Handbook of Poultry Nutrition

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Preface

There has been considerable increase in the utilization of soybean meal and other soy products like soybean oil, full fat soybeans in poultry feeds in recent years. This handbook on poultry nutrition has been prepared by the American Soybean Association to assist poultry feed millers, nutritionists and poultry farmers to formulate good quality poultry feeds. ASA intends this document to be an easily readable reference manual reviewing each and every aspect of poultry nutrition.

The American Soybean Association encourages constructive comments on this handbook, including suggestions to be included in subsequent editions. Affiliated specialists and consultants to the American Soybean Association are willing to assist poultry feed millers, poultry producers, poultry organizations, and universities with additional information on how to improve quality of feed by using soybean products.

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CHAPTER ONE

Indian Feed Industry

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Introduction

The animal feed industry in India has been in existence for around 35 years now. It developed with the advent of cross-breeding in cattle. The growth of the feed industry is linked to the phenomenal growth of layer and broiler production in the country. Over the past 10 years, aqua feeds are also being produced for fish and prawns. Today, the industry caters mainly to the dairy and poultry sectors.

The Livestock Industry

The comparative growth rates of cattle and poultry sectors, and population of animals are given in Table 1. India is the world's biggest producer of milk and has the world's largest population of cattle and buffaloes as well. The Indian dairy industry is predominant and spread all over the country, however, only a small number of organised dairy farms exist. Cross-breeding has been between domestic cow breeds and either Jersey or Holstein-Friesian breeds. The buffaloes are unique in India, with their milk having 7-8% fat.

India is the world's fourth biggest producer of eggs. In contrast to the other livestock industries, the poultry industry in India is more scientific and well organised. It is also continuously adopting modern technologies for pure line breeding, latest management practices, environmentally controlled houses, improved vaccines, medicines, poultry processing units, processed chickens, hatching egg export and excellent feed quality. Breeding and feed management practices have improved through education, training, competition and expansion.

Table 1. Comparative growth rates of cattle and poultry sectors and population of animals

Dairy annual growth rate - 5%		**Poultry annual growth rates** **Commercial layer - 6-7%** **Commercial broiler - 15-18%**	
Population and per capita consumption			
Crossbred cows, (million)	10	Commercial layers, (million)	150
Improved cows, (million)	15	Commercial broilers, (million)	650
Improved buffaloes, (million)	36	Breeders stock, (million)	6.5
Milk production, (million tonnes)	78	Egg production, (million)	40,000
Per capita consumption, (g/day)	240	Per capita availability, (eggs/year)	40
		Poultry meat, (million tonnes)	1.0
		Poultry meat per capita availability, (g/year)	1,000
		Poultry feed production, (million tonnes)	9.0

Source: *CLFMA: Published reports in various Indian Dairy and Poultry Journals*

Currently, the poultry industry is going through a phase of integration in broilers, which is likely to change the face of the industry. Although this phenomenon is new, it is expected that there will be rapid changes towards integration, as more and more farmers are finding it difficult to run their farms with marginal profits or negative margins.

Feedstuff Availability

The production of feed ingredients and solvent extracted cakes is given in Table 2. The ingredients commonly used in animal feeds are given in Table 3. Despite demand from the domestic feed industry, India exports large quantities of solvent extractions, mainly soybean meal, to earn foreign exchange in the process. Exports of compound feed as well as that of finished products like chicken, eggs, milk and its products should be promoted instead of oilseed meals.

The uniqueness of cattle feed lies in the usage of hulls or shells, commonly known as "chunis", and the non-inclusion of any material of animal origin, including the bone-based DCP. This has been done not out of

Table 2. Production of feed ingredients and solvent meals in India (2000-2001)

Commodity	Production Million tons	Export Million tons	Remarks
Maize	10.2		Maize is an important cereal in animal feeds.
Sorghum	9.3		
Rice bran, deoiled	2.95	0.005	About 4.7 million tonnes is used in animal feeds, 3.5 million tonnes in the starch industry and 2.5 million tonnes for human consumption.
Soybean meal	3.86	1.90	Soybean meal is most popular for animal feed.
Peanut meal	2.65	0.02	
Rapeseed meal	3.7	0.1	
Sunflower meal	0.53	0.05	
Cottonseed cake	3.87		

Source: *Data collected from the SEA, Government of India publications, Fertiliser Statistics and ISSN*

Table 3. Ingredients commonly used in animal feeds

Maize, Sorghum, Bajra (millet)	Soybean meal	Horse gram chuni
Rice bran, Wheat bran	Groundnut (Peanut) meal	Black gram chuni
Rice bran extractions	Rapeseed meal, Sesame meal	Pigeon Pea chuni
Tapioca	Sunflower meal, Cottonseed meal	
Molasses	Copra meal, Guar meal	Dicalcium phosphate (DCP)
	Meat meal, Meat-cum-bone meal	Bone origin Mineral based
	Fish meal	

fear of any zoonotic problems, but due to the deep-rooted belief that the cow is a sacred animal and must, therefore, be a vegetarian.

Fish meal and meat meal were popularly used in poultry feed, but with the increased production and availability of soybean meal and better awareness, soybean meal has replaced them in most poultry rations mainly for broilers. The induction of soybean meal has also been aided by the fact that farmers have faced production problems due to bacterial contamination of fish and meat meal, whose quality has also not been consistent.

The Indian economy is agro-based. However, the yield per hectare is lower than in many countries as is evident from Table 4.

Table 4. Average yield of select crops

Type	Tons/hectare World's highest		India
Soybean	USA	2.62	1.0
Rapeseed	France	3.52	1.0
Sunflower	Argentina	1.78	1.0
Groundnut	USA	2.82	1.5
Sesame	China	0.78	0.6
Maize	USA	7.9	1.71

Source: *Compiled and collected from SEA Publications 2000, Fertiliser statistics ISSN 0971-0767*

Related Issues

i. Import of maize

Import of maize was under restricted entry. From April 2000, imports have been allowed under the open general licence (OGL). But with 15% duty and grain inspection fee, there is no price parity.

ii. Shortage of edible oil

There is a shortage of edible oil in the country as a result of which India is regularly importing edible oils.

iii. Standardisation and regulation of animal feed manufacturers

The Government through its institutions (Bureau of Indian Standards, BIS) publishes animal feed standards as guidelines. Industry also has its own guidelines. Currently, there is no official compulsion on the industry to use BIS standards. But the government is planning to bring animal feeds under the Essential Commodity Act, something with which the industry is not comfortable.

The organised sector of the compound feed industry is reeling under the problems of huge idle capacity, about 50% or more in some cases. Indian and global players also are adding fresh capacities. There is need to conduct generic promotion of compound feed usage by educating farmers regarding its advantages. Also, ingredients used in the animal feed industry do not attract the Essential Commodity Act. Changes, if any, in Government standards are slow, prolonged and difficult to arrive at because of participative conflicts and various lobbying.

iv. Classification of animal feed supplements/additives for import (OGL vs. restricted entry)

The world over, animal feed supplements/additives are covered under Chapter 23.09 of the "Harmonised System of Nomenclature" (HSN). India is a signatory to the HSN. However, the Indian Government included animal feed supplements/additives under the restricted category in October 1995, instead of including it under the "free" category for import as per HSN.

v. Counter-vailing Duty (CVD) on amino acids

Essential amino acids like DL-Methionine, L-Lysine hydrochloride and L-Threonine are not manufactured in India. The Government has reduced the import duty on these amino acids to 10%, with a view to promoting animal husbandry. However, the Government continues to impose a countervailing duty (CVD) and other additional duties.

vi. Sales tax

Sales tax is being imposed on animal feeds in some states. If a uniform sales tax of 4%, which is currently under consideration, is applied, it will increase feed prices.

vii. Integration

Integration is a new phenomenon, about five-six years old, and it has already spread to many parts of the country. If integration succeeds, there will be few small farmers, few major feed units, few parent stock hatcheries and so on. There will be clustering of integrators and this may bring about a complete change in both poultry as well as feed industry.

New Challenges and Industry Response

- India should allow import of oilseeds rather than imports of edible oils. That will help the solvent extraction industry to utilize their extraction capacity and will also make more oilseed meals available for the Indian feed industry.

- India should promote exports of compound feed and finished products from the livestock industry instead of exports of oil seed meals.

- India needs high-yielding varieties of cereals and oilseeds, and proper application of irrigation, fertilisers, pesticides, etc., to meet the feed requirements of its growing livestock population.

- If India becomes active in the export of dressed chicken and eggs as well as milk products, it will have to adopt international standards. That would mean restrictions on usage of animal by-products and antibiotics in feed.

- Emphasis has to be placed on eco-friendly products. Research and development has to focus on biotechnological products like probiotics, prebiotics, yeast, mannans, acidifiers, herbal growth promoters, anti-pollutants and other nature friendly products.

- Feed formulation will go through a sea change.

CHAPTER TWO

Digestion and Metabolism

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Digestion and Absorption

Feed consumed by a chicken undergoes changes in its digestive tract, with the complex nutrients being converted into simple nutrients in intestines. This is known as digestion. Enzymes produced in the digestive system have a specific function in breaking down complex molecules into simpler units of respective nutrients for absorption. The digestive and absorptive processes in a chicken are rapid and take less than three hours.

Digestive System

The description and function of each part is given in Table 1.

The digestive secretions and their action are shown in Table 2. The layout of digestion in chicken is shown in Fig 1. The end products of digestion are given in Table 3.

Table 1. Description and functions of the digestive system in a chicken

	Description	Function
Mouth (Beak)		The food stays just a short time.
Upper horny mandible	Attached to skull	
Lower horny mandible	Hinged	
Hard palate	Divided by a narrow slit in the centre that is open to the nasal passages	Hard palate contains slit. Therefore, the bird scoops water and elevate its head. Water thus runs down the esophagus by gravity.
Soft palate	Absent	
Tongue	Dagger shaped	Rough surface at the back helps force food into the esophagus
		Few taste buds (about 24) are present. Sense of taste is poor.
Salivary glands		Saliva mainly acts as a lubricant, aiding easy food passage.
Esophagus	A long tube	Food passes along it from pharynx (back of the mouth) and crop to the proventriculus.
Crop	Extends on one side just before it enters the body cavity into a pouch called crop.	Food material remains for varying lengths of time, depending on the particle size, amount consumed, quantity of the ingesta in the gizzard, etc.
		Crop acts as a storage place for food. No enzymes are produced in the crop. Feed particles are softened.
Proventriculus (True stomach)	Connects esophagus and gizzard	Produces gastric juice that contains pepsinogen and hydrochloric acid.
		Food is held here for a short time.
		Little or no digestion takes place.
Gizzard (Muscular stomach)	Lies between proventriculus and upper small intestine (duodenum).	Enzymatic secretions are absent. Digestion continues by the secretions of proventriculus.
	Composed of two pairs of very powerful muscles. Mucosa is thick.	Gizzard exerts great force and food material undergoes mechanical grinding.
		Abrasive materials like grit, rock, gravel, etc., aid grinding of food particles.

	Description	Function
Small intestine	First part of the small intestine forms a loop known as the Duodenum. Jejunum and ileum (lower small intestine) are not very distinct. The epithelial lining of small intestine has large surface area (villai) for rapid absorption of nutrients.	Enzymes secreted through pancreas and from intestinal wall complete the digestive process. Nutrients digested are absorbed through small intestine.
Caeca	Two blind pouches lying between small and large intestines.	Caeca have little function in digestion. Soft material passes in and out. Some microbial digestion of fibre may take place.
Rectum	About twice the diameter of small intestine. Relatively short.	Water resorption takes place.
Cloaca	The bulbous end of the digestive tract.	A common outlet of digestive, urinary and reproductive canals.
Vent	External opening of the cloaca.	
Pancreas	Lies within the duodenal loop of the small intestine.	Secretes pancreatic juice into the distal/posterior end of duodenum by way of pancreatic ducts.
Liver	Two lobes (right and left) The right bile duct is enlarged to form the gall bladder.	Secretes bile, a light sticky yellow-green fluid. Bile flows into the lower end of the duodenum through two bile ducts. Bile contains bile acids (taurocholic and glycocholic acids). Bile aids digestion and absorption of fats and fat-soluble vitamins. Bile is temporarily stored in the gall bladder.

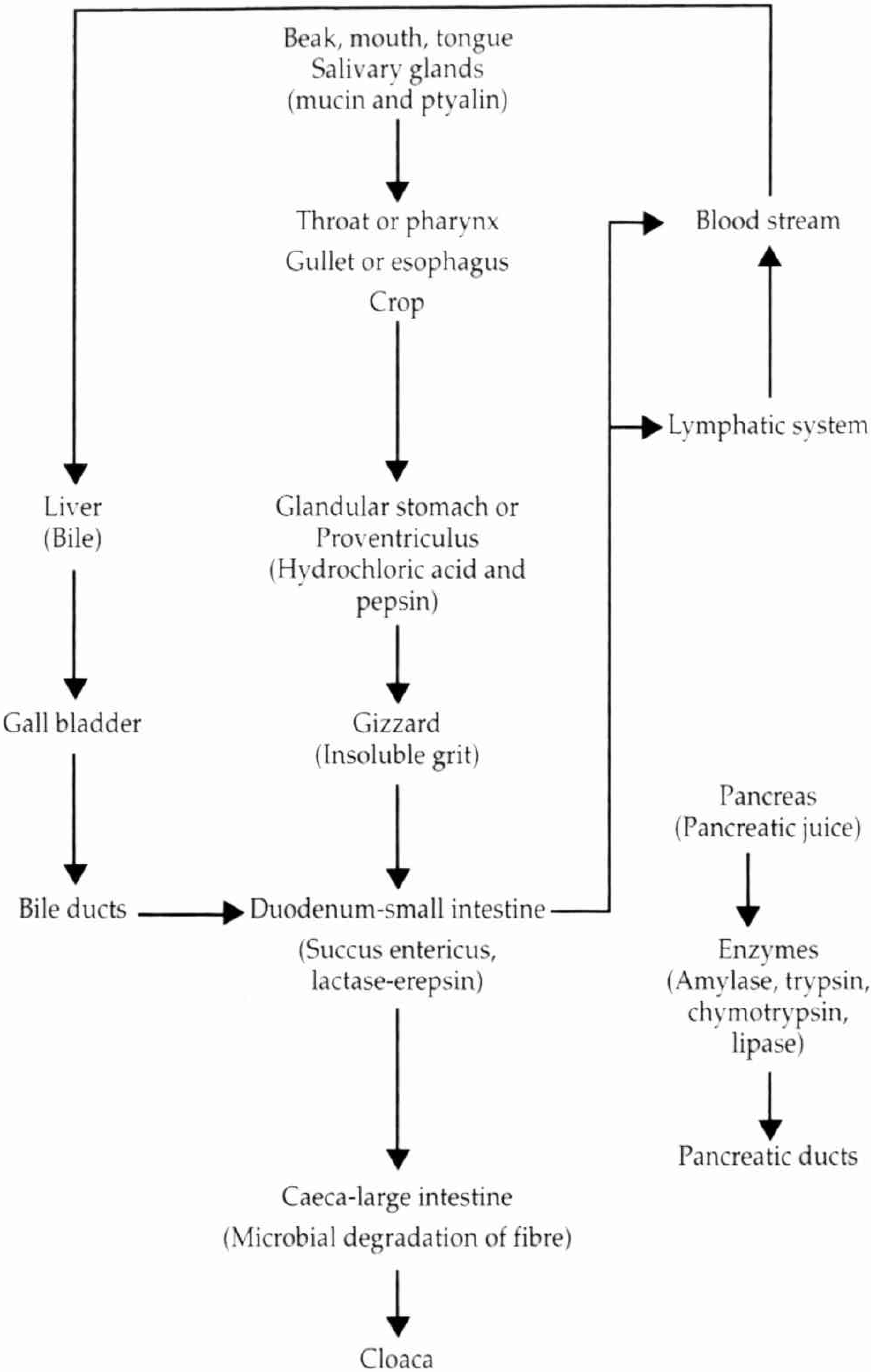

Fig 1. Different parts of digestive tract and their significance in digestion and absorption

