and glycerol is generally metabolized to propionic acid while the fatty acids pass to the duodenum, where they are absorbed.



Rumenal Carbohydrate Fermentation

Omasum

The *omasum* is ellipsoidal in form. Lies to the right of the median line from the 7thto the 11thrib. The *parietal surface* faces to the right and is related to the diaphragm and liver. The visceral surface faces to the left and is in contact with right face of rumen, reticulum and abomasum. It is connected at its upper part with the reticulum. Below it joins the abomasum.

The bovine omasum lies ventrally in the intrathoracic part of the abdominal cavity, to the right of the median plane, between the ventral sac of the rumen on the left and the abdominal wall on the right. Craniodorsally, it is related to the liver. The cavity of omasum is occupied by about a hundred longitudinal muscular folds - the *lamina omasi (omasal leaves).*A total number of laminae 90-130. A groove *sulcus omasi* extends from the reticulo-omasal opening to the omaso-abomasal opening. The omaso-abomasal orifice is oval and about 4 inches long.

Functions of omasum

- It functions as the gateway to the abomasum, filtering large particles back to the reticulo-rumen and allowing fine particles and fluid to be passed to the abomasum.
- Though the complete function of this compartment is unknown, it does aid in water resorption and recycling of buffers for the saliva.
- The omasum provides for resumed fermentation and absorption.

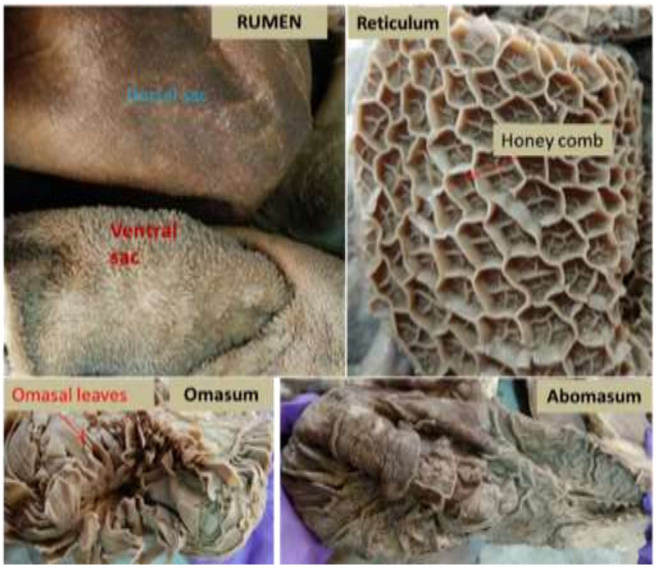
- It may function to absorb residual volatile fatty acids and bicarbonate.

Abomasum

The abomasum is the most distal compartment, following the fore stomach's three compartments. It is a bent, pear-shaped sac that is set off from the omasum by a deep annular constriction. It lies on the abdominal floor from the xiphoid cartilage backward. The glandular part of the stomach resembles a simple stomach and is divided into a fundus, a body, and a pyloric part. Fundic gland zone occupied by twelve or more spiral folds. In the pyloric part, folds reduce in size and present a wrinkled appearance. Connective tissue elevation called *torus pyloricus* close to pyloric passage.

Functions:

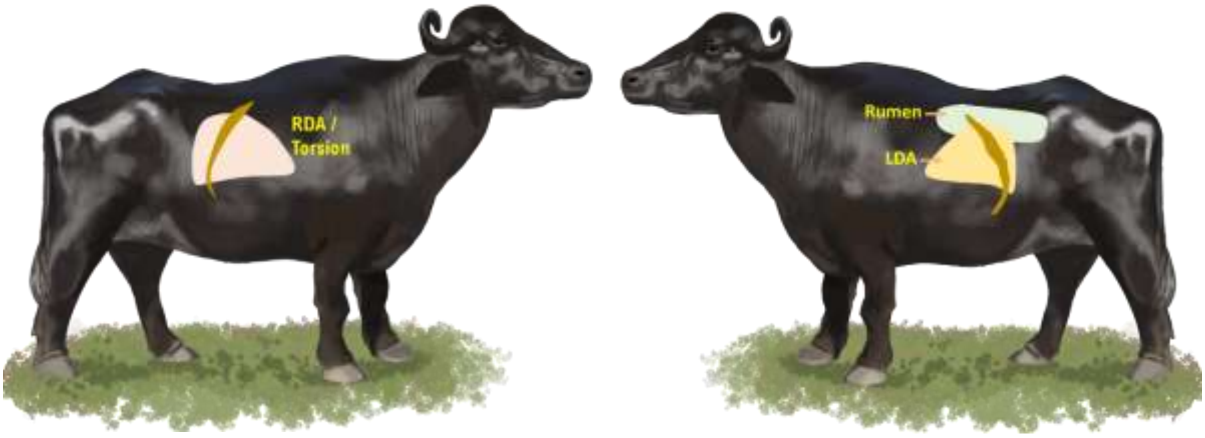
The abomasum is the "true stomach", and it functions much like the simple stomach producing acid and some enzymes to start protein digestion. It handles large masses of bacteria, and the abomasum secretes lysozyme, an enzyme that efficiently breaks down bacterial cell walls.



Clinical perspective:

A normal rumen has a doughy texture with a small gas cap in its dorsal regions and usually is not distended above a plane formed by the coxofemoral joints. Peritonitis, gas distention, and pain can cause a reflex inhibition of gastrointestinal motility. Assessment of rumen function is often made by observing rumen contraction (1-2 cycles/ minute) and can be felt when the hand is placed into the left paralumbar fossa. Increased gas collection within the rumen could be seen with frothy or free gas bloat.The rumen is examined by both auscultation and palpation. The force of the contraction should displace the lateral body wall at least 1 to 2 cm.The ruminal contraction on auscultation sounds like a dull roar that begins quietly, builds to a climax, and then fades away. Weak or nonexistent ruminal contractions can be a symptom of a variety of illnesses, including hypocalcemia and peritonitis. Hypermotility happenssometimes linked to vagal indigestion in some cases.

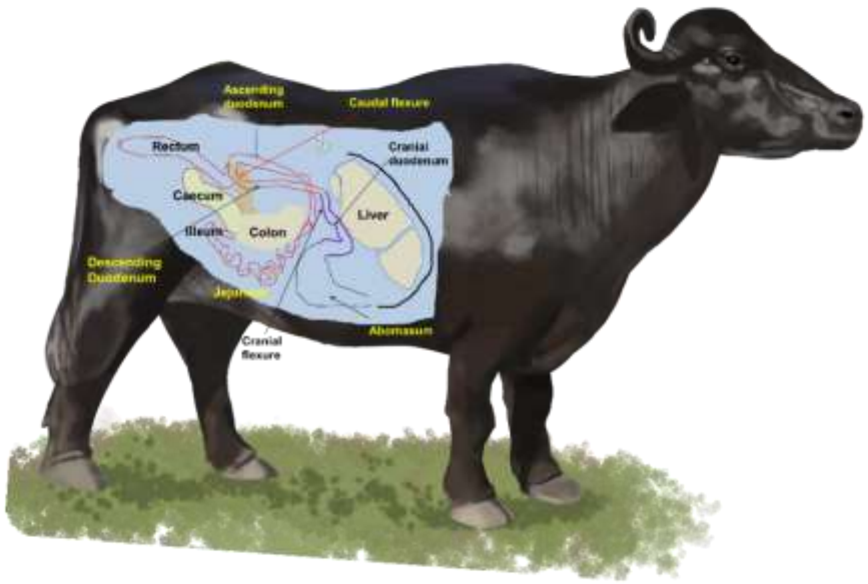
Auscultation and concurrent percussion can detect a "pinging" sound caused by trapped gas in the abdominal organs; the sound's localization to regions can assist in identifyingthe portion of the digestive tube involved. If the cecum is inflated and packed with gas, an abdominal ping can be heard on the right side, reaching caudally to the tuber coxae and cranially via the para-lumbar fossa and under the ribs.Gas pings associated with a right-sided displacement, or the abomasum torsion, can extend cranially as the ninth intercostal space and caudally into the paralumbar fossa. In simple right-sideddisplacements or dilations of the abomasum, the only significant finding may be the small gas ping localized to the abomasum in a cow with a depressed appetite and decreased milk production.Gas pings on the left side can be attributed to the rumen or a left displaced abomasum (LDA). The auscultation of a gas ping is mostly restricted to the paralumbar fossa's dorsal side. The paralumbar fossa is completely occupied by pings connected to the ruminal tympany; they can reach dorsally to the spinal column but typically do not cross to the right side. The thirteenth rib is typically the caudal extent of the displacement; however, it might extend into the paralumbar fossa, in which case the shape of the abomasum can be felt readily.By rectal palpating the rumen, rumen gas can be further distinguished from gas trapped in an LDA.



Intestine of Ruminants:

The intestine extends from the pylorus of the stomach to the anus and is divided into the small intestine (duodenum, jejunum, and ileum) and large intestine (caecum, colon, and rectum). Anal canal is the short terminal portion of the digestive tract. It occupies comparatively small area than stomach in ruminants and is confined to the right part of abdominal cavity. Suspended from roof of abdominal cavity by a common peritoneal fold called common mesentery.
Small Intestine starts from pylorus and terminates at the Ileocecal opening. Duodenum begins at pylorus at the ventral end of the 8^{th} or 9^{th} intercostal space and consists of three parts (Cranial duodenum, Descending duodenum and Ascending duodenum).

Ventral to pancreas duodenum turns ventrally at left side of cranial mesenteric artery and is continued by jejunum. The pancreatic duct enters descending duodenum 30-40 cm distal to bile duct. Bile duct enter pylorus at second bend of S shaped curve about 50-70 cm distal to pylorus.



Jejunum:

Jejunum is the longest and most mobile part of small intestine due to long mesentery and anatomically characterized by numerous jejunal coils. It lies mainly in the space bounded medially by rumen’s ventral sac, dorsally by the large intestine, laterally and ventrally by abdominal wall and anteriorly by omasum and abomasum. The position also depends on the fullness of rumen and the size of the uterus (in females). Some coils may be found behind the rumen against the left flank. Large numbers of elongated jejunal (mesenteric) lymph nodes are present within the double layers of the mesojejunum.

Ileum:

It is the straight and shortest terminal partof the small intestine passing cranially ventral to the cecum, to which it is connected by the ileocecal fold. It enters the large intestine at ileocaecocolic junction.

Large Intestine (Ox):

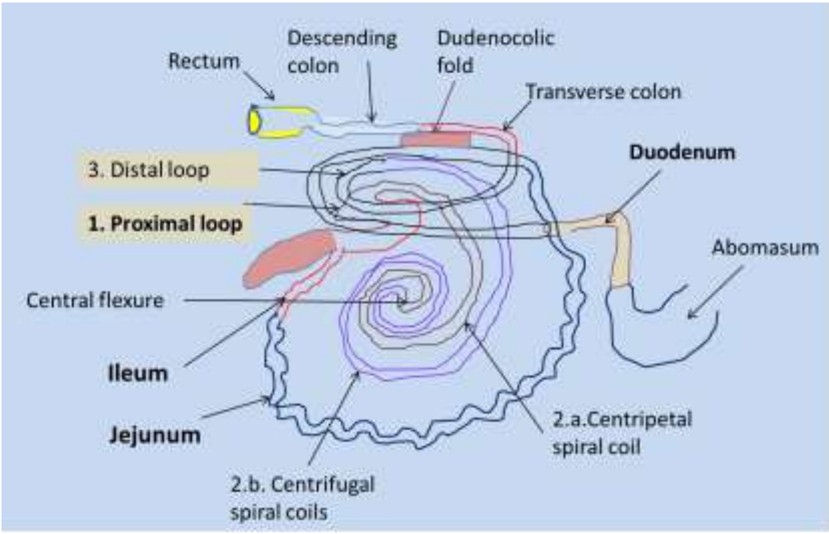
The large intestine extends from the terminal part of the ileum and extends up to anus and is comprised of Caecum, colon, and Rectum.

Caecum:

The caecum is a blind tube (cul-de-sac) intercalated between the small intestine and colon. It measures about 75 cm in length and is about 12 cm long. Cranially continuous in front with the colon, and rounded caudal blind end commonly lies at the pelvic inlet.

Colon:

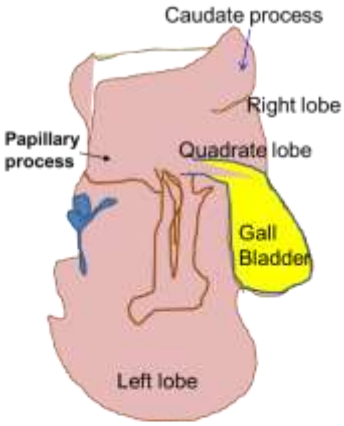
The colon is subdivided into ascending colon, transverse colon, and descending colon. The ascending Colon comprises of the proximal loop, spiral loop and distal loop. The proximal loop forms a S shaped curve and is situated between caecum and descending duodenum in the caudodorsal part of abdominal cavity followed by spiral loop which is like an elliptical disc. Spiral loop comprises of one and a half centripetal coils which spiral towards centre and at central flexure it reverses direction and with centrifugal coils return towards periphery. Number of centrifugal coils is equal to centripetal coils. Distal loop is present medial to proximal loop and ascending duodenum and is continuous with transverse colon. Transverse colon passes in front of cranial mesenteric artery from right to left to become descending colon. Descending colon passes caudally together with ascending duodenum in the left side of abdominal cavity and becomes continuous with rectum.



Rectum:
It extends from the pelvic inlet to the anus.It is related dorsally to the roof of the pelvic cavity, ventrally to the bladder and urethra in the male or uterus and vagina in the female.
Anus:
The anus is the terminal part of the alimentary canal. The muscles of the anus regulate the opening and closure of the anus.
Liver:

The liver is the largest gland in the body, which occupies the abdominal cavity and is responsible for bile secretion, glycogen storage, drug detoxification, plasma protein production, and hemopoietic organ in foetal life. It lies in the abdominal cavity almost entirely to the right of the median plane and extends obliquely downward and forward from the 7^{th} or 8^{th} to the 13^{th} rib. It presents two faces (Parietal or diaphragmatic surface and visceral surface) and four borders. The liver of ruminant is divided into left lobe, right lobe, caudate lobe, and quadrate lobe. Bile is secreted by hepatocytes and enters the bile canaliculi, which are narrow intercellular canals between the hepatocytes. Bile formed in the bile canaliculi moves into the bile ducts that fuse to form the common hepatic duct.

Bile is composed of ions, water, bile acids, cholesterol, the phospholipid lecithin, bile pigments, and bile salts (sodium and potassium salts of bile acids, primarily cholic acids and chenodeoxycholic acids). The liver may convert glucose to glycogen (glycogenesis) when blood sugar levels are high, and it can also break down glycogen to glucose (glycogenolysis) when blood sugar levels are low. Hepatocytes can store triglycerides, which can also utilize fatty acids to make ATP and lipoproteins. The liver can produce cholesterol. In order to employ the deamination of amino acids for ATP production, hepatocytes remove them. Additionally, hepatocytes produce lipids and carbs from certain amino acids. Different types of plasma proteins can be made by hepatocytes. The liver is a crucial detoxifying organ. The liver serves as the main organ for storing vitamin B12 and fat-soluble vitamins. Kupffer cells eliminate old blood cells and potential pathogens from the hepatic portal blood. The kidneys, skin, and liver work together to create the active form of vitamin D.



Gall Bladder:

The gall bladder in ruminants is a pear-shaped sacthat lies partly on the visceral surface. Its neck is continued by the cystic duct, which joins the hepatic duct to form the common bile duct - ductus choledochus, which opens into the ventral part of the S-shaped curve of the duodenum.The gall bladder stores bile, discharges into the duodenum when necessary, and concentrates the bile by absorption through the folded mucosa.

Pancreas:

Commonly known as sweetbreador abdominal salivary gland, it is present mostly at the right of the median plane andis attached to the visceral surface of the liver by the mesentery. It is divided into right and left lobes joined by a body.There is only one accessory pancreatic duct (Santorini's duct) which arises from the right lobe and enters descending duodenum 30-40 cm distal to the bile duct on the major duodenal papilla.

Both endocrine and exocrine functions are performed by the pancreas. Its exocrine role is to release the enzymes required for the digestion of all nutrients, including lipids, proteins, nucleic acids, and carbohydrates. Most of the pancreatic juice is water but contains salts, sodium bicarbonate, and enzymes. A few protein-digesting enzymes in the pancreas are pancreatic amylase, trypsin, chymotrypsin, carboxypeptidase, elastase, pancreatic lipase, ribonuclease, and deoxyribonuclease.Cholecystokinin is secreted in response to partially digested lipids and proteins in the duodenal lumen, which in turn triggers the release of pancreatic enzymes. Reduced pH in the duodenum lumen induces secretin release, which in turn stimulates the pancreatic release of bicarbonate ions.

Chapter 2

Understanding Green: Acquaintance with Different Green Fodders and Their Cultivation Practices

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Green forages are considered to be the backbone of dairy farming, as the low productivity of the milch animals is due to inadequate supply of green fodder. Cultivated fodder, crop residues and fodder from forests, permanent pastures and grazing lands are the three major sources of fodder supply in India. The fodder production scenario in country i.e. multiplicity of forage crops grown in different seasons and regions, surplus and deficit in different regions, non-commercial nature of crops and production of forage with minimal inputs from degraded and marginal lands has led to huge gap in fodder availability and requirement (Gosh *et al.*, 2016). At present, India alone faces a net deficit of 30.65% green fodder and 11.85% dry forage (Palsaniya and Gupta, 2021; Kumar, 2021). Successful livestock management involves optimizing the availability of feed with the requirement of animal as efficiently and economically as possible. Regular supply of fodder is essential for the production and economic returns from the dairy farming sector (Brar *et al.*, 2016).

Round the year fodder supply is very important in order to stabilize animal production. Diverse group of cultivated forage crops *viz.* Sorghum, pearl millet, maize, guinea grass, dinanath grass, oats, barley, teosinte, coix, cowpea, berseem, lucerne, cluster bean, horse gram, ricebean, lathyrus and shaftal are grown in different parts of the country as per the ecological adaptability of the species. Nutritional quality of different non-legume fodders is given in table 1.

Table 1: Comparative nutritional quality of different fodders crops.

Fodder Crop	Crude Protein (%)	Total digestible nutrients (%)	NDF (%)	ADF (%)
Kharif				
Maize	9-10	66.2	60-64	38-41
Bajra	7-10	58.2	56-64	38-41
Sorghum	9-10	55.6	60-65	37-42
Napier-bajra hybrid	8-10	59.3	--	--
Guinea Grass	10.8	62.4	--	--
Guara	17-20	60.0	42-48	37-42
Cowpea	20-24	61.2	43-49	34-37
Rabi				
Berseem	17-22	60.5	42-49	35-38
Shaftal	21.0	58.5	--	--
Lucerne	22.0	59.5	--	--
Senji	18.0	62.0	--	--
Oats	10-11	64.0	88-63	30-32
Raygrass	16.0	63.5	--	--

Anonymous (2022) , Anonymous (2023), Kumar *et al* (2012)

Production potential of forage crops can be altered with changes in agronomic practices. Higher plant densities are favorable for forage crops than grain crops, however forage crops also have maximum limit of increase in plant population (Subrahmanya*et al.,* 2017). Fertilizer application is one of the principle factor that directly influences the fodder yield and quality. Forage dry matter yield of maize responded linearly to fertilizer rate (Kumar *et al*., 2015). Under low fertility soils, application of 125% recommended dose of fertiliser (RDF) gave better growth, yield and quality of fodder maize (Subrahmanya*et al.,* 2017). Among different nutrients, micronutrient especially zinc plays an important role in quality fodder production. Zinc is involved in the immune system of animals, deficiency of which affects the health and milk production severely. The deficiency of zinc in soil will lead to poor yield as well as quality of fodder. Soil and foliar application of zinc sulphate has significant effect on fodder and nutrients yields, quality and Zn dynamics of maize fodder. Forage corn provides high-energy content, but its crude protein content is relatively low. Corn-legume intercrops could noticeably increase forage quantity and enhance its quality as well and also decrease requirements for protein supplements compare with corn monoculture (Baghdadi *et al.,*2016).

Under conventional feeding system farmers practice's daily cutting and carrying of fodders for feeding to the livestock. This practice leads to increase in lignin content of fodder crop with maturity and advancement of age. Lignin is hard to digest and needs more energy effecting net energy balance of the animals (Brar *et al*., 2016). Shortage of feed and fodders led to development of alternative fodder production systems involving conservation and storage methodologies for providing the feed to the livestock.Silage can help in sustenance of provision for round the year fodder for dairy animals. When the grains of corn are in milk stage, surplus fodder, if conserved as silage, helps not only in providing nutritionally uniform feed but also spares land for cultivation of other crops (Brar *et al.,* 2017). Different research trials conducted on silage production in recent years indicate that it could replace the conventional fodder without any ill-effect on intake of fodder, its digestibility and milk production potential of dairy animals (Chaudhary *et al*., 2014).Kizilsimsek*et al. (*2020) reported that growing legumes in maize stands even at a low rate could improve silage quality in terms of dry matter recovery (DMR), neutral detergent fibre (NDF) content, digestible dry matter (DDM) rate, dry matter intake (DMI) and especially crude protein (CP) concentrations.

The cultivation of different fodder crops under different agronomic aspects is discussed under the relevant headings.

Cultivation of fodder crops

1) **Selection of cultivar**

Development and identification of suitable cultivars of fodder crops is an important issue for harnessing the full production potential of both cultivated lands. There is need to develop varieties with quick early growth, higher rate of dry matter accumulation and longer leaf area duration in relation to climatic conditions.

Table 2: Recommended varieties of *kharif* fodders

Fodder Crop	Varieties forgrowing regions of country	Varieties for Punjab
Maize	African Tall, Jawahar Vijay, Moti	J1007, J1006
Bajra	L74, Rajasthan-171, WCC-75, MH-179, RajBajra , CO-8	PCB 166,PCB165
Sorghum	PC 6, PC 9, PC 23, HC 136, HC 171, HC 260	SL 46, SL 45
Napier-bajra hybrid	CO-1,2 & 3, PBL-83, 233,231 NB-21	PBN 342, PBN 346
Guinea Grass	Bundel guinea -1	PGG 1998
Guara	FS-277, AHG-75, 365, BG-1,2 RGC-936, 471,197 &G-34, 80	Guara 80
Cowpea	UPC-287, 5286, EC-4216, CO-1, CS-88, C-14	CL 367

Anonymous 2023, Anonymous 2022, Raddy et al 2022, Kumar et al 2012

Table 3: Recommended varieties of *rabi* fodders

Fodder Crop	Varieties for North/Central Zone/Growing region	Varieties for Punjab
Berseem	Mescavi, Wardan, BL- 22, BL-2	BL 44, BL 43, BL 42, BL 10
Shaftal	SH 4, SH 69, Shaftal 69	Shaftal 69
Lucerne	Sirsa 8, Anand 2, 3, CO 1, RL 88 and T9	LL Composite 5
Senji	Safed 76, FOS 1, YSL 106	YSL 106
Oats	HFO 114, Kent, OS 6, OS 7	OL 15, OL 14, OL 13, OL 10
Ryegrass		Punjab Ryegrass 2, Punjab Ryegrass 1

Anonymous 2023, Anonymous 2022, Raddy et al 2022, Kumar et al 2012

2. Planting methods & Density

Forage crops response in a different way to plant densities under different environmental conditions and cultural practices which influence forage yield and quality (Subrahmanya*et al.*, 2017). Increases in plant density often result in higher forage yield, but this is dependent on a number of factors, including climatic conditions of growing region, plant size and leaf area. In order to optimize the use of moisture, nutrients and solar radiation, seed must be planted under optimum density. Optimum plant densities resulted in better light absorption by flag leaves which have high photosynthesis efficiency and enhanced forage yield.

3. Nutrient Management

Plants required 17 essential nutrients for their growth and development. Adequate supply of nutrients at each growth stage is highly essential for good yield and quality of fodder (Subrahmanya*et al.*, 2017).Fertilizer application is one of the principal factor that directly influence fodder yield. It influences DM yield by influencing leaf area index, leaf area duration and photosynthetic efficiency. Nitrogen is a primary nutrient required by crops plants for their growth and development and plays a key role in vegetative growth fodder crops. The application of nitrogen increased the forage yield as well as improves its quality especially its protein contents. Application of nitrogen increase fodder nutritive value by increasing crude protein and by reducing ash and fiber contents.

Phosphorus is also primary nutrient to plant growth and development and an integral part of nucleic acid and is essential for cellular respiration and for metabolic activity. Use of phosphorus along with nitrogen increased fodder yield and quality by increasing plant height, and the number of leaves per plant. Khan *et al.* (2014) reported that application of nitrogen and phosphatic fertilizer resulted in increase in number of leaves, plant height, leaf area and vegetative growth thus resulted in higher green fodder yield of crop. Subrahmanya*et al.* (2017) reported that in sandy clay loam soil, low in available nitrogen, medium in available phosphorus and high in available potassium with neutral pH, application of 125% recommended dose of fertiliser (RDF) resulted in highest green fodder yield and dry matter yield. The crude protein content and ether extract was maximum and level of neutral detergent fibre (NDF) & acid detergent fibre (ADF) was lowest under under 125% RDF. Kumar *et al.* (2017) reported that under soils low in available nitrogen, medium in available phosphorus and high in available potash, application of 125 % RDF resulted in higher green fodder yield, crude protein content, ether extract, ash content as compared to 105 % RDF. It is also reported that NDF, ADF and acid detergent lignin (ADL) showed declining trend with increase in fertility levels. This is due to fact that the higher supply of nitrogen along with phosphorous resulted into higher protein synthesis and lowered the soluble carbohydrates which could be responsible for lower content of NDF, ADF and ADL in fodder maize.