1. Maize Normal

2. Maize medium sized

3. *Maize Weevil attacked*

4. *Maize with cob and dust*

5. Maize Normal

6. Maize Normal and Moldy

7. Bajra (pearl millet) Normal and large sized

8. Bajra (pearl millet) small uneven sized

9 . Jowar (sorghum) normal, white

10. Jowar (sorghum) with husk

11. Jowar (sorghum) poor quality

12. Rice full grains

13. Rice - broken grains

14. Rice broken - moderate quality

15. Rice broken - Very poor quality

16. Rice polish - A good quality rice polish

Table 2. Digestive secretions and their action

Digestive secretion	Principle components	Site of action	Action
Saliva from Salivary glands	Water, mucus, salts	Mouth and crop	Softens food for easy passage. Provides neutral medium for action of salivary amylase.
	Salivary amylase (Ptyalin)		Splits starch into dextrin and maltose.
	Water		Further softens food.
	Mucus		Prevents gastric juice from damaging the stomach wall.
Gastric juice from gastric glands of proventriculus	Hydrochloric acid (HCl)	Gizzard and duodenum	Converts pepsinogen to pepsin.
	Pepsinogen		Pepsinogen gets converted to pepsin by HCl and also by pepsin itself. Pepsin splits proteins to peptones and proteoses.
Bile from liver	Water Bile salts, cholesterol, phospholipids	Small intestine	Neutralises the acidity of digesta and emulsifys fats.
	Bile pigments		Waste materials excreted through faeces.
	Water, alkaline salts		Increases alkalinity in intestine.
	Pancreatic lipase		Splits fats into fatty acids and monoglycerides.
	Pancreatic amylase	Small intestine	Splits starch and dextrin to maltose and isomaltose.
Pancreatic juice from pancreas	Trypsin and Chymotrypsin		Splits certain proteins, proteoses and peptones to shorter polypeptides and liberates some amino acids.
Intestinal juice from duodenal glands and goblet cells of small intestine	Water, mucus	Small intestine	Protects intestinal mucosa.
	Enterokinase		Activates trypsinogen to trypsin.
	Carboxypeptidase and Aminopeptidase		Splits amino acids from poly peptide chains.
	Dipeptidase		Splits dipeptide residues.
	Maltase and isomaltase		Splits maltose and isomaltose into glucose.
	Sucrase		Splits sucrose into glucose and fructose.

Table 3. End products of digestion

Nutrient	End product of digestion	Main site of absorption
Carbohydrates (Starch and sugars)	Glucose	Small Intestine
Crude fibre		Not utilised
Fats	Monoglycerides, fatty acids and glycerol	Small intestine
Proteins	Amino acids	Small intestine
Minerals	As mineral elements	Small intestine
Vitamins	As vitamins	Small intestine

Metabolism

The absorbed nutrients are metabolised in the body to perform various functions like maintenance of life, body and feather growth, egg production, fat deposition, activity, etc. The metabolism of carbohydrates, fats and proteins is described briefly in this section. Excess carbohydrates and proteins are not deposited in the body as such. They are converted into fat and deposited in the body. Minerals and vitamins after absorption perform various functions as detailed in the chapter on 'Nutrients and their Functions'.

Metabolism of Carbohydrates

Glucose is used as available source of energy. The excess of glucose and a few other simple sugars are converted into glycogen (animal starch) by the liver and muscle. The storage capacity for glycogen is very limited. When the bird's storage capacity reaches its maximum, the additional glucose in the blood stream is converted into fat. The fat is deposited as adipose tissue in various parts of the body. In times of demand for more energy, the stored glycogen is converted back to glucose. The schematic metabolism of carbohydrates is given in Fig 2.

Metabolism of Fat

Fats are converted into fatty acids for energy, egg production, or stored as body fat. Fats are not excreted. Excess is deposited in the fat cells in

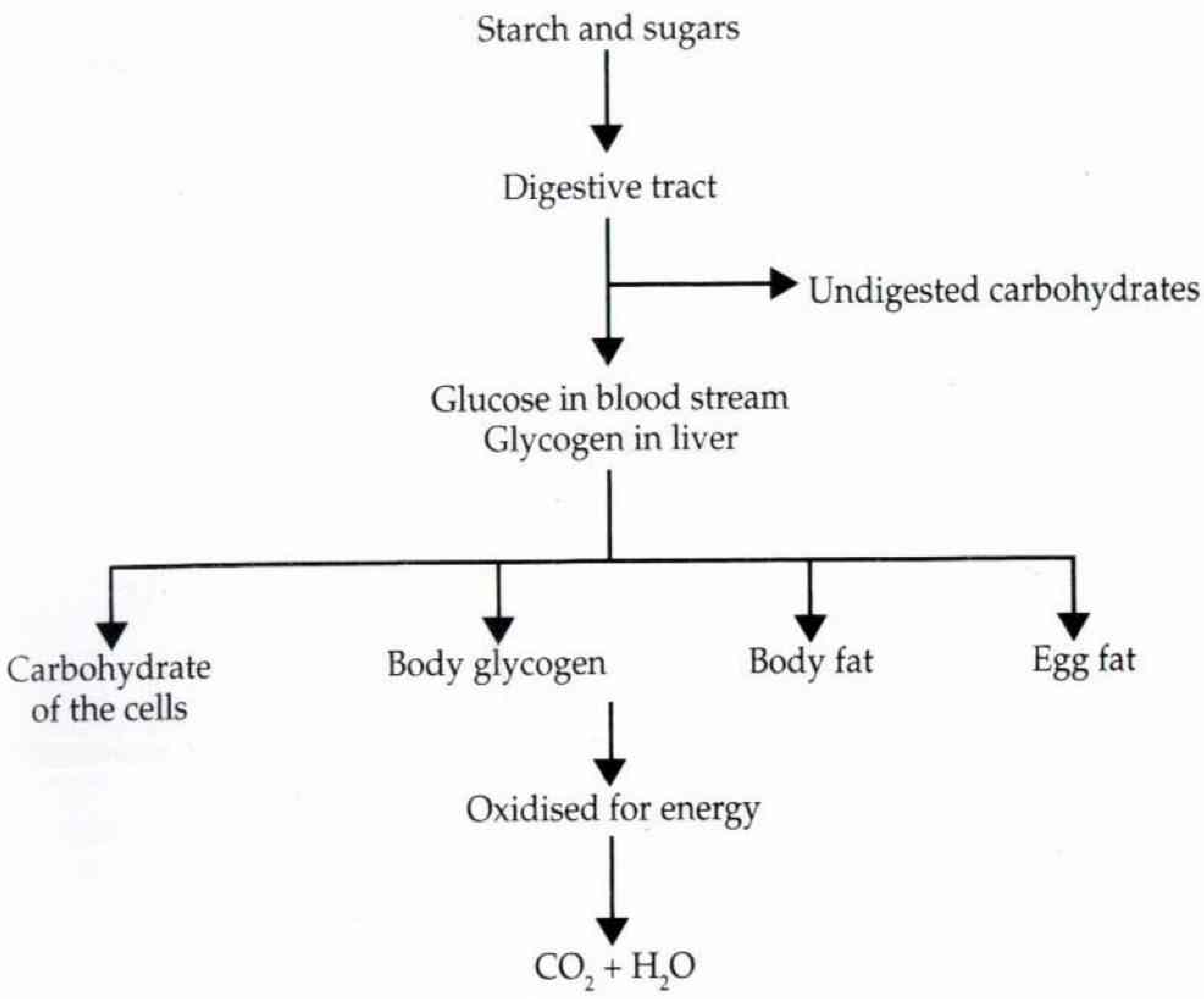

Fig 2. The metabolism of carbohydrates

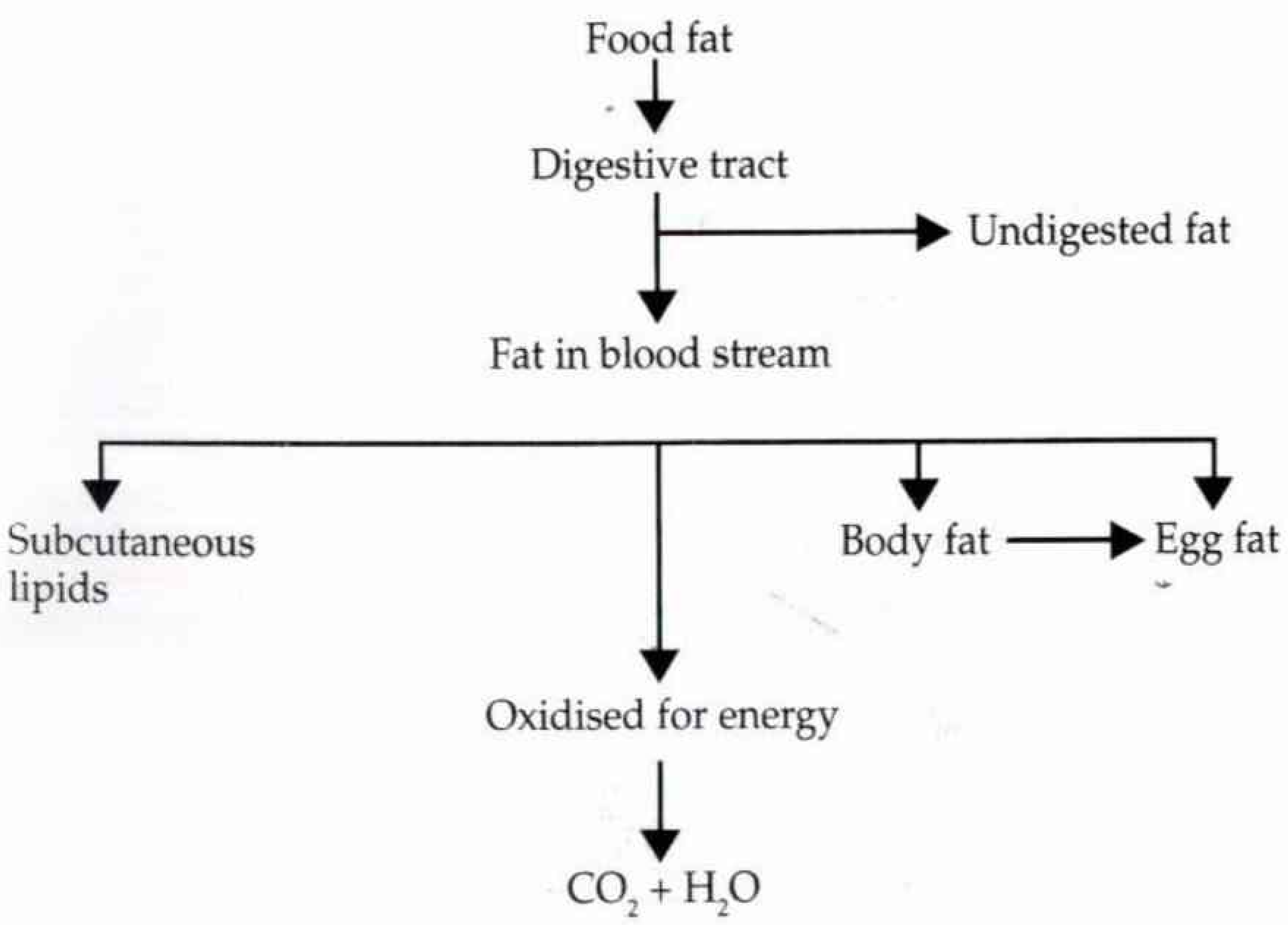

Fig 3. The metabolism of fats

the body. If the carbohydrate, protein or fat consumed by the bird is greater than the required quantity, fat gets deposited in body. If the energy intake is lowered below the requirement, the stored fat is catabolised for energy. The schematic metabolism of fats is given in Fig 3.

Metabolism of Proteins

Absorbed amino acids are used to form various tissues of the body, for repair of the tissue, egg production, etc. Excess intake of amino acids is used for energy through de-amination (removal of ammonia). Excess nitrogen derived from unutilised amino acids is excreted as uric acid through the kidneys. The schematic metabolism of proteins is given in Fig 4.

Metabolism of nutrients and inter-relationship of proteins, fat and carbohydrate metabolism is shown in Fig 5.