Among different nutrients, zinc plays important role in quality fodder production and there are clearly direct linkages between the occurrence of deficiencies in soils, in food/fodder crops, and in animal and human nutrition. Zinc is an essential mineral nutrient and a cofactor of over 300 enzymes and proteins involved in cell division, nucleic acid metabolism and protein synthesis. About 50% of Indian soils are deficient in Zn causing low levels of Zn and yield losses in fodder crops and hence affecting the health of the livestock. In soils deficient in available zinc, soil and foliar applied zinc sulphate had significant effect on growth, green fodder, dry matter yield and quality of maize fodder (Kumar *et al.,* 2016). They further noted that, highest green fodder yield, dry matter yield and zinc concentration of maize was obtained with soil application $ZnSO_4$ at 20 kg/ha followed by 10 kg/ha $ZnSO_4$ + 0.5% foliar spray at 30 DAS and 0.5% foliar sprays at 30 and 45 DAS.

4. Weed management

Weed infestation in fodder crops impose heavy competition to crop for growth factors and a loss of 30-40 % of applied nutrients was reported by Mundra *et al*. (2002). Admixture of weeds with fodder during harvest like *Coccinia grandis* and *Trianthema*, reduces palatability of green fodder and thus affects milk production of milch animals. Toxic symptoms of some weed species in livestock is given in table 4.

Weeds compete with crop for available resources resulted in yield loss, declining the quality of produce and also harbor many associated disease causing pathogens and pests. The maximum yield loss was noticed, when the weeds are not checked during critical crop-weed competition period. Weed management during early crop growth stage proved effective in reducing weed competition increasing crop yields.

In fodder crops, management of weeds by hand weeding and mechanical weeding is very effective but some time it is not practicable due to moist soil and is also time and labour consuming. Under such conditions, chemical weed control has been proved very effective in reducing weed competition in the early stages and increasing green fodder yields. Mukherjee *et al*. (2019) reported that application of atrazine at the dose of 0.75 kg/ha and above as pre-emergence, showed selectivity and effectiveness in controlling weeds in fodder maize. However, atrazine residues were found from 0.008 to 0.531μg/g in the green fodder maize at 60 days after application. Kaur et al (2016) recorded the effective control of grass and broad-leaf weeds in maize by post-emergence application of non-selective herbicides paraquat at the dose of 500 g ha^{-1} and glyphosate at the dose of 900 g ha^{-1} and 1800 g ha^{-1} as a directed spray when the weeds were at 2-4 leaf stage.

Table 4: Toxic weeds for livestock

Weed species	Toxic symptoms
Ranunculus spp.	Oral and gastrointestinal irritation. Inflammation and blisters where plant juice touched the animal.
Xanthium strumarium	Weakness, depression, nausea, vomiting, rapid weak pulse, twisting of neck muscles
Datura stramonium	Increased heart rate, tremble, become delirious, appear to be hallucinating, have convulsions, become comatose, and may die.
Sorghum halepense	Deep and rapid breathing, anxious and stressed, trembling, incoordination, attempts to urinate and defecate and collapsing leading to death.
Asclepias spp.	Muscle tremors and spasms, bloat, increased heart rate, difficult breathing, and occasionally death.
Solanum spp.	Abdominal pain, stupidity, dilation of pupils, loss of appetite, diarrhoea, loss of muscular coordination, unconscious and death.
Brassica spp.	Oral and gastrointestinal irritation is most common leading to head shaking, salivating, colic, abdominal pain, vomiting and possibly diarrhoea.
Euphorbia spp.	Nausea, vomiting and diarrhea. Contact with sap causes inflammation of skin.
Eupatorium rugosum	Depression, stiff gait, muscle tremors, trembling, partial throat paralysis, jaundice, passage of hard feces and prostration. Death may be sudden with no prior signs of toxicity. Because tremetol is excreted in the milk, nursing animals will be affected by the toxin
Croton capitatus	Vomiting, diarrhoea and nervousness are primary symptoms.

Mishra and Shukla (2022)

5. Stage of harvesting of crop

Optimum time of harvest is the most important factor influencing the quality of fodder. Early harvesting of crop resulted in lower dry matter yield per unit area while advancing crop maturity leads to decrease in protein content, available energy, daily nutrient intake and digestibility due to lower carbohydrate content and more lignin in green fodder.

Table 5: Optimum stage of harvesting of different fodder crops

Fodder Crop	Optimum stage for harvesting	Days after sowing
Kharif		
Maize	Milk stage	50-60
Bajra	At ear initiation	45-55
Sorghum	Boot to milk stage	65-80
Napier-bajra hybrid	One meter high	50-55
Guinea Grass	One meter high	55-60
Guara	Pod initiation stage	90-100
Cowpea	Pre flowering stage	55-65

Rabi		
Berseem	--	60
Shaftal	--	55
Lucerne	--	75
Senji	Full blossom	--
Oats	Boot to milk stage	65-70
Raygrass	--	55

Anonymous (2022) and Anonymous (2023)

6. Nonlegume - legume Intercropping

Green fodder from non leguminous crops provide high-energy content, but its crude protein (CP) content and biological value are relatively low which can be increased by incorporating protein-rich leguminous crop such as cowpea. Growing of non leguminous fodders in mixture with legumes has potential to improve palatability and digestibility of fodder. Corn-legume intercrops could increase forage quantity as well as quality and decrease requirements for protein supplements compared with the monocultures. The objective behind the non legume – legume forage intercropping is to efficiently utilization of resources such as space, light and nutrients and to increase the production of quality fodder. Proper spatial arrangements, planting rates and the maturity dates of components in non legume - legume intercropping enhance biodiversity and have many advantages over monocropping (Htet*et al*.. 2016).

Baghdadi *et al*. (2016) reported that intercropping of corn-soybean under different combination ratio enhanced the forage quality in terms of CP yield, CP content, NDF, ADF concentrations as compared to the sole cropping of corn. They further reported that DM yield of the corn-soybean with 50:50 combination ratio is at par with monoculture corn, but had a higher protein yield and good quality of forage and silage than monoculture corn.

Dahmardeh *et al.* (2009) reported highest green fodder yield by sowing the maize and cowpea in ratio of 100:100. Intercropping of maize-cowpea also resulted in increase in forage quality. Ginwal*et al.* (2019) reported the maximum green fodder yield and dry matter yield with intercropping of maize + cowpea (2:1) and maize + guar (2:1) intercropping combinations. In terms of economics of different treatments, the highest net income and B:C ratio was recorded with maize + cowpea (2:1) intercropping combination.

Preservation of maize fodder as silage

Forage preservation as silage is a key element for productive and efficient ruminant livestock farms as it permits a better supply of quality feed when forage production is low or dormant. It also provides farmers with a means of preserving forage when production is faster than can be adequately utilized by grazing animals and prevents lush growth from becoming too mature. It provides a uniform level of high quality forage for ruminant livestock throughout the year.

Silage is the product from a series of processes by which cut forage of high moisture content is fermented to produce a stable feed which resists further breakdown in anaerobic storage (Kumar *et al*. 2019). Silage is as nutritious as green fodders as it preserves the nutrients in the original form and hence it is as good for animal feeding as green fodder itself. Among different forage crops, maize is considered to be one of the best cereal fodder crop used or preservation as silage. Corn silage is preferred because of its relatively constant nutritive value, high yield and higher water soluble carbohydrates for fermentation to lactic acid. Production of high-quality silage is dependent on both controllable and uncontrollable factors. During silage making, the palatability of fodder crop increased as hard stem on fermentation in silage becomes soft, this helps in easy digestion by dairy animals and the anti quality components are either destroyed or lowered during silage fermentation (Chaudhary *et al.,* 2012). The production of quality silage depends upon number of agronomic factors discussed below.

Selection of variety

In order to get maximum yield of quality forage in minimum time, selection of cultivar is very important. Climatic conditions, especially growing period longevity affect cultivar selection directly (Ileri*et al*., 2018). Hybrid selected for silage production should have high forage yield, high total digestibility, low fiber levels and highly digestible stover and also having high grain yield, because grain is highly digestible and adds greatly to total dry matter (Jeff Hinen, 2006).

In a study conducted by Brar *et al.* (2019), three hybrids of maize were tested at the farmer's field for silage making *i.e*., P1844, DOW2244 and P31Y45. They reported thatthere was no significant difference among the hybrids with respect to dry matter, crude protein, NDF, ADL, pH, ammonia-N and buffering capacity. In case of ADF, the minimum value was recorded under P31Y45, which was statistically at par with P1844 and significantly lower than DOW2244 (Table 6) and concluded that if the crop is managed properly, all cultivars have the ability to produce good quality forage leading to good quality silage.Brar *et al* 2021 reported that the silages prepared from hybrids PMH 10 and DKC 9108 recorded significantly better fermentation characteristics, nutritive value in comparison to silage of composite J1006 and are best suitable for cultivation during spring season for quality silage production.

Table 6: Silage quality of different maize cultivars

Cultivar	Dry matter	Crude protein	NDF	ADF	ADL	pH	Reference
	g/100g (%)						
P1844	31.8	7.5	43.4	28.9	--	4.0	Brar *et al*, 2017
PAC 746	20.9	7.6	64.8	40.8	--	3.5	
P1844	26.95	9.44	65.05	37.78	5.69	3.85	Brar *et al*, 2019
DOW2244	26.49	9.65	63.47	41.88	5.81	3.88	
P31Y45	27.90	9.86	59.94	32.68	4.33	3.80	
DKC 9108	22.47	8.15	65.50	35.97	5.27	4.29	Brar *et al*, 2021
PMH 10	19.53	8.44	66.40	35.77	4.10	4.10	

Stage of harvesting of crop

Optimum time of harvest is the most important factor influencing the quality of corn silage. Early harvesting of crop resulted in lower dry matter yield per unit area while advancing crop maturity leads to decrease in protein content, available energy, daily nutrient intake and digestibility due to lower carbohydrate content and more lignin in green fodder. Corn should be harvested for silage between 60-70% moisture content to ensure good storage and fermentation in silo (Jeff Hinen, 2006).

Maize is best suited to be ensiled when the grains are in the milking stage or at 2.5 milk line score (MLS) i.e. the milk line is halfway down the grain, is considered best stage to harvest maize for silage Griffiths *et al*. (2004). Production of quality silage by harvesting of crop at dent stage or near 2.5 MLS was reported by Brar *et al*. (2017)

The milk line is use for rough estimation of whole plant moisture level for harvest. Milk line is the division between the milky sugar in the developing kernel and the starch developed from those sugars. It is visually inspected by breaking the ear of corn in half. Notice the starch development from the top of the kernel towards its tip attaches to the cob.

Storage of green forage

Quality of silage also affected method of storage and period of ensiling (Brar *et al.* 2019). Time taken to fill silo pit/bunker and adequate packing density of green fodder in silo pit/bunker is also a very important factor determining the quality of silage.

The longer filling time of chaffed fodder in silo effect the maintained anaerobic conditions properly leading to increased aflatoxin level (Brar *et al*. 2017). Rapid elimination of oxygen from silo pit was critical for the prevention of storage moulds as subsequent aeration of silage can cause fungi to proliferate and if conditions are suitable, mycotoxin may be produced. For proper storage of silage by maintaining anaerobic conditions, the silo pit should be filled within two days and fodder should be ensiled for minimum 45 days (Brar *et al*. 2019).

Ruppel *et al.* (1992) reported that corn silage DM loss in bunker silos after 180 days of storage was reduced from 20.2 to 10 %, as the density of storage was increased from 10 to 22 lb DM/ft^3. Dry matter through this process can be significantly reduced by forcing as much oxygen out of the pile as possible before the bacteria can utilize it by increasing the overall compaction density. The packing density of 15 lb DM/ft^{3}or greater is optimum to minimize dry matter loss.

Conclusion

Always use recommended varieties of fodder crops to ensure maximum yield of quality fodder.Sowing of fodder crop with recommended seed rate to ensure optimum plant population, give better growth and yield of fodder crops.Fertilizers should be used on soil test basis and under low fertility soils, application of 125% RDF gave better growth, yield and quality of fodder.In Zn deficient soils, productivity and quality of fodder can be enhanced by Zn fertilization as basal or foliar application.Intercropping of legume and non-legume fodders increase green fodder yield and forage quality of as compare to its monoculture.Preservation of corn as silage provides a uniform level of high quality forage for ruminant livestock throughout the year. In order to prepare quality corn silage, crop should be harvested at 2.5 milk line score i.e. the milk line is halfway down the grain.Time taken to fill silo pit/bunker and adequate packing density of green fodder in silo pit/bunker is also a very important factor determining the quality of silage.

References

Anonymous (2022) *Package of Practices for Rabi Crops of Punjab*. Punjab Agricultural University, Ludhiana.

Anonymous (2023) *Package of Practices for Kharif Crops of Punjab*. Punjab Agricultural University, Ludhiana.

Baghdadi A, Halim R A, Ghasemzadhe A, Ebrahim M, Othman R and Yusof M M (2016) Effect of intercropping of corn and soybean on dry matter yield and nutritive value of forage corn. *Legume Research***39**: 976-981.

Brar N S, Kumar B ,Hundal J S, Singla A, Kumar A and Verma H K (2021) Maize (*Zea mays*) cultivars evaluation for herbage yield and silage quality. *Indian J Agric Sci* **91** (8): 1131–5

Brar N S, Kumar B, Kaur J, Kumar A, Verma H K, Singh R and Singh P (2019a) Qualitative study of corn silage of cattle farms in subtropical conditions of Indo-Gangetic plains. *Range Management& Agroforestry* **40**: 306-312.

Brar N S, Kumar B, Singh P, Kumar A and Singh P (2017) Qualitative assessment of silage prepared at farmer's field in Tarn Taran district of Punjab. *Indian J AnimNutr***34**: 357-360.

Brar N S, Singh P, Kumar A, Kumar B and Sashipal (2016) Maize silage feeding via-a-vis milk production in crossbred dairy cows in Tarn Taran district of Punjab. *Progressive Research***11**: 269-270.

Chaudhary D P, Jat S L, Kumar R, Kumar A and Kumar B (2014) Fodder quality of maize: its preservation. In: *Maize: Nutrition Dynamics and Noveluses,* (Chaudhary DP, Sandeep Kumar and Sapna Singh, Editors). Springer India. pp. 153-160. doi. 10.1007/978-81-32-1623-0_13.

Chaudhary D P, Kumar A, Mandnania S S, Srivastave P and Kumar R S(2012) Silage Making. pp 18. Maize as fodder? An alternative approach. (Publisher: Directorate of Maize Research, PUSA campus, New Delhi)

Dahmardeh M, Ghanbari A, Syasar B and Ramroudi M (2009) Effect of intercropping maize (*Zea mays* L.) with cow pea (*Vigna unguiculata* L.) on green forage yield and quality evaluation. *Asian Journal of Plant Sciences***8**: 235-239.

Ghosh P K, Palsaniya D R and Srinivasan R (2016) Forage research in India: Issues and strategies *Agric Res J* **53**: 1-12

Ginwal D S, Kumar R, Ram H, Dutta S, Arjun M and Hindoriya P S (2019) Fodder productivity and profitability of different maize and legume intercropping systems.*Indian Journal of Agricultural Sciences* **89** : 1451–1455.

Griffiths, N.W., F.J. Mickan, and A.G. Kaiser (2004) Crops and bi-products for silage. In: *Successful Silage* (A.G. Kaiser, J.W. Piltz, H.M. Burns and N.W. Griffiths; eds.) Dairy Australia and New South Wales Department of Primary Industries, Orange, NSW. pp 110-141.

Htet M N S , Soomro R N2 and Bo H J (2016) Effect of Different Planting Structure of Maize and Soybean Intercropping on Fodder Production and Silage Quality. *Current Agriculture Research Journal***4**: 125-130.

Ileri O, Carpici E B, Erbeyi B, Avci S and Koc A (2018). Effect of sowing methods on silage yield and quality of some corn cultivars grown in second crop season under irrigated conditions of central Anatolia, Turkey. *Turkish Journal of Field Crops* **23**:72-79.

Jeff Hinen M S (2006) *The Big 6*- Focus on the 6 kews to quality corn silage. 2006 Mid-South Ruminant Nutrition Conference.

Kaur T, Kaur S and Bhullar M S (2016) Management of complex weed flora in maize with post emergence herbicides. *Indian J Weed Sci* **48**: 390–393.

Khan A, Munsif F, Akhtar K, Afridi M Z, Zahoor A Z, Fahad S, Ullah R, Khan F A and Din M (2014) Response of Fodder Maize to Various Levels of Nitrogen and Phosphorus. *American Journal of Plant Sciences***5**: 2323-2329. http://dx.doi.org/10.4236/ajps.2014.515246

Kizilsimsek M, Gunaydin T, Aslan A, Keklik K and Acikgoz H (2020) Improving Silage Feed Quality of Maize Intercropped with Some Legumes. Turkish Journal of Agricultural and Natural Sciences 7: 165–169

Kumar B, Brar N S, Verma H K, Kumar A and Singh R (2019) Nutritious feed for farm animals during lean period: Silage and Hay- A Review. *Forage Research***45**: 10-22.

Kumar R, Rathore D K, Meena B S, Ashutosh, Singh M, Kumar U and Meena V K (2016) Enhancing productivity and quality of fodder maize through soil and foliar zinc nutrition. *Indian J. Agric. Res*. **50**: 259-263.

Kumar R, Singh M, Meena B S, Kumar S, Yadav M R, Parihar C M, Ram H, Meena R K, Meena V K and Kumar U (2017) Quality characteristics and nutrient yield of fodder maize (*Zea mays*) as influenced by seeding density and nutrient levels in Indo-Gangetic Plains. *Indian Journal of Agricultural Sciences***87**: 1203–1208.

Kumar R, Singh M, Tomar S K, Meena B S, and Rathore D K (2015) Productivity and nutritive parameters of fodder maize under varying plant density and fertility levels for improved animal productivity. *Indian Journal of Animal Research* **50**: 199-202.

Kumar S (2021) Intensive Forage Development Technologies Pp 39-44. In:*Training Manual, Workshop of All India Fodder Production Officers: Kharif* . Eds. Sharma P, Govindasamy P, Gupta G and Choudhary BB. ICAR- Indian Grassland and Fodder Research Institute, Jhansi (U.P.)

Kumar S, Agrawal R K, Dixit A K, Rai Arvind K, Singh J B and Rai S K (2012) Forage production systems in irrigated lands. In: *Forage Production Technology for Arable Lands*. Pp 2-20. Indian Grassland and Fodder Research Institute, Jhansi, Up, India.

Mishra A and Shukla S N (2022) Impact of toxic weeds on livestock. In: *Technological glimpses on weeds and their management* (Eds Mishra J S, Kumar S and Rao A N). Indian Society of Weed Science, Jabalpur, India; p. 67–70.

Mukherjee P K, Sondhia S, Singh P and Sagar R L (2019) Atrazine use to control weeds and its residue determination in fodder crops of maize and sorghum. *Indian J Weed Sci* **51**: 163–168.

Mundra S L, Vyas A K, Malival P L (2002) Effect of weed and nutrient management on nutrient uptake by maize (*Zea mays* L.) and weeds. *Indian J Agron***47**: 378-383.

Palsaniya D R and Gupta G (2021). Non-Conventional Fodder Resources. Pp 54-64. *Training Manual, Workshop of All India Fodder Production Officers: Kharif* . Eds. Sharma P, Govindasamy P, Gupta G and Choudhary B B. ICAR- Indian Grassland and Fodder Research Institute, Jhansi (U.P.)

Reddy MB, Kumar A, Meena RK, Ram H, Kumar R, Saxena A, Singh M, Pandey R, Singh O, Singh S and Rani A (2022) Role of agro-interventions in fodder production in the face of climate change. In: Basic climate smart technologies of fodder production and conservation. Agronomy Section, ICAR-NDRI, Karnal, pp 11-25.

Ruppel K A (1992) Effect of bunker silo management on hay crop nutrient management. M.S. Thesis, Cornell University, Ithaca, NY.

Subrahmanya DJ, Kumar R, Tragi N, Ram H, Singh M, Meena RK, Tamta A and Pandey A K(2017) Yield of fodder maize (*Zea mays*) and its chemical composition under varying plant densties and nutrient management. *Indian Journal of Animal Nutrition* **34**: 425-429

Chapter 3

TOTAL MIXED RATION (TMR) FEEDING TO DAIRY ANIMALS

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Balanced ration is a prerequisite for successful dairy farming. An animal of high genetic potential will become a medium milk producer if feed is not properly balanced. Unbalanced feeding leads to low milk production, lower growth in heifers, impaired reproduction and low immunity. In India, majority of farmers keep animals under mixed farming system doing both crop production and animal husbandry. Such farmers rely more on crop residues like wheat straw and paddy straw for feeding to animals. Crop residues are inherently low in essential nutrients and animals subsisting on these produce lower quantity of milk. On the other hand, the farmers who take dairy farming as their main profession tend to feed more balanced ration and their milk production/animal is also higher. TMR feeding has some advantages:

- Well balanced ration will be fed with each bite and feed efficiency utilization increases up to 4%.
- Unpalatable feed ingredients can be incorporated in ration.
- It reduces sub acuteruminal acidosis by making roughage and concentrate available at the same time to rumen microbes. By keep rumen pH above 6 most of time, the milk fat depression and lameness will be eliminated.
- Feeding can be mechanized.
- Milk production will be increased by about 5-8%.
- TMR feeding also increases milk fat %age.

Table-1: A study on TMR feeding to lactating dairy cows in the University.

Parameter	Control	TMR
Week-1 DMI, kg/d	21.46±0.09	20.23±0.68
Week-2 DMI	22.37±0.22	22.45±0.14
Week-3 DMI	21.68±0.40	21.76±0.32
Week-4 DMI	20.63±0.43	21.68±0.20
Week-5 DMI	17.36±0.15	16.87±0.15
Metabolic Body weight, kg	113.87±6.76	94.26±4.75
Milk production wk-1	19.15±1.38	21.70±0.24
Wk-2	19.17±1.80	19.85±1.75

Wk-3	19.50±1.70	19.07±2.69
Wk-4	19.95±1.25	19.32±1.36
Wk-5	18.35±1.79	18.77±1.12
Milk/kg $W^{0.75}$	0.169±0.019	0.204±0.025
RFI- DMI and Milk yield	-1.06±0.35	1.19±0.31

Implementing TMR feeding is complicated and has also some costs, in terms of capital and management, involved. These are as follows:

- Since TMR is fed to large no of animals at a farm so any miscalculation can have drastic effect on milk production.
- Individual feeding is not possible.
- Some equipment's are required like TMR wagon and tractor.
- Need to be aware of nutrient requirements of different groups of dairy animals in detail.
- Mechanized delivery from TMR wagon needs specialized sheds and may be difficult in old structure which are not suitable for this purpose.
- TMR is implemented only with silages as the quality of fodder needs to be similar over medium time intervals for calculation of TMR formula.
- As TMR is fed usually once daily so feed needs to be pushed periodically.
- For small farm it may be more costly than conventional system.

Before formulating a total mixed ration we have to keep in mind the following points:

- Type of forage being fed. Complete analysis of silage needs to be done based on which TMR is formulated.
- Milk yield and milk fat % of the target animal.
- Stage of lactation and body condition score. In late lactation, animals with good body condition score (3.0 or above) require less energy in their ration.
- TMR should contain 50% DM otherwise intake will be depressed.
- It should be fed fresh and twice a day during summer and once during winter months.

TMR for 20 kg milk/d

Requirement of energy, protein, calcium and phosphorus depend upon body weight and milk production.

Table.2.Nutrient requirements for milk production.

Milk production kg/d(3.5% fat)	DMI (kg/d)	NE_L (Mcal/d)	CP %	Calcium %	Phosphorus %
20	17	23.0	16	0.62	0.35
30	21	31.5	18	0.70	0.38

To calculate the energy required for 20 kg milk with 3.5% fat.

0.70 Mcal NE_L/kg milk x 20 = 14

9 Mcal is required for maintenance for 500 kg animal

Total requirement is 9 + 14 = 23 Mcal NE_L/d. For first lactation animals, we have to give growth allowance also. For 500 g/d growth, 2.4 MCal NE_L and 320 g/d protein is required. This will add in addition to the requirement for maintenance and milk production. Protein requirement for milk production is 85 gm/kg milk in cows.

Environmental temperature also plays a role in energy requirement. Exposure to cold increases the energy requirement of the animal.

The starting point in balancing the dairy cow ration is knowing quantity and quality of green fodder/silage/hay. For example if we have green sorghum fodder at optimum stage of harvest, it will have 25% dry matter, 8% crude protein and 0.9Mcal NE_L/kg DM. In early lactation, we fix forage concentrate ratio at 60: 40 for medium yielders (approx. 4000 kg milk/lactation) and 50: 50 for high yielders(approx. 6000 kg milk/lactation). Taking the example of a cow having 500 kg body weight and producing 20 kg milk per day, we can proceed in following manner:

DMI = 17 kg/d (Table-1)

From Green fodder = 8.5 kg

(50% of DMI)

Crude protein from green = 8.5x 0.08 = 0.68 kg

Energy = 7.65 MCal NE_L

Table-3. Contribution of DM, energy and protein from concentrate and fodder.

Requirement	DMI	NE_L	CP, kg
Total	17	23	2.7 (17 x 0.16)

From fodder	8.5	7.65	0.68
Balance	8.5	15.35	2.02

We need concentrate which has

$$CP\ \% = \frac{2.02}{8.5} \times 100 = 23.76\%$$

$$NE_L = \frac{15.35}{8.5} X100 = 1.80\ Mcal/kg$$

For making concentrate mixture of required crude protein per cent, Pearson square method can be used. It is described below:

Pearson square method

First fix the ingredients
- 2.0% bypass fat
- 1.5% mineral mixture
- 1% salt
- 4.5% molasses
- 0.5% buffer
- 0.1% toxin binder
- 0.1% yeast
- 0.05% chelated trace minerals
- 0.25% limestone powder

Total = 10

These 10 parts of concentrate will not supply any protein, therefore, balance 90 kg should contain 23.76 kg crude protein

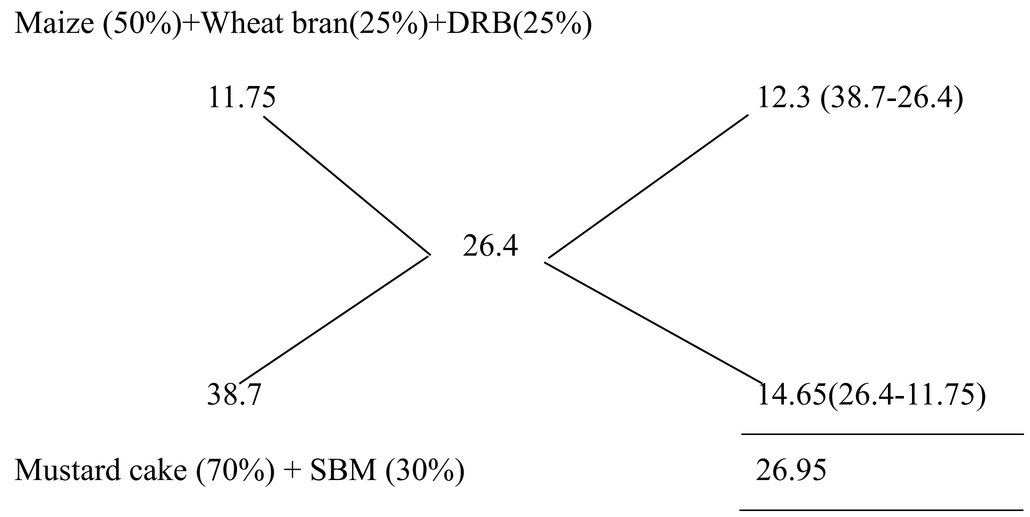
$$On\ \%age\ basis = \frac{23.76}{90} \times 100 = 26.4\%\ CP$$

Then select energy ingredients like maize, wheat bran and deoiled rice bran. Give weighted value to calculate the crude protein % of these energy ingredients. Here we have taken 50% maize, 25% wheat bran and 25% deoiled rice bran. The crude protein per cent in these are 9, 13 and 16 %, respectively. The average CP of grain mix will be

(50 x 0.09) + (25 x 0.13) + (25 x 0.16) = 11.75%

Similarly protein mix of mustard cake is (70%) and soy bean meal (30%) having CP % of 36 and 45%, respectively. Their average CP will be 38.7%.

Then applying the Pearson square method:



90 kg will contain = (12.3/26.95) x 90 = 41.08 kg grain mix

= (14.65/26.95)x 90 = 48.92 kg protein mix

Grain mix required:

Maize = 41.08 x 0.5 = 20.54 kg

Wheat bran = 41.08 x 0.25 = 10.27 kg

DRB = 41.08 x 0.25 = 10.27 kg

Protein mix required

Mustard cake = 48.92 x 0.7 = 34.24 kg

SBM = 48.92 x 0.3 = 14.68 kg

The final composition of concentrate mixture

Parts per 100 kg					
Maize Wheat bran DRB Mustard cake SBM Mineral mixture Salt	= = = = = = =	20.54 10.27 10.27 34.24 14.68 1.5 1.0	Buffer Toxin binder Yeast Chelated MM Molasses Bypass fat Limestone powder	= = = = = = =	0.5 0.1 0.1 0.05 4.5 2.0 0.25

Table-4: Formulation of TMR for cow yielding 20 kg milk/d.

Ingredients	**DM, kg/Ani.**	**CP %**	**Total CP (kg)**	**NE_L/kg**	**Total NE_L**
Sorghum	8.5 (34 kg fresh)	8	0.68	0.9	7.65
Maize	1.75	9	0.16	2.01	3.5
Wheat bran	0.87	13	0.11	1.61	1.40
DRB	0.87	16	0.14	1.50	1.3
Mustard cake	2.91	36	1.05	1.75	5.09
SBM	1.25	45	0.56	2.2	2.75
Bypass fat	0.25	-	--	4.1	1.04
Molasses	0.27	-	--	1.76	0.47
MM, salt, yeast.trace min etc.	0.35	--	--	--	--
Total	**17.0**		**2.70**		**23.21**

The quantity of concentrate ingredients per animal per day was calculated by taking proportion of each ingredient from 8.5 kg daily concentrate allowance.For example the above concentrate contains 20.54 % maize in it. The daily maize intake by the animal will be 8.5x0.2054=1.75 kg.

If we take DM level (92% approx.) in to consideration then

$$\text{On as such basis the conc. offered /ani/d} = \frac{8.5}{0.92} = 9.24 \text{ kg}$$

Properly balanced ration not only increases the milk production but also lowers the cost of milk production as a well balanced ration will have higher efficiency of conversion of ration

DM to milk solids. On an average the dairy ration should be balanced on fortnightly basis depending upon change in milk production and quality and quantity of available green fodder.

TMR for 30 kg milk

Requirement of energy, protein, calcium and phosphorus depend upon body weight and milk production.

To calculate the energy required for 30 kg milk with 3.5% fat.

0.70 Mcal NE_L/kg milk x 30 = 21

9 Mcal is required for maintenance for 500 kg animal

Total requirement is 9 + 21 = 29Mcal NE_L/d. For first lactation animals, we have to give growth allowance also. For 500 g/d growth, 2.4 MCal NE_L and 320 g/d protein is required. This will add in addition to the requirement for maintenance and milk production. Protein requirement for milk production is 85 gm/kg milk in cows.

Environmental temperature also plays a role in energy requirement. Exposure to cold increases the energy requirement of the animal.

The starting point in balancing the dairy cow ration is knowing quantity and quality of green fodder/silage/hay. For example if we have green sorghum silage at optimum stage of harvest, it will have 25% dry matter, 8% crude protein and 1.07Mcal NE_L/kg DM. In early lactation, we fix forage concentrate ratio at 50: 50 for medium yielders (approx. 4000 kg milk/lactation) and 50: 50 for high yielders (approx. 6000 kg milk/lactation). Taking the example of a cow having 500 kg body weight and producing 30 kg milk per day, we can proceed in following manner:

DMI = 21 kg/d (Table-1)

From Green fodder = 8.4 kg

(40% of DMI)

Wheat straw=2.1 kg (10% of DMI)

Crude protein from silage =8.4 x 0.08 = 0.672 kg

Crude protein from wheat straw= 2.1 X 0.035= 0.07

Total CP from roughages (Silage+straw) = 0.745 Kg

Energy from roughages (Silage+straw) = 10.67MCal NE_L

Table-5. Contribution of DM, energy and protein from concentrate and fodder.

Requirement	DMI	NE_L	CP, kg
Total	21	31.5	3.78 (21 x 0.18)
From fodder	10.50	10.67	0.745

Balance	10.50	20.83	3.03

We need concentrate which has

$$CP\ \% = \frac{3.03}{10.50} \times 100 = 28.86\%$$

$$NE_L = \frac{20.83}{10.5} X100 = 1.98 Mcal/kg$$

For making concentrate mixture of required crude protein per cent, Pearson square method can be used. It is described below:

Pearson square method

First fix the ingredients
2.5% bypass fat
2.0% mineral mixture
1.5% salt
3.25% molasses
1.0% buffer
0.1% toxin binder
0.1% yeast
0.05% chelated trace minerals
0.5% limestone powder
1.0 % Urea
Total = 12

These 10 parts of concentrate will not supply any protein, therefore, balance 90 kg should contain 24.70 kg crude protein

CP required in concentrate= 28.86
CP from 1% Urea= 2.87
Balance =28.86-2.87=25.99

$$\text{On \%age basis} = \frac{25.99}{88} \times 100 = 29.53\%\ CP$$

Then select energy ingredients like maize, wheat bran and deoiled rice bran. Give weighted value to calculate the crude protein % of these energy ingredients. Here we have taken 50% maize, 25% wheat bran and 25% deoiled rice bran. The crude protein Mustard cake and soybean meal in 50 and 50 per cent. The average CP of grain mix will be

(50 x 0.09) + (25 x 0.13) + (25 x 0.16) = 11.75%

Similarly protein mix of mustard cake is (50%) and soy bean meal (50%) having CP % of 37 and 49, respectively. Their average CP will be 43%.
Then applying the Pearson square method:

Maize (60%)+Wheat bran(25%)+DRB(15%)

10.55 13.47 (43-29.53)

29.53

43 18.98(29.5-10.55)

Mustard cake (50%) + SBM (50%) 32.45

88 kg will contain = (13.47/32.45) x 88 =36.53 kg grain mix

= (18.98/32.45)x 88 = 58.49 kg protein mix

Grain mix required:

Maize = 36.53 x 0.6 = 21.92 kg

Wheat bran = 36.53 x 0.25 = 9.13 kg

DRB = 36.53 x 0.15 = 5.48 kg

Protein mix required

Mustard cake = 58.49 x 0.5 = 29.24 kg

SBM = 58.49 x 0.5 = 29.24 kg

The final composition of concentrate mixture Parts per 100 kg

Maize = 21.92

Wheat bran = 9.13

DRB = 5.48

Mustard cake = 29.24

SBM = 29.24

Mineral mixture = 2.0

Salt = 1.0

Buffer = 1.0

Toxin binder = 0.1

Yeast = 0.1

Chelated MM = 0.05

Molasses = 3.0

Bypass fat = 3.25

Limestone powder = 0.5

Urea =1.0

Table-6: Formulation of TMR for cow yielding 30 kg milk/d.

Ingredients	**DM, kg/Ani.**	**CP %**	**Total CP (kg)**	**NE_L/kg**	**Total NE_L**
Sorghum	8.4(33.6kg freshsilage)	8	0.67	1.07	8.99
Wheat straw	2.1	3.5	0.07	0.80	1.68
Maize	2.30	9	0.21	2.02	4.65
Wheat bran	0.96	13	0.12	1.61	1.54
DRB	0.58	16	0.09	1.50	0.86
Mustard cake	3.07	37	1.13	1.75	5.37
SBM	3.07	49	1.50	2.2	6.75
Bypass fat	0.34	-	--	4.1	1.38
Molasses	0.32	-	--	1.76	0.54
Urea	0.105		0.30	-	-
MM, salt, yeast.trace min, limestone powder etc.	0.55	--	--	--	--
Total	**21.0**		**3.97**		**31.76**

The quantity of concentrate ingredients per animal per day was calculated by taking proportion of each ingredient from 10.5 kg (DM) daily concentrate allowance.For example the above concentrate contains 21.92 % maize in it. The daily maize intake by the animal will be 10.5x0.2192=2.30 kg.

If we take DM level (92% approx.) in to consideration then

$$\text{On as such basis the conc. offered /ani/d} = \frac{10.5}{0.92} = 11.41 \text{ kg}$$

Properly balanced TMR not only increases the milk production but also lowers the cost of milk production as a well balanced ration will have higher efficiency of conversion of ration DM to milk solids. On an average the dairy ration should be balanced on fortnightly basis depending upon change in milk production and quality and quantity of available green fodder.

Chapter 4

Standards Specification and Ration Formulation for Different Categories of Dairy Animals

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Milk yield of dairy animals (cows and buffaloes) depends upon four main factors: (a) genetic ability; (b) feeding program; (c) herd management; and (d) health. As dairy animals continue to improve genetically, we must also improve nutrition and management to allow these animals to produce to their inherited potential. A good feeding programme must consider the nutrient requirements, available ingredients, season, formulations, quantity fed, and how and when the feeds are offered. Encouraging a lactating animal to eat large amounts of feed is the key to productive and efficient milk production. Select feeds to ensure maximum intake. All the nutrients the dairy animal requires for milk production (except water) are in the dry material of the feed. High dry matter intake (DMI) results in high nutrient intake and high milk yield. Table 1 depicts the maintenance requirements for bovines as per ICAR 2013.

Table1. Maintenance requirements for DMI, Energy & Protein for Lactating animals.

BW (Kg)	DMI	TDN (Kg)	ME (Mcal)	MP (g)	RDP (g)	CP (g)
300	6.48	2.62	9.47	191	298	351
400	8.64	3.27	11.82	237	370	436
500	10.8	3.88	14.04	280	438	515
600	12.96	4.47	16.15	321	502	591
700	15.12	5.03	18.19	361	563	663

DMI of milking animals in early lactation may be reduced up to 20% below the values in Table 1. Early lactating animals have reduced appetites. Problems such as difficult calving, milk fever, retained placenta after birth or twisted stomach will further depress DMI. Most animals increase in DMI gradually after calving and peak in DMI by 10 to 12 weeks of lactation. Similarly feed intake decreases around 15% during the last week before calving. It is therefore, recommended that laxative feed (wheat bran/molasses) may be fed for a few days before calving. Dietary supplementation of an anionic mineral mixture is also recommended during the last month of pregnancy to facilitate mobilization of more calcium and phosphorus from bones at the onset of lactation.

Cattle and buffaloes should be fed suitably, so as to make way for restoring body weight loss during first 2-3 months of lactation. The body condition score must improve to 3.5 in a 5 point scale. Accordingly, provisions for weight gain must be made. It is recommended that for every 1 kg weight gain in lactating animals, the supply of 10.5 Mcal or 2.9 kg TDN is desirable. The energy, protein requirements of cattle and buffaloes per litre of milk are given in table 2 & 3 respectively.

Table 2: DM, energy and protein requirements per kg milk in cattle

Fat (%)	**DMI (Kg)**	**TDN (Kg)**	**ME)Mcal)**	**MP (g)**	**RDP (g)**	**RUP (g)**	**CP (g)**
3	0.450	0.290	1.05	51	44	44	96
4	0.510	0.330	1.20	51	50	37	96
5	0.570	0.370	1.34	51	56	30	96
6	0.640	0.410	1.50	51	62	23	96

Table 3: DM, energy and protein requirements per kg milk in buffaloes

Fat (%)	**DMI (Kg)**	**TDN (Kg)**	**ME)Mcal)**	**MP (g)**	**RDP (g)**	**RUP (g)**	**CP (g)**
6	0.670	0.440	1.58	66	66	46	124
7	0.740	0.480	1.73	66	72	39	124
8	0.800	0.520	1.88	66	78	31	124
9	0.860	0.560	2.02	66	85	24	124

Heifers that have not reached to their adult weight must be supplied with nutrients for the growth, in addition to requirements for lactation. Additional 20% of maintenance energy during first lactation and 10% in second lactation should be supplied to such animals. After six months of pregnancy, the growth of fetus increases significantly. The estimation of nutrient requirements during late pregnancy requires accurate values for rates of nutrient accretion in conceptus tissues.

Total ration DM should be between 50 and 70%. Wetter or drier rations limit DM consumption. When silages are fed heavily DMI declines by 0.02% of body weight for each 1% decrease in total ration DM. Maximum DMI depends on continuous access to fresh, clean, cool water. Miltch animals drink about 5 litres of water for each kg milk (eg. a cow producing 40 litres of milk will consume 200 litres of water). Lactating animals are thirsty and hungry immediately after milking, decreasing water intake by 40% results in a 16 to 24% decline in

DMI and a large decrease in milk yield. These animals need more water in hot weather. Cows will reduce DMI when environmental temperature exceeds 28·C, usually due to reduced fodder intake. Cows experience severe heat stress when temperature exceeds 28·C, when relative humidity exceeds 75% or when the two values added exceed 100. DMI may be depressed by 15 to 20% on hot summer days. Summer DMI improves when you offer at least 60% of the ration fed at cooler hours or during night.

Fodders or roughages are feeds high in fibre (eg. Sorghum, Bajra, Oats, Berseem and Corn silage). The DMI from roughage determines the amount and type of the concentrate required in the ration. An economical feeding program is one based on high consumption of high quality roughages. Roughage intake depends on forage quality, size of the animal and concentrates levels. Milking cows can consume 1.8 to 2.2% of body weight daily as DM from average quality dry roughage. Roughage quality is partly determined by fibre levels. Fibre content increases as the forage crop matures. High fibre forage has lower palatability, reduced protein levels, and is less digestible than high quality material. Undigested feed cannot pass out of the rumen. The miltch animal cannot consume more feed until the feed in the rumen is digested. High fibre forages reduce DMI. A cow can eat 3% of body weight as DM from excellent silage but only 1.5% from poor one. The nutrient value of fodders depends on plant species, stage of maturity, and on harvesting and storage systems and losses.

Fodder dry matter intake is also dependent upon NDF content. For example, fodder NDF intake in mid lactation is about 0.9% of body weight. This means that a 550 Kg cow could consume 550 x 0.9% = 4.95 kg NDF. If good maize fodder contains 55% NDF, then the animal could eat 4.95 x 100/55 = 9.0 kg of dry matter from this silage. Ration NDF should be 25 to 28% of DM. Most NDF (75%) should come from roughages. Silages should be chopped in such a way as to ensure at least 15 to 20% of the particles are more than 3.8 cm (1 1/2 in.) long, to stimulate cud chewing. Dairy animals should spend most of their non-eating time chewing their cud. Underfeeding "effective" fibre causes off-feed problems and fat depression in milk. When the ration contains adequate "effective" fibre and NDF from forages, it is not necessary to include long stemmed dry fodder in the dairy ration. A minimum level of forage intake should be set. Very low forage intake leads to rumen acidosis, milk fat depression and twisted stomachs. A ration ADF of 19% and NDF of 28% (of DM) keeps the rumen functioning properly and promotes normal cud chewing. For high producing, early lactation cows and buffaloes, at least 40% of the ration DM should come from roughages. This gives minimum forage to concentrate ration of 40:60. When corn silage is above 45% of the roughage DM, a 45:55 ratio is appropriate. More roughage (less grain) can be fed to cows in late lactation or at low production levels. Forage: Concentrate ratios above 80:20 can support 20 kg of milk yield if roughage quality is good.

Recently, particularly in large dairy farms (> 100 animals); the trend of total mixed ration is gaining momentum. All the materials of ration (fodder, straw, grains, cakes, premix etc) are put in TMR machine having capacity around 10-12 quintal. The composition of TMR for different categories of cows is presented in table 4.

Table 4: Composition of Total Mixed Rations

	Levels of Milk Produced Per Day					
	<20 kg	**30 kg**	**40 kg**	**50 kg**	**Fresh**	**Dry**
Protein						
Crude protein %	12- 15	16	17	18	19	12
DIP, % of CP	63	61	60	55	55	-
UIP, % of CP	37	39	40	45	45	-
Energy						
NEI, Mcal/kg	1.42-1.52	1.62	1.72	1.72	1.67	1.25
TDN, % of DM	63 - 67	71	75	75	73	56
Fibre						
Crude fibre, %	17	17	15	15	17	22
ADF, %	21	21	19	19	21	27
NDF, %	28	28	25	25	28	35
Minerals						
Calcium, %	.43-.51	.58	.64	.66	.77	.39
Phosphorous, %	.28-.33	.37	.41	.41	.48	.24
Potassium, %	.9	.9	1.0	1.0	1.0	.65
Magnesium, %	.2	.2	.25	.25	.25	.2
Sulphur, %	.2	.2	.2	.2	.2	.16
Sodium, %	.18	.18	.18	.18	.18	.1
Chlorine, %	.25	.25	.25	.25	.25	.2

In TMR fed herds where two milking rations (high and low

Manganese,ppm	40	40	40	40	40	40
Copper, ppm	10	10	10	10	10	10
Zinc, ppm	40	40	40	40	40	40
Iron, ppm	50	50	50	50	50	50
Cobalt, ppm	.1	.1	.1	.1	.1	.1
Iodine, ppm	.6	.6	.6	.6	.6	.6
Vitamins						
Vitamin A, lU/kg	3200	3200	3200	3200	4000	4000
Vitamin D, lU/kg	1000	1000	1000	1000	1000	1200
Vitamin E, lU/kg	15	15	15	15	15	15

production level) are fed, animals can be moved into either group. Feeding some TMR prior to calving will help cows and buffaloes to adapt to high levels of grain in the TMR. Animals should have all the feed they want, when they want to eat it.

Feed according to nutrient requirements once the animal has reached her peak of production (5 to 7 weeks in buffaloes, 6 to 8 weeks for cows, and 10 to 12 weeks for first calf heifers). Concentrate requirement depends upon: milk yield, fat test, stage of lactation, body weight, body condition, quantity of forage eaten and quality of forage. The better the quality of roughage she eats, the less feed she requires. Forage testing and actual measurements of forage intake are needed to formulate a balanced ration for the milking herd.

Dairy animals will restore body condition lost in early lactation if peak grain levels are maintained until 10 to 12 weeks in lactation. This encourages reproductive cycling and conception, since this is normally the time when the animal is rebred. A good animal, at high grain intake, will peak in milk at 6 to 8 weeks, and still be producing at this level 3 to 4 weeks later. From 10 to 12 weeks until dry off, adjust the grain allowance monthly, based on the DHI test results, and body condition. If only enough grain is offered to cover the milk yield requirements, the cow is unable to gain back needed condition. At dry off, she will be thin, and she will likely produce less milk, fat and protein in the next lactation. About 2 to 3 kg extra grain is required per day (above what is needed for milk) during the last 100 days of lactation to restore body weight. Protein content of a grain mixture depends on the type and quality of forage, milk yield, fat % and stage of lactation (Table 5).

Table 5: Recommended crude protein content and protein fractions in grain mixtures matched with forage programs

Forage Program	Grain Mix CP%	Protein Fractions inGrain Mix
75% corn silage with 25% legume hay	18-20	high DIP
75% corn silage with 25% grass hay	20-22	high DIP
50% corn silage50% grass hay	17-20	high DIP
50% corn silage, 50% legume hay	15-17	medium DIP
Legume hay crop		
leafy, early cut	12-14	low DIP
late cut	15-18	medium DIP
Grass haycrop		
good quality, early cut	15-17	medium DIP
late cut	17-20	high DIP
Mixed (legume/grass) haycrop average quality	15-16	medium DIP
Pasture		
excellent quality	14-16	low DIP
good to fair quality	15-17	medium DIP

Protein not digested by rumen microbes is undegradable intake protein (UIP). This is often called "bypass" or "escape" protein because it bypasses the rumen without being digested. Some plant source feeds high in UIP are roasted soybeans, corn distillers' grains, brewer's grains and corn gluten meal. About 35 to 45% of the ration protein should be UIP. The 35% level is suitable for mid to late lactation cows. Fresh, high producing cows need 40 to 45% UIP in the ration DM. Cows fed high levels of dietary fat require UIP levels of 45 to 50%. Animal source bypass proteins (meat meal, fish meal, blood meal) are more expensive per ton than plant bypass proteins. When priced per unit UIP, animal source UIP feeds are economical. Bypass proteins of animal origin contain protein components (amino acids) which are similar to those found in milk. Therefore, animal source proteins are high quality bypass protein. Animal source UIP feeds are not very palatable. Feed them in small amounts or in a commercial or pelleted feed.

A lack of dietary energy causes the cow to rely excessively on body reserves. Rapid body fat mobilization, along with low feed and/or energy intake, leads to ketosis (acetonemia). Cows losing weight are in negative energy balance. They show weaker heats and have lower conception rate than cows gaining in condition and in positive energy balance. Most high producing cows, in early lactation are in a mild (subclinical) state of ketosis, which causes few problems except gradual body weight loss.

Corn is the least expensive grain. It is the highest energy grain followed by barley, then oats. Grains contain high levels of starch. When rumen microbes digest starch, they produce acidic end products. Rumen acidity increases, reducing fibre digestion. This may lead to "off feed", a decline in milk yield and fat test depression. Increase the ration energy density by feeding more, high energy grain. Keep fibre levels high enough for good rumen and cow health.

Non-fibre carbohydrates (NFC) are rapidly digested and include sugars, starches and pectin. NFC is calculated as: 100 - (NDF + Crude Protein + Fat + Ash). Non-fibre carbohydrate levels in the total ration dry matter should not fall below 20 to 25%, nor go above 40 to 45%. Rations formulated for 35 to 37% NFC (D.M. basis) should avoid metabolic disturbances related to feeding high levels of starches in grains and concentrate mixtures. For diets high in corn silage or grain, use of high-fibre byproduct feeds may help reduce the starch load on the rumen. Byproducts such as soyhulls, wheat bran, brewers and distillers grains are low in NFC and work well in high production rations.

When grain levels are maximized, a more costly way to increase the energy level is to add fat. Fat is too expensive to feed to any cows that are not in early lactation or above 35 to 40 kg milk. Fat contains over 2.25 times the energy value of grain. Added fat improves energy balance by reducing body weight loss, improving persistence of production and assisting in an early return to positive energy balance.

There are 3 main types of fat:

- Unsaturated fats (liquid at room temperature). Eg. corn oil, soy-bean oil (in whole soybeans), cottonseed oil (in whole cottonseed).
- Saturated fats (solid at room temperature). Eg. tallow.

- Protected fats: Fats treated or combined with another substance to prevent breakdown in the rumen. eg. Megalac®, Energy Booster® and other commercial products.

Grain mix ingredients naturally contain 3 to 4% fat. Include additional fat to a maximum total of 7 to 8% of ration DM. Multiple sources of fat can be fed. Guidelines are in Table 6. Overfeeding of unprotected fats (especially vegetable oils) is detrimental. About 2.5 kg of roasted beans or whole cottonseed will provide 0.5 kg fat. Exceeding the limits results in rumen metabolism problems, reduced fiber digestion and may depress fat and protein yields test. When including high levels of fat (especially unprotected fat) in the diet make sure that:

- ration calcium levels exceed 1% of diet dry matter
- ration magnesium levels exceed 0.3% of diet dry matter
- ration Vitamin E levels are increased to 1000 or more I.U. per cow per day to prevent oxidation of the fat and off-flavoured milk
- rumen UIP levels are 45 to 50% of ration protein Follow these grain and fat feeding guidelines to allow each cow to reach peak production at or close to her genetic potential. The advantage of maximum peak production is to maintain a higher level of milk yield throughout the lactation.

Table 6: Guidelines for fat inclusion in dairy rations

Type of Fat	**Fat (% of DMI)**	**Fat Intake (kg per day)**
Natural sources (forages, grains etc.)	2 - 3%	0.75
Unprotected sources (tallow, oilseeds)	2- 3%	0.5
Protected sources (calcium soaps, prilled fats, encapsulated fats)	2 - 3%	0.5 - 0.6

Grain fed separately (not in a TMR) should be of medium coarse grind or rolled. The rate of starch digestion can be improved if grain is adequately processed. This is desirable when the ration contains high levels of degradable protein. It allows the rumen microbes to use starch and protein simultaneously, and promotes maximum microbial growth. Fine grinding is undesirable when it creates a pasty and unpalatable feed. Finely ground grain may lead to butterfat depression and rumen upsets on high grain diets. In TMR's, where palatability is less of a problem, grain can be processed finely without problems. Whole grain is not readily digestible.