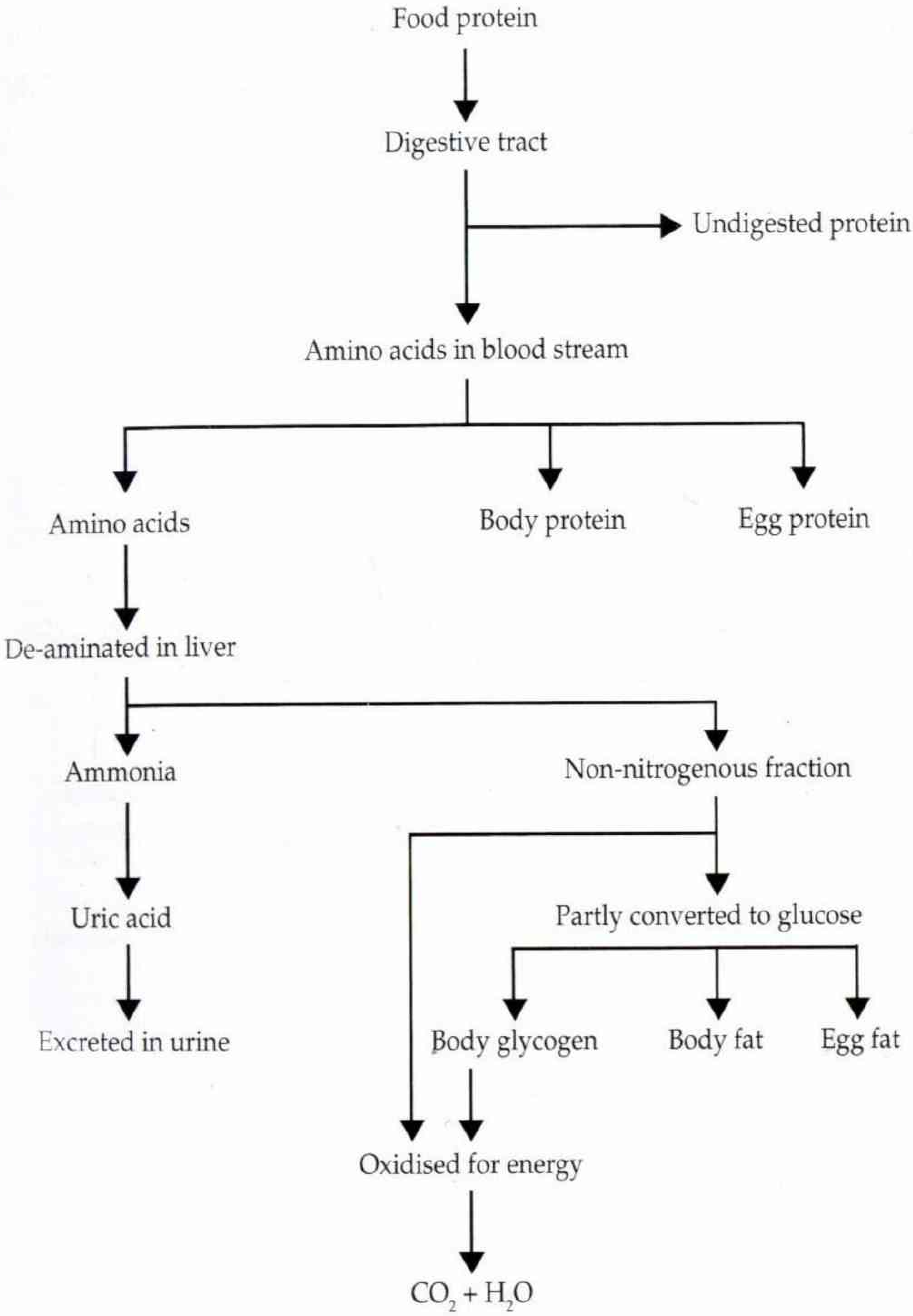

Fig 4. The metabolism of proteins

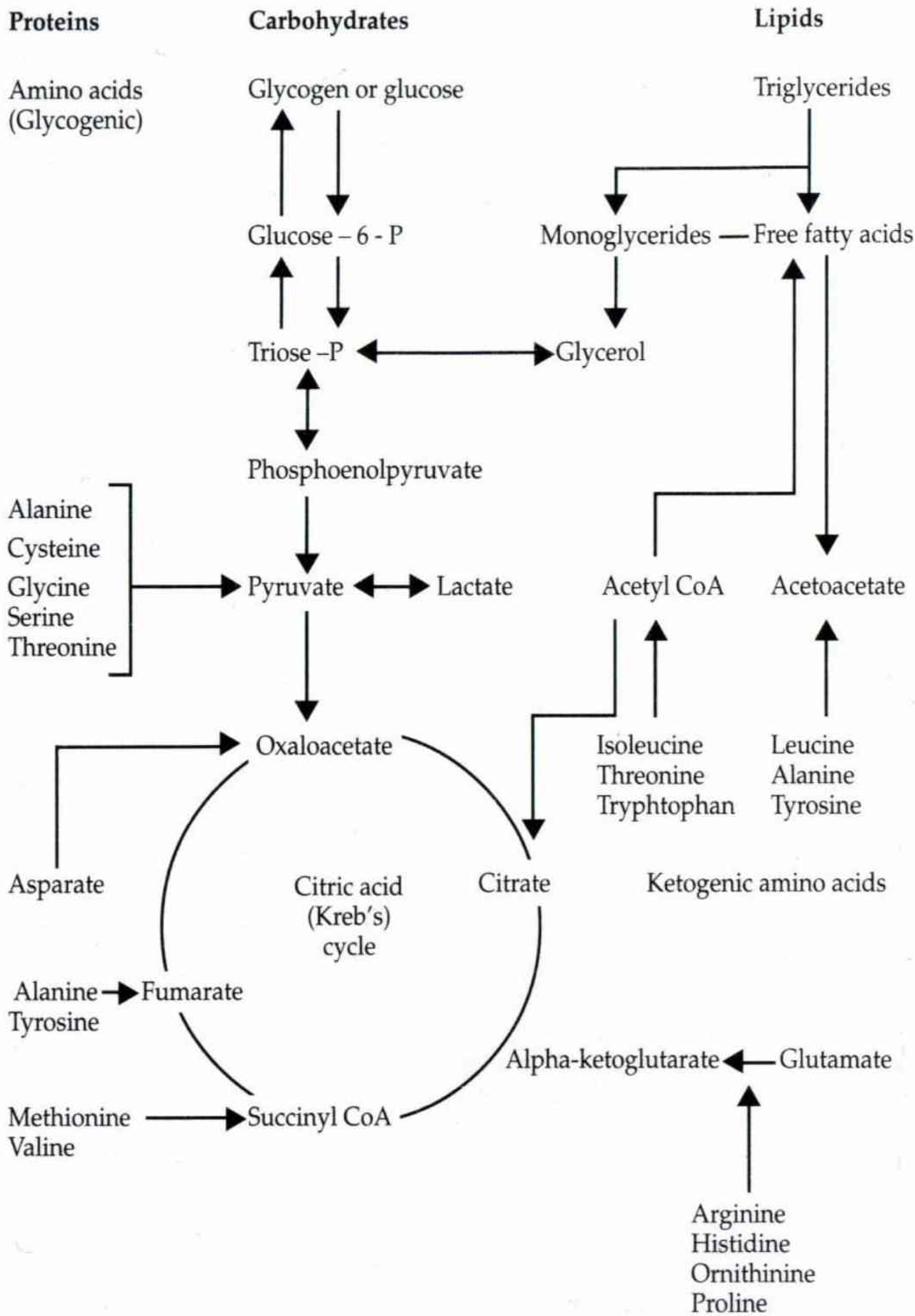

Fig 6. Metabolism of carbohydrates, fats and amino acids

CHAPTER THREE

Nutrients and their Functions

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The nutrients required by a chicken are:

1. Water	2. Carbohydrates	3. Protein
4. Lipids	5. Minerals	6. Vitamins

1. Water

Water can be regarded as an essential nutrient. The water content in the body decreases with age. A week-old chick's body contains about 85% water, an adult chicken's about 55% and an egg 65%.

Functions

i. A major component of blood, intercellular and intracellular fluids.
ii. Regulates osmotic pressure, electrolyte concentrations and body temperature.
iii. Essential in digestion, metabolism and transport of nutrients and also in transport and excretion of waste products.

Deficiency

i. Reduced feed intake, growth and egg production
ii. Death if water loss from the body is more than 20%

Sources

i. Drinking water (major source)
ii. Moisture present in feed ingredients
iii. Water produced due to metabolism of nutrients

2. Carbohydrates

i. Principal energy source in food for poultry.
ii. Chief constituents of plants. They form 50-80% of the dried weight of plants.
iii. The carbohydrate content in the animal body is negligible, i.e. less than 1%.
iv. Some carbohydrates have a special role in structure, function and metabolism of cells.

Classification

The classification of carbohydrates is as follows:

Carbohydrates				
Monosaccharides		Oligosaccharides	Polysaccharides	
I. Pentoses	II. Hexoses	i. Disaccharides	I. Hexosans	II. Pentosans
i. Arabinose	i. Glucose	ii. Trisaccharides	i. Cellulose	i. Arabans
ii. Xylose	ii. Galactose		ii. Starch	ii. Xylans
iii. Ribose	iii. Fructose		iii. Glycogen	

Among carbohydrates, starch, disaccharides and to some extent, pentosans are the energy sources for chickens. Starch is the reserve carbohydrate of seeds and tubers. It is a polymer of glucose. It consists of amylose and amylopectin. On digestion, starch yields glucose. Glycogen (animal starch), found in animals, is similar to starch but is more branched.

The disaccharides of nutritional significance to chickens are sucrose and maltose. Sucrose contains glucose and fructose, while maltose contains glucose only. Individual sugar molecules are released on digestion. Lactose, the sugar present in milk, is a disaccharide consisting of glucose and galactose. Chickens cannot digest lactose. Pentosans are hemicelluloses.

Cellulose, hemicelluloses (mainly arabans and xylans), and lignin (crude fibre) are not digestible by chickens. Crude fibre, if present in feed at high level, may reduce the performance of chickens.

Soluble non-starch polysaccharides

i. The non-starch polysaccharides (pentosans, some other polysaccharides) are non-digestible.
ii. May depress the performance of chickens. These are called anti-nutrients.
iii. They increase visosity of digesta and reduce digestion of nutrients.

3. Proteins and amino acids

Chicken body contains about 20% protein on as such basis and about 75% on a dry matter basis. Amino acids are the constituents of proteins. Chickens need amino acids but not proteins as such. Several types of proteins are present in the body. The protein content in feed ingredients is variable.

Functions

i. Components of structural tissues (skin, feathers, bone matrix, ligaments, muscles, connective tissue, beak) and cells (lipoproteins, nucleoproteins, glycoproteins).
ii. Blood proteins maintain homeostasis, regulate osmotic pressure and are involved in clotting.
iii. Carry several nutrients in the blood (calcium, iron, fat soluble vitamins, fatty metabolites).
iv. All enzymes and many hormones are proteins.
v. Involved in absorption and transportation of nutrients and metabolites.
vi. Proteins, as antibodies, are concerned in immunological functions.
vii. Associated with genes.

Deficiency

i. Depression in growth, egg production, egg weight and feed efficiency
ii. Weight loss
iii. Immunosuppression
iv. Increased susceptibility to diseases

Classification of Proteins

The classification of proteins is as follows.

Proteins		
Fibrous proteins	Globular proteins	Conjugated proteins
i. Collagen ii. Elastin iii. Keratin	i. Albumin ii. Globulin iii. Histones	i. Nucleoproteins ii. Mucoproteins iii. Glycoproteins iv. Protamines iv. Lipoproteins v. Phosphoproteins vi. Others

Non-protein nitrogenous substances

Proteins contain nitrogen. However, some nitrogen containing substances are not proteins. They are known as non-protein nitrogenous (NPN) substances.

Sources

i. Feed ingredients
ii. Protein hydrolysates and synthetic amino acids (Lysine, methionine, threonine)

Amino acids

These are further discussed in the chapter on Nutrient Requirements and Allowances.

4. Fats

i. Body fat is variable dependent on species, age, sex and level of nutrition.

ii. Minimum body fat compatible with life appears to be not less than 2% of body weight. Sometimes, 50% of the body weight of a bird may be fat.

Functions

i. Structural and functional components of cell membranes
ii. Carriers of fat soluble vitamins
iii. Energy reserves in the bird
iv. Concentrated form of energy. Fats contain 2.5 times more energy than carbohydrates.

Classification

The classification of fats is as follows.

i. Neutral fats
ii. Phosphoglycerides
iii. Compound fats
iv. Phospholipids Galactolipids
v. False fats Pigments Sterols Waxes

Essential fatty acids

Certain fatty acids contain double bond in their structure and they are called unsaturated fatty acids. If the double bonds are more than one, the fatty acids are called polyunsaturated fatty acids (PUFA). Polyunsaturated fatty acids are susceptible to oxidation, which is preceded by an induction period that can be shortened by increased temperature, presence of oxygen, radiation and by minute amounts of peroxides. Trace minerals like copper and iron act as catalysts in oxidation of fats. Once induced, the reaction is auto-catalytic and proceeds rapidly. The oxidation products (aldehydes, ketones, etc.) are toxic. Anti-oxidants are added in fat-rich substances to prevent oxidation.

Certain polyunsaturated fatty acids, required by chickens, cannot be synthesised in the body and are to be provided in the diet. These are called essential fatty acids: Linoleic, γ-linolenic, and arachidonic fatty acids. Linoleic acid has to be provided in diet. Vegetable fats are the sources of linoleic acid. Linoleic and arachidonic acids are the structural components of the phospholipids found in cell membranes. Linoleic acid is the only essential fatty acid in poultry.

Functions

i. Growth
ii. Maintaining egg weight
iii. Spermatogenesis
iv. Embryonic development

Deficiency

i. Poor growth
ii. Low production
iii. Reduced egg size
iv. Poor fertility, hatchability

Energy

Functions

Energy is a function of nutrients. Energy is required for:

i. Maintenance of cells
ii. Metabolic functions
iii. Growth
iv. Activity
v. Production

Deficiency

i. Loss of body fat
ii. Lowered metabolic functions
iii. Reduced growth and production
iv. Loss in body weight

Excess Energy

i. Nutritional deficiencies on imbalanced diets
ii. More fat deposition

Sources - Feed

i. Carbohydrates
ii. Fats
iii. Proteins

The energy stored in these nutrients is released in the body during metabolism. Carbohydrates and fats are the principal sources of energy, while amino acids (proteins) are primarily utilised for synthesis of body proteins. Excess amino acids are catabolised, releasing energy. However, the use of protein as energy is costlier than from carbohydrates and fats.

5. Minerals

i. Minerals are the inorganic constituents of feeds and body tissues. They constitute around 4% of the body weight.
ii. Minerals are the structural components of the body (Ca, P, Mg and F).
iii. They maintain acid-base balance as principal cations (Ca, Mg, K, Na, Fe, Mn and Zn) and anions (Cl, I, PO_4).
iv. Act as catalysts in enzyme and hormonal functions.
v. Act as immunomodulators.
vi. Body cannot synthesise minerals; therefore, they have to be supplied through diet (Essential minerals).