Energy is being wasted when corn appears undigested in the manure. Causes of grain in manure are high grain levels, rapid feed passage, low fibre levels or under processing of grain. Grind corn and cob meal medium fine. The largest particles should be the size of a pea. Pelleting of the grain mixture is helpful where rapid intake is required, or when grain is only fed in a milking parlour. When fibre levels in the diet are adequate, pelleted feeds will not depress at percent.

Use feeding management strategies to improve feed DMI and milk production. Feed management tips are:

- Feed grain meals of less than 4 kg of grain per feeding
- Feed grain in several small meals daily rather than two large ones, especially in hot weather
- Feed protein supplement after or with the grain meal
- Feed a forage meal 1 to 1 1/2 hours before a grain meal
- Combine forages (eg. haylage plus silage) or feed a TMR
- Have fresh feed available in bunks or mangers after milking time
- Adapt feeding strategies to the eating behaviour of your cows
- Feed forages several times and TMR's at least twice daily
- Sweep feed up to tied cows frequently
- Clean mangers and bunks daily especially in hot weather
- Clean water bowls and troughs frequently
- Provide at least 60 cm (2 feet) of bunk space per cow
- Allow cows access to feed for at least 22 hours of the day
- Healthy, contented cows eat more feed
- Frequent foot trimming will improve cow mobility and intake .

Chapter 5

Axle of Dairy Farming: Scientific Calf Rearing

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The dairy industry's future lies on calves. Calf management must be effective and sufficient for the dairy sector to succeed. By enhancing farm-level management measures that seek to minimise calving intervals, boost calving and fertility rates, reduce stillbirth and pre-weaned calf mortalities, and reduce sick heifers in the herd, it is possible to efficiently and economically replace the dairy herd.

Healthier the calf, higher will be the growth rate. Growth starts at fertilization and majority (about 70%) of it occurred in the last trimester of gestation. Intra uterine growth of foetus has a major influence on subsequent growth after birth, because birth weight is closely related to growth rate

Breed	Average calf weight at birth
Indigenous cow	20-25 Kg
Cross bred cow	30-35 Kg
Jersey Cow	18-25 Kg
Buffalo	25-30 Kg

Late-pregnancy animal care and management is essential for a healthy calf. Diet should be adequate to support foetus growth and maintenance especially during the last trimester.Poor nutrition leads to the decrease of growth rate and death of neonatal calves. Calf mortality, which results in a considerable financial loss, is one of the main reasons limiting the profitability of a dairy enterprise. Under standard managemental conditions, a minimum mortality rate of 5% is usually acceptable to the dairy farm. Thus, nutritional management of calves reduces mortality and herd health status of the farm remains in a good position.

Overall management of calves

The overall management of the calves can be considered in three stages;

Prenatal management

Calves expand exponentially during the last trimester of pregnancy. So, extra nutrients should be given to the pregnant animals during the last trimester of gestation.

A cow should be fed with 15-20 kg green fodder daily to make colostrum rich in vitamin A. If green fodder is not available, the calf should get 10,000 international units (IU) of vitamin A in its first meal. For the next seven days, doses may be decreased to 5,000 IU, and thereafter the dose may range from 1000 to 2000 IU per day. Supplementation of vitamin A is necessary because calves are unable to convert carotene into vitamin A. Clean water should be made available round the clock. Dry matter requirement should be adequately fulfilled considering the body weight, production and stage of pregnancy to the mother. The dam should be housed in a clean, dry and well-ventilated shed. To protect the calves from a variety of illnesses, proper hygiene, management, and biosecurity measures should be adopted.

Parturition (Calving) Care

Give the animal bran mash, boiled millet, and a small amount of jaggery around the time of calving. This will aid in the separation and ejection of the foetal membranes in addition to promoting milk production.

Postnatal Care

The calf's mouth and nasal mucous should be cleaned after calving. If the calves do not begin breathing on their own, the chest walls should be pressed and released alternatively with the hands. It is important to clean the calf, ligate the navel chord, and take precautions against the common cold and infectious infections. The calf's navel chord is knotted about 2.5 cm out from the body and is then cut about 1 cm below the ligature. To stop infection, iodine tincture (7%) is administered to the wound.

At birth, reticulo-rumen is non-functional in calves and hence feeding of calves should be treated as a non-ruminant animal that lasts up to 3 months.

	Percentage of total stomach capacity			
	Rumen	Reticulum	Omasum	Abomasum
New born	25	5	10	60
Adult	80	5	7-8	7-8

The most critical period in the life of a calf is 2-3 weeks, during this period the digestive system is not mature enough but it is developing rapidly with regards to digestive secretion and enzymatic activities. Feeding system of calves has been divided into three phases (Table 1)

Table 1 Phases of digestive system development of calves

Phases	Duration	Diet requited
Liquid feeding Phase	Birth to 2 or 3 week	Milk or high quality milk replacer and water
Transition Phase	2 or 3 week to weaning	Milk or high quality milk replacer, calf starter and water
Ruminant Phase	From weaning onwards	Dry feed and water

Feeding of colostrum should be done at the rate of 10% of calf's body weight on day 0 with about 500 mL being fed within 30 minutes of its birth without waiting for the expulsion of the placenta. If colostrum is not available, artificial colostrum should be fed with 50 or more grams of immunoglobulins per litre. Artificial colostrum is prepared by using an egg, half a litre of fresh warm water, half litre whole milk, one teaspoonful of castor oil/cod liver oil. New born calf is kept warm in a dry, clean and well-ventilated place preferably on a bedding of straw. After the colostrum´ feeding period, whole milk should be provided to the calf until 15 days of age @1/10th of the calf's body weight. Milk replacer can be fed along with the whole milk. Feeding milk less than recommended level results in poor growth and overfeeding and sudden change in the quantity of milk offered increases digestive upset and diarrhoea. Overfeeding milk may also decrease consumption of dry feed, thus prolonging the weaning time of calves.

Importance of colostrum Feeding

Colostrum supplies important proteins called immunoglobulin's(IgG, IgA, IgM) to the calves. They are very important for the general health and survivability of the calves. Several factors influence the passive transfer of Ig from the colostrum to the calf. They include Ig mass ingested, time of colostrum ingestion, method of feeding colostrum, genetic factors, physiological and environmental factors. Immunoglobulins are transferred across the intestinal epithelial cells only during the first few hours of life. Immunoglobulin's from the colostrum absorb into the circulation from the small intestines of the neonatal calf by a process of micropinocytosis (Blood *et al.,* 1982). Maximum absorption occurs within the first 6-8 hours after birth (Blom, 1982), thereafter absorption of immunoglobulin decreases. Calves with an inadequate level of circulating IgG are four times more likely to die and twice more likely to become ill than calves with adequate circulating immunoglobulin's (White *et al.,* 1986). Calves are born with little immunity against diseases. Immunoglobulin protects the calves against septicemic diseases and systemic invasion by microorganisms, hence feeding of colostrum within half an hour of birth is indispensable. Every hours delay in colostrum feeding during the first 12 h of life the chance of a calf becoming ill increases by 10% (Moran, 2011). IgG constitute 80-85% of all immunoglobulins in colostrum and protect the calf from a wide range of diseases. It last longest in calf blood stream with a half life of 21 days. IgA and IgM comprises 8-10 % and 5-12% respectively. Half life of IgM is 4 days and IgA is 2 days. This colostral immunity gives protection to the calf for at least 2 months from the diseases which his/her mother had faced in precalving period.

Colostrum contains numerous nutrients such as protein, fat, carbohydrates, vitamins and minerals. Fat and lactose provide energy in the colostrum, are necessary for the calf to begin thermogenesis (heat production) and maintain body temperature.

Table : Composition of colostrum and milk

Items	**Colostrum**			**Milk**
	1st Milking	**2nd Milking**	**3rd Milking**	
Solid (%)	23.9	17.9	14.1	12.9
Protein (%)	14.0	8.4	5.1	3.1
IgG(mg/ml)	32.0	25.0	15.0	0.6
Fat (%)	6.7	5.4	3.9	4.0
Lactose (%)	2.7	3.9	4.4	5.0
Minerals (%)	1.1	1.0	0.8	0.7
VitaminA (ug/dl)	295.0	190.0	113.0	34.0

Sources: J Dairy science 61:1033-1060

Colostrum is also rich in numerous non-nutritive components like growth hormones (insulin-like growth factor I and II, epidermal growth factor, transforming growth factor, and nerve growth factor) as well as insulin, cortisol, and thyroxin. Calf should not be fed colostrum from cow with mastitis and do not use colostrum from cow that has been on form for less than six weeks. Colostrum also reported to possess bactericidal properties as clear from the following research

Table: Effects of early colostrum feeding on intestinal *E.coli* attachment in calf

Feeding	**Results**
E.coli fed alone	Bacterial attachment to intestine and level of *E.coli* in circulation high

Colostrum and *E.coli* fed togather	No bacterial attachment to intestine
Colostrum fed alone, *E.coli* fed after one hour later	No bacteria attached to intestine and no *E.coli* in circulation. High level of circulating antibodies

Source: J Dairy Science 60: 1416-1421

Constipation in young calves is caused by poor/no feeding of colostrum, early inclusion of dry fodders, improper watering schedule. The act of defecation is usually difficult and accompanied by much straining. Faeces are dry, hard, small bulk in shape and are passed at infrequent intervals. Apart from nutritional significance, colostrum also possesses laxative action thus help in evacuating accumulated faeces in the intestines. Feeding 30-50 g of castor oil to calves is effective against constipation.

Why colostrums get coagulated on heating but milk does not?

Colostrums contain higher amount of albumin and globulins. So when colostrums are heated, these proteins get coagulated. But in milk these albumin and globulin are in traces, so milk does not get coagulated.

Feeding of milk replacer

Whole milk is the most natural feed for calves, but due to its high cost and competition with humans for food, it is well replaced by a calf milk replacer. Milk replacer is constituted of high-quality low-cost ingredients, having a nutritional composition similar to milk. It is more economic choice for raising calf than whole milk. It is provided to calves until rumen start functioning well. It is introduced on the 10th day of birth and its quantity can be gradually increased with a decrease in the amount of whole milk. It helps in the proper development and growth of calves reducing calves mortality. Extra energy should be fed during cold weather to maintain core body temperature. In cold weather, the calf should be provided 25-50% more whole milk or milk replacer. Milk replacer should contain 10 to 22% crude fat, 18 to 22% crude protein and 0.5% crude fiber. Milk replacer containing 20% fat should be given to calves during cold weather. Milk replacers having 15 to 20% fat may be useful in minimizing scours and promote faster growth. Ingredients used for the formation of milk replacer (Table 2) should be of good quality with high biological value.

Table 2 Composition of Milk replacer

Ingredients	Quantity (kg)
Wheat	10
Fish meal	12
Linseed meal	40
Milk	13
Coconut oil	7
Linseed oil	3
Citric acid	1.5
Molasses	10
Mineral mixture	3
Butyric acid	0.3
Antibiotic mixture	0.3
Vitamin- A, B_2, D	0.015

Feeding of calf Starter

Calves up to 2 weeks of age are usally kept on whole milk or milk replacer diet. Around this stage start feeding calf starter to the calf. Calf starter is a solid feed consisting of ground grains, oil cakes, animal protein supplements and brans fortified with vitamins, minerals and antibiotic feed supplements (Table 3). Ingredients of calf starter can be altered according to availability and feed cost. It should have higher digestibility and energy and protein content. The crude protein content of calf starter should be 23-26% and total digestible nutrient 75-80%. It should contain less than 7% fiber because a low level of fibrous material benefits starter intake and calf growth. Importance of feeding high quality and palatable calf starter lies in the fact that it provides readily fermentable carbohydrate. Fermentation of these carbohydrates leads to the production of volatile fatty acids which are responsible for early rumen development.Feeding of grain at an early stage was found to enhance the pappilae growth along with a much thicker and vascularized rumen wall as compared to feeding of hay at the same stage. The later increase the rumen size through stretching of rumen wall. So, feeding of grain and hay may help in the early weaning of the calf.

Table 3 Composition of Calf starter

Ingredients	Quantity (Kg)
Barley	40
Groundnut cake	25
Soybean cake	25
Dried skim milk	8
Mineral mixture	1
Vitamins	1
Irradiated yeast	25 g/100 Kg

Table 4 Feeding schedule of claves up to three months

Age (days)	Colostrum (kg/day)	Whole milk (kg/day)	Calf starter (kg/day)	Good quality hay (kg/day)
1-4	1/10th of BW	-	-	-
5-14	-	1/10th of BW	-	-
15-28	-	1/20th of BW	0.1	0.25
29-42	-	1.0	0.3	0.40
43-56	-	0.5	0.5	0.50
57-70	-	-	0.75	0.75
71-90	-	-	1.0	1.00

Can the adult dairy animal ration or lactation ration can be give to the calf as a starter ration?

No, adult dairy animal ration or lactation ration can't be given to newly born calf as a starter ration because this type of ration have lesser protein, more fibre content, no B- complex vitamins, no coccidiostat, no antibiotic, no yeast and some time no molasses. In adult animal, rumen bugs can synthesize vitamin B complex, so no need to supplement these from externally but in calves' rumen is not developed; so, they need them in their feed. Similarly coccidiostat and antibiotic are added in calf starter to prevent the incidence of diarrohea and to promote the growth by preventing the growth of pathogen in GI Tract.

Supplementations of micronutrients

Calves fed milk and milk replacers are deficient in some minerals and vitamins like Fe, Zn and Vitamin C. These nutrients can be supplemented to the calves from day one or added to the milk replacers or calf starters. Some minerals and vitamins like Cu, Zn, Se, Mn, Vitamin A, C and E can be supplemented to the calves to boost their immunity and antioxidant status so that they would effectively fight the diseases. Organic mineral chelates have been found to produce more desirable results compared to inorganic minerals like organic zinc was found to be more bioavailable, show higher average daily gain and energy utilization from feed than the inorganic zinc (Malik *et al.,* 2017).

Feeding of calf after weaning

If the calf starts eating dry feed earlier (approximately 1.0-1.5 kg/day), then there is a possibility of early weaning and it is economical for the farmer. Calf starter should be provided at second week of age. The fibre content of feed should be less than 10%. Calves have limited capacity to utilize non-protein nitrogen and therefore urea is not added in feed but 5-7% molasses can be added to increase the palatability of feed.

Grower and heifer Feeding

When calf completes three months of age, then there is a shift from starter to growing ration. High-quality adlib forage, 0.5 kg wheat straw and 1.5-2 kg grower concentrate are needed to feed during this phase. The protein content in ration should be 15-18%. The grower concentrate may be formulated by adding 55 kg maize, 15 kg oats, 20 kg soyabean. 7 kg molasses, 2 kg limestone powder, 2 kg DCP and 0.5 kg minerals in addition to smaller amounts of vitamin A, D and E. Grower meal offers to the calves from 90 to a80 days of age. After six months of age, grower switch to the heifer meal.

After 6 months of age, heifers may feed with herd concentrate having 20% CP and 63% TDN. Avoid high plane of nutrition because it reduces growth of milk secretory tissue which may further compromise lifetime milk production ability. About 5-7 kg of maize silage (>30% DM), 2 kg wheat straw and 2 kg concentrate mixture per head per day can fulfil their nutritional demands. The concentrate mixture may be formulated by mixing 30 kg maize, 15 kg mustard cake, 15 kg soyabean meal, 20 kg wheat bran, 17 kg rice bran, 2 kg mineral mixture and 1 kg salt. Dietary inclusion of feed additives, vitamins and good management will further prove as milestone in improving heifer’s performance.

Other points to ponder upon

- Vaccinate the female calf against the brucellosis during 4-8 months of age.
- Deworming of calf (3-4 months) must be done to get the maximum growth.
- Disbudding can be done in 1-2 weeks of age.
- Tag the animal for identification.
- Ensure the adlib water supply to calf from 4th day of age to rest of their life as it was found to improve growth performance.
- Keep the proper record.

References:

Afzal M, Javed MH, Anjum AD. Calf mortality: Seasonal pattern, age distribution and causes of mortality. Pakistan Vet J, 3:30-33, 1983.

Bebe BO, Abdulrazak SA, Ogore PO, Ondiek JO, Fujihara T. A note on risk factors for calf mortality in large-scale dairy farms in the tropics: A case study on Rift Valley area of Kenya. Asian-Aust J Anim Sci, 14:855-857, 2001.

Blom JY. The relationship between serum immunoglobulin values and incidence of respiratory diseases and enteritis in calves. Nord Vet-Med, 34:276-284, 1982.

Blood DC, Radostits OM. Veterinary Medicine, 7th Ed, ELBS, Oxford, 1989.

Jenny BF, Cramling GE, Glaze TM. Management factors associated with calf mortality in South Carolina dairy herds. J Dairy Sci, 64:2284-2289, 1981.

Malik TA, Mir SH, Pal RP: Chelated Versus Inorganic Zinc Supplementation in Ruminants. Nutri Food Sci Int J, 4:555633, 2017.

Moran JB. Factors affecting high mortality rates of dairy replacement calves and heifers in the tropics and strategies for their reduction. Asian-Aust J Anim Sci, *24*:1318-1328, 2011.

Umoh JU. Relative survival of calves in a university herd in Zaire, Nigeria. British Vet J, 138:507-514, 1982.

White DG, Andrews AH. Adequate concentration of circulating colostral proteins for market calves. Vet Record, 119:112-114, 1986.

Chapter 6

Money Spending to Money Earning: Understanding Transition Feeding

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The transition period in dairy cows is characterised by a series of metabolic, endocrine, physiological, and immunological adaptations, including negative energy balance, hypocalcemia, liver dysfunction, an overt systemic inflammatory response, and oxidative stress. Around parturition, dairy animals experience various physiological, metabolic, and hormonal changes on the transition from non-lactating pregnant to lactating non-pregnant, termed the "transition period". The period of 3 weeks before and 3 weeks after calving is critically important to manage animal health and equally challenging to achieve peak milk production and maintain reproductive efficiency (Roche et al. 2013). Cows are at highest risk of health disorders during this stage as a result of failures in management, including nutrition and others, which affect physiological and metabolic adaptation (Loor et al. 2013).

Animal performance and reproductive efficiency may be impaired by inadequate nutritional support and intake and may develop other metabolic disorders. Grossly, cows around parturition can consume 1.7–2.0% dry matter intake (DMI), but daily milk production peaks at about 5-8 weeks. A deficiency of energy intake through DM may create a negative energy balance for 6–8 weeks, resulting in the mobilisation of body reserves, especially fat and protein. Metabolic adaptations of their hepatic gluconeogenesis and beta-oxidative metabolism begin with the production of -hydroxybutyrate and unesterified fatty acids, failure may lead to production or metabolic diseases. Proper nutritional management and accurate transitional feeding can improve animal milk yield, FCE, and reproductive efficiency, and minimise the incidence of metabolic disease. The main goals are to increase animal DMI, increase nutrient density, improve protein quality, improve concentrate-to-feed ratio, balance NDF and NFC content, and optimise particle size.

Proper nutritional management of the transition animal is needed to achieve peak milk production 5 to 6 weeks after calving and sustain this peak for a longer period of time. To match the rapidly increasing milk production, the demand for glucose for lactose synthesis increases immediately after calving, when feed intake has not yet reached its maximum. Certainly, dairy cows may suffer from negative energy balance (NEB) for 6–8 weeks after giving birth (Butler et al. 1989). Correct feeding and management during the transition period have a profound effect on dry matter intake (DMI). DMI is a major factor influencing both milk yield and body weight change in early lactation. A higher DMI earlier in lactation reduces the time that cows are in negative energy balance. Minimising the duration and extent of a negative energy balance also has a positive impact on reproduction (Gummer et al. 1995). Nutrient requirements following parturition are much higher than those of dry-off animals, which may vary with milk production and mammary gland demands for milk lactose, fat, and protein synthesis. Similarly, the requirement for calcium and other minerals also increases with an increase in milk volume (Goff et al. 1997). Animals with superior genetic homeorhetic traits can direct the majority of their nutrients towards milk production (Shoshani et al. 2014). When the body mobilises fats and proteins, non-esterified fatty acids (NEFA) and amino acids are used as fuel sources by the liver, and NEB may occur. Non-esterified fatty acid (NEFA) concentrations may be elevated, resulting in significant NEFA conversion to ketones, such as BHBA, in the liver. Elevated NEFA concentrations may impair neutrophil viability (Scalia et al. 2006), and high BHBA concentrations in the blood can cause subclinical ketosis (SCK). SCK is known to suppress the immune system and act as a gateway to several other production diseases. The calcium requirement of the mammary gland for producing 10 kg of colostrum on the day of parturition is more than double that of foetal growth in late gestation (Goff et al. 1997). The onset of lactation places such a high demand on calcium homeostasis mechanisms that most cows develop hypocalcemia at calving. In some cases, plasma calcium concentrations become insufficient to support nerve and muscle function, which may result in parturient paresis or milk fever.

Reduced dry matter intake

According to Grummer (1995) and Mulligan et al. (2006), DMI drops can be up to 30–35 percent during the last three weeks of pregnancy. Low DMI can also be caused by health problems that cause inflammatory conditions (such as metritis, mastitis, lameness, and so on) by releasing pro-inflammatory cytokines, which are proteins (5–20 kDa). Cows with the highest inflammatory indices appear to be affected by NEB and increased hydroxybutyric acid (BHBA) levels. Retained placenta, metritis, and endometritis are all diseases of immune function that begin at least 2 weeks before calving. The distribution of production diseases indicates which areas of nutrition require attention during the transition period. A high rate of lameness, for example, is more indicative of rumen acidosis, whereas a high rate of displaced abomasum could be due to subclinical ketosis (SCK) and/or hypocalcaemia. NEB, BCS, rumen health, calcium status, trace elements, and antioxidant status in the blood are areas to monitor.

BCS management

The energy intake through diet cannot meet the requirements of the peak lactation curve at the initial phase. As a result, animals experience negative energy balance (NEB) and begin mobilising body reserves for at least 6 weeks, which is a normal physiological procedure. Negative energy balance (NEB) induces catabolism of body tissue to meet energy requirements during late gestation and early lactation, resulting in decreased BCS, rumen fermentation, and milk production, as well as the possibility of triggering metabolic syndrome (Kim and Suh, 2006). The BCS during the lactation cycle is most likely the most important aspect of dairy cow management for ensuring a healthy transition from gestation to lactation. Overconditioned dairy cows (BCS>4.0) have a much greater reduction in feed intake immediately before calving than underconditioned cows (Mulligan et al. 2006). While feeding such cows, the goal should be not to lose more than one BCS (in the scale of 1–5) after calving, which could be managed by maximising DMI during the close-up period, which in turn depends on the dietary factors affecting hunger and satiety centres in the brain of mammals.

Nutritional Strategies for transition cows

Increasing feed intake

The first goal of gradually increasing DMI in transition animals by providing an easily digestible diet is to stabilise rumen health, improve ruminations, and increase feeding frequency. Different interventions in diet formulation, such as monitoring fibre content and effective particle size, as well as soluble fibre sources, can improve DMI intake during the close-up stage and for a few days after calving. A few studies have found that including aromatic compounds improves DMI in animals. These include essential oils, herbs, spices, and extracts with flavouring properties, particularly aromatic phenolic compounds found in thyme, clove, and other herbs and spices. A phytogenic feed additive improved feed and energy intakes (1.2 percent) in cows in a recent trial in the Czech Republic. Furthermore, milk yield increased by 5.1 percent, as did daily milk solids production (fat by 6.7 percent, protein by 1.7 percent, and lactose by 4.8 percent). The energy-corrected milk (ECM) was improved by 3.5%. More importantly, optimal nutrient composition, roughage concentrate ratio, and particle size, as well as increasing or decreasing dietary NFC or NDF, can all strongly stimulate DMI during the transition stage.

Increasing feed conversion efficiency (FCE)

The second tool for assisting the newly calved cow (i.e., immediately following parturition) is to increase FCE by increasing digestibility and efficiency of nutrient utilisation from the feed. This can be accomplished by feeding beneficial rumen microbiota functional components such as nucleotides and glucans. While a variety of yeast products contain such components, it has been demonstrated that the autolysis of whole yeast cells into fragments increases microbial numbers in the rumen. The increased microbial population improves feed digestibility and increases acetate, propionate, and butyrate production, resulting in a better energy balance and higher beef or milk production.

Increasing density of ration

The energy requirements during advanced pregnancy and early lactation are unusually high throughout the entire production cycle. Because DMI is the most important constraint, the alternative is to either increase energy density (by feeding more maize or adding oil seeds or protected fat) or reduce the roughage to concentrate (R:C) ratio. It has also been reported that milk production is positively related to DM and water intake. Maize, wheat, sorghum, and pearl millet are common feedstuffs used to provide energy to animals. The particle size of hard-coated cereal grains is very important in terms of nutrient utilisation efficiency. The total starch content of a high-yielder's diet should be between 20 and 25 percent. Such cows' diets must provide the required 10 MJ ME/kg DMI with 16 percent CP. The net energy of lactation (NEL) required in the diets of cows and heifers during the transition period to meet requirements for maintenance and gestation revealed that heifers require more dietary energy due to lower feed intake and additional energy requirements to support growth. Grain must be introduced into the cow's ration at least three weeks before the due date, and heifers at least five weeks. The energy density per kilogramme of DM intake should be between 1.56 and 1.62 Mcal NEL (NRC, 2001). The total starch content of a high yielder's diet should be between 20 and 25 percent. Such cows' diets must provide the required 10 MJ ME/kg DMI with 16 percent CP. Dietary supplementation of oils can also increase the density of a ration. Bypass fat is poorly soluble in the rumen and is not bio-hydrogenated in the rumen.

Manipulating dietary protein

By increasing microbial protein synthesis in the rumen, a 5% increase in DMI can reduce CP requirements by 1%. It has been reported that increasing the UDP content by up to 56% through dietary manipulation improves milk yield, quality (milk protein), weight loss, first-time conception rate, and pregnancy rate. The level of UDP has a significant impact on the availability of N for rumen microbes. Low UDP will not only impair the animal's performance but will also result in ammonia loss from the rumen. *In-vitro* studies revealed that a diet containing ME at 110 or 120% of NRC with UDP (24% of dietary CP) supplemented with niacin gave the best response as far as digestibility of nutrients and availability of ME were concerned (Grewal et al. 2012).