The essential and critical minerals are given in the chapter on Nutrient Requirements andSpecifications (8). The sources of minerals are given in the chapter on Feed Sources (5a).

Calcium (Ca) and phosphorus (P)

Ca and P are discussed together because these minerals co-exist in the animal system.

i. Majority of the Ca and P is in the bones.
ii. Vegetable feed ingredients are deficit in Ca and P. Animal protein supplements, especially fish meal and meat-cum-bone meal, contain considerable quantity of these minerals.
iii. P present in vegetable feed ingredients is in the forms of phytin phosphorus (PP) and non-phytin phosphorus (NPP). Monogastric animals, including birds, cannot utilise the PP. About 30% phosphorus in vegetable feed ingredients is considered to be NPP. Entire P in feed ingredients of animal origin is NPP.
iv. Supplementation of Ca and P is required to meet the requirement of poultry.
v. Optimum level of vitamin D_3 is essential for proper absorption and utilisation of Ca and P. Higher dietary levels of vitamin D may help at wider Ca and P ratio.

Functions

Calcium

i. Structural constituent in skeleton (nearly 99%) and egg shell
ii. Controls cell permeability
iii. Essential for neuromuscular excitability
iv. Concerned in blood clotting
v. Co-factor for many enzymes

Phosphorus

i. Component of bone. Nearly (80%) body P is in bone
ii. Structural constituent in cell: As a component of phosphoprotein, phospholipid and nucleoprotein
iii. Concerned in energy release: Cell oxidative phosphorylation
iv. Component of cell buffer system

Deficiency

i. Loss of appetite and weakness
ii. In young birds
Rickets

iii. In layers
    Decreased egg production
    Cage layer fatigue
    Reduced egg size
    Poor shell quality
    Blood spots
    Yolk mottling
iv. In breeders
    Decreased hatchability
    Poor performance of offspring

Sodium (Na) and Chloride (Cl)

These two elements are broadly similar in function and requirements. Sodium is the principal cation, while chloride is the major anion in extracellular fluid.

i. Plant sources are deficient in sodium and chloride.
ii. Animal feed ingredients, such as fish meal and meat-cum-bone meal, are good sources of sodium and chloride.

Functions

i. Helps in maintaining pH and volume of body fluid
ii. Necessary for transmitting energy impulses in nerves
iii. Essential in absorption of certain essential nutrients
iv. Necessary for proper function of enzyme systems of cell nucleus and mitochondria
v. Essential component of gastric juice and bile
vi. Activation of intestinal amylase

Deficiency

i. Loss of appetite, growth retardation, poor feed utilisation (impairment of protein and energy metabolism)
ii. Decrease in plasma fluid volume
iii. Gonadal inactivity

iv. Reduced egg production and hatchability
v. Cannibalism
vi. Moulting in layers

Salt toxicity

Too much of salt, either through feed or drinking water, causes salt toxicity or salt injury, which is characterised by dehydration of body cells and death.

Potassium (K)

Practical feed ingredients contain adequate amounts of potassium.

Functions

i. As a principal cation, maintains acid-base equilibrium and osmotic balance
ii. Concerned in transportation of nerve impulses to muscles
iii. Concerned in transport of oxygen and carbon dioxide in blood
iv. Cofactor for many metabolic enzymes

Deficiency

i. Reduced appetite, depressed growth, muscular weakness and paralysis
ii. Intracellular acidosis
iii. Titanic seizure
iv. Reduced egg production and shell quality

Magnesium (Mg)

Practical diets are normally adequate in magnesium and hence supplementation is not needed.

Functions

i. An integral part of bone
ii. Co-factor for several enzymes (e.g. Thiamin pyrophosphatase)

iii. Essential for activation of several enzymes (galactokinase, phosphoglucokinase, isocitrate dehydrogenase, enolase, etc.)
iv. Required in oxidative phosphorylation

Deficiency

i. Anorexia and depressed growth
ii. Poor feathering, panting and gasping
iii. Nervous symptoms like hyperirritability, tetany, muscular in-coordination
iv. Decreased egg production, egg weight and shell quality

Iron (Fe)

Typical poultry diets are generally high enough to meet the requirement.Iron in feed ingredients of animal origin is not easily assimilated.

Functions

i. An essential component of haemoglobin and myoglobin (oxygen carriers)
ii. An integral part of several enzymes (oxidases, oxygenase, peroxidase, catalase) and electron transport (cytochromes)
iii. Essential for pigmentation of feathers along with lysine and folic acid in coloured feather chicken

The requirement of iron increases during certain conditions.

i. Blood loss (debeaking, parasitic infestation, etc.)
ii. When feeds contain gossypol, phytin and tannins
iii. Excess dietary levels of phosphorus, copper or manganese reduce iron absorption

Deficiency

i. Macrocytic and hypochromic anaemia
ii. Low growth rate

iii. Poor feathering
    Depigmentation of feathers in colour plumage birds
iv. Embryonic mortality (9 to 15d)
    Hatched out chicks – weak, anaemic, reduced haemoglobin

Manganese (Mn)

Rice bran, wheat bran, wheat middlings and alfalfa meal are good sources of manganese.

Functions

i. An integral component of many enzymes like arginase, pyruvate carboxylase and manganese superoxide dismutase
ii. Activates several enzymes like hydrolases, kinases, decarboxylases and transferases
iii. Involved in development of bone organic matrix
iv. Helps in biosynthesis of choline and cholesterol i.e. lipid metabolism
v. Essential for insulin synthesis i.e. glucose utilisation
vi. Maintenance of immune system (neutrophils and macrophages)
vii. Involved in normal functioning of central nervous system
viii. Activates glycosyl transpharase involved in the synthesis of mucopolysaccharides (perosis)
ix. Manganese ions strongly inhibit lipid peroxidation
x. Required for oxidative phosphorylation in mitochondria

Deficiency

Excess dietary levels of calcium, phosphorus, iron or cobalt decrease the utilisation of manganese in chicken. Calcium phosphate formed in the lower intestine might result in the removal of soluble manganese.

i. Perosis (chondrodystrophy): Both legs may be affected.
   Thickened and enlarged hock joint, twisting and bending of tibia and tarsometatarsus, thickening and shortening of long bones, slipping of achilles tendon from its condyle.
   Choline, biotin and other B complex vitamin deficiencies also cause perosis.

ii. Breeders:
Reduced growth, hatchability, poor shell quality, chondrodystrophy in embryos, characterised by poor growth, edema, protruded abdomen, round head, parrot beak
Micromelia: abnormally small, and imperfectly developed extremities (legs, wings, spinal column)
iii. Ataxia and star gazing posture

Zinc (Zn)

Common poultry feed ingredients are deficit in zinc.

Absorption of zinc is influenced by the concentration of phytate, calcium, fibre, copper, cadmium and chromium in the diet.

Functions

i. Activator or a component of enzymes (Carbonic anhydrase, alkaline phosphatase, alcohol dehydrogenase, carboxypeptidase and nucleic acid polymerase)
ii. Influences production, secretion and storage of testosterone, insulin and adrenal corticosteroids
iii. Acts as an antioxidant and protects cell membrane (sulfhydryl group of membrane)
iv. Essential for the integrity of immune system
v. Maintains water balance

Deficiency

i. Decrease in the weight of lymphoid organs (thymus, bursa, spleen) and the count of circulating lymphocytes
ii. Young chicks: Retarded growth, shortening and thickening of leg bones, enlargement of hock joint, scaling of skin on shanks
iii. Breeders:
Reduced hatchability
Embryonic abnormalities: shortened legs, curvature of spine, shortened and fusion of lumbar vertebrae, missing toes and in extreme cases missing legs. Hatched out chicks too weak to stand, accelerated and laboured breathing

iv. Reduced feed intake, feed utilisation, delayed sexual maturity, reduced egg production
v. Poor feathering:
Ranging from a frizzle appearance to near failure of feather to emerge from the follicle

Copper (Cu)

Excess molybdenum, calcium, iron and sulphur may lower copper utilisation.

Functions

i. Helps in red blood cell formation
ii. An integral part of lysyl oxidase, which plays an essential role in cross-linking of connective tissue protein (collagen and elastin)
iii. As a component of cytochrome oxidase helps in synthesis of phospholipid, an essential component of myelin sheath
iv. Essential for proper utilisation of iron in a way to synthesise haemoglobin and myoglobin
v. As a component of cytochrome oxidase, involved in electron transport mechanisms
vi. Supports the immune status through copper, zinc and manganese dependant superoxide dismutase
vii. Participates in the process of osteogenesis and pigmentation of feathers

Deficiency

i. Anemia
ii. Enlargement, thickening and sometimes rupture of aorta due to defective elastin formation
iii. Fragile long bones and lameness
iv. Shell-less and misshapen eggs
iv. In breeders, reduced egg production and hatchability
v. Embryonic mortality at 3-4 d of incubation

Iodine (I)

About 70-80% iodine is concentrated in the thyroid glands.

Functions

The role of iodine in animal system is through thyroxine, which is essential for

i. Thermoregulation
ii. Intermediary metabolism
iii. Cell oxidation
iv. Neuromuscular function
v. Growth and reproduction

Deficiency

i. Enlargement of thyroid gland (goitre) by interfering with thyroid hormone synthesis
ii. Poor growth, egg production, egg size
iii. Abnormally long and lacy feathers
iv. Accumulation of fat
v. Decreased hatchability (low iodine in egg)
vi. Decreased sperm count

Selenium (Se)

Selenium is an essential element. However, the difference between toxic and requirement levels of the mineral is narrow.

Selenium in organic form (selenomethionine or selenocystine) is rapidly absorbed compared to its inorganic form (sodium selenite).

Functions

i. Protects the cellular and sub-cellular membrane from oxidation. Glutathione peroxidase, a selenium dependant enzyme aids in protecting these membranes by destroying the peroxides before they attack the cellular membrane.

ii. Essential for adequate immunity. Selenium and vitamin E protect leukocytes and macrophages during phagocytosis. These two nutrients also play a role in preservation of cell mitochondria and microsomes, which produce antibodies.
iii. Along with vitamin E, forms a complex with heavy metals like cadmium, mercury and silver and reduces their ill-effects.
iv. A component of purine and pyrimidine bases, i.e. structural component of nucleic acids.

Deficiency

Selenium deficiency causes three conditions:

i. Exudative diathesis
Exudative diathesis is characterised by subcutaneous accumulation of green-blue fluid on breast and abdomen and tissue haemorrhage. Prevented completely by selenium or vitamin E
ii. Nutritional muscular dystrophy
Deficiency of selenium, vitamin E and sulphur containing amino acids causes nutritional muscular dystrophy, characterised by dystrophy (development of white striations) of skeletal muscles, especially breast muscle.
Prevented by vitamin E or selenium
iii. Pancreatic dystrophy
Selenium deficiency in diet containing even higher levels of vitamin E (200 to 1000 ppm) and sulphur containing amino acids causes pancreatic dystrophy.
iv. Reduction of egg production and embryonic survivability in layers fed low selenium diet containing no supplemental vitamin E.

Prevented completely by selenium

Cobalt (Co)

Constituent of Vitamin B_{12} but cobalt as such is not essential for poultry.

Fluorine (F)

i. Fluorine is a toxic element. However, fluorine is essential in small quantities for some species.

ii. Generally, the source of F in poultry feed is through rock phosphate, bone meal, deep well water and rarely fish. The absorption / utilisation of fluorine from these sources is less (less than 50%) compared to sodium fluoride.
iv. Defluorinated phosphorus compounds should not contain more than 100 ppm fluorine.
v. A level of 2 ppm fluorine is considered as the upper limit in water for poultry.

Maximum tolerance level of different minerals for chicken

The tolerance of chicken to any particular mineral is dependent on several factors like :

i. Physiological state
ii. Age
iii. Adaptation
iv. Level of production
v. Breed
vi. Biological availability
vii. Interrelationship of minerals
viii. Season

The tolerance level, toxic level and toxic symptoms, and lesions of minerals are given in Table 1.

6. Vitamins

Vitamins are a group of complex organic compounds, present in minute amounts in natural feed and are essential for normal metabolism.

Classification

They have been classified into two groups depending on their solubility

i. Fat soluble vitamins (vitamin A, D, E and K)
ii. Water soluble vitamins (B complex group and ascorbic acid)

Table 1. Tolerance and toxic levels and symptoms, and lesions of mineral toxicity in chickens

Mineral	Tolerable level	Toxic Level	Toxic symptoms & Lesions
Calcium	Growers 1.2 % Layers 5 %		i. Deficiency of phosphorus ii. Deficiency of other minerals (Magnesium, Iron, Iodine, Zinc, Manganese) iii. Antagonises vitamin K function iv. In growers, nephritis, urate deposition in ureters, visceral gout
Chloride		1.5 %	i. Reduced growth
Cobalt	10 mg/kg	100 mg/kg	i. Reduced growth
Copper	300 mg/kg	800 mg/kg	i. Necrosis of liver cells ii. Destruction of vitamin E iii. Reduced growth iv. Gizzard erosion
Iodine	300 mg/kg	500 mg/kg	i. Goitre ii. Reduced growth iii. Reduced egg production, egg size and hatchability
Iron	1000 mg/kg	4500 mg/kg	i. Adsorbs vitamins and trace minerals ii. Formation of insoluble phosphates iii. Rickets
Magnesium	Chicks 0.3 % Adults 0.5 %	1 %	i. Poor growth and low egg production ii. Reduced bone ash iii. Poor shell quality iv. Wet droppings
Manganese	2000 mg/kg	4000 mg/kg	i. Poor growth
Phosphorus	0.8 % (NPP)		i. Deficiency of calcium ii. Deficiency of other minerals (Magnesium, Iron, Iodine, Zinc, Manganese)
Potassium	2 %		i. Wet droppings
Selenium	2 mg/kg	10 mg/kg	i. Poor growth ii. Low egg production and hatchability

Mineral	Tolerable level	Toxic Level	Toxic symptoms & Lesions
Sodium		0.9 %	i. Reduced growth and egg production
			ii. Wet litter
Sodium chloride	1.5 %	2 %	i. Increase water intake
			ii. Wet droppings
			iii. Edema
			iv. Poor growth and egg production
			v. Nervousness
			vi. Paralysis
Zinc	1000 mg/kg	1500 mg/kg	i. Reduced growth
			ii. Muscular dystrophy
			iii. Reduced bone ash
			iv. Exudative diathesis
Toxic elements			
Aluminium		1000 mg/kg	i. Reduced growth
			ii. Rickets
			iii. Reduced egg production
Barium		200 mg/kg	i. Reduced growth
Bromine		5000 mg/kg	i. Reduced growth
Cadmium	0.5 mg/kg	12 mg/kg	i. Reduced growth and egg production
Chromium		300 mg/kg	i. Reduced growth
			ii. Reduced egg quality
Fluorine	200 mg/kg	500 mg/kg	i. Gets deposited in bones and soft tissues
			ii. Metabolic disorders
			iii. Reduced growth and hatchability
Lead		200 mg/kg	i. Reduced growth and egg production
Mercury	2 mg/kg	5 mg/kg	i. Reduced growth
			ii. Mortality
Molybdenum	100 mg/kg	300 mg/kg	i. Reduced growth
			ii. Reduced egg production and hatchability
Nickel		400 mg/kg	i. Reduced growth
Nitrates		450 mg/kg	i. Reduced growth

Mineral	Tolerable level	Toxic Level	Toxic symptoms & Lesions
Nitrite		650 mg/kg	i. Decrease vitamin A in liver ii. Thyroid enlargement
Silver		200 mg/kg	i. Reduced growth ii. Anemia iii. Exudative diathesis (Prevented by Vitamin E or Se) iv. Enlarged heart v. Muscular dystrophy (Prevented by Cu + Se)
Strontium		6000 mg/kg	i. Reduced growth
Sulphate		8000 mg/kg	i. Reduced growth and egg production
Tungsten		500 mg/kg	i. Reduced growth
Vanadium	10 mg/kg	15 mg/kg	i. Reduced growth and egg production ii. Lowered albumen quality

i. Fat soluble vitamins are stored in the body while the excess intake of water soluble vitamins (except B_{12}) are excreted rapidly. Therefore, a continual supply of water soluble vitamins is essential to avoid their deficiencies.
ii. Too high intake of fat soluble vitamins (vitamin A, D and E) causes toxicity.