Increasing dietary minerals

Cow's milk contains calcium, chloride, potassium, magnesium, and sodium. Milk contains the majority of the B-complex vitamins. A minor vitamin and mineral deficiency may not have a significant impact on milk quantity and quality. However, calcium is one of the critical elements in the ration that must be carefully considered in transition cows. The demand for calcium increases drastically at the start of lactation, resulting in a sudden drop in blood calcium levels, a condition known as hypocalcaemia. This promotes the release of parathyroid hormone (PTH), which promotes bone resorption (Goff et al., 1997). The PTH activates vitamin D3, which increases intestinal Ca absorption and mobilises bone Ca. To avoid milk fever, the best feeding management practise is to provide a low Ca (50 g/day) diet during the final 2-3 weeks of pregnancy, which should be increased to 100 g/d at least two days before parturition. Following parturition, the diet should include enough magnesium, an essential activator of vitamin D3 in the liver. The anionic diet (12 meq/100 g DM) had no effect on mastitis or milk fever in cows. Metabolic acidosis caused by a negative dietary cation-anion difference (DCAD) promotes calcium mobilisation from bone, whereas high dietary potassium levels and positive DCAD inhibit this process (Horst et al. 1997). Subclinical hypocalcemia is believed to be a contributing factor in disorders such as displaced abomasum and ketosis.

Manipulating dietary fibre level and particle size

For optimal animal production, the rumen should be as efficient as possible in terms of mixing, rumination, and emptying. Active bouts of rumination aid in feed breakdown and saliva secretion, which aid in rumen pH control. Complete feed for high-yielding cows should contain no less than 21% ADF or 28% NDF (NRC, 2001). The forage DMI as a percentage of BW should be between 1.4 and 2.4 percent (Ishler and Adams, 2016). Individual NDF intakes by high-yielding cows can reach 1.3–1.4 percent of BW. Forage NDF intake as a percentage of bodyweight should be around 0.8–0.9 (Heinrichs et al., 2016), or it should not exceed 17–18% of total DMI. However, it can be increased to 30–34 percent by using wheat bran, orange peel, or citrus pulp, which are high in soluble fibre (pectins). Rumen pH is stabilised by a proper balance of slowly fermentable (fibrous) and rapidly fermentable NFC, as well as an optimal PEF length, which stimulates rumen mixing, rumination, and saliva production. Beauchemin et al. (2008) fed small amounts of cereal straw (0.5 kg/day) as a source of structural fibre and of appropriate length (4–8 cm), and structure was fully incorporated into mixed rations, with encouraging animal performance results. Smaller particle sizes (6 mm) may reduce dairy cattle's feed bunk sorting behaviour. Because of sorting activity, rations with a higher proportion of longer particles (>19 mm) are more likely to have a larger difference between the feed initially offered and that consumed throughout the day (Beauchemin et al., 2008; Kononoff et al., 2016).

REFERENCES

Bell AW. Regulation of organic nutrient metabolism during transition from late pregnancy to early lactation. Journal of Dairy Science 1995; 73:2804–19.

Butler WR, Smith RD. Interrelationships between energy balance and postpartum reproductive function in dairy cows. Journal of Dairy Science 1989; 72:767–83.

Goff JP, Horst RL. Effects of the addition of potassium or sodium, but not calcium, to prepartum rations on milk fever in dairy cows. Journal of Dairy Science 1997; 80:176.

Grewal RS, Wadhwa M, Bakshi MPS. Effect of metabolizable energy and rumen undegradable protein levels supplemented with or without vitamins on the in-vitro fermentation of complete feeds. Indian Journal of Animal Nutrition 2012; 29:9–14.

Grinberg N, Elazar S, Rosenshine I, Shpigel NY. Beta-hydroxybutyrate abrogates formation of bovine neutrophil extracellular traps and bactericidal activity against mammary pathogenic Escherichia coli. Infection and Immunity 2008; 76:2802–7.

Grummer RR. Impact of changes in organic nutrient metabolism on the transition dairy cow. Journal of Animal Science 1995; 73:2820–33.

Hayirli A, Grummer RR, Nordheim E, Crump PM, Beede DK, et al. Prediction equations for dry matter intake of transition cows fed diets that vary in nutrient composition. Journal of Dairy Science 1999; 82(Suppl. 1):113.

Horst RL, Goff JP, Reinhardt TA, Buxton DR. Strategies for preventing milk fever in dairy cattle. Journal of Dairy Science 1997; 80:1269–80.

Kim IH, Suh GH. Effect of the amount of body condition loss from the dry to near calving periods on the subsequent body condition change, occurrence of postpartum diseases, metabolic parameters and reproductive performance in Holstein dairy cows.Theriogenology 2003;60:1445–56.

Loor JJ, Bertoni G, Hosseini A, Roche JR, Trevisi E. Functional welfare-using biochemical and molecular technologies to understand better the welfare state of peripartal dairy cattle. Animal Production Science 2013; 53:931–53.

Mulligan FJ, O'Grady LO, Rice DA, Doherty ML. A herd health approach to dairy cow nutrtition and production diseases of the transition cow. Animal Reproduction Science 2006; 96:331–53.

NRC. Nutrient Requirement for Dairy Cattle. National Research Council, National Academy of Science, Washington, DC; 2001.

Roche JR, Bell AW, Overton TR, LoorJJ.Nutritional management of the transition cow in the 21st century – a paradigm shift in thinking. Animal Production Science 2013; 53:1000–23.

Scalia D, Lacetera N, Bernabucci U, Demeyere K, Duchateau L, Burvenich H. In vitro effects of nonesterified fatty acids on bovine neutrophils oxidative burst and viability. Journal of Dairy Science 2006; 89:147–54.

Shoshani E, Rozen S, Doekes JJ. Effect of a short dry period on milk yield and content, colostrum quality, fertility, and metabolic status of Holstein cows. Journal of Dairy Science 2014; 97:2909–22.

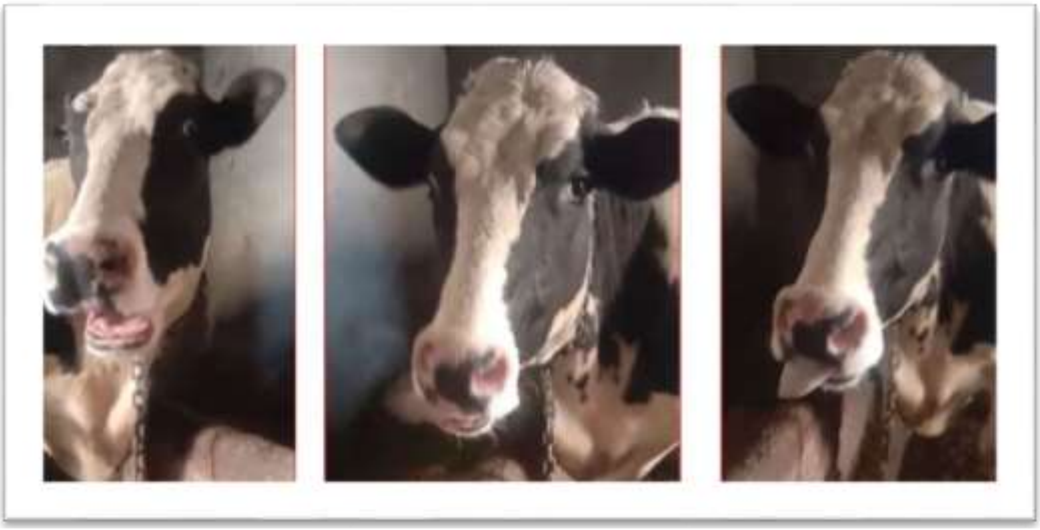
Kononoff PJ, Heinrichs AJ. Forage and TMR particle size and effects on rumen fermentation of dairy cattle. www.articles. extension.org/dairy_cattle; 2012 extension. 2016 retrieved 25.9.2016.

Ishler VA, Adams RS. Troubleshooting Problems with Milkfat Depression. extension. psu. edu.© The Pennsylvania State University; 2016; DAS 99–2. p. 1–6

Heinrichs AJ, Jones CM, Bailey KE. Milk Components: Understanding the Causes and Importance of Milk fat and Protein Variation in Your Dairy Herd. extension. psu. edu.© The Pennsylvania State University; 2016;DAS 05–97. p. 1–5.

Beauchemin KA, Eriksen A, Norgaard P, Rode LM. Short communication: salivary secretion during meals in lactating dairy cattle. Journal of Dairy Science 2008; 91:2077–81.

Chapter 7



Dr.

Underfeedingand Overfeeding

Metabolic Diseases of Dairy Animals

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Any living system will work efficiently only when its physiological processes are running at optimal levels. Excess or lack of anything will have detrimental effect on the well-being and production status of any livestock individual. Deficiencies are most encountered in dairy animals and that too in high producing animals especially in their third lactation or beyond. Initiation of lactation puts a heavy burden on the body reserves of the animal. If the body reserves are already depleted (during pre-partum period), the animal becomes highly prone to develop some kind of metabolic disorder (like primary ketosis, fatty liver syndrome, creeping syndrome, haemoglobinuria, milk fever, hypomagnesaemic tetany etc.) immediately after calving. Overfeeding of a particular ingredient will also have a heavy toll on the production status of the animal. The most important metabolic disorders related to overfeeding are rumen acidosis, laminitis, displaced abomasum, vaginal prolapse etc. The present paper will deal with both types of metabolic disorders.

A. Metabolic Disorders Occurring due to Deficiency of a Nutrient

1. **Acetonaemia (Ketosis):** Ruminants rely on short chain fatty acids known as volatile fatty acids (VFAs) for their energy requirements. These VFAs are propionic, butyric, and acetic acids. Propionic acid is the main precursor of glucose. Since, glucose is poorly absorbed from rumen, therefore, all natural efforts are directed towards production of more quantities of VFAs only. This is the reason why ruminants do not thrive on starch-based diets as is the case with non-ruminants. They, rather, depend upon fibre-based diets.

Animals usually draw VFAs from dietary sources. When the dietary sources are insufficient (due to underfeeding or lowered feed intake as in post-partum periodor the quality of roughage being very poor) to meet the animal's requirements, theyhave toutilize their body reserves for this purpose. During such circumstances, body fats get mobilized and oxidized. This leads to production of acetyl CoA. Due to lack of energy, more and more acetyl CoA is produced. However, liver cannot cope up with large quantities of this acetyl CoA. The excess of acetyl CoA, then, gets converted into acetoacetate and β-hydoxybutyrate, the so-called ketone bodies and a pathological condition known as acetonaemia or ketosis ensues.

Along with forced underfeeding, higher demands of energy and lowered feed intake especially in high yielding animals in post-partum period makes the animal more prone to development of ketosis. Ketogenic diets especially silage with increased content of butyrate also predisposes the animal to ketosis.

Clinical signs of ketosis include shifting of preference of the animal from eating concentrate diets and green fodders to dry fodders (wheat straw, paddy straw, maize stover etc.) only. The breath, milk and urine may have sweet smell because of presence of ketone bodies. The milk yield drops suddenly.

The cases of ketosis can be effectively treated with intravenous administration of concentrated glucose followed by oral administration of glucose precursors like propylene glycol. Inclusion of molasses and cobalt sulphate in the diet of the affected animal will hasten recovery. Corticosteroid therapy with dexamethasone will promote gluconeogenesis, thereby, providing glucose from sources other than carbohydrates.

Fatty Liver: This condition is usually associated with development of ketosis. When a particular animal encounters negative energy balance because of any reason, its body reserves of fats are mobilized and oxidized. During the process, non-esterified fatty acids (NEFA) are released into blood. These NEFAs are taken up by liver where they are oxidized through TCA cycle to release energy. A part of it also gets esterified to fat again i.e. triacylglycerol (TAG). When the amount of NEFAs is too high, large number of TAG molecules are generated. These fats cannot be utilized immediately, so, they get stored in liver cells. The condition where hepatocytes are full of fats is known as fatty liver syndrome. This condition results in poor milk production. Once fatty liver sets in, there will be further depression in feed intake. Prominent ketotic signs can also be observed in the affected animals.

- **Parturient Hypocalcaemia:** It is also called parturient paresis or milk fever. It occurs due to acute deficiency of ionic calcium. The animal can become deficient in ionic calcium because of underfeeding of calcium salts following calving or because of failure of mobilization of sufficient quantities of calcium from the body reserves during post-parturient period. Sometimes, the dietary contents of calcium are sufficient but intestinal conditions make it unabsorbable.

  This metabolic disorder is mostly encountered in high yielding animals following third calving. Most of the animals are marginally deficient in blood calcium levels around parturition. High phosphorus in the diet along with high alkalizing agents like sodium bicarbonate, reduced apatite and decreased intestinal motility predispose such animals to develop milk fever.

  In the initial stages, the affected animal may show ataxia with stiff limbs. As the disease progresses, the animal becomes depressed with signs of muscular weakness. This leads to prostration. At this stage the animal shows reluctance to stand-up after lying down. If proper treatment is not instituted at this stage, the animal will turn her neck towards one side and put her head on the flank region. The pupils become slightly dilated. The ruminal motility gets reduced drastically leading to reduced defaecation. The faeces will be dry and mostly in the form of small balls.

The treatment is aimed at restoring blood calcium levels as soon as possible. Calcium boro-gluconate is administered intravenously very slowly followed by oral feeding of calcium chloride in the form of a gel twice at an interval of four days. Sometimes, relapses do occur. To prevent such incidences, cholecalciferol (24 lakh units) may be administered beforehand to generate calcium receptors in older animals.

- **Creeping Syndrome:** The downer cow syndrome usually occurs due to metabolic causes (Hypocalcaemia, hypophosphataemia, hypomagnesaemia, hypokalaemia, ketosis etc.) toxic causes (coliform mastitis, septic metritis, peritonitis etc.) or physical injuries (ligament ruptures, obturator nerve paralysis etc.). The downer cows remain recumbent for longer periods. When a downer cow moves (more appropriately 'creeps') from one place to another place over a certain period, she is called to be suffering from 'creeping syndrome'.

  Creeping syndromeis encountered in cases of hypophosphataemia. It occurs due to diets low in digestible phosphates. Administration of inorganic phosphates especially sodium ortho-phosphate ($NaH_2PO_4.2H_2O$) over a few days often prove fruitful in such cases.

- **Hypomagnesaemic Tetany:** Magnesium plays an important role in many metabolic pathways in ruminants. Magnesium along with potassium are two very important intracellular ions. Like calcium, the ionic form of magnesium found in blood is the most active formphysiologically. However, it is not under any hormonal control. That is why ruminants have torely on its regular supply through dietary sources. Though, legumes are good source of magnesium in Rabi season, still, inclusion of mineral mixture in concentrate ration is very essential for the constant supply of magnesium. Feeding of mineral mixture deficient in magnesium salts often lead to hypomagnesaemia in ruminants. Feeding of grasses only that too fast growing young lush green grasses often lead to magnesium deficiency.

  The affected animal, often, shows hyper aesthetic signs. Ataxia, staggers, convulsions due to neuromuscular irritability are the prominent signs in hypomagnesaemia. Due to increase muscular activity, animal may show signs of hyperthermia. Tetanic muscle spasms can be observed in later stages. The author observed many cases of hypomagnesaemia misdiagnosed as that of rabies by field veterinarians. Observation of blood magnesium levels and response to test therapy can be employed effectively to diagnose it.

Parenteral administration (intravenous) of magnesium sulphate (of analytical grade) or magnesium hypophosphyte followed by oral feeding of magnesium oxide may alleviate the symptoms quickly.

- **Post Parturient Haemoglobinuria:** The average life span of RBCs in ruminants is 120 days. The worn-out RBCs get separated from blood stream when they happen to pass through reticulo-endothelial system of spleen. The cell membrane of RBCs consists of phospholipids. Dairy animals receiving diets deficient in phosphorus for relatively long periods develop hypophosphataemia. This leads to formation of weak cell membranes in RBCs owing to lower levels of phospholipids. When such RBCs happen to pass through spleen, they get ruptured easily because of weaker cell membranes. Under such scenario, haemoglobin of ruptured RBCs comes directly into the plasma. Because of rupture of excessive number of RBCs, whole of haemoglobin could not get recycled. The circulating haemoglobin enters urine through glomerular filters, thereby, imparting red colour to urine. Presence of haemoglobin in urine is, thus, called haemoglobinuria.

  This condition is mostly observed in high yielding animals during post parturient period in third or greater parities. That is why it is called post-parturient haemoglobinuria.

  During initial stages, the animal continues to take feed as usual. Thus, the owner often fails to notice the change in urine colour in first few days. After this, milk yield drops. Animal starts showing inappetence. Frequency of urination also drops. Animal develops dehydration and weakness. Mucous membranes become pale. If the treatment is not started in time, the animal collapses in a few days.

  The treatment includes administration of inorganic phosphates (sodium orthophosphates) for a few days. It should be noted that organic phosphorus preparations will be of little use in ruminants. Urine pH should be maintained in alkaline range to avoid crystallization of haemoglobin molecules. Ascorbic acid administration often favours quick recovery.

B. Metabolic Disorders Occurring due to Excess of a Nutrient

Intake of nutrients in excess of their requirement can also hamper healthy status of the animal. A few of metabolic conditions associated with overfeeding are discussed below:

1. **Rumen Acidosis:** Ruminants are usually accustomed to feeding fibre-based diets (roughages). These roughages are converted to short chain fatty acids by microbial fermentation under anaerobic conditions of rumen. These short chain fatty acids are absorbed immediately through ruminal wall. These are involved in generation of energy molecules and many other metabolites.

   Feeding of excessive quantities of readily fermentable carbohydrates like wheat, barley, molasses etc. often leads to over-production of lactic acid, thereby, causing drop in rumen pH.This changed milieu of the rumen alters the spectrum of microbial population. The lactobacilli overpower the other species, thereby, leading to further drop in rumen pH through over-production of lactic acid. This causes ruminal stasis. The animal becomes off-feed and depressed. In early stages, there will be diarrhoea that shift to a state of constipation in later stages. Ruminal stasis often causes bloat. Heart and respiration rates will be on higher side. In untreated animals, lactic acid gets absorbed into circulation leading to metabolic acidosis and laminitis. Under such circumstances, animal becomes recumbent and dies in a few days.

   The treatment is aimed at stopping the further intake of readily fermentable carbohydrates. The change in ruminal pH can be reversed by feeding alkalizing agents like sodium bicarbonate. Administration of antihistaminics as quickly as possible often saves the affected animal.

2. **Laminitis:** It is the inflammation of laminae present in the hoofs of ruminants. During metabolic acidosis, excessive quantities of lactic acid reach the laminae, thereby, causing release of high quantity of histamine. This histamine causes inflammation of the laminae. The condition becomes very painful. The affected animal fails to bear its own body weight and goes down.

   Laminitis can be treated with antihistaminics. Metabolic acidosis can be controlled with administration of Ringer's lactate.

3. **Displaced Abomasum:** During late stages of gestation, the gravid uterus pushes the abomasum upwards to adjust in the available space within the abdominal cavity. After calving, the abomasum must return to its original position on the floor of the abdominal cavity. In over-conditioned animals at calving or when the animal receives high quantities of concentrate ration near parturition, the abomasum fails to return to its original position owing to over production of gases in abomasum. Atony of abomasum also causes accumulation of such gases in abomasum. Symptoms of displaced abomasum include anorexia, reduced rumination and drop in milk yield.

Displaced abomasum is usually treated by conservative methods by rolling the animal and manipulating the abomasal area with hands. Surgery can also beattempted.

4. **Vaginal prolapse:** In ruminants, the energy and protein ratio in ration should be 2.4:1. When only carbohydrates are fed without the inclusion of any protein source, then, carbohydrates get converted to fats that get deposited around internal genital organs. In such situations, even a slight episode of straining during constipation may cause vaginal mucosa to protrude out. Thus, vaginal prolapse can occur due to a metabolic disorder when excess quantities of fats are there around tubular genitalia. Such conditions can easily be prevented by giving balanced rations.

Thus, underfeeding (deficiencies) as well as overfeeding can cause disturbances in ruminants. For getting optimum production, the diet must contain a balance of all types of nutrients.

Chapter 8

Smart feeding: Feeding Under Different Climatic Conditions and Influence of Feed on Milk Production and Composition

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Indian livestock sector specifically dairy animalslarge dairy cattle and buffaloescontinuously contributed to the rural economy. Animal productivity and health are significantly influenced by the environment. Under ideal environmental conditions, domesticated animals exhibit their full reproductive capacity, normal behavior, and optimal health. Winter (December to February), summer (March to May), monsoon (rainy) seasons (June to September), and post-monsoon periods (October and November) are the four main climatic seasons in India. Although the majority of the country is covered by the hot, humid summer months (April to September) temperature (25 to 45°C maximum daily temperature in most parts of the country), it is plausible that this will make animals more susceptible to heat exhaustion.While this upper limit applies to many areas of the nation, it is particularly true of the South Eastern region, which includes the states of Andhra Pradesh and Tamil Nadu, and the arid region of Rajasthan, Haryana, and Punjab. However, in a few places in India, such as Ladhak, or other 10,000 and 12,000 feet altitudes, the temperature can change from 35 C to -35 C. Fodder shortage brought on by snow and poor quality fodder make animals' stress levels even worse. Nutritional management under various climatic conditions is therefore crucial. Based on comparable meteorological conditions, the entire year can be divided into four seasons, i.e.

(i) Winter season (January and February)

(ii) Hot weather season (March to May)

(iii) Hot humid season (June - September)

(iv) winter/post monsoon season (October to December).

The production of livestock, soil productivity, pasture availability, crop yield, water quality and quantity, vectors, pathogens, and parasites will all be impacted by climate change in both direct and indirect ways (Sejian et a., 2015). The maximum comfortable temperature for best milk production in India is 27°C, which is about two degrees higher than the maximum reported in temperate nations (Dutt et al., 1992).

The temperature humidity index (THI) is an excellent tool for assessing a species' tolerance to heat. When THI reaches 72, milk production and feed intake decrease, and they sharply continue to do so once it exceeds 76 (Molee et al., 2011). According to Noordhuize et al. (2015), each unit increase in THI over 72 results in a 0.2 kg reduction in milk yield. From 10 to more than 25% of milk production can be lost (Upadhyay et al., 2009a). Per unit increase in THI, the average daily milk yield per cow (kg) decreased by 0.886 (West, 1999). The yield dropped between 10 and 30% in the first lactation and between 5 and 20% in the second and/or third lactation. Mid lactation saw a smaller degree of milk yield decline than either late or early lactation. In comparison to breeds found in temperate countries, cattle breeds from India have smaller mature body sizes, grow more slowly, and produce less milk. However, the breeds are resilient and well adapted to heat stress and subpar diets, conditions that are typical of tropical nations. Because of variations in genetic make-up, mature body size and growth rate, feed quality, climatic conditions, and differences in nutrient utilisation efficiency, these animals' nutritional needs are likely different from those recommended in feeding standards of temperate countries (NRC, 1989; AFRC, 1990).

Feeding during hot- humid climate

The most crucial nutrient for cows is water. There should always be fresh, clean water available, and providing cool water during the summer may have benefits. The water trough should be shaded to promote drinking during the hottest part of the day and possibly keep the water cool. According to research, drinking chilled water keeps cows cooler and increases feed intake. It might be advantageous to cover troughs or use insulated waterers to stop cool well water from warming up.

Early morning or late evening should be the best times to feed because it is cooler. Animals that are unable to adapt experience a variety of physiological and biochemical changes, which can have negative effects on their health. Given the drop in feed intake that occurs in hot weather, energy is a crucial nutrient. You can increase the amount of concentrates (grains) and decrease the amount of forages in your diet to increase the amount of energy you consume. Increasing concentrates to more than 55 to 60 percent of the diet's dry matter is risky, though, and can lead to low milk fat content, acidosis, cows going off feed, laminitis, and decreased nutrient use efficiency. In particular during the summer when feed intake is low, additional dietary fat is a great way to boost the energy content of the diet. A healthy diet should contain no more than 5 to 6 percent of its dry matter as dietary fat. Whole oilseeds, like whole cottonseed and whole soybeans, are both excellent sources of fat and protein. Specialty fats that are inactive or inert in the rumen are known as manufactured rumen escape or 'bypass' fats. When a high-fat addition is necessary, it is recommended that 13 of the fat come from natural feed ingredients, 13 come from oilseeds or tallow, and 13 come from rumen bypass fats.

Protein:

Due to decreased feed intake during heat stress, the amount of crude protein in summer diets frequently needs to be increased (West, 1999). Huber et al. (1994) showed that heat stressed cows fed lower levels of soluble protein had higher milk yields and dry matter intakes (DMI). When compared to diets with lower degradable protein (59%) or lower CP (16%), Huber et al. (1994) found that heat-stressed cows fed a highly degradable protein diet (65% of crude protein

(CP)) had a 6% reduction in DMI and an 11% decrease in milk yield. This is in line with recent advice that says adding dietary CP specifically, rumen-undegradable protein—is not beneficial (Arieli et al., 2006).The quantity of crude protein in summer diets frequently needs to be increased because to lower feed intake during heat stress (West, 1999). According to Huber et al. (1994), heat stressed cows given lower amounts of soluble protein produced more milk and consumed more dry matter (DMI) during the day. Huber et al. (1994) discovered that heat-stressed cows fed a highly degradable protein diet (65% of crude protein (CP)) experienced a 6% drop in DMI and an 11% loss in milk output when compared to diets with lower degradable protein (59%) or lower CP (16%). This concurs with recent recommendations that increasing dietary CP—specifically, rumen-undegradable protein—is not advantageous (Arieli et al., 2006). Highly degradable protein diets might be harmful because of this, according to one theory.