The list of vitamins to be supplemented in diet is given in the chapter on Nutrient Requirements and Specifications (8).

Fat soluble vitamins

Vitamin A

i. Vitamin A is considered as the most important from a practical point of view.
ii. The vitamin A precursors (carotenoids) are available in certain plant materials, which are converted into vitamin A in the intestine of chickens.
iii. The absorbed vitamin A is stored in the liver (90%) and other tissues.

iv. One IU of vitamin A is equal to 0.3 mg of retinol or 0.55 mg of retinol palmitate.

Functions

Vitamin A is essential for

i. Vision (Rhodopsin formation)
ii. Bone growth (regulate the activity of osteoblast and osteoclasts)
iii. Reproduction (testosterone synthesis)
iv. Epithelial integrity (cross linking between lipid and protein in cell wall)
v. Immunological response (membrane integrity and maintenance of adrenal gland)

Deficiency

i. Reduced growth
ii. Decrease in resistance to disease
iii. Eye lesions and muscular in-coordination
iv. Decrease in egg production, hatchability and increase in embryonic mortality
v. Degeneration of mucus membrane may result in secondary bacterial infection

Sources

i. Fish and fish solubles are the richest sources of vitamin A. Green leafy vegetables are another good sources, with the degree of greenness indicating the concentration of carotenoid.
ii. Trace minerals in feed, particularly copper, are detrimental to vitamin A stability.
iii. Antioxidants, emulsifying agents, gelatin and sugar can improve the stability of vitamin A in feed.
iv. Steam pelleting may destroy the supplemental vitamin up to 40%.

Vitamin D

i. Vitamin D is also called as "sunshine vitamin", "antirachitic vitamin". It is good for chickens under modern commercial rearing, as they are not exposed to sunlight.
ii. Vitamin D exists in two forms, i.e. ergocalciferol (D_2) and cholecalciferol (D_3). Cholecalciferol is more potent (30 times) than ergocalciferol in poultry. Ergoclaciferol is from plant source while cholecalciferol is from animal source.
iii. Precursor of vitamin D_3 (7–dehydrocholesterol) is converted into cholecalciferol when exposed to sunlight (UV irradiation).
iv. The requirement of vitamin D_3 increases several folds at inadequate levels or improper ratio of Ca and / or P in diet.
v. One ICU of vitamin D is equal to 0.025 mg of vitamin D_3.

Functions

i. Enhancement of intestinal absorption, mobilisation, retention and bone deposition of Ca and P through production of Ca binding protein
ii. Elevates plasma Ca and P levels sufficient to maintain normal bone mineralisation
iii. Helps in regulation of immune cell function

Deficiency

i. Rickets sit in a squatting position, reluctant to walk, stiff legged gait, Soft beak, claws, leg and other bones
ii. Depigmentation of feathers
iii. Reduced egg production
iv. Thin shelled or shell-less eggs
v. Reduced hatchability of eggs
vi. Embryos (18-19d): Soft beak fails to pip the shell

Vitamin E

An excellent natural anti-oxidant for fats and fat soluble vitamins

i. Pelleting (high heat and moisture) may destroy the vitamin when no anti-oxidant is present. Presence of heat, oxygen, trace minerals and oxidised fat also accelerate oxidation of the vitamin during storage.
ii. One IU of vitamin E equals to 1 mg of dl-µ-tocopheryl acetate or 0.909 mg of dl-µ-tocopherol.

Functions

i. Acts as a potent biological anti-oxidant. This vitamin interrupts the production of free radicals from unsaturated fatty acids
ii. Involved in formation of phospholipid in biological membrane
iii. Enhances disease resistance in chicken by protecting the leukocytes and macrophages during pathogen invasion into the body
iv. Involved in cell oxidation – reduction reactions
v. Alleviate the toxic effect of heavy metals like cadmium and mercury
vi. Along with selenium, protects the phospholipids of cell membrane

Deficiency

i. Exudative diathesis
ii. Encephalomalacia
iii. Muscular dystrophy
iv. Sterility in males
v. Reduced hatchability due to early (fourth day) embryonic mortality

i. Exudative diathesis (subcutaneous edema)

Exudative diathesis (ED) is a result of increased capillary permeability. This condition is more severe when vitamin E deficiency is accompanied by deficiency of sulphur amino acids. Both vitamin E and Se are involved in preventing this condition, but when Se is severely deficient, vitamin E is also ineffective in preventing ED. Se or cystine can totally prevent this condition. Larger doses of Se are required in prevention of ED when the diet is deficit in vitamin E, methionine and cystine.

ii. Encephalomalacia (crazy chick disease, ataxia, head retraction and cycling with legs).

During the rapid phase of brain development, the deficiency of vitamin E results in nutritional encephalomalacia. This condition is a result of haemorrhages and edema within cerebellum. Selenium is ineffective while synthetic anti-oxidants (DPPD, methylene blue, DBC, BHT, BHA, etc.) check this condition.

iii. Muscular dystrophy

On diets low in vitamin E and sulphur containing amino acids, chicks develop a degenerative condition called muscular dystrophy characterised by the appearance of white striations in the skeletal muscle.

Sources

i. Vegetable oils
ii. Cereal byproducts containing oil

Vitamin K

Functions

i. Required for synthesis of blood clotting factors II (prothrombin), VII, IX and X in liver. Prothrombin is converted to thrombin, which facilitates the conversion of soluble fibrinogen into insoluble fibrin. The fibrin polymerises into strands and enmeshes red blood cells into the blood clot.

Deficiency

Deficiency of vitamin K may occur during coccidiosis and subsequent treatment with sulpha drugs, presence or ingestion of mycotoxins, sulphaquinoxalin, dicumarol, warfarin or arsanilic acid. Chicks during early stage of growth are highly susceptible to deficiency compared to adult birds.

i. Impaired blood clotting

Chicks hatched from parents with vitamin K deficiency may bleed to death even on any slight injury.

ii. Severe internal haemorrhages in several parts of the body
iii. Gizzard erosion

Sources

i. Cereals and oil cakes contain small amounts of vitamin K while animal sources like liver and fish meal are its good sources.
ii. Birds reared on litter floor can access vitamin K through coprophagy.

Water soluble vitamins

Vitamin B_1 (Thiamin)

Functions

i. Essential for release of energy from nutrients during their oxidation in the body. Thiamin undergoes phosphorylation in liver to form the metabolically active form i.e., thiamin pyrophosphate (TPP) or cocarboxylase. The coenzyme plays a role in all enzymatic decarboxylation of µ keto acids.
ii. Plays an important role in synthesis of nucleic acids (pentose phosphate cycle).
iii. Essential for membrane integrity and function of nerve cell.
iv. Concerned in synthesis of acetyl choline and fatty acids
v. Concerned in release of energy and transport of sodium in the nerve cell

Deficiency

i. Polyneuritis. Thiamin deficiency may lead to accumulation of intermediates of carbohydrate metabolism surrounding the nerves and thereby causes nerve cell damage
ii. Loss of appetite, impairment of digestion, emaciation and general weakness
iii. Nervous symptoms like opisthotonus or star-gazing and frequent convulsions
iv. Cardiac abnormalities like enlargement of heart, edema and slowing of heart beat
v. Atrophy of reproductive organs in chronic deficiency

Sources

i. Cereal by-products

Vitamin B_2 (Riboflavin)

i. Riboflavin is resistant to heat treatment but degrades rapidly when exposed to light.
ii. Practical feed ingredients are deficit in riboflavin.

Functions

i. Essential for generation of energy during metabolism of carbohydrates, fats and proteins.
ii. In the form of FMN and FAD, participates in several enzymes (oxidases and dehydrogenases), that are essential for transfer of electrons in biological oxidation – reduction reactions.
iii. Plays an important role in oxidation reactions in cornea.

Deficiency

i. Chicks: Characteristic curled toe paralysis due to enlargement of sciatic and brachial nerves. Toes curled inwards and chicks walk on hock. Chicks reluctant to move. Legs become paralysed.
ii. Normal appetite, retarded growth, diarrhea and death. Wing feathers are disproportionately long.
iii. In breeders, reduced egg production and hatchability
iv. Embryos are dwarf and exhibit marked micromelia. The down feathers fail to emerge (clubbed down condition).

Niacin

Functions

i. Essential for release of energy from nutrients. Niacin in the form of NAD and NADP are essential for several enzymes involved in metabolism of carbohydrates, proteins and lipids.

17. Rice polish, very good quality adulterated with rice husk

18. Deoiled Rice bran

19. Wheat full but with immature grains

20. Wheat broken with weed seed

21. *Wheat broken majority of portion is weed seed*

22. *Soybean meal - A good quality yellow variety*

23. *Soyabean meal - Dull white/brown*

24. *Groundnut Cake - Dull white/brown*

25 . Groundnut Cake - Brown in colour, Normal

26. Groundnut Cake

27 . *Rapeseed meal*

28. *Sunflower meal*

29. *Dry Fish - leather fish variety*

30. *Fish Heads*

31. Fish meal - note meaty portions, scale and bones

32. Fish meal brown in colour high in sand

ii. Important for biosynthesis of nucleic acids via hexose monophosphate shunt (NADP).

Deficiency

i. Enlargement of tibiotarsal joints, bowing of legs, poor feathering and dermatitis of feet and head. Achilles tendon rarely slips from its condyles.
ii. In chicks, reduced feed intake and growth rate
iii. "Black tongue" characterised by inflammation of tongue, mouth cavity and esophagus.
iv. In layers, loss of weight, reduced egg production and hatchability.

Sources

i. In cereal grains and their by-products, niacin is in bound form and is not available to chickens. Oilseeds contain 40% of their total niacin in bound form.
ii. Animal protein sources are good sources and majority of niacin is available to the chicken.

Vitamin B_6 (pyridoxol, pyridoxal and pyridoxamine)

i. The requirement of vitamin B_6 increases with the level of protein, amino acids and their ratio in the diet.
ii. Supplemental vitamin B_6 may be essential in corn-SBM diet

Functions

i. Concerned in amino acid biosynthesis and catabolism
ii. Essential for synthesis of biogenic amines (histamine, hydroxytyramine, serotonin, ethanol amine and purine).
iii. Essential for production of energy from the metabolism of carbohydrates, fats, proteins and also in tricarboxylic acid cycle.

Deficiency

i. Characteristic posture with wings slightly spread and head resting on the ground, birds run aimlessly with the characteristic posture. In more severe deficiency, violent convulsions followed by death.
ii. Reduced appetite and growth and poor feathering
iii. Marked increase in gizzard erosion
iv. Hyper excitability
v. In layers, reduction in egg production and hatchability

Pantothenic Acid

i. Additional supplementation is essential.
ii. Pantothenic acid is very sensitive to moist heat. Pelleting of feed may cause loss of the vitamin.

Functions

i. Plays an important role in the biological system in the form of coenzyme A and acetyl carrier protein.
ii. Enhances antibody titres by incorporation of amino acids in blood albumin
iii. Coenzyme A is essential for fatty acid oxidation, while ACP is essential for fatty acids biosynthesis
iv. Essential for the synthesis of acetyl choline, the chemical transmitter at the nerve synapses
v. Biosynthesis of haemoglobin
vi. Involved in formation of citric acid.

Deficiency

i. Reduced growth, poor feed conversion
ii. Poor feathering
iii. Dermatitis at the corners and near the beak. Lesions may also occur on feet like cracks and fissures in the skin between toes and the feet bottom. In some cases skin layers of feet thicken, cornify and wart-like lesions may develop on the balls of the feet.

iv. In pantothenic acid deficiency, dermatitis of the feet is most common, while in biotin deficiency, dermatitis attacks the footpads and is often more severe compared to pantothenic acid deficiency.
v. Severe depression in hatchability and embryonic mortality during last phase of incubation. The embryos are edematous with subcutaneous haemorrhages.

Sources

i. Cereal byproducts like rice germ, wheat bran, peanut meal, cane molasses and alfalfa

Biotin (Vitamin H)

i. Bio-availability of biotin is more from vegetable feed ingredients than animal sources.
ii. Pelleting has little effect on biotin content in the feeds.

Functions

i. Involved in conversion of carbohydrate to proteins and vice-versa as well as conversion of protein and carbohydrate to fat.
ii. Essential for maintaining normal blood glucose level.
iii. The enzymes containing biotin are involved in carbon dioxide transport and fixing in tissues.
iv. Functions in transcarboxylation, protein synthesis, deamination of amino acids, purine synthesis and nucleic acid metabolism.
v. In fatty acid metabolism, biotin is required to fix carbon dioxide to acetyl CoA to form malonyl CoA that is a primary reaction in fatty acid synthesis.
vi. Biotin is a coenzyme in the metabolism of linoleic acid.