Fiber:

Fibre: The cow's diet must have fibre for the rumen to operate properly. The heat-stressed cow will consume less forages because the digestion and metabolism of fibre generates more heat than the digestion of concentrates. In order to promote larger intake during hot weather, the fibre level of the meal should be somewhat lowered. To maintain normal rumen function, the ADF content should not be less than 18% and the NDF content should not be less than 28–30% of the ration's dry matter. Because there is less effective fibre in the diet, it is dangerous to increase concentrates to more than 55 to 60 percent of the daily ration. According to Grant (1997), a roughage NDF value of 60% still offers enough fibre for the production of fat-corrected milk. The minimal dietary NDF need of 23% DM and the roughage NDF percentage of 55% dietary NDF, on the other hand, are thought to provide sufficient effective NDF for dairy cows in the tropics, according to Kanjanapruthipong and Thaboot (2006). There are various things that may be done to stop cows from picking and choosing what goes into their meals.

- Chop hays and combine in a complete mixed ration.
- Add silages to a whole mixed ration as the only source of fodder.
- Use wet foods to provide moisture and flavour to dry hay diets, such as wet brewer's grains and silages.
- Utilise digestible NDF sources, such as fresh or dry sugarbeet pulp
- Chop hays and mix into a total mixed ration.
- When combining dry diets, add water to increase intake and decrease sorting.

- Feed more palatable, high-quality forages.
- Chaffing hays before combining them into total mixed meals enhances utilisation of lower-quality hays when necessary and reduces waste.

High moisture feeds like silages, green chop forages, and byproducts like wet brewers grains are referred to as succulent feedstuffs. Succulent feeds are preferred by cows, thus include them in the dairy diet may increase consumption when it's hot and humid outside. However, an overly wet diet may impede intake, thus caution must be taken to ensure that rations for hot weather do not exceed 50 to 55 percent moisture. Succulent feeds spoil more rapidly than dry feeds, especially during hot weather, and feed bunks should be cleaned daily to prevent spoiled feed from reducing feed consumption.

Minerals and DCAD:

Mineral needs for cattle change during hot weather. Cows sweat just like other mammals, but their sweat contains a large amount of potassium (K), unlike humans, whose sweat contains more sodium (Na). Consequently, K requirements increase during summer. In addition, cows need more Na during summer, and magnesium needs to be boosted when high dietary K is fed. Dry matter intake was improved when dietary K was greater than NRC recommendations during hot weather (Schneider et al., 1986). Feed intake was improved when diets contained 0.55 vs. 0.18% Na during hot weather Schneider et al. (1986). Current ranges for mineral supplementation during heat stress are:

Potassium: 1.4 to 1.6% of DM

Sodium: 0.35 to .45% of DM

Magnesium: 0.35% of DM

A ratio or balance of ions may affect performance by influencing buffering systems in the body. Escobosa et al. (1984) were the first to evaluate diets fed to lactating cows during heat stress using the electrolyte or cation balance equation, later termed as dietary cation-anion difference (DCAD). They reported greater DMI for diets containing 320 meq Na + K – Cl/kg of feed DM vs. diets containing 195 and -144 meq, suggesting that an alkaline diet based on DCAD may be beneficial to heat-stressed dairy cows.

Feed Additives

Buffers

Buffers such as sodium bicarbonate are especially useful in low fiber diets, diets based on corn silage, when cows can select against forage consumption, and particularly during hot weather. Fed at about 0.75% to 1.0% of diet DM, bicarb can help keep cows on feed and maintain milk fat percentage. Besides to this, potassium carbonate-based buffers has been fed to balance DCAD.

Water soluble B complex vitamin niacin or rumen-protected niacin can support heat load dissipation through peripheral vasodilation and mammary tissue dilation (Muller et al., 1986). Six grams of niacin were fed to lactating cows, and when compared with the controls, there was only a 1 liter increase in milk with niacin. However, when cows producing >32 liter of milk were evaluated, the higher producers responded with 5.3 liter more milk. Various Yeast cultures and fungal products has been studied for their effect on the maintenance of a stable rumen environment. Some have shown additional benefits during hot weather. Better protein use, stable rumen pH, and better fiber digestion are potential benefits of these products.

Feeding during winter/ post-monsoon season

Usually, winter or post monsoon season climatic conditions are favorablefor most of the part of India, however, few parts of Ladakh temperature variation has been seen from 35 C to -35 C, fodder scarcity, as well as challenging environmental conditions, may create difficulties for the survival. For the management of animals during cold climatic conditions, provide lukewarm water to the animals, feed high calories in their diet, and balance diet at high crude fiberfed for the crude protein and energy requirements. During winter season leguminous fodder of goof nutritive value is available, however feeding must be done on TMR based with dry fodder. For high yielder feeding solely on leguminous fodder must be balanced for their optimum RUP: UDP. A few of the feeding management under winter climate are listed below:

a. It may be tried to increase the amount of protein (17.5% vs. 14.5% CP) and energy (77% vs. 70-72% TDN). Rations with around 20% fibre, compared to 17% fibre in animal feed, might boost milk's fat content.

b. In comparison to animals housed in sheds, animals kept outdoors will require 15 to 20% more feed throughout the season.

2. Stocks for winter: Other ways to address the forage scarcity might be taken into consideration besides farmed fodders and tree leaves:

a. Concentrates in the shape of cakes, meals, cubes, UMMB Licks, and feed blocks.

b. Hay, silage, haylage, leaf meal, etc. are examples of conserved forage.

c. Storing agriculture leftovers like straw and leftover grain.

e. Aquatic plants, such as Typhaangustata, etc.

Reference:

Arieli, A., G. Adin, and I. Bruckental. 2006.The effect of protein intake on performanceof cows in hot environmental temperatures. J.Dairy Sci. 87:620–629.

Grant, R.J. 1997. Interactions among foragesand non foragefiber sources. J. Dairy Sci.80:1438-1446.

Huber, J.T., G. Higginbotham, R.A. Gomez- Alarcon, R.B. Taylor, K.H. Chen, S.C. Chan,and Z. Wu.1994. Heat stress interactions withprotein, supplemental fat and fungal cultures.J. Dairy Sci. 77:2080-2090.

Kanjanapruthipong, J., and B. Thaboot. 2006.Effects of neutral detergent fiber from ricestraw on blood metabolites and productivity ofdairy cows in the tropics. Asian-Aust. J. Anim.Sci. 19 (3): 356-362.

Molee, A., Bundasak, B. Petladda, K. and Plern, M. (2011). Suitable percentage ofHolstein in crossbred dairy cattle in climate change situation. Journal of Animal andVeterinary Advance. **10**(7): 828-831.

National Research Council. 1989. 6th rev. ed., Natl. Acad. Press. Washington, DC.

Sejian, V., Bhatta, R., Soren, N. M., Malik, P. K., Ravindra, J. P., Prasad, C. S., & Lal, R. (2015). *Introduction to concepts of climate change impact on livestock and its adaptation and mitigation* (pp. 1-23). Springer India.

Singh, S.V. and Upadhyay, R.C. (2009). Impact of temperature rise on physiologicalfunction, thermal balance and milk production of lactating Karan fries and Sahiwal cows.Indian Veterinary Journal. 86 (2): 141-144.

West, J. W., Mullinix, B. G. and Bernard, J. K. 2003. Effects of hot, humid weather onmilk temperature, dry matter intake, and milk yield of lactating dairy cows. J. Dairy.Sci.86:232–242.

Chapter 9

Cost cutting: Use of Straw, Stover and Unconventional Feed Stuffs in Dairy Animals

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India is pre-dominantly an agricultural country with around 70 per cent of its population lives in villages. The livelihood of most of the rural population of India depends on agriculture and animal husbandry. India has a large livestock population. 535.78 million as per 20th livestock census (National Livestock Census, 2019), representing a 4.6 percent increase over the previous Livestock Census in 2012. Although India has the largest population of livestock in the world, but their productivity is comparatively low (Katoch et al., 2017).

One of the reasons for this is the shortage of conventional feed resources due to growing population and rapid urbanization which has continued to shrink the cultivated land across India. Due to shortage of feedstuffs, the gap between nutrient availability and requirements is continuously increasing. Therefore, in the present scenario, better utilization of already existing feedstuffs and exploration of new feed resources is required to overcome the problem of feed scarcity. Due to sustained hike in prices of traditional feed ingredients like cereal grains, protein meals and other feed commodities, the present situation demands to find less expensive and safe alternatives to feed the animals. Use of feed sources including agro-industrial by products and agricultural waste is an alternate way to provide the nutrients to livestock.

Use of cereal straws/stovers in dairy animals feeding

Many kinds of cereal straws are produced each year worldwide.Amongthem, corn stover, rice straw and wheat straw are the byproducts of corn, rice and wheat after grain harvesting, respectively. Some cereal straw and stovers are utilized as roughage for ruminants after dehydration, ensiling, or ammonification treatments, and some are used as compost. Still, most cereal straw is burnt in the fields resulting in a massive waste of resources and environmental pollution. The use of dried cereal straws as feed forherbivorous livestock is common in developing countries due to theshortage of high-quality forages. Due to increasing global economic and environmental concerns, more attention has been given to the possibility of the efficient use of cereal straw as a source of roughage for ruminants.

Nutritional characteristics of cereal straws

Cereal straws are the air-dry residues or byproducts of the cerealcrops after the grain is harvested. The nutritive value of corn stover, rice straw,and wheat straw for ruminants is relatively low due to its highlignocellulosic content (lignin, 5.83% to 7.20%, DM basis) and lowcontent of crude protein (CP, 1.88% to 8.40%, DM basis) (Table 1),metabolizable energy, minerals, vitamins, and easily fermentedcarbohydrates, as well as their poor palatability and low nutrientdigestibility (NRC, 2001), which restricts the ruminal synthesis ofmicrobial protein (MCP) in dairy cows. In addition to itsabundant content of cell walls, the ruminal degradability of ricestraw is limited by its epidermal surface, in which a high concentrationof silica exists and acts as a physical barrier preventingbacterial attachment. The low CP and highfiber content in cereal straws, especially for their high proportion of lignin and silica, are the main nutritional constraints for using strawas feed source in dairy cow. The *in vitro* DM degradation in corn stover is generally higher thanin rice straw (52.7% vs. 45.3%; Chen et al. 2017). Thus, the low rumen degradation andapparent digestibility of cereal straw is one of main constraints forusing straw as feed source in dairy cows.

Table1. The reported chemical composition of wheat straw, rice straw and corn stover (% DM)

Parameter	**Wheat straw**	**Rice straw**	**Corn stover**
Organic matter	90.4-94.2	85.0-87.9	92.1-93.8
Crude protein	1.88-4.60	4.80-6.88	5.30-8.40
Ether extract	1.20-1.60	2.10	0.84-2.00
Non-fiber carbohydrates	7.30	5.20	11.6-20.2
Neutral detergent fiber	75.0-87.4	66.2-76.9	52.1-76.2
Acid detergent fiber	53.6-58.2	40.4-45.5	30.4-48.1
Lignin	8.90-19.0	5.83-18.5	5.91-7.20
Silica	7.30	5.32-11.7	0.37-2.68

(Man and Wiktorsson 2001; Pan and Sano 2005; Eun et al. 2006; Ko et al. 2006; Li et al.2012; Litherland et al. 2013; Wang et al. 2014; Shi et al. 2015; Omidi-Mirzaee et al. 2017; Hanlon et al. 2020).

Potential measures to optimize the use of cereal straw in dairy animals

Considerable efforts have been made to improve the utilization efficiency and feeding value of cereal straws using treatments to enhance their digestibility, including biological, chemical, and physical pretreatments as well as providing nutritional supplements based on the lack of nutrients in cereal straws. However, the commercial application of these strategies is limited due to cost, potential environmental problems, and animal health issues. From the view of animal nutritionists, the potential treatments to improve the utilization efficiency of cereal straw by dairy animals which can be adopted at field level have been discussed below.

Natural fermentation of straws

Natural fermentation of straws/stovers with urea is one of the attractive ways to improve the nutritive value of poorquality crop residues. The straw is moistened to 40% moisture by the addition of 3.5% urea solution. This is fermented by open stacking method for 9 days. For each batch of 400 kg, 14 kg urea dissolved in 200 L water was sprinkled on 386 kg chaffed straw and stacked in the open or in a shed for 9 days. The process involves a combination of treatments. For example, physical (use of chaffed straw and rise in stack temperature to 55°C during fermentation) biological (release of ammonia by the hydrolysis of urea and its utilization by the microbes for their proliferation thereby enriching the straw with microbial protein) and chemical (penetration of NH_3 into cell wall, which breaks the alkali labile lignocellulose bond). More than 85% of the added urea was hydrolysed by 9th day, thereby eliminating the chances of urea toxicity to animals (Wadhwa and Bakshi, 2011).

The 9-day fermented wheat straw (FWS) or rice straw (FRS) daily supplemented with mineral mixture and vitamin A (or carotene) could meet both energy and protein requirements for maintenance of adult buffaloes and cows (Kaur et al. 2008). The better utilization of nutrients resulted in higher weight gain in buffalo calves fed FWS/FRS (Wadhwa et al. 2010) and also improved productive and reproductive performances of lactating buffaloes (Lamba et al. 2002).

The processed straws/stalks/stovers, if used judiciously, could serve as a source of nutrients for dairy animals. The method has universal application in improving the nutritive value of many cereal straws (wheat, rice, barley, oat) maize stovers, sorghum and pearl millet stalks. Pathogenic microbes like Salmonella or *E. coli* were never detected in any of the stacks. The shelf life of the FWS/FRS is more than one year. After the stipulated period of 9 days, the stack should not be dismantled rather the required quantity of feed should be taken from one side of the stack. If required, it can be mixed with untreated straw and can be fed to the animals.

Baling/densification of grasses/crop residues

The rice straw can be baled by using a fully automatic field/stationary baler. Each bale has the dimension of 3×1.5×1.25 feet and weights around 28-35 kg. The bales can be transported to drought and flood prone areas. The baled rice straw can be enriched by sprinkling urea solution and keep the bales for 9 days fermentation with or without covering with polyethylene sheet, before transporting. Such value addition would not only increase the nutritive value and palatability of crop residues (Kaur et al. 2007) but also save storage space and reduce transport costs and wastage. Fermented rice-straw in bales and stack was found to have higher crude protein and lower fiber content in comparison to the untreated rice-straw (Table 2). The blocks made by hydraulic press (pressure of 300 kg/cm^2 and moisture content of 12%) result in increase in bulk density or decrease in volume.

Table 2. Chemical composition of rice straw, % DM basis

Parameter	Untreated	Urea treated	
		Stack	Bale
Organic matter	85.8	84.3	85.5
Crude protein	4.5	7.9	7.7
NDF	82.0	76.0	78.0
Hemicellulose	31.0	23.5	26.0

Kaur et al. 2007

Densified complete feed blocks (DCFBs)

DCFB is a total balanced ration (blend of all nutrients in required proportion for 24 h) for a dairy animal. It is one of the best systems of delivering nutrients to bovines. The roughage to concentrate ratio in the DCFBs depends upon the level of production, stage of lactation and the physiological status of the animal (FAO, 2012). The roughage/forage part in DCFBs is generally the crop residues such as cereal and millet straws/stovers, sugarcane bagasse, gram straw, groundnut haulms, mustard straw, groundnut straw (Sharma, 2006), forest grasses or tree leaves. The concentrate ingredients may be non-conventional or conventional such as oilseed cakes, urea, molasses, brans, minerals and vitamins. The blocks have also been used as carriers for different bioactive compounds, feed additives like bypass nutrients, non-ionic surfactants, nutraceuticals (FAO, 2012). Density of the straw-based feed blocks is about 450 kg/ m^3. The DM intake and DM digestibility of crop residue based complete feed blocks varied between 2.5 to 4.23 kg/100 kg BW and 42.5 to 64.58%, respectively (Sharma, 2006). The straw blocks containing straw 86, molasses 10, mineral mixture 2, urea 1 and salt 1 parts can meet the maintenance requirement of the animals (FAO, 2012).

The crop residues should not be more than 60, 50 and 40% in the DCFBs manufactured for animals producing 5-10, 10-15 and 15-20 kg milk per day, respectively. Similarly, the CP and total digestible nutrients (TDN) content vary between 7-14 and 45-65%, respectively. A superior quality block of 14 kg has sufficient nutrients for animals producing 20 kg milk/ day (FAO, 2012). The DCFBs have number of advantages for example easy handling, require less space during transportation and storage. About 3 times more feed (by weight) can be accommodated and transported within the same space than the loose straw. It also reduces the wastage of feed. By feeding DCFBs, the labour expenditure is reduced by 30-40% and transportation cost is also reduced considerably. The feeding of DCFB is simple, hassle-free, less time consuming and reduces selection of ingredients (FAO, 2012).

Unconventional feed resources: The feeds which have not been used traditionally in animal feeding are unconventional/non-conventional/novel feed resources. In this aspect, few novel feedstuffs – *Phalaris minor* seeds, guar meal, rice glutenmeal, rice distillers dried grain with solubles (DDGS), waste bread, tomato pomacewhose practical worth is relatively lesser-known to the scientific community have been discussed below.

***Phalaris minor* seeds:** *P. minor* (littleseed canary grass) belongs to Graminae family. It is commonly known as *Gullidanda*, *mandusi* and *gehun ka mama*. Itgerminates from November to January and matures in March-April. Favourable temperature for germination is 10-20ºC. It has an erect stem with distinct nodes and internodes and at maturity the plants are taller than wheat. *P. minor* produces 300-450 seeds per panicle. There are 8-10 species of *Phalaris*, but these are so closelyrelated that it is difficult to distinguish one from the other.

Kaur *et al.* (2006) reported 83% of *in vitro* organic matter digestibility in *Phalaris* seeds as compared with 92% for corn with the corresponding energy content of 8.9 and9.5 MJ/kg, respectively concluding the potential of *Phalaris* seeds to replace traditionalcereals up to 75% in the concentrate mixture. In addition, starch content of *Phalaris* seeds (50%) is comparable with that of barley (51%) but lower than corn (65%) and wheat (62%) (Kaur and Thakur, 2016). Furthermore, it was deduced that *Phalaris minor* seedscould constitute 50% (w/w) of concentrate mixture for buffaloes without inflicting theirnutrient utilisation and health (Kaur et al., 2009). Regarding lactation performance, Kaur *et al.* (2017) concluded that *Phalaris* seeds can economically replace corn by 75% in concentrate mixture of Karan-Fries cows without any apparent adverse effect on intake, nutrient utilisation, milk yield, composition, liver enzymes and reproductive performance.

Guar meal: Guar or cluster bean (*Cyamopsis tetragonoloba*) is an annual drought tolerantleguminous crop of arid regions producing 5-12 hard seeds contained in a pod. Indiabeing the leading country in total guar seed production (>15 lakh tonnes) notably fromthe states of Rajasthan and Haryana, contributes to 80% of world guar trade. Major commercial utility of guar today is for its high viscous galactomannangum (a natural hydrocolloid) which has various industrial applications. Guar meal is theprincipal by-product of guar gum production, which is made up of a mixture of guargerms (25%) and hulls (75%). In India, guar meal is available mainly in two forms likeguar meal churi (40-48% protein) and guar meal korma (50-55% protein), classified onthe basis of protein content. Amino acid composition reveals that guar meal is one of the best protein sources as it is rich in lysine (1.72% DM) and sulfur containing amino acids (0.96% DM) at a concentration greater than that of GNC with comparablemethionine content (Jongwe et al. 2014) and energy value (80% total digestible nutrients). The major constraint in its feeding is its bitter taste, which affects the palatability of feed.

Incriminating factors like trypsin inhibitors, haemagglutinins, saponins and phytic acid, besides 18-20% of residual gum impedes its complete utilisation. Therefore, roasted/toasted guar meal which is low in incrimination factors and less bitter in taste is employedin feeding monogastric animals. Nevertheless, guar meal supports optimum growth andlactation performance of dairy ruminants.

A better growth rate and feed conversion ratio in growing crossbred calves fedguar meal replacing 50% groundnut cake (21% in concentrate) for a period of 90 dayswas observed. However, at 75% inclusion, performance was reduced; nonetheless, uponsupplementation of sweetener (Sucram®) and flavour (Lactovanilla®), respectively at0.025% in the concentrate mixture, growth rate was improved (Goswami et al.2012)without influencing any blood metabolites. Similarly, Grewal et al. (2014) noted that guarby-products like guar *korma*, roasted guar *korma* and guar *churi*could safely replace8% of soybean meal in the concentrate mixture of buffaloes. In a lactation study (Jongwe et al. 2014), it wasevident that milk production was similar in Sahiwal cows receiving guar meal replacing75% of GNC (21% in concentrate) in the concentrate mixture. Moreover, milk yieldand composition as well as blood concentrations of glucose and urea nitrogen were notaltered by dietary inclusion of guar meal. It is noteworthy to mentionhere that although cows generally do not relish the guar meal-based concentrate mixtureinitially, they get accustomed to its taste over a period of 15-20 days (Jongwe et al. 2014).

Rice gluten meal (RGM): The RGM is the by-product obtained after wet-milling extraction of most of thestarch from rice grain leaving behind brownish coloured protein-rich powdery material.It contains 47.5% CP and 3.1% ether extract. In a pioneering study conducted at ICAR-NDRI, Karnal, 50 and 75% of RGM was substitutedisonitrogenously with groundnut cake (GNC) in the concentrate mixture of Karan Fries growing cattle. A 90-day feeding trial confirmed that RGM at both the levels didnot exhibit any adverse effect on dry matter intake, digestibility of nutrients, nitrogenbalance, growth performance as well as haematological variables. Regarding aminoacid profile, RGM contained almost all essential and non-essential amino acids withslightly higher concentration (as % CP) methionine (2%) than GNC (1.2%). Based onthe recommendations of this study that RGM could replace 75% nitrogen (N)of GNC, another study comparedthe by-products RGM andcorn gluten meal (CGM) in growing Sahiwal cattle. On physical basis, the 3 concentratemixtures used in this experiment contained GNC, RGM and CGM at 30, 22.7 and17.5%, respectively. It was observed over a period of 3 months that nutrient intake anddigestibility were similar across diets, while N balance and growth rate were greater($P<0.05$) for calves receiving CGM-based diets than GNC, but comparable with that ofRGM-based diet. Furthermore, there was no change in any of the blood metabolites suchas glucose, total protein, plasma urea N and non-esterified fatty acids. In another study, Mahesh and Thakur (2018) examined comparative nutritional potential of GNC, RGMand CGM by replacing 50% of GNC by RGM and CGM isonitrogenously in early lactatingMurrah buffaloes for 120 days. No major changes were detected in terms of intake anddigestibility; however, buffaloes fed CGM-based diet produced higher ($P<0.05$) milkyield than GNC, but comparable to RGM-based diet. Owing to relatively higher rumenresistant protein, CGM-based diets led to lower ($P<0.01$) milk andplasma urea N levels.Based on these trials, it was concluded that RGM can be incorporated in theconcentrate mixture at 21-23% for growing cattle and 14% for lactating buffaloes.

Rice dried distillers' grains (Rice DDGS): The DDGS is a by-product of ethanol industry. Corn DDGS has been successfullyused as an ingredient in dairy rations worldwide. However, recently, rice grains are alsobeing utilised by the distilleries yielding rice DDGS (47% CP) as a potential by-productthat is valued as a livestock feed. A study was conducted at NDRI on 18 lactating Murrahbuffaloes in which the concentrate mixture containing 25%and 10% GNC and mustard cake werereplaced at 50 and 75% levels on CP basis with rice DDGS. Milk yield, milk component yield (fat, protein, lactose and SNF) were higher in rice DDGS fed buffaloes. Overallmean milk urea and plasma urea values were lower in rice DDGS fed groups. Methaneproduction was lower in 75% RDDGS fed group than the other two groups. Feed cost perkg 6% FCM production was lower in the RDDGS fed buffaloes. Digestibility of nutrients, net energy balance, microbial protein synthesis and nitrogen balance was similar in allthe three groups. It was concluded that RDDGS can be utilized as an alternative proteinsource replacing 75% of GNC and MOC in the concentrate mixture on CP basis oflactating buffaloes with improved milk production with added advantage in terms ofreduction in methane emission and feed cost per unit milk production.

Chandrika et al (2021) conducteda 90 day growth trial was conducted on 10-15 month old male buffalo (Murrah) calves (average initial body weight 252.92+17.0 kg. The animals in control group were fed with basal diet consisting of chopped wheat straw, berseem fodder and SBM based conventional concentrate mixture and animals in experimental groups 2 and 3 were fed wheat straw, berseem and concentrate mixtures in which SBM was replaced with DDGS at 50% and 75% levels on N basis, respectively. Digestibility of nutrients and nitrogen balance was comparable in all the groups, indicating RDDGS did not have any adverse effect on nutrient digestibility and nitrogen retention. RDDGS inclusion as a partial replacement of soybean meal had no deleterious effect on blood profile (total protein, cholesterol, triglycerides, BUN, glucose) and the values of all parameters were within the physiological range. It was concluded that RDDGS can replace soybean meal upto 75 percent in the concentrate mixture of buffalo calves on N basis without any adverse effect on palatability, digestibility of nutrients, nitrogen balance and health of the animals.

Waste bread: In bread manufacturing industry two types of wastes are produced, bread waste and waste bread. The bread waste is generated while manufacturing bread, it includes low quality products, default size or texture, burnt products, bread shreddings and dough waste etc. The bread waste is used as energy source in the ration of ruminants, swine and poultry and economize the feeding cost. Cereal grains like wheat could be replaced completely by waste bread (WB) on nitrogen basis without any deleterious effect on the digestibility of nutrients, N-utilization, nutritive value or growth of animals. Moreover, keeping in view the cost of wheat (Rs 19-20/kg) and WB (Rs 7-9/kg), the feeding of animals could be economized through WB incorporated rations (Bhargava et al. 2022).

Tomato pomace: India is the second highest producer of tomatoes (19.76 million tonnes (mt)/ annum) after China (60.81 mt/annum) in the world. The leftover material after the extraction of pulp from tomatoes from tomato processing industry is called tomato pomace (TP). It is a mixture of skin, core, seeds and residual pulp constituting 10-20% of processed tomatoes. But with the advancement in processing technology, TP constitutes only 2.0- 2.5% of processed tomatoes. Only 2.5% of fruits and vegetables produced in India are processed in the organized sector. In spite of very low quantity of fruit and vegetables being processed, approximately 1.81mt of fruit and vegetable wastes is generated. At present about $13x10^3$ tonnes TP is generated per annum in India. A large proportion of these wastes end up in landfills or rivers, causing environmental hazards. Pollution can be reduced considerably by recycling of these wastes through animal feed. However, the major constraints in using these wastes as livestock feed are their high moisture content. Bakshi et al (2023) evaluated tomato pomace in the TMR of growing buffalo calves. Fresh tomato pomace was procured free of cost from Punjab Agro Juices Pvt Ltd, Hoshiarpur. It was spread on a concrete floor, sun dried and ground in a willey mill to pass through 1mm screen. The fractionation of proteins revealed that TP is a rich source of soluble proteins (albumin and globulins) as compared to insoluble fractions (prolamins and glutelins). Besides 2,2-diphenyl-1- picryl-hydrazyl-hydrate (DPPH) an antioxidant, it also contained other bio-active compounds like total phenolics, anthocyanins, saponins, vitamin C and flavonoids. TP is a rich source of carotenoids like lycopene and â-carotene. The tomato pomace replaced 50 and 100% of concentrate mixture. It was concluded that tomato pomace is a rich source of protein (21. 50 %), ether extract (11%) and bio-active compounds can replace concentrate mixture on N basis from 50-100% in the diet of growing buffalo calves.

Conclusion

In conclusion, the straws and stovers fermented with urea in stacks or bales or used in complete feed blocks, have great potential as livestock feed. The use of straw in this way can both contribute to the feed basket and avoid environmental problems that arise from the current practice of burning straw. Novel feed resources like*Phalaris minor* seeds*,* guar mealrice gluten meal, rice DDGS, waste bread and tomato pomace can be used in the diet of dairy animals, depending on the availability. The cost of ration can be economized when compared with conventional feedstuffs.

References

Bakshi, M.P.S. Kaur, Jasmine and Wadhwa, M. 2023. Utilization of tomato (*Lycopersicon esculentum*) pomace with or without waste bread in the ration of growing and adult male buffaloes. Anim. Nutr. Feed Tech. 23: 13-24.

Bhargava, A., Wadhwa, M. and Bakshi, M.P.S. 2022. Impact of waste bread on the nutrient utilization and performance of buffalo calves. Indian J. Anim. Nutr. 39 (2): 130-139.

Chandrika R.N., Kaur, Jasmine Singh, C., Lamba, J.S. and Grewal, R.S. 2021. Effect of feeding dried distillers grains with solubles on nutrient utilization and blood biochemical profile of buffalo calves. J. Anim. Res. (11)3: 409-414.

Chen L., Ren A., Zhou C.S., Tan Z.L. 2017. Effects of Lactobacillus acidophilus supplementation for improving in vitro rumen fermentation characteristics of cereal straws. Ital. J. Anim. Sci. 16:52-60.

Chererayi Jongwe, S.S. Thakur, Jasmine Kaur and M.S. Mahesh. 2014. Effect of replacing groundnut cake with guar meal (*Cyamopsis tetragonoloba*) in concentrate mixture with and without added sweetener and flavour on production performance of Sahiwal Cows Indian J. Anim. Nutr. 31 (2): 138-142.

Eun J.S., Beauchemin K.A., Hong S.H., Bauer M.W. 2006. Exogenous enzymes added to untreated or ammoniated rice straw: effects on *in vitro* fermentation characteristics and degradability. Anim Feed Sci Technol. 131:87-102.

FAO. 2012. Crop residue based densified total mixed rationA user-friendly approach to utilise food crop byproducts for ruminant production, (T.K. Walli, M.R.nGarg and H. P.S. Makkar). FAO Animal Production and Health Paper No. 172. Rome, Italy.

Grewal, R.S., Lamba, J.S., Ahuja, C.S., Amanpeet Kaur and Saijpaul, S. 2014. Evaluation of guar by-products as replacement of soyabean meal in buffaloes. Indian J. Anim. Nutr., 31(2): 119-123.

Hanlon M.E., Moorby J.M., McConochie H.R., Foskolos A. 2020. Effects of addition of nutritionally improved straw in dairy cow diets at 2 starch levels. J Dairy Sci. 103:10233-44.

Jasmine Kaur and S. S. Thakur. 2016. Characterization of carbohydrates and proteins in *Phalaris minor* seeds by Cornell net carbohydrate and protein system. Curr. Sci.110 (7).

Jasmine Kaur, S.S. Thakur and A.K. Tyagi. 2017. Effect of replacement of maize grains by *Phalaris minor* seeds in the concentrate mixture on milk production and milk fatty acid profile in crossbred cows. Indian J. Anim. Nutr. 34 (4): 402-407

Katoch, R., S.K. Singh, A. Tripathi and N. Kumar, 2017: Effect of seasonal variation in biochemical composition of leaves of fodder trees prevalent in the mid-hill region of Himachal Pradesh. Range Mgt. & Agroforestry. **38**: 234-240.

Kaur, J., M. Wadhwa, M.S. Pannu and M.P.S. Bakshi. 2009. Effect of graded levels of *Phalaris minor*seeds on the nutrient utilization in buffaloes. Indian J. Anim. Nutr. 26(1): 17-22.

Kaur, J., S. Kaushal, M. S. Pannu, M. Wadhwa and M. P. S. Bakshi. 2006. *Phalaris minor* seeds-substitute of wheat grains in the diet of buffaloes. Indian J. Anim. Nutr. 23(2): 67-71.

Kaur, K., Kaur, J., Wadhwa, M. and Bakshi, M.P.S. 2007. Natural fermentation of rice straw in bales and stack and its evaluation as livestock feed. Indian J. Anim. Nutr. 24: 88-91.

Kaur, K., Kaur, J., Wadhwa, M., Balwinder Kumar and Bakshi, M.P.S. 2008. Fermented rice straw as a source of nutrients for ruminants. Indian J. Anim. Nutr. 25: 195- 200.

Ko Y., Kim J., Adesogan A., Ha H., Kim S. 2006. The effect of replacing rice straw with dry wormwood (Artemisia sp.) on intake, digestibility, nitrogen balance and ruminal fermentation characteristics in sheep. Anim Feed Sci Technol. 125:99-110.

Lamba, J.S., Wadhwa, M. and Bakshi, M.P.S. 2002. Effect of feeding naturally fermented urea wheat straw on the productive and reproductive performance of milch buffaloes (*Bubalus bubalis*). J. Buffalo Sci. Technol. 8: 72-79.

Li Z., Zhai H., Zhang Y., Yu L. 2012. Cell morphology and chemical characteristics of corn stover fractions. Ind Crop Prod. 37:130-6.

Litherland N.B., da Silva D.N., Hansen W.P., Davis L., Emanuele S., Blalock H. 2013. Effects of prepartum controlled-energy wheat straw and grass hay diets supplemented with starch or sugar on periparturient dairy cow performance and lipid metabolism. J Dairy Sci. 96:3050-63.

Mahesh, M.S. and Thakur, S.S. 2018. Rice gluten meal, an agro-industrial by-product, supports performance attributes in lactating Murrah buffaloes (*Bubalus bubalis*). Journal of Cleaner Production. 177:655-664.

Man N.V. and Wiktorsson H. 2001. The effect of replacing grass with urea treated fresh rice straw in daily cow diet. Asian Australas J Anim Sci. 14:1090-7.

National livestock census. (2019). 20th Livestock census. All India reports. Ministry of Agriculture, Department of Animal Husbandry, Dairying and Fisheries, Krishi Bhawan, New Delhi.

NRC. 2001. Nutrient requirements of dairy cattle. 7th ed. Washington: National Academies Press.

Omidi-Mirzaee H., Ghasemi E., Ghorbani G.R., Khorvash M. 2017. Chewing activity, metabolic profile and performance of high- producing dairy cows fed conventional forages, wheat straw or rice straw. S. Afr. J. Anim. Sci. 47:342-51.

Pan X., Sano Y. 2005. Fractionation of wheat straw by atmospheric acetic acid process. Bioresour Technol. 96:1256-63.

Sharma, T. 2006. Feed processing as complete feed block for sustainable animal production in arid and semi-arid regions. In: "Feeding of Livestock during Draught and Scarcity- A Short Course" held at Central Arid Zone Research Institute, Jodhpur, India from 1-10 November, 2006. pp 43-56.

Shi H.T., Li S.L., Cao Z.J., Wang Y.J., Alugongo G.M., Doane P.H. 2015. Effects of replacing wild rye, corn silage, or corn grain with CaO-treated corn stover and dried distillers grains with solubles in lactating cow diets on performance, digestibility, and profitability. J Dairy Sci. 98:7183-93.

Wadhwa, M. and Bakshi, M.P.S. 2011. Processing and evaluation of poor-quality crop residues as livestock feed. In: "Proc. Successes and Failures with Animal Nutrition Practices and Technologies in Developing Countries". (H.P.S. Makkar; ed.). FAO Electronic Conference, 1-30 September 2010, Rome, Italy. pp 51-56.

Wadhwa, M., Kaur, K. and Bakshi, M.P.S. 2010. Effect of naturally fermented rice straw based diet on the performance of buffalo calves. Indian J. Anim. Sci. 80: 249-252.

Wang B., Mao S.Y., Yang H.J., Wu Y.M., Wang J.K., Li S.L., Shen Z.M., Liu J.X. 2014. Effects of alfalfaand cereal straw as a forage source on nutrient digestibility and lactation performancein lactating dairy cows. J Dairy Sci. 97: 7706-15.

Chapter 10

Performance enhancing: Adding supplements/ additives in dairy animals feed

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Precise feeding in high producing dairy animals to meet its requirements in a cost-effective manner has become extremely challengeable for both farmers as well as animal nutritionist recently in India considering ever increasing raw material prices of feed ingredients.Additionally,with the introduction of high producing germ various new challenges in feeding viz. transition, early lactation and heat stress etc. has introduced where, it becomes quite difficult to meet animals' nutrient demands considering a limited intake of nutrients in all the above conditions. Therefore, it has become key to enhance the animal's production efficiency through use of various feed additives for sustainability of modern intensive dairy farming.

Feed additives are substances that are added to animal feed to improve feed quality, nutrient uptake, digestion, and gut health. They are typically added in small amounts to the animal's diet, and can be made from a variety of materials, including minerals, vitamins, amino acids, and other nutrients.Feed additives can be used to improve animal performance, health, and welfare, and are commonly used in livestock production. They can help to increase feed efficiency, reduce feed costs, prevent disease, and improve overall animal health.There are several different types of feed additives, including antibiotics, probiotics, prebiotics, enzymes, antioxidants, acidifiers, and natural additives such as herbs, essential oils, and plant extracts. Each type of feed additive has its own specific benefits and is used for different purposes.However, it's important to use feed additives responsibly and to carefully consider their potential impacts on animal health and the environment. The use of certain feed additives, such as antibiotics, has been linked to the development of antibiotic resistance, and many countries are now limiting their use in animal production. Therefore, it's important to use feed additives only when necessary and in accordance with established guidelines and regulations. The feed additives are of two types 1) nutrient and 2) non-nutrient feed additive which are briefly discussed in this chapter.

1. Rumen protected protein/bypass protein/amino-acids

Dairy animals have a major role in nutrition security of human being by convertingfibrous plant and low-quality material into high-quality animal products i.e., milk due to presence of ruminal microbiota. These microbes not only help in utilisation of fibrous plant material but also help in meeting the protein requirement (2/3rd to 3/4th) of the host animals by supplying microbial crude protein (MCP) which is digested in lower gastro intestinal tract (GIT). In dairy animals' dietary protein which is soluble/degradable (RDP) in rumen converted into peptides and amino acids which are further hydrolysed to ammonia, organic acid and carbon dioxide. This ammonia serves as primary nitrogenous base for MCP synthesis. Portion of dietary protein not soluble in rumen content is referred as rumen undegradable dietary protein (RUP) and digested in lower GIT and meet the protein or amino acid requirement of the dairy animals. Moreover, good quality protein sources can be converted to ammonia by extensive degradation in rumen leading to loss of valuable protein source. Certain physiological as well as environmental conditions like transition phase, high milk production and growth performance, heat stress etc., the protein requirement of host animals is not fully met from MCP and dietary protein due to inadequate dry matter intake. Increasing crude protein (CP) concentration in diet is not a suitable method to meet the protein requirement as the CP content increases from 13-21% it decreases the conception rates from 68.5 to 50% in dairy animals.In order to obtain and maintain high productivity it is necessary to meet post ruminal digestible protein in sufficient amount. The most effective waysto achieve or supplysufficient post ruminal protein or amino acid addition of rumen protected protein or amino acids in the diet of dairy animals.Therefore, balancing protein content of the diet on the basis of RDP and RUP or rumen-protected limiting AAs are more precise and can reduce the cost of diets and improve overall utilization of dietary protein (Robinson, 2010). Rumen protected amino acids (RPAA) are a type of feed additive used in animal nutrition to increase the availability of essential amino acids in ruminant diets. RPAA are designed to resist microbial degradation in the rumen and therefore increase the amount of intact amino acids that reach the lower digestive tract, where they can be absorbed and utilized by the animal. Concerning tropical field conditions, where animals mainly subsist on high roughage and maize based diets, methionine and lysine are considered to be the first two co-limiting amino acids (Gami*et al.,* 2017). Therefore, rations balanced for RDP or RUP using rumen protected protein sources and limiting amino acids, either alone or in combination; increases milk energy and yield, milk protein percentage, proportion of dietary N captured as milk N and milk/DM intake ratio. In this context recently Tauqir et al. (2022) reported that supplementation of protected methionine at 35 g per day to early lactating Nili-Ravi buffaloes increased milk protein percentage by 3.26 % as compared to control group. Earlier Amrutkar et al. (2015) reported that under Indian conditions supplementation of 5 g rumen protected methionine with 20 g rumen protected lysine before calving and 7 g rumen protected methionine with 60 g rumen protected lysine; after calving had positive effect on milk quantity and quality in cross-bred dairy cows. Moreover, supplementation of rumen protected methionine and lysine not only increased the post ruminal amino acid level but also helpful in lowering over all protein level of diet in turn reduces the cost of feeding. Overall, the use of RPAA in ruminant diets has been shown to improve animal growth, milk production, and reproductive performance, particularly in high-producing animals with high nutrient requirements. However, it is important to carefully balance the diet to ensure that all nutrient requirements are met and to avoid overfeeding RPAA, which can be costly and potentially detrimental to animal health.

2. Rumen protected fat/bypass fat:

By-pass fat" is a term used to describe a type of fat which is treated or coated in a way that allows it to bypass the rumen and be absorbed in the small intestine. In ruminants, the rumen is the first compartment of the stomach where microbial fermentation of feed takes place. This means that when fats are consumed, they are hydrolysed by rumen microbes and fatty acids produced are biodehydrogenatedby rumen microbes. Further, if fat percentage in the ration is above 3% then it has following negative effects on the rumen fermentation

A) Coating of the fibrous portion of the diet with the lipids thereby preventing attack by the microorganisms

B) Modification in the rumen population concerned with the cellulose digestion

C) Inhibition of the activity of the rumen microorganisms due to an effect on cell permeability brought about by absorption of the fatty acids on cell wall or due to an anti-metabolite effect
D) Reduction in the availability of minerals (Ca and Mg) essential for the microbial activity

In dairy animals there are certain physiological stages like transition phase, early lactating stage, heat stress etc where animals are not able to consume required quantity of feed. In these states there is deficiency of energy and animals enters into the state of negative energy balance which affects both animals' health and production. In these conditions, energy dense ration is the one of strategy to counter reduced feed intake. Cereal grains supplementation is one of the promisingstrategies to increase energy density of rations, but higher level of these tend to cause rumen acidosis and negatively affecting animals' health and production. On the other hand, dietary fat is more efficient than carbohydrate or protein in terms of generating ATPs, so it is helpful in lowering heat increment and also incorporates preformed fatty acids into milk fat. So, supplementation of fat in such a form that do not interact with rumen microbesand is absorbed in the small intestine, where it can provide a more concentrated source of energy for the animal (Palmquist and Jenkins 2017).Hence, it will improve the animal's energy intake, leading to improve growth, milk production, and reproduction. By-pass fat can be made from a variety of sources, including vegetable oils, animal fats, and marine oils, and it is often coated with a protective layer of protein or other materials to prevent it from being broken down by the rumen microbes. Generally, it is practiced that first 3% fat of total DM intake in animals should be provided through various oilseeds while, that in excess of 3% should be supplied as inert fat. It is further stated that ration of high yielding dairy animals should contain 4-6% fat, including fat from natural feeds, oilseed and bypass fat in equi proportions and incorporation of prillled fat (a type of bypass fat) up to 9% of dietary DM had no adverse effect on nutrient utilization in buffaloes (Sharma, 2004). Various previous studies have shown that supplementation of prilled fat at a rate of 75 g from 45 days before calving till calvingand 150 g till 70thday of lactation had increased milk production and reproduction performance of dairy animals (Yadav et al., 2015). Recently, Ranaweera et al (2020) also reported that supplementation of bypass fat at 1.6 % of DMI or 200 g per day during early lactating cows increased milk yield by 31.6 % in crossbred animals. Therefore, rumen bypass fat is a potential energy supplement in dairy cow rations however, supplementation should be adopted after due consideration of their cost- benefit ratio.

3. Rumen protected vitamins

Earlier studies reported that ruminal synthesis of B vitamins is sufficient to meet out the requirement of dairy animals and the vitamins synthesised by bacterial species is sufficient to meet the requirement of other bacterial species by cross feeding in rumen and this ruminal synthesis of vitamin is sufficient to meet the requirement of host animals. However, Van Gylswyk et al. (1992) reported that certain B vitamins from rumen microbial synthesis was too low to meet the optimal growth of some other species of bacteria in the rumen. Further, in modern intensive dairy farming the production of animals has been improved tremendously and their feeding habits have been changed over few decades. So, it can be assumed that B-vitamin supply by rumen microbes and requirements of dairy animals are not matching.This is evident from the recent numerous studies which have reported that dietary supplementation of B vitamins to dairy animals has beneficial effect on milk production, nutrients digestibility and reproductive health (Schwab et al., 2005; Li et al., 2016; Evans et al., 2020). More recently, Brisson et al. (2022) reported that rumen digestible NDF concentration had a negative effect on the ruminal synthesis of riboflavion(B_2), niacin (B_3) and vitamin B_6, whereas rumen digestible starch concentration had a negative effect on the ruminal synthesis of thiamine (B_1) and a positive effect on ruminal synthesis of folic acid (B_9). Kaur *et al.* (2019) reported that supplementation of protected vitamin B complex improved endometrial mRNA expression of genes involved in immune system, steroid hormone regulation and nutrient transportation in pregnant animals thus directly affecting animal fertility. Wu et al., (2020) reported that in steer supplementation of folic acid at 8 mg/kg and pantothenic acid at 60 mg/ kg DMI had improved ruminal microbial growth and digestibility of nutrients in steer. Whereas, Wang et al. (2022) reported that supplementation of rumen protected riboflavin and pantothenic acid at a rate 60 mg and 35 mg per kg DM, respectively in bulls improved growth and total tract digestibility of the nutrients.

Niacin, nicotinic acid, or vitamin B_3 induced skin vasodilatation and increased heat loss at the periphery (Di Costanzo et al., 1997), hence it is mainly used as heat alleviating additive in dairy animals. Supplementation of niacin in rumen unprotected form upto 36 g/d which showed little or no impact on animal's performance under heat stress condition (Schwab *et al.,* 2005; Lohölter*et al.,* 2013). On the other hand, Zimbelmanet al.(2013) reported that supplementation of rumen-protected niacin (RPN) at a rate of 12 g/day in the diet was sufficient to reduce heat stress and increase milk yield of dairy cows. However, during transition phase supplementation of RPN had negative effect on animals' health as it blocks lipolysis to such an extent that cows entered into severe negative energy balance. So, the optimum level of RPN for early lactating animals is 3.5 g/d while, during heat stress a dose of 12 g/d can be given to mid and late lactating animals.

Biotin acts as a cofactor of different enzymes required for glucose and fatty acid synthesis and impaired activity of these enzymes may lead to metabolic disorders during lactation and transition. Further, it has been reported that biotin was not extensively metabolized in the rumen and it did not require ruminal protection (NRC, 2001). Based on previous studies it has been concluded that supplementation of approximately 20 mg of biotin increased milk yield with no effect on milk constituents

Choline another vitamin has major role in fat metabolism particularly synthesis of phosphatidylcholine and very low-density lipoproteins (VLDL).In dairy animals,dietary choline is degraded upto98 %, respectively in rumen thereby necessitating the use of rumen protected choline (RP-choline). Depending upon physiological stage. productivity, breed and diet of animals On the basis of previous studies, a dose of 15 to 60 g/day of RP-choline is to be added to improve productivity and health of dairy animals.

4. Probiotics

Probiotics are living microorganisms that, when administered in adequate amounts, confer a health benefit on the host. In ruminants, probiotics are used to improve feed digestion, increase nutrient absorption, and enhance overall animal health. Probiotics for ruminants are usually composed of bacteria or yeast species that are either native or non-native to the ruminant gut.The use of probiotics in ruminants has gained popularity due to their potential to improve animal performance, particularly in areas of feed efficiency, milk production, and disease resistance. Probiotics can also help reduce the incidence of digestive disorders such as acidosis, bloat, and diarrhoea.One common probiotic used in ruminant nutrition is lactic acid bacteria, which helps improve rumen fermentation and pH balance. Yeast species, such as Saccharomyces cerevisiae, are also used as probiotics to improve rumen function and fiber digestion. Other probiotics used in ruminants include Bacillus species and Bifidobacterium species.It is important to note that the effectiveness of probiotics in ruminants is dependent on factors such as the specific microorganisms used, their dosage, the animal's diet, and the overall health of the animal. Further, protected active dried yeast (1.7×10^{10}cfu/g) at 3-3.5 g per day per animals exhibited post-ruminal activity and improved whole tract organic matter digestibilityand intestinal health by stimulating the relative abundance of *Prevotella*(Jiao et al., 2017;Ran et al., 2020)

5. Flavours

Flavors are often added to ruminant feed to improve feed intake and increase the palatability of the feed. Palatability is a complex and key concept that reflects those characteristics of a feed which invoke a sensory response in the animal to eat (Favreau-Peigne et al. 2013). These sensory responses are generally based on both pre and post ingestive stimuli which are integrated by animals to evaluate the palatability of feed and influenced the feed intake. Ruminants, such as cattle and sheep, have a highly developed sense of smell and taste (calves and cattle 25000 taste buds are present) and they can detect as well as differentiate between different flavours.There are several types of flavours that can be added to ruminant feed, including natural and artificial flavours. Natural flavours are derived from natural sources, such as plants, animals, and fermentation products, while artificial flavours are chemically synthesized.Some common natural flavours used in ruminant feed include molasses, citrus extracts, and apple flavouring. These flavours are often added to improve the taste of feed and increase feed intake. Molasses, in particular, is commonly used in ruminant feed as a source of energy and to improve palatability.

Artificial flavours, such as vanillin and ethylvanillin, are also used in ruminant feed. Theseflavours often added to mask the unpleasant smell of unconventional feedstuffs and improve the taste of low-quality unconventional feed and encourage feed intake.Excessive use of flavours can lead to overconsumption of feed, which can have negative health consequences for the animal. Additionally, some flavours may interact with other components of the feed, leading to changes in nutrient availability and digestion. Further animals may adapt to one type of flavour over a period of time so mixture of flavour can be used.

6. **Toxin binders**

Mycotoxins can have negative effects on production and reproduction in cattle, depending on the type and level of exposure. Here are some of the potential effects of mycotoxins on cattle:

a) Reduced feed intake: Mycotoxins can cause reduced feed intake, leading to decreased production and weight loss.
b) Decreased milk production: Milk production can be decreased due to mycotoxin exposure, especially in the case of milk aflatoxin contamination.
c) Reduced milk quality: Mycotoxin contamination can affect the quality of milk, leading to decreased milk components and increased somatic cell counts.
d) Reproductive issues: Mycotoxins can cause reproductive issues such as delayed onset of puberty, reduced fertility, and increased embryonic death.
e) Immunosuppression: Mycotoxins can suppress the immune system, making cattle more susceptible to diseases and infections.
f) Liver damage: Some mycotoxins, such as aflatoxins, can cause liver damage, leading to reduced liver function and performance.
g) Lameness: Mycotoxins can also lead to lameness in cattle, which can affect their mobility and overall performance.

The severity of these effects can vary depending on the level and duration of mycotoxin exposure, as well as the age and health status of the cattle. It is important to take measures to prevent mycotoxin contamination and to monitor feed and milk quality to identify any issues early on.

Toxin binders are feed additives that are used in ruminants to prevent the harmful effects of mycotoxins and other toxins. Toxin binders generally work by binding to the mycotoxins and other toxins in the feed, preventing them from being absorbed by the animal's gasto intestinal tract (GIT). This reduces the harmful effects of the toxins and allows the animal to better utilize the nutrients in the feed.There are several types of toxin binders used in ruminants, including adsorbents, clay minerals, and yeast cell walls. Adsorbents, such as activated carbon, bentonite, and zeolite, work by physically binding to the mycotoxins in the feed.Yeast cell walls, such as those derived from *Saccharomyces cerevisiae*, work by binding to mycotoxins and other toxins and preventing their absorption.It is important to note that the effectiveness of toxin binders can vary depending on the type of toxin and the dosage and type of binder used. As, Mehany et al. (2019) reported that inclusion of bentonite at the level of 2% of DM intake as toxin binder had the best positive effect on digestibility and rumen fermentation of lactating Friesian cows. Whereas Diaz et al. (2004) reported that sodium bentonites at 1.2% of feed and yeast cell wall product (MTB-100) at 0.05% in feed showed good potential as AFB1 binders. Additionally, toxin binders should be used in conjunction with good management practices, such as proper feed storage and hygiene, to minimize the risk of mycotoxin contamination in the first place.Overall, the use of toxin binders can be an effective tool in managing mycotoxin contamination in ruminants and improving animal health and performance.

7. Organic acids

Organic acids can be used as feed additives in animal nutrition to improve animal performance and health. Here are some of the potential benefits of using organic acids in animal feed:

a) Improved gut health: Organic acids can help maintain the acidic environment in the gut, which can promote the growth of beneficial bacteria and reduce the growth of harmful bacteria. This can lead to improved gut health, nutrient absorption, and overall animal performance.
b) Reduced pathogen growth: Organic acids can have antimicrobial properties that can reduce the growth of pathogenic bacteria, such as Salmonella and E. coli, in the gut and in feed.
c) Improved feed quality: Organic acids can help preserve feed quality by reducing the growth of mold and other fungi that can lead to mycotoxin contamination.
d) Improved performance: Organic acids have been shown to improve feed efficiency, weight gain, and overall animal performance in some studies.