Deficiency

Utilisation of biotin is reduced if feed is infested with mould or contains rancid fats.

i. In chicks, poor growth and feed efficiency, perosis, ataxia, crooked legs and parrot beak

ii. Dermatitis (See pantothenic acid deficiency)
iii. Disturbed and broken feathers
iv. In breeders, reduced hatchability

Folacin

i. Folacin is a general name to describe folic acid and related compounds.
ii. Folacin is sensitive to light and heat.
iii. High protein diets (folacin required for uric acid formation) or diets infested with moulds and supplementation of diets with sulfa drugs increase the dietary requirement of folacin.

Functions

i. As tetrahydrofolic acid, it plays a key role in transfer of single carbon units.
ii. Required for maintaining immune system.

Deficiency

i. Anemia, poor growth and poor feathering.
ii. Depigmentation of coloured feathers. Folacin, along with lysine and iron, is required for normal feather pigmentation.
iii. In breeders, poor hatchability and increase in embryonic mortality during last days of incubation.
iv. Perosis or slipped tendon: Folacin deficiency causes abnormal development of hyaline cartilage and poor ossification.

Vitamin B_{12} (Cyanocobalamin)

i. Vitamin B_{12} is synthesised only by microorganisms and is not found in plant feed ingredients.
ii. Cobalt is an integral part of the vitamin (4.5%).
iii. B_{12} is stable in premixes containing minerals and also during pelletisation of the feed.
iv. The requirement of vitamin B_{12} is higher for birds reared on wire compared to litter floor.

Functions

i. In transmethylation and biosynthesis of labile methyl groups, nutrients like choline, methionine and folacin also function with vitamin B_{12}.
ii. Involved in transfer or synthesis of one carbon units (methyl groups).
iii. Concerned in synthesis of purines, pyrimidines and proteins.

Deficiency

i. In breeders, reduced hatchability (embryonic mortality at 17th day, characterised by embryonic deformities – extensive atrophy of thigh muscles).
ii. Anaemia, gizzard erosion and fattyness of heart, liver and kidney.
iii. In layers, reduction in egg weight.
iv. Nervous disorders, perosis (deficiency of vitamin B_{12} may cause perosis in chicks fed diets containing deficit levels of choline, methionine or betaine).
v. Reduced feed intake, weight gain, feed efficiency and poor feathering.

Choline

i. Synthesised in liver.
ii. Highly hygroscopic.
iii. Stable during pelletisation and extrusion cooking, and also in multi-vitamin premixes but decreases the stability of other vitamins in the premix.
iii. Increasing the levels of dietary protein or fat increases choline requirements.

Functions

i. Structural component of cell (lecithin, sphingomyelin, etc.).
ii. As a constituent of phospholipids needed for normal maturation of cartilage matrix of the bone.
iii. Plays an important role in fat metabolism.

iv. Prevents fatty liver by mobilising fat as lecithin and increasing fatty acid utilisation.
v. Essential for acetyl choline synthesis.
vi. Acts as a labile methyl group donor which plays role in the synthesis of methionine from homocystine.

Deficiency

i. In young chicks, Perosis: Characterised by pin-point haemorrhages, apparent flattening of hock joint. Achilles tendon slips from its condyles.
ii. Layers can synthesise sufficient choline for maintaining egg production and its supplementation may maintain egg size.
iii. Fatty liver

Sources

i. Fish, cereal by-products and oilseed meals
ii. Methionine has a sparing effect on choline requirements.

Vitamin C (Ascorbic acid)

i. The vitamin has two forms 1) reduced form and 2) oxidised dehydroxyascorbic acid.
ii. The reduced form is readily oxidised to dehydroascorbic acid and here vitamin C acts as an anti-oxidant.
iii. Vitamin C is readily destroyed by oxidation and therefore, exposure to oxygen, copper or iron may destroy it.

Functions

i. Essential for collagen synthesis: Hydroxylation of proline and lysine, which is essential for formation of cross-links in the fibre.
ii. Related to reversible oxidation and reduction characteristics of vitamin C
iii. Plays a role in electron transfer in the cells.
iv. Ascorbic acid is essential for conversion of tetrahydrofolic acid from folacin and utilisation of vitamin B_{12}, which are essential for prevention of anaemia.

v. Plays an important role in metabolism of tyrosine.
vi. Stimulates phagocytic activity and formation of antibodies.
vii. Ascorbic acid, due to its reducing and chelating properties, facilitates the absorption, mobilisation and distribution of metal ions throughout the body.
viii. Synthesis of carnitine, which facilitates metabolism of fats (triglycerides), is dependent of vitamin C.
ix. Essential for steroid genesis

Vitamin C is synthesised in poultry. In newly-hatched chicks and adults exposed to severe stress, synthesis may not be adequate. Supplementation of ascorbic acid in the diets (100 – 200 ppm) of birds exposed to stress (rapid growth, exposure to heat or cold, starvation, transportation, coccidiosis, fowl typhoid) is beneficial.

Toxicity of Vitamins A, D_3 and E

The toxic level, toxic symptoms and lesions of Vitamin A, D_3 and E are as follows.

Vitamin	Toxic level	Symptoms and lesions
Vitamin A	2,000,000 IU/kg	i. Antagonises absorption of vitamin D_3 and E
		ii. Rachitic bones
Vitamin D_3	300,000 IU/kg	i. Hypercalcemia
		ii. Soft tissue mineralisation
Vitamin E	40,000 mg/kg	i. Poor growth
		ii. Soft tissue mineralisation

CHAPTER FOUR

Measure of Nutritive Value of Feed Ingredients and Feed

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Feed ingredients need to be analysed for their nutritive value before they are incorporated in diet and compound feeds. In the chapter on feed analytical laboratory, the type of nutrients analysed depending on the laboratory is given. Depending on the type of ingredient, the nutrients have to be selected for their analysis. The principal parameters to be analysed in different ingredients are given in Table 1. Amino acids are estimated in an amino acid analyser. The estimation of trace minerals, vitamins, mycotoxins, non-starch polysaccharides, enzymes, feed additives and pesticide residues involves specialised equipment and procedures.

Table 1. Principal parameters to be considered in different feed ingredients for analysis

Feed Ingredient	Moisture	Protein	EE	CF	AIA	Ca	P	Others
Maize and other cereal grains	✓							Thiram Mycotoxins
Ragi	✓			✓	✓			
Sorghum	✓							Tannins
Rice bran Rice polishings	✓	✓	✓	✓				Iodine number
DORB	✓	✓		✓	✓			

Feed Ingredient	Moisture	Protein	EE	CF	AIA	Ca	P	Others
Salseed meal	✓	✓						Tannins
Soybean, full fat	✓	✓	✓	✓				Urease activity
Soybean meal	✓	✓		✓	✓			Urease activity
Groundnut meal	✓	✓	✓	✓				Nonprotein nitrogen Mycotoxins
Groundnut meal extraction	✓	✓		✓				Nonprotein nitrogen Mycotoxins
Sunflower meal	✓	✓	✓	✓				Mycotoxins
Copra meal	✓	✓	✓	✓				Mycotoxins
Mustard meal	✓	✓	✓	✓				Mycotoxins
Guar meal	✓	✓	✓	✓				Mycotoxins
Safflower meal	✓	✓		✓	✓			Mycotoxins
Cottonseed meal	✓	✓		✓				Gossypol
Fish and fish meal	✓	✓	✓	✓	✓	✓	✓	Nonprotein nitrogen Salt Bacteria
Meat meal Meat-cum-bone	✓	✓		✓	✓	✓	✓	Nonprotein nitrogen Bacteria
Dicalcium phosphate	✓				✓	✓	✓	Loss on ignition
Rock phosphate	✓				✓	✓	✓	Magnesium Fluorine
Bone meal	✓			✓	✓	✓	✓	Clostridia count
Shell grit	✓				✓	✓		
Stone grit	✓				✓	✓		
Marble chips	✓				✓	✓		
Calcite powder	✓				✓	✓		
Oil	✓		✓					Iodine number
Molasses	✓							Sugar brick test

The basic principles in estimation of measurement for proximate principles (moisture, protein, ether extract, crude fibre, total ash and nitrogen free extract), acid insoluble ash (AIA), calcium, phosphorus and salt (sodium chloride) are given in Table 2.

Table 2. Measurement of proximate principles, AIA, calcium, phosphorus and salt

S.No.	Nutrient	Estimation	Remarks
I	Chemical analysis		
1	Moisture	Drying the sample at 100 °C overnight to a constant weight	Volatile nutrients lost during heating. Moisture can be estimated at low temperature and reduced pressure. Instant moisture analyser available commercially
2	Crude protein	Estimation of nitrogen and multiplying the nitrogen with 6.25	Overestimation of protein with NPN compounds. True protein method is available but not popular.
3	Ether extract	Extraction of sample with organic solvents like diethyl ether, benzene, hexane etc.	Fat soluble non-fatty substances (fat soluble vitamins, chlorophyll, alkaloids, resins, etc.) also are extracted and cause overestimation of fat.
4	Crude fibre	Successive refluxing of feed samples with dilute acid and alkali.	Underestimation of CF value.
5	Total ash	Inorganic residue left after ignition of feed sample at 600 °C.	Represents total inorganic matter, including silica. Certain volatile inorganics like iodine, chlorine, selenium, etc. lost during heating.
5	AIA	Extraction of total ash with hot dilute acids	Represents sand or silica

S.No.	Nutrient	Estimation	Remarks
6	NFE	100 - (sum of values for water, crude protein, ether extract, crude fibre and total ash)	Represents non-cellulose portion of feed carbohydrate
7	Calcium	Titrimetric method Atomic absorption spectrophotometry	Overestimates calcium, unless carefully done.
8	Phosphorus, total	Titrimetric method	Underestimates phosphorus, unless carefully done.
		Colorimetric method	More reliable
9	Phosphorus, phytin	Colorimetric method	Difference between total and phytin phosphorus is non-phytin phosphorus
10	Salt	Titrimetric method	Involves estimation of chloride
		Flame photometry	More reliable. Estimates sodium
		Atomic absorption spectrophotometry	More reliable. Estimates sodium

Gross energy is estimated in a bomb calorimeter. In chickens, energy is expressed in terms of metabolisable energy. A schematic partitioning of energy utilisation in a chicken is given in Fig 1.

Metabolisable energy content can be estimated by prediction equations involving proximate principles, sugars, starch and certain anti-nutrients.

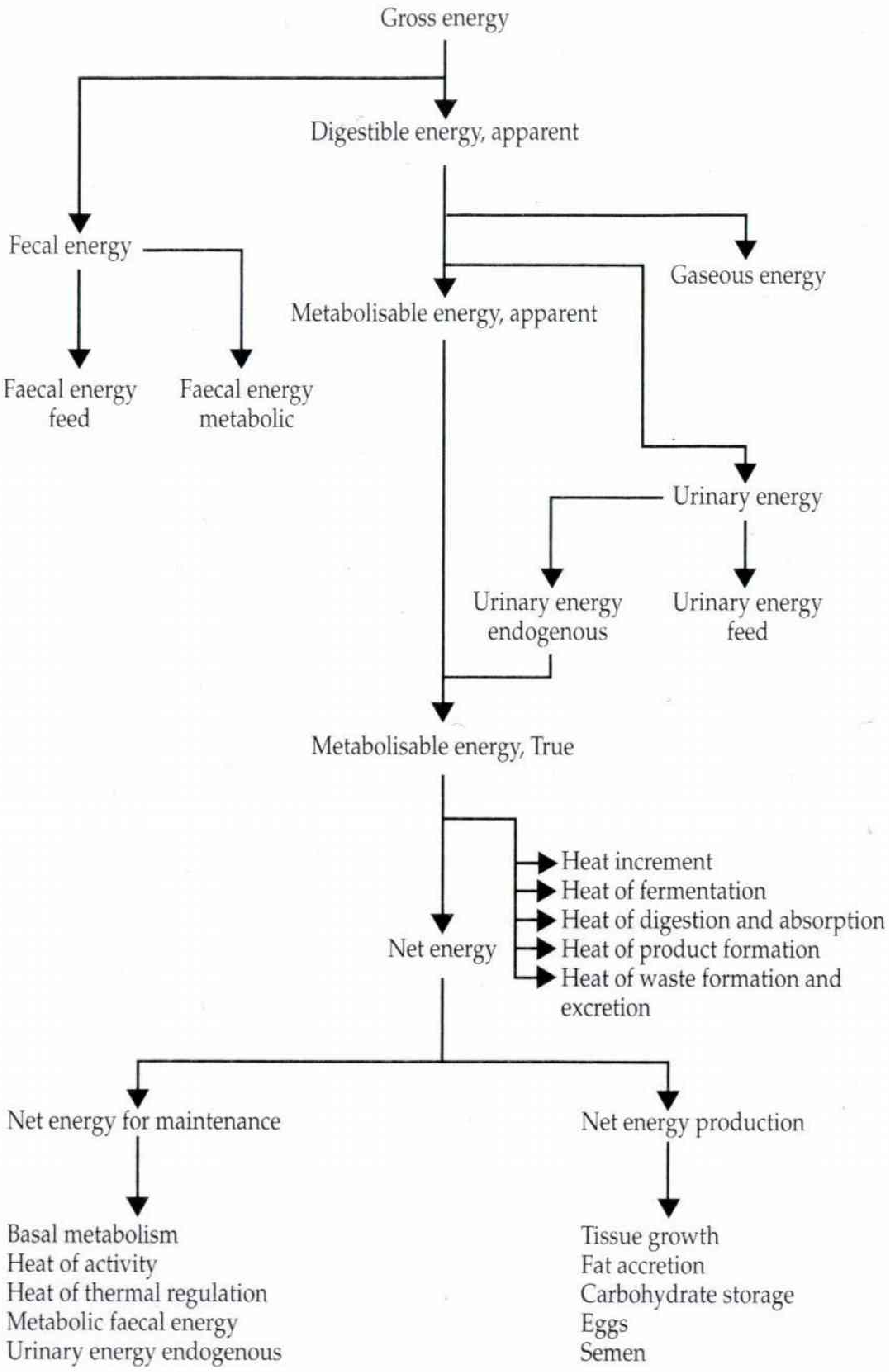

Fig 1. A schematic partitioning of energy utilisation in a chicken

CHAPTER FIVE a

Feed Sources

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Many feed sources supply several nutrients. Depending on the quantitative nutrient supply, those may be termed as energy sources, protein sources, etc.

Energy Sources

Energy sources include

i. Cereal grains
ii. Grain byproducts
iii. Industrial and forest wastes
iv. Miscellaneous materials

Cereal grains

Maize (*Zea mays*)

Maize is the principal energy source used in poultry diets in most of the countries. It contains the highest amount of energy (ME 3350 kcal/kg) among cereal grains and is highly palatable. Yellow maize unlike white maize, provides carotene and xanthophyll pigments for colouration of egg yolk, poultry fat and skin. Maize is also an excellent source of linoleic acid. However, maize protein is mainly deficient in tryptophan and lysine. Maize is also more susceptible for infestation with mycotoxin-producing fungi than other grains such as wheat, sorghum and millets.

Sorghum (*Sorghum vulgare*)

Sorghum contains slightly lower energy but more protein than maize (ME 3200 kcal/kg; Protein 10%). Sorghum protein is deficit in lysine, methionine and arginine. Light coloured sorghum varieties can be used as the principal energy sources. Darker varieties, that are bird resistant, can contain tannins in the seed coat and should be used less.

Wheat (*Triticum aestivum*)

Wheat is a good energy source next to maize and sorghum (ME 3100 kcal/kg). Its protein content is highly variable (11 to 14%). Wheat is used principally for human consumption. Wheat protein is deficient in methionine and threonine. Wheat contains indigestible non-starch polysaccharides (arabinoxylans) that reduce the performance of poultry. The enzyme, xylanase, may be used when wheat is incorporated in feed at high level.

Rice, (*Oryza sativa*), rice brokens, rice param

Rice is the staple cereal food in many parts of India. It is low in protein (7 - 8%). Rice unsuitable for human consumption can be used for poultry at low level.

Rice broken is a byproduct of the milling industry. Its quality is much variable and good quality rice broken can be used in poultry feeds.

Rice param is similar to rice broken but is mixed with variable quantity of bran, resulting in variable quality.

Barley (*Hordeum vulgare*)

Barley contains less energy (ME 2900 kcal/kg) but more protein (10%) than maize. The protein in barley is deficient in lysine and methionine, and it contains β-D-glucans that are not digested and cause wet and sticky droppings due to increased viscosity of intestinal contents. Enzyme, β-glucanase, is commercially available that splits β-D-glucans and increases the nutritive value of barley. Barley is less suitable for poultry.

Millets

Millets are small grains. Bajra, korra, ragi, etc. are millet varieties used for poultry.

Bajra (pearl millet, *Pennisetum typhoides*) and korra (foxtail millet, *Setaria italica*) can be used as the sole source of energy in poultry diets. Ragi (finger millet, *Eleusine coracana*) is a satisfactory source of energy for egg type chicken but not for broilers. The protein of ragi and korra are deficient in lysine. All these grains do not contribute pigments.

Grain byproducts

Rice bran

Rice bran and rice polishings can be used for poultry feeding. However, in Asian countries, because of milling procedures, the differentiation between rice bran and rice polishings is difficult and rice bran includes both. Rice bran contains about 13% protein, 13% fat and 13% fibre. It is a good source of energy (ME 2900 kcal/kg) and B-complex group of vitamins. It is high in phytate (1.28%). Rice bran, because of its oil content and the presence of lipolytic enzymes is prone to cause rancidity. Antioxidants are recommended while storing rice bran. Rice bran has a good amino acid profile compared to cereal grains. It is slightly deficient in lysine.

Deoiled rice bran that contains about 1% oil only, is also available for poultry feeding. Its protein content is slightly higher than that of rice bran. The ME content is about 2000 kcal/kg.

Wheat (*Triticum aestivum*) bran

Wheat bran is a poor source of energy for poultry (ME 1300 kcal/kg). It is deficient in lysine and methionine and is high in fibre (11%) and phytate (0.95%).

Forest and industrial wastes

Sal (*Shorea robusta*) seed meal, deoiled

Salseed meal, deoiled contains about 2400 kcal ME/kg and it contains tannins (3.5 to 13%). It cannot be included at higher levels. It is deficient in methionine and threonine.

Molasses

Molasses are obtained as a byproduct of the sugarcane industry (cane molasses). It is palatable, reduces dustiness and improves pelleting. Higher levels in feed cause handling problems (15%) and wet litter problems. Its usage should be restricted to less than 5%.

Mango (*Mangifera indica*) kernel meal

Mango kernel meal contains about ME 2000 kcal/kg and tannins (0.5%). Hydrocyanic acid (HCN) present in it is eliminated during deoiling and drying process.

Fats and oils

Animal fats (ME 7700 kcal/kg) and vegetable oils (ME 8000 kcal/kg) are excellent sources of energy. Supplemental fats to feeds may give extracaloric effect. They also reduce dustiness, improve palatability and appearance of feed. Vegetable oils also provide essential fatty acids. Fats and oils tend to get rancid, especially when stored for a long time at high temperatures.

Miscellaneous feed ingredients

Tapioca (*Manihot esculenta Crantz*) meal or cassava meal

Tapioca meal is obtained from the roots of tapioca. It contains low fibre and high starch. It is a good source of energy containing about ME 3300 kcal/kg. It contains cyanogenic glucosides (HCN 15-400 mg/kg). Drying the roots eliminates most of the HCN (about 85%).

Leucaena (*Leucaena leucocephala*) leaf meal or subabul leaf meal

Leucaena leaf meal contains ME 1500 kcal/kg. It is a fair source of protein (19%) and contains mimosine (3-5%), a free toxic amino acid and tannins (0.95%). It may have adverse effects on hatchability.

Peanut (*Arachis hypogaea*) or groundnut leaf meal

Peanut or groundnut leaf meal contains about 14% protein. It is high in fibre (25%). It is a good source of carotene (100 mg/kg). However, the carotene content may decline (20 mg/kg) on storage.

Sweet potato (*Ipomea batatas*) tuber meal

Sweet potato tuber is a good source of energy (ME 3500 kcal/kg) and low in protein (6%). It contains antitrypsins. On drying, the antitrypsins are denatured.

Poultry manure, dried

Poultry manure dried from cage or deep litter practices can be used as a feed ingredient for poultry. It is a good source of protein (20%), calcium (4%), but a poor source of energy (ME 1000 kcal/kg). It is high in uric acid (10%). Using poultry manure in feed can lead to problems due to the presence of pathogenic organisms.

Protein Sources

Protein sources can be of two types - vegetable sources and animal sources.

Vegetable protein sources

Soybean (*Glycine max*) meal

Soybean seeds contain 18% oil. Soybean for poultry feeding is available as full fat soybeans and soybean meal, solvent extracted.Soybean meal is the largest produced oilseed meal in the world with production estimated to be 115 million metric tonnes in 2000. The largest producer was USA - 31%, followed by Brazil -15%, China/Taiwan -14%, Argentina - 12%, and India - 3.2%. Most countries with feed industries have soybean-crushing facilities but the size and sophistication of operations differ widely making the final product variable between sources. An understanding of quality control and product specifications of this important ingredient is economically prudent especially when one considers that up to 75% of the amino acid requirements of a typical broiler or swine grower feed may come from soybean meal. Soybean meal used in India exists in solvent extracted material containing hulls. Full fat soybean is also available, produced by extrusion or dry roasting in small-scale plants. It contains 38-40% protein and 18-20% fat.

Protein and energy content vary in soybean meal depending on protein level of the beans, residual fat after processing and whether or not hulls have been removed. The protein content of dehulled material ranges from 47.5 to 49% or more and material with hulls ranges from 40 to 50% with 44% considered the norm.

All processed soybean meal uses a heating or cooking process to destroy anti-nutritional factors contained in raw beans. These components if not deactivated reduce nutrient availability to the animal. The most notable of these factors are the protease inhibitors which bind and render unavailable the digestive enzymes trypsin and chymotrypsin. Also important are allergenic proteins such as conglycinin and β-conglycinin that reduce efficiency and increase scouring in very young animals such as piglets.

Soybean meal is an excellent source of lysine, tryptophan and threonine but is deficient in methionine. The amino acids in corn protein and soy protein combine well to provide a balanced mixture for most poultry requiring only minimal levels of synthetic methionine to be used. Digestibility of lysine and methionine is over 89% in properly processed soybean meal. Variation in total amino acid content of soybean meal is lower than that observed in fishmeal, canola and rapeseed and most likely other protein meals although little published information are available.

The energy level of soybean meal depends on residual oil, fibre content and ash levels. Metabolizable energy levels for poultry have been estimated to be 120 to 250 kcal/kg higher for dehulled meal versus meal containing hulls (Novus, 1994; Rhone Poulenc, 1993).

Properly processed soybean meal is an excellent ingredient that can be used as the sole protein supplement for virtually any class of animal with no restrictions except perhaps in piglet prestarter feed (20 to 25% maximum) or shrimp feed (15 to 20%).

Soybean meal is sometimes adulterated with moisture (water), sand, rice bran, deoiled rice bran, urea and under-processed or over-processed soybean meal. It is desirable that adulterants are detected physically, chemically and microscopically.

Rapeseed meal and Mustard meal

Rapeseed and mustard are used synonymously under practical conditions. Rapeseed and mustard belong to the genus Brassica. The common varieties of mustard and rape seed include *Sarson* (Brassica campestris var *sarson* - yellow *sarson*; Brassica campestris var dichotoma - brown *sarson*); *Rai* (Brassica juncea – *raya* or *laha*; Brassica alba – *safed rai*; Brassica nigra – *kali rai*; Brassica tournefortii – *Punjabi rai*); *Toria* (Brassica campestris var toria – *lahi*) and *Tori* (Erucea sativo – *taramira*). The seeds contain 40% oil.

Rapeseed meal ranks second to soybean meal in terms of total world production of protein meals. According to Oilworld (2000) estimates, total world production of rapeseed meal in 2000 was 22.3 million metric tonnes. The major producers are China, India, Germany, Canada and Japan.

The rapeseed meal produced in China, India and certain parts of Europe has high levels of glucosinolates, erucic acid and other anti-nutritional factors. The new varieties developed in Canada in the middle of the 1970s have much lower levels of glucosinolates (<30 micromoles per gram) and erucic acid (<2%). These nutritionally superior 'double zero' varieties are commercially known as Canola. Canola is becoming widely accepted and is also grown in the USA, Europe and Australia.

Canola meal is more yellow in colour than the darker brown colour of rapeseed meal. The yellow varieties are derived from *Brassica campestris* while darker types are derived from *B. napus.*

The quality of rapeseed meal is influenced by the varieties of rapeseed used for oil extraction and the method of extraction process. The optimum temperature for conditioning ranges from 100 to 105 ^{0}C for a duration of 15-20 minutes. The conditioning process destroys the enzyme myrosinase, which converts glucosinolates to the goitrogenic and "hot" tasting compounds: oxazolidone-2-thione and isothiocyanate. The excessively high processing temperature often encountered in production of rapeseed meal reduces digestibility of essential amino acids.

In terms of nutrient composition, canola and rapeseed meal have lower protein (total nitrogen) and energy than soybean meal. In addition to high fibre content, the low energy value of these meals is also attributed to the presence of pentosan polymers, a form of non-starch polysaccharide with poor digestibility. The combination of high fibre and lower energy value seriously limit the use of canola and rapeseed in high-density broiler diets. In terms of mineral content, rapeseed and canola have higher calcium and phosphorus content than soybean meal, although about 65% of the phosphorus is in the phytate form and not available. Canola and rapeseed meal also contain high levels of sulfur (around 1.1% versus 0.4% in soybean meal) that may cause leg abnormalities (Summers, 1989). Therefore sulfur level in feed and water should be monitored when using canola and/or rapeseed meal. Total sulfate and sulfur intake expressed as elemental sulfur in the feed should be kept below 0.4%.

Canola and rapeseed meal have a reasonably well-balanced amino acid profile but are deficient in lysine. In general, amino acid digestibility is lower than soybean meal especially for poultry. Therefore, when using rapeseed meal in poultry feeds, it is crucial to pay particular attention to the balance as well as the digestibility of amino acids in the final formulation.

Because of its glucosinolate content, the use of rapeseed meal is often associated with a reduction in growth rate and poor palatability of feed. If the level of inclusion is higher than 5% in layer feed, a fishy taint or off flavour in the yolk of eggs from heavy strain brown egg layers will occur. This is due to the presence of a choline ester, sinapine, which promotes the accumulation of trimethylamine in the yolk. Above the 10% inclusion level, hemorrhagic fatty liver is often observed with associated higher levels of mortality. In broilers, the use of rapeseed meal has been suggested to off-flavours in meat. At 30% inclusion in broiler diets, leg abnormalities have been reported. At dietary levels higher than 5% rapeseed meal may result in enlarged thyroids, kidneys and livers in certain species especially starting and growing swine. The use of canola meal instead of rapeseed meal reduces considerably the problems described above except those related to sinapine. The Canola Council of Canada recommends the maximum inclusion rates as follows: Poultry starter/grower - 20% and poultry layer/breeder - 10%.

Peanut (*Arachis hypogaea*) meal or Groundnut meal

Peanut kernels contain 40% oil. Peanut meal or groundnut meal was an important protein source for poultry feeding till a few years earlier. Now-a-days, soybean meal is the important protein source. Groundnut meal is a readily available protein source by-product from the extraction of groundnut, which is a popular human food in many parts of the world. Total world production in 2000 was estimated to be 7.0 million metric tonnes. China and India were the major producing countries.

The nutrient composition of the meal varies greatly according to the oil extraction method used. The quantity of hulls present directly affects fibre and therefore energy content of the meal. Solvent extracted groundnut meal generally has less than 1.5% fat. The fat content of expeller groundnut meal is variable depending on the efficiency of oil extraction. With prolonged storage under the warm and humid conditions in the tropics, residual oil is a negative feature as it is easily oxidized. The meal quality is then greatly reduced due to poor palatability, toxicity and decreased energy value.

Groundnut meal has a poor amino acid profile that is deficient in methionine, lysine and tryptophan relative to soybean meal. Moreover, the poorly balanced amino acids have low digestibility. It is therefore necessary to supplement the feed with additional crystalline amino acids when groundnut meal is used.

Like most legume seeds, groundnuts contain trypsin inhibitors and other protease inhibitors. Proper processing is required to destroy these anti-nutritional factors. The other undesirable constituent often associated with groundnut meal is aflatoxin produced by the fungus *Aspergillus flavus* that infests groundnuts before, during and after harvest. Ducklings, turkey poults and broiler chicks are most sensitive to aflatoxin. This mycotoxin causes hemorrhages in the liver, kidneys and breast muscle and reduced immune competence. Aflatoxin B_1 levels as low as 250 ppb are known to exert these effects. Because of the widespread occurrence of aflatoxin and its impact on human health, many authorities have now set limits on the amount permitted in the feed ingredients and feeds. The US Food and Drug Administration, for example, has set a limit of 100 ppb for interstate shipment of feeds. Generally, groundnut meal is not recommended in young poultry diets for fear of contamination with mycotoxins. High quality groundnut meal can be used at levels up to 6% in broilers and 9% in layers with good results.