Some common organic acids used in animal feed include acetic acid, propionic acid, formic acid, and lactic acid. The optimal level of organic acid supplementation can vary depending on the type of animal and the specific conditions, but in general, levels of 0.2-1.0% of feed can be used. Gheller et al. (2020) reported that formic acid, sodium formate and propionic acid added at a rate of 4 ml/ kg total mixed ration (as such basis) improved feed intake and milk production performance of the dairy animals.

8. Herbs

Herbs have been used as feed additives in ruminant nutrition for their potential benefits in improving animal performance and health. Here are some potential benefits of using herbs as feed additives in ruminants:

a) Improved digestion: Some herbs, such as fennel, anise, and caraway, have been shown to have carminative effects that can improve digestion in ruminants. Other herbs, such as thyme, oregano, and rosemary, contain essential oils that can improve nutrient digestion and absorption.
b) Antimicrobial properties: Certain herbs, such as garlic, oregano, and thyme, contain natural antimicrobial compounds that can help reduce the growth of harmful bacteria in the rumen and improve animal health.
c) Improved immune function: Some herbs, such as echinacea and ginseng, contain compounds that can support immune function and help ruminants better resist infections and diseases.
d) Increased milk production: Some herbs, such as fenugreek and fennel, have been shown to increase milk production in dairy cattle.
e) Reduced stress: Certain herbs, such as chamomile and valerian, contain compounds that can help reduce stress and promote calmness in ruminants.

Common herbs or their residue like aloe vera waste, amla fruit (Indian gooseberry) pomace and jamun fruit shreds from fruit processing plants fed at a rate of 2 % in the diet of animals (200-250 g/ day) increased milk production by 10.6 % used as feed additives in ruminant nutrition (Singh et al., 2021and Singla et al., 2021).

9. Essential oils

Essential oils are volatile, aromatic compounds extracted from plants that are widely used in various industries, including the food, cosmetic, and healthcare sectors. In ruminants, essential oils are often used as feed additives to improve animal performance, health, and welfare. Research studies have shown that certain essential oils can have positive effects on ruminant nutrition, such as enhancing feed intake, digestibility, and nutrient utilization. They may also have antimicrobial and antioxidant properties, which can improve gut health and reduce the risk of diseases such as mastitis and rumen acidosis.Their growth promoting property is due to the ability to cause cytoplasmic coagulation resulting in cell lysis(Burt, 2004). Essential oils have broad range of effects on rumen fermentation and nutrient digestibility. Various studies have shown that essential oils have the potential to favourably alter rumen metabolism and also show immuno-stimulating properties when used at 1-2 % in the diet of animals. (McIntosh et al., 2003;Standen and Myers, 2004).However, the use of essential oils in ruminant diets needs to be carefully managed, as some essential oils may have negative effects on animal health and productivity if overused or used inappropriately. For example, high doses of certain essential oils may cause digestive upset, decreased feed intake, or even toxicity.

10. Buffers

Buffers are substances that can help to stabilize the pH of the rumen in ruminant animals such as cattle, sheep, and goats. The rumen is a large fermentation vat that contains billions of microorganisms, which break down the fibrous plant material that ruminants eat.During fermentation, the microorganisms produce volatile fatty acids (VFAs) as a by-product, which can accumulate and lower the pH of the rumen. If the pH drops too low, it can disrupt the microbial population and reduce feed intake, nutrient digestion, and overall animal performance.Buffers can help to maintain the pH of the rumen within the optimal range (around pH 6.0-7.0) by neutralizing the excess acid produced during fermentation. Commonly used buffers in ruminant diets include sodium bicarbonate (baking soda), magnesium oxide, and calcium carbonate (limestone).Buffer supplementation is particularly important in high-concentrate diets, which are commonly fed to dairy and beef cattle to maximize milk production and weight gain. High energy content of the provided diets will ensure maximum productivity, but can lead to severe consequences like ruminal acidosis resulting in reduced productivity and eventually reduced profitability of the farm. High-concentrate diets contain a high proportion of grains and other rapidly fermentable carbohydrates, which can lead to a rapid accumulation of VFAs and a decrease in rumen pH.In an attempt to manage ruminal acidosis, feed additive i.e., buffers are the most common compounds used. These can be provided through endogenous production (via saliva) and/or through dietary buffers of which sodium bicarbonate is the compound most commonly used upto 1 % in the diet of animals (Chalupa *et al.*, 1996). The appropriate buffer choice and level depend on various factors such as the animal species, diet composition, stage of production, and environmental conditions.

11. Mineral mixture supplementation:

Generally, about 40 mineral elements that occur in quantifiable amount in nature and out of them about 20 mineral elements are considered essential for human and animal. These essential mineral elements are further classified into two main groups according to their concentration in the animal body i.e.,macro minerals and micro minerals.Macro minerals (major minerals; expressed in term of percentage) are required in relatively large amount and are used in the synthesis of structural tissues such as calcium, phosphorus, magnesium, sodium, potassium, chlorine and sulphur. Micro minerals (minor minerals or trace minerals; expressed in terms of part per million (PPM)) are required in trace amount and usually function as activators or as a component of enzyme system such as iron, copper, iodine, cobalt, manganese, zinc, fluorine, selenium, molybdenum, chromium, nickel, silicon, tin etc.

General function: The functions of minerals in animal nutrition are interrelated. The general function of minerals and trace elements can be summarized below

i) Minerals are constituent of skeletal structure like bones and teeth

ii) Minerals help in regulating acid-base equilibrium

iii) Minerals serve as structural constituents of soft tissues.

iv) Minerals help in maintaining the colloidal state of body matter and regulating some of the physical properties of colloidal systems like viscosity, diffusion and osmotic pressure.

v) Minerals serve as essential components of many enzymes, vitamins, hormones, and respiratory pigments, or as cofactors in metabolism, catalysts and enzyme activators.

Therefore, minerals are essential component to achieve optimum milk production, reproductive and overall health of dairy animals. Further, animal cannot synthesise minerals inside its body and usually feeds and fodders fed to the dairy animals do not provide all the minerals in the required quantity. Moreover, level of minerals in feeds and fodder varies from region to region, so, it become necessary to produce region specific mineral mixture accordingly.

12. Uromin lick

Uromin lick or urea-molasses-mineral block (UMMB) or is a nutritional strategy for dairy animals to provide them with a constant source of fermentable nitrogen, energy and minerals to promote rumen microbes activity throughout the day. UMMB along with low quality roughages enables to satisfy the nutrient requirement of the rumen microorganisms, creating a better environment for the fermentation of fibrous material and increasing production of microbial protein and volatile fatty acids. Urea, after hydrolyzing into ammonia in the rumen, provides a nitrogen source for the rumen microflora and molasses as source of readily fermentable energy along with optimum level of minerals (phosphorus and sulphur) increases the efficiency of ammonia to microbial crude protein.

References:

Amrutkar, S. A., Pawar, S. P., Thakur, S. S., Kewalramani, N. J., and Mahesh, M. S. (2015). Dietary supplementation of rumen-protected methionine, lysine and choline improves lactation performance and blood metabolic profile of Karan-Fries cows. *Agricultural research*. *4*(4): 396-404.

Brisson, V., Girard, C. L., Metcalf, J. A., Castagnino, D. S., Dijkstra, J., & Ellis, J. L. (2022). Meta-analysis of apparent ruminal synthesis and postruminal flow of B vitamins in dairy cows. Journal of Dairy Science, 105(9), 7399-7415.

Chalupa, W., Galligan, D. T., & Ferguson, J. D. (1996). Animal nutrition and management in the 21st century: dairy cattle. Animal feed science and technology, 58(1-2), 1-18.

Di Costanzo, A., Spain, J. N., & Spiers, D. E. (1997). Supplementation of nicotinic acid for lactating Holstein cows under heat stress conditions. Journal of Dairy Science, 80(6), 1200-1206.

Diaz D, Hagler W, Blackwelder J, Eve J, Hopkins B, Anderson K, Jones F, Whitlow L. 2004. Aflatoxin binders II: reduction of aflatoxin M1 in milk by sequestering agents of cows consuming aflatoxin in feed. Mycopathologia 157:233–41.

Evans, E., H. Leclerc, and E. Santin. 2020. Lactational performance in dairy cows receiving a rumen-protected B-vitamin blend during lactation: Meta-analysis of 65 studies. J. Dairy Sci. 103(E-Suppl. 1):286.

Favreau-Peigne A, Baumont R, Ginane C (2013) Food sensory characteristics: their unconsidered roles in the feeding behaviour of domestic ruminants. Animal 7:806-813.

Gami, R., Thakur, S. S., and Mahesh, M. S. (2017). Protein sparing effect of dietary rumen protected lysine plus methionine in growing Murrah buffaloes (Bubalus bubalis). *Proceedings of the National Academy of Sciences, India Section B: Biological Sciences87*(3): 885-891.

Gheller L, Ghizzi L, Takiya CS, Grigoletto NTS, Silva TBP, Marques JA, Dias MSS, Freu G, Rennó FP (2021) Diferent organic acid preparations on fermentation and microbiological profle, chemical composition, and aerobic stability of whole-plant corn silage. Anim Feed Sci Technol 281:115083

Govindaraju, M., K. V. Sathasivam and K Marimuthu. 2021. Waste to wealth: value recovery from bakery wastes. Sustainability, 13(5), 2835.

Havlin, J. M., Robinson, P. H., and Garrett, J. E. (2016). Niacin feeding to fresh dairy cows: Immediate effects on health and milk production. *Animal Production Science*. *57*(6): 1069-1078.

Havlin, J. M., Robinson, P. H., and Garrett, J. E. (2018). Effects on post-fresh period milk production and fertility as a result of prior niacin supplementation of dairy cows during their fresh period. *Livestock Science*. *214*: 73-78.

Jiao, P. X., Wei, L. Y., Walker, N. D., Liu, F. Z., Chen, L. Y., Beauchemin, K. A., and Yang, W. Z. (2017). Comparison of non-encapsulated and encapsulated active dried yeast on ruminal pH and fermentation, and site and extent of feed digestion in beef heifers fed high-grain diets. *Animal Feed Science and Technology*. *228*: 13-22

Li, H. Q., Q. Liu, C. Wang, Z. M. Yang, G. Guo, W. J. Huo, C. X. Pei, Y. L. Zhang, S. L. Zhang, H. Wang, J. X. Liu, and Y. X. Huang. 2016. Effects of dietary supplements of rumen-protected folic acid on lactation performance, energy balance, blood parameters and reproductive performance in dairy cows. Anim. Feed Sci. Technol. 213:55–63.

Lohölter, M., Meyer, U., Rauls, C., Rehage, J., and Dänicke, S. (2013). Effects of niacin supplementation and dietary concentrate proportion on body temperature, ruminal pH and milk performance of primiparous dairy cows. *Archives of animal nutrition*. *67*(3): 202-218.

McIntosh, F. M., Williams, P., Losa, R., Wallace, R. J., Beever, D. A., & Newbold, C. J. (2003). Effects of essential oils on ruminal microorganisms and their protein metabolism. Applied and environmental microbiology, 69(8), 5011-5014.

Mehany, A. A., & Shams, A. S. E. (2019). Effect of Toxin Binder on Productive Performance of Lactating Friesian Cows. Journal of Animal and Poultry Production, 10(12), 405-413.

National Research Council. (2001). *Nutrient requirements of dairy cattle: 2001*. National Academies Press.

Palmquist, D. L. (1991). Influence of source and amount of dietary fat on digestibility in lactating cows. *Journal of Dairy Science*. *74*(4): 1354-1360.

Ran, T., Jiao, P., AlZahal, O., Xie, X., Beauchemin, K. A., Niu, D., & Yang, W. (2020). Fecal bacterial community of finishing beef steers fed ruminally protected and non-protected active dried yeast. Journal of Animal Science, 98(4).

Ranaweera, K. K. T. N., Mahipala, M. K., & Weerasinghe, W. M. P. B. (2020). Influence of rumen bypass fat supplementation during early lactation in tropical crossbred dairy cattle. Tropical animal health and production, 52, 1403-1411.

Robinson, P. H. (2010). Impacts of manipulating ration metabolizable lysine and methionine levels on the performance of lactating dairy cows: A systematic review of the literature. *Livestock Science*. *127*(2-3): 115-126.

Schwab, E. C., D. Z. Caraviello, and R. D. Shaver. 2005. Review: A meta-analysis of lactation responses to supplemental dietary niacin in dairy cows. Prof. Anim. Sci. 21:239–247.

Sharma, D.D. (2004). Deviation of feed industry towards quality feed production. Proceedings of the All India Dairy Husbandry Officers Workshop, October 14-15, 2004, Dairy Extension Divison, National Dairy Research Institute, Karnal, India. pp: 28-33.

Singh, P., Hundal, J. S., Patra, A. K., Wadhwa, M., & Sharma, A. (2021). Sustainable utilization of Aloe vera waste in the diet of lactating cows for improvement of milk production performance and reduction of carbon footprint. Journal of Cleaner Production, 288, 125118.

Singla, A., Hundal, J. S., Patra, A. K., Wadhwa, M., Nagarajappa, V., & Malhotra, P. (2021). Effect of dietary supplementation of Emblica officinalis fruit pomace on methane emission, ruminal fermentation, nutrient utilization, and milk production performance in buffaloes. Environmental Science and Pollution Research, 28, 18120-18133.

Standen, M. D., & Myers, S. P. (2004). The roles of essential oils in the modulation of immune function and inflammation: survey of aromatherapy educators. International journal of aromatherapy, 14(4), 150-161.

Tauqir, N. A., Faraz, A., Waheed, A., Mustafa, A. B., Sheikh, I. S., Pugliese, M., & Nazir, S. (2022). Effect of Methionine Supplemented Feed on Nili-Ravi Buffalo Milk Yield and Composition.

Van Gylswyk NO, Wejdemar K &Kulander K (1992). Comparative growth rates of various rumen bacteria in clarified rumen fluid from cows and sheep fed different diets. Appl Environ Microbiol 58, 99–105.

Wang, C., Zhang, J., Liu, Q., Guo, G., Huo, W. J., Pei, C. X., Chen, L. & Zhang, Y. W. (2022). Rumen protected riboflavin and rumen protected pantothenate improved growth performance, nutrient digestion and rumen fermentation in Angus bulls. *Animal Feed Science and Technology*, *291*, 115394.

Wu, H. M., J. Zhang, C. Wang, Q. Liu, G. Guo, W. J. Huo, L. Chen, Y. L. Zhang, C. X. Pei, and S. L. Zhang. 2021. Effects of riboflavin supplementation on performance, nutrient digestion, rumen microbiota composition and activities of Holstein bulls. Br. J. Nutr. 126:1288–1295.

Yadav, G., Roy, A. K., and Singh, M. (2015). Effect of prilled fat supplementation on milk production performance of crossbred cows. *Indian Journal of Animal Nutrition*. *32*(2): 133-138.

Zimbelman, R. B., Collier, R. J., and Bilby, T. R. (2013). Effects of utilizing rumen protected niacin on core body temperature as well as milk production and composition in lactating dairy cows during heat stress. *Animal feed science and technology*. *180*(1-4): 26-33.

Chapter 11

Cool Nutrient: Importance of Water in Dairy Animals

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Dairy farming is a widely practiced occupation among Indian farmers. A vast number of studies from the past have repeatedly proved that dairy farming is mainly a component of mixed farming of crops and animals (Gangil *et al*, 2019). It is a well-recognized fact that feed accounts for a major share of production cost in a livestock enterprise. Water is perhaps the most undervalued among the nutrients required by dairy animals. Fresh water is a rare resource on our planet; rarer still are the sources of potable water. Around 71% of the surface of earth is covered by water and freshwater is only 2.5 % of the total water on earth. Nearly 99% of freshwater is locked in glaciers and icecaps or stored as groundwater; the rest is present as surface water, in the atmosphere and the living beings (Shiklomanov I, 1993; U S Geological Survey).

Table 1: Water composition

S. No.	**Particulars**	**Proportion of water (%)**	**Reference**
1.	Calf Body	80	Wickramasinghe, 2019
2.	Adult Animal Body	60- 70 56-81	Scroeder, 2015 Murphy, 1992
3.	Succulent Fodders	70-90	ICAR, 2013
4.	Concentrates	10	ICAR, 2013
5.	Milk	87	Scroeder, 2015

Water is essential to all life on earth constituting over 70% of the living mass of plants and animals (Table 1). A loss of 10-20 % of the body water can result in the animal's death. Freedom from malnutrition, hunger and thirst is one of the five freedoms that define animal welfare (WOAH). Considering the role of water in nutrient digestion, absorption and assimilation, a balanced diet would be incomplete without the right quantity of water, not to forget its quality. Water is also required for a number of other physiological processes in the body. It helps to maintain normal body temperature; it aids the transport of nutrients to different organs, tissues and cells; facilitates various processes in reproduction; and it helps in excretion of toxins from the body. All the biochemical processes in the body need water (ICAR, 2013).

The high heat capacity of water allows the body to maintain homeostasis. An animal is able to transfer heat to the environment efficiently due to the high heat of vaporization. The high heat of fusion is responsible for partially protecting the body from freezing. The dielectric constant and high surface tension make it a good solvent and facilitate capillary uptake (Murphy, 1992). Water is also required for bathing the animals, washing the sheds and disposal of wastes. Outside the premises of the dairy farm, it is required for growing crops for fodder supply and grains.

Sources of water

The water requirement of dairy animals is fulfilled from the water in feed and fodder; metabolic water and drinking water. The major requirement for water is fulfilled by drinking water. Dairy animals must be allowed free access to drinking water since water intake varies with DMI, environmental temperature as well as milk production. Therefore different animals have different requirements.

Potable water must be free from odor; should be clear and devoid of colour. It should not have any flavor or taste and it should be free from contamination by toxins. Water should not have any disease causing microbes. Water troughs must be regulary cleaned and disinfected in case microbial contamination is detected. The source of water must also be tested and treated accordingly. The salt content of water must be closely regulated. Sodium, chlorine, potassium and inorganic contaminants (carbonate, sulphate and nitrate) in water can have an adverse on the health of the animal. Nitrates and nitrites can indirectly cause oxygen deficit in the body. Salt content above 2500 ppm increases the animal's thirst and osmotic pressure of blood. It also decreases DMI and subsequently milk production. The pH range of water may have an influence over palatability.

Table 2: Water content in feed and fodder

Sr. No.	Particulars	Water (%)
1.	Forages	75
2.	Silage	70
3.		15-18
4.	Straw	10
5.	Grains, Bran, Polish, Oilseed cakes	10

Table 3: Metabolic water produced from metabolism of nutrients

Sr. No.	Nutrient (100 gram)	Water (gram)
1.	Protein	40
2.	Carbohydrates	60
3.	Fat	107

Table 4: Select quality parameters of potable water

Sr. No.	Particulars	Required amount (ppm)	Maximum limit (ppm)
1.	Total Dissolved Solids	1000	4000
2.	Total salt	500	1000
3.	Salinity	200	500
4.	Hardness	150	350
5.	pH	6.8-7.2	5.0-9.0
6.	Nitrate	40	200
7.	Nitrite	0	1
8.	Cyanide	0	0.015
9.	Insecticide residue	0	0.004

Estimating the daily requirement of water for dairy cattle

Generally speaking, a dairy animal requires 100 liters of water per day, out of which 40 liters of drinking water is needed to support milk production of upto 10 liters per day. Additional 3 liters are needed for every liter of milk produced above this limit (ICAR). But it is important to note that daily water consumption can change drastically with change in feeding schedule, environmental temperature, Dry Matter Intake, physiological status and water quality, among other factors (ILRI, 2015).

1. Age: Calves maintain a higher percentage of water in their body (80%) as compared to adults (60%). A one month old calf can consume around 5-8 liters of water a day. Water requirement increases with body weight until the calf attains adulthood. Water scarcity

can severely affect the growth rate of the calves. When calves have access to drinking water along with milk or milk replacer, their growth rate tends to be higher. They will also reportedly start consuming concentrate early (ILRI, 2015)

2. Water temperature: The ideal temperature of drinking water has been estimated to be around 25 degree Celsius. Any variation of water temperature is likely to reduce water intake.
3. Breed: Exotic breeds have a lower thermoneutral zone as compared to buffaloes and indigenous breeds of cattle. Exotic breeds require more water as compared to indigenous cattle. In general, buffaloes consume more water as compared to cattle. Buffaloes also prefer to cool themselves in pond water during summers. This further increases the water footprint in buffalo farms.
4. Housing: Animals reared under free range require more water as compared to those that remain tied. Exercise increases the daily water requirement.
5. Climate: Dairy animals reared in arid and semi-arid conditions require more water.
6. Physiological status: Pregnant animals tend to drink more water as compared to non-pregnant animals. Lactating animals need more water as compared to dry animals. Around 4 liter of drinking water is required to support 1 kg of milk.
7. Feed and Fodder: Dairy animals consume less water when ad lib green fodder is available. Water requirement increases with increase in dry fodder. Animals also consume more water when the proportion of oil seed cakes in the feed is more. Concentrate ration contains 1% salt. Any change in the proportion of salt leads to change in water consumption.
8. Water Quality: Animals prefer to drink water that is clear and odorless. Water quality is determined by factors such as presence and level of minerals, microbes, organic matter, inorganic elements and heavy metals. Deterioration in water quality shall have a bearing upon reproductive as well as productive health of the animals (Giri *et al*, 2020)

Water requirement of dairy animals is not only limited to drinking water. The direct use of water is attributed to drinking, bathing and service whereas indirect use is associated with production of fodder and concentrates. The total volume of fresh water used for the production of 1 kg of milk during the entirety of the milk production chain is expressed as the water footprint of milk. Around ninety percent of the water footprint is associated with animal feeding. Balanced nutrition and Total Mixed Ration can drastically reduce the water footprint of milk (NDDB). Various workers have developed equations to estimate water consumption of dairy cows (Linn and Knight). Dairy NRC 2001 has recommended the equation developed by Murphy *et al* (1983). Free Water Intake (kg/ day)= 15.99 + (1.58 x DMI, kg/day) + (0.9 x milk, kg/day) + (0.05 x Na intake, g/day) + (1.20 x min. temperature C). According to this equation, dairy animals can drink between 92 to 138 liters water per day (Linn and Raeth-Knight; Erickson and Kalscheur, 2020). Dairy animals derive 60-80% of their water requirement from direct consumption while 25-35% comes from the water from feed. Milking cows are known to drink 90- 150 liters of drinking water, if freely available. Cows can spend a time in the range of 10-60 minutes for drinking water every day and water intake can be as high as 12 liters per minute when the animal is thirsty.

Cows have been observed to drink water more frequently at the time of feeding or after milking. Milking cows can drink upto 50 percent of their daily requirement within an hour after milking.. Apart from the behavior of the cows, external factors also influence the daily water intake. Therefore, watering space, flow rate of water, distance from the feeder as well as the number and location of water troughs must be carefully considered. A flow rate of 90 liters of water per minute into the trough is considered optimum. Water troughs must be located close to the milking parlour exit and manger for the convenience of the cows. When the manger and water trough are located in close proximity and the animals are able to eat and drink freely, DMI and milk production can increase. In free range systems, the location of the source of water must not be more than 600 feet from the grazing animals (Scroeder, 2015; Becker, 2021).

Conclusion

Water is the most important nutrient for dairy animals considering the amount of intake as well as its role in digestion, absorption and assimilation of the other nutrients. Water helps to maintain homeostasis, regulates various biochemical processes, thus maintaining a healthy environment for production. Water quality as well as quantity must be considered as a primary requirement for dairy animals of all ages for maintaining healthy and productive herd.

References

Becker C. 2021. The Value of Water. PennState Extension. The Pennsylvania State University. Retrieved from https://extension.psu.edu/the-value-of-water.

Erickson P S and Kalscheur K F. 2020. Nutrition and feeding of dairy cattle. Animal Agriculture: 157-180. doi: 10.1016/B978-0-12-817052-6.00009-4.

Giri A, Bharti V K, Kalia S, Arora A, Balaje S S and Chaurasia O P. 2020. A review on water quality and dairy cattle health: a special emphasis on high altitude region. Applied Water Science (10).

ILRI. 2015. Water for dairy cattle and buffalo in Pakistan. ILRI Pakistan fact sheet 12.

Linn J and Raeth-Knight M. Water quality and quality for dairy cattle. Retrieved from https://manitowoc.extension.wisc.edu/files/2010/05/Water-Quality-and-Quantity-for-Dairy-Cattle.pdf.

Monteith J. 1972. Latent Heat of Vaporization in Thermal Physiology. Nature New Biology 236(96). https://doi.org/10.1038/newbio236096a0.

Murphy M R. 1992. Water Metabolism of Dairy Cattle. Journal of Dairy Science 75: 326-333.

Saun R J. 2022. Nutritional requirements of dairy cattle. MSD Manual.

Schroeder J W. 2015. Water Needs and Quality Guidelines for Dairy Cattle. AS1369. North Dakota State University.

Retrieved from https://www.ag.ndsu.edu/publications/livestock/water-needs-and-quality guidelines-for-dairy-cattle.

Shiklomanov I. 1993. World fresh water resources. Water in crisis: A guide to the world's fresh water resources. Edited by Peter H Gleick.

U S Geological Survey. Retrieved from https://www.usgs.gov/media/images/distribution-water-and-above-earth.

Wikramasinghe H K J P, Kramer A J, Appuhamy J A D R N. 2019. Drinking water intake of newborn dairy calves and its effects on feed intake, growth performance, health status, and nutrient digestibility. Journal of Dairy Science 102 (1): 377-387.

Yousef M K. 1985. Stress Physiology in Livestock (1). CRC Press, Boca Raton in Das R, Sailo L, Verma N, Bharti P, Saikia J, Imtiwati and Kumar R. 2016. Impact of heat stress on health and performance of dairy animals: a review. Veterinary World (9): 260-268.

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