Sunflower (*Helianthus annus*) meal

Total world production of sunflower meal was 10.7 million metric tonnes in 2000. The main producers are the former USSR, EEC, Argentina, USA and China.

The nutrient composition of sunflower meal varies according to the quality of the seed and methods used for oil extraction. Expeller sunflower meal because of higher residual oil content has a higher energy level than solvent extracted meal . The quality also depends on whether or not the seeds are dehulled prior to oil extraction. Dehulled sunflower meal will have a protein content in excess of 40% and a crude fibre of 13% or less. Partial dehulling produce meals of 30 to 35% protein whereas whole sunflower meal has about 25% crude protein.

The crude fibre of partially dehulled or non-dehulled sunflower meal exceeds 20% and thus is a major limiting factor for use in poultry and swine feed. The high variability in quality of sunflower meal due to differing levels of hulls present is the most important limiting factor with the use of this ingredient. Further, the processing temperature has a significant influence on the quality of sunflower meal. Low temperature processing is desirable to prevent denaturation of lysine and other valuable amino acids.

Sunflower meal contains high levels of chlorogenic acid a tannin like compound that inhibits activity of digestive enzymes (trypsin, chymotrypsin, amylase and lipase). Because chlorogenic acid is uncondensed and non-hydrolysable, its content of 1% or more of a total of 3-3.5% phenolic compounds in sunflower meal is not reported in tannin assays. Additions of methionine and choline are required to counteract the effect of chlorogenic acid. Chlorogenic acid is also a precursor of ortho-quinones that occur through the action of the plant enzyme polyphenol oxidase. These compounds react to polymerise lysine during processing or in the gut. The requirement for both methionine and lysine are thus increased when sunflower meal is used in the diet.

Unlike soybean meal, sunflower meal is high in methionine but low in lysine and threonine. Therefore the two ingredients, when used together, improve the amino acid balance of the feed. If the sunflower meal inclusion rate is high, further supplementation with lysine will still be necessary. Sunflower meal generally has lower amino acid digestibility than soybean meal. This should be taken into consideration when sunflower meal is used to partially replace either soybean meal or fishmeal.

Sunflower meal is not recommended for use in high nutrient density feeds because of its high fibre and low energy content. In broiler and layer feed, up to one-half of the soybean meal may be substituted with good quality sunflower meal provided synthetic L-lysine HCl is supplemented. However, when partially dehulled sunflower meals are used, feed efficiency would be reduced significantly, reflecting the additional fibre and lower energy in the sunflower meal. In broiler diets, it is recommended that only high quality dehulled sunflower meal be used.

Cotton (*Gossypium Spp*) seed meal

The physical composition of cotton seed is: oil 17%, hull 23%, meal 52% and linters 8%. Cotton seed meal ranks third among the total oilseed meals produced in the world. Total production in 2000 was 14.9 million metric tons. China, India and the USA are major producers. Typical yield from whole cotton seeds are 50% meal, 22% hulls and 16% oil. When compared to soybean meal, cotton seed meal has a slightly lower protein of about 41% but a much higher fibre content of 11 to 13%. Depending on the processing method employed, the energy content is influenced by the residual oil present in the meal. In terms of amino composition, cotton seed meal is inferior in four of the most important essential amino acids, lysine, methionine, threonine and tryptophan. Digestibility of these amino acids is lower than that found in soybean meal. The use of cotton seed meal in poultry feed will require supplementation with both L-lysine HCl and DL-methionine.

Gossypol is a recognized toxic component of cotton seed meal limiting its use in monogastric animals. Free gossypol can damage the myocardium and liver resulting in cardiac edema, dyspnea, weakness and anorexia. Dietary gossypol also causes olive-green yolks in stored eggs as a result of a chemical reaction between the gossypol and iron in the egg. Cotton seed also contains the cyclopropenoid fatty acids, malvalic and sterculic acid. These cause pink discolouration of egg albumin when fed to layers and are also know to alter liver metabolism making aflatoxin more toxic.

Expeller processed meals may contain lower levels of free gossypol (0.02 to 0.05%) than solvent extracted meals (0.04 to 0.4%). Cotton seed meals having less than 0.03% free gossypol may be termed as low gossypol meals. Gossypol can bind with iron in the ratio 1:4. In absence of analytical values of free gossypol, it may be assumed that cotton seed meal contains about 0.3% free gossypol for the purpose of detoxification with ferrous sulphate (1.2% iron as ferrous sulphate). Iron in excess (2.25% as ferrous sulphate) is toxic for chicken.

Glandless cotton varieties devoid of gossypol have been developed and are much better suited for feeding of poultry and swine. However due to the lower cotton production potential of these varieties only limited quantities are available. Traditional cotton seed meal is normally limited to 2% in broiler and layer feed, and should be avoided in duck formulations if aflatoxin is a concern.

Coconut *(Cocos nucifera)* meal (Copra meal)

Copra is obtained from the kernel of coconut fruit, which has been sun, dried or dried using drying machines. The major producing countries are the Philippines and Indonesia, which account for about two-thirds of the world's total 2000 production of 1.8 million metric tons. From the copra, about 30 to 40% by weight is extracted as coconut oil. The residue, in the form of dried cake chunks, is further reduced by grinding to copra meal. Copra produced by the expeller process has a residual oil content of about 8%. This is sometimes reduced further by solvent extraction depending on the market demand for oil, which at the present time is quite high. Copra meal is problematic because of the high variability in oil content, contamination with mold and high levels of poorly digested non-starch polysaccharides.

Most copra meal encountered in the trade falls between 9 and 16% residual oil content. However, some meals produced by small-scale expeller extraction process or using poor equipment may have residual oil contents above 20% while solvent extracted meals may contain less than 2% oil. When it contains high residual level of oil copra meal is a valuable source of energy for swine and poultry. Coconut oil is composed predominantly of short chain saturated fatty acids (50% C12:0; 15% C14:0) that are easily digested and has high energy content.

High moisture, poor drying conditions and poor storage contribute to a high incidence of mold contamination in copra. Copra is an ideal medium for mycotoxin formation. Also, high moisture levels and high storage temperature favour oxidation of residual oil, which in turn affects palatability of the meal. The high fibre content in copra meal seriously limits its use in poultry diets. The fibre is high in polymers called mannans that have low digestibility and often have a laxative effect in poultry and swine.

Copra meal has a protein content much lower than soybean meal ranging from 19 to 23%. The protein quality is poor both in terms of its amino acid balance and digestibility. The digestibility of amino acids may be further reduced when excessive temperature is used during processing. The amino acid composition of copra meal is inferior to many other protein sources. It is deficient in important essential amino acids such as lysine, methionine, threonine and histidine but high in arginine. As excess arginine is known antagonize lysine utilization, high copra meal levels may have a negative effect on the growth rate in swine and poultry. Thus, lysine supplementation is very important when using copra meal to correct deficiency and reduce the antagonism by arginine. High quality copra meal is usually restricted to about 3 or 4% in poultry diets.

Sesame (*Sesamum indicum*) meal

Sesame is a minor oilseed crop that is often available in Asian countries. Total world production in 2000 was 0.83 million metric tonnes with major producers being India, China, Sudan, Burma and Mexico. The nutrient composition of high quality sesame meal compares favourably with that of soybean meal. However variability exists depending on the varieties used, the degree of decortication and the processing methods. The hull of the sesame seed accounts for 15 to 29% of the whole seed. The hull can be separated from the kernel in decorticating machines or by soaking and rubbing the seed by hand. Most harvesting of sesame is also done by hand. Removal of the hull results in a reduction of fibre of approximately 50% and increases the protein content, digestibility and palatability of the meal. Occasionally, the seed is milled without decortication in order to improve the efficiency of oil extraction. However, the meal resulting from such processing is of relatively poor nutritive quality. The protein content of different varieties ranges from 41% to 58%. An average protein content of 40% and 5% fat is typical for expeller sesame meal. Solvent extracted meals contain slightly higher protein content of 42 to 45% and less than 3% fat. The energy content is lower than in the soybean meal and appears to be related to its high ash content of 10-12%.

Sesame meal is an excellent source of methionine, cystine and tryptophan but is very low in lysine and threonine. The amino acid composition of sesame meal complements most other oilseed proteins and in particular, soybean meal. Studies have shown that a soybean meal/sesame meal ratio of 2:1 gives good growth responses in chicks. Almost 80% of sesame protein is reported to be digestible. Prolonged heating during processing or grinding may severely depresses the availability of amino acids. Processing sesame at high temperature can also result in the destruction of cystine causing a sulfur amino acid deficiency.

Sesame seeds contain high levels of oxalic acid (35 mg/100 g) and phytic acid (5%). The darker coloured varieties are higher in these anti-nutritional factors than red coloured varieties. Oxalic acid and phytate are known to interfere with mineral metabolism and decrease availability of calcium, phosphorus, magnesium, zinc and iron. The oxalic acid may also cause kidney lesions and reduces palatability problem due to bitter taste. Decortication of seeds removes the oxalates, but has little effect on phytate. Phytate can be degraded through the use of feed enzymes containing active phytase or by using uncooked wheat in the feed, which contains appreciable levels of phytase. Sesame meal is popular in poultry diets mainly due to its high sulfur amino acid and essential fatty acid content. It must be noted that due to its low lysine content and low lysine digestibility, supplementation with the synthetic lysine is necessary. The exclusive use of decorticated meal will help to avoid palatability problems.

Palm (*Elaeis quineensis*) kernel meal

Palm kernel meal is produced mainly in Malaysia, Indonesia, Nigeria and Thailand as a residue of the oil extraction of palm fruit. Total world production in 2000 was estimated to be 3.4 million metric tons.

Palm kernels are covered by thick shells that must be cracked open, removed and subjected to steam conditioning before the oil extraction process. The quality of meal depends largely on the amount of shell removed. The meal is normally produced by an expeller process leaving a residual oil content of about 6%. With solvent extraction, the meal ranges from 1 to 2% residual oil. Among the oil meals, palm kernel meal has the lowest protein content normally ranging from 16 to 18%. Protein as low as 13% and a fibre exceeding 20% can occur if shells and fruit fibre are not removed efficiently. Due to the high fibre, the energy content of palm kernel meal is rather low, especially for poultry. Over half of the fibre in palm kernel meal is in the neutral detergent form and contains high levels of galactomannans such as β-(1,4)-D-mannan (Daud and Jarvis, 1992). The potential for improving nutritional value of palm kernel meal with supplemental feed enzymes is high.

As with the peanut and copra meal, the amino acid profile of palm kernel meal is very poor both in terms of amino acid balance and digestibility. It is deficient in lysine, methionine and tryptophan. In poultry, lysine and methionine digestibility has been estimated to be as low as 59% compared to 90% in soybean meal. The digestibility of other essential amino acids is also low. The poor amino acid digestibility is attributed to protein entrapment in carbohydrate complexes as well as the high temperatures used during the oil extraction process.

Because of its high fibre and poor amino acid digestibility, palm kernel meal is probably best suited for use in ruminant feeds. The use of palm kernel meal in poultry feed should be restricted because of its poor protein quality, high fibre content and low energy value. Contamination of palm kernel meal with shell material has been reported to cause damage to the intestinal lining in poultry.

Safflower (*Carthamus tinctorius*) meal

Safflower seeds contain 30% oil and 40% hull. Safflower meal is high in fibre (60% hull) and low in protein (20%). Safflower protein is low in lysine and methionine. It also contains anti-nutritional components (phenolic glucosides). Pasting or impaction of beaks may occur in chicks on diets containing high level of safflower meal.

Linseed (*Linum usitatissimum*) meal

Linseed meal is low in lysine and tryptophan. It contains the anti-nutritional factors, linatin (an antipyridoxine) and linamarin (a cyanogenic glucoside: HCN 10-300mg/kg meal). The indigestible mucilage coating of the seed acts as a laxative and causes beak necrosis.

Niger (*Guizotia abyssinica*) seed cake

Niger seeds contain about 35% oil and niger seed cake about 35% crude protein. The protein is deficient in lysine, methionine and tryptophan.

Karanja (*Pongamia glabra* Vent.) meal

Karanja seeds contain 28% oil. Solvent extracted karanja seed cake contains about 30% protein. The oil contains several anti-nutrients, the important one being karanjine (1.47 mg/ml oil). Solvent-extracted karanja meal may be used in poultry.

Rubber (*Hevea brasiliensis*) seed meal

Rubber seed meal contains about 26% protein. It is deficient in lysine and sulphur containing amino acids. The high level of HCN (1200-2000 mg/kg) present in fresh rubber seeds decreases to safe levels (20-40 mg/kg) on storage and processing. In breeders, a high level of rubber seed meal delays sexual maturity, adverseiy affects semen quality and reduces fertility and hatchability.

Ambadi (*Hibiscus cannabinus*) meal

Ambadi seeds contain 18% oil and its meal contains about 28% protein and 22% fibre. Tannins (0.35%) are present in ambadi meal and cyclopropenoid fatty acids in the oil. The protein is low in lysine and methionine.

Maize (*Zea mays*) gluten meal

Maize gluten meal, a byproduct of the starch industry from maize, is a good source of protein, high in methionine and sulphur containing amino acids, but low in lysine and tryptophan. It is frequently contaminated with aflatoxin because of the poor quality maize used for the manufacture of starch and also because of inadequate care of the residual meal. Maize gluten meal is a good source of xanthophyll pigments and it may contain fermented maize extractives and or maize germ meal.

Maize (*Zea mays*) gluten feed

Maize gluten feed is similar to maize gluten meal, but contains more bran and consequently less protein (23%). It may or may not contain fermented maize extractives and maize germ meal.

Mahua (*Madhuca indica*) seed meal

Mahua seed meal contains about 20% protein. Mowrin, a saponins (19%) and tannins (1.5%) are present in mahua seed meal. It is unsuitable for poultry.

Mahua (*Madhuca indica*) flower residue meal

Mahua flower residue meal contains about 16% protein and 25% fibre. Mahua flower residue may contain toxic principles. It should be restricted in poultry feeds.

Guar (*Cyamopsis tetragonoloba*) meal

Guar is a legume grown for the gum present in seeds coat. The guar meal after extraction of gum contains about 40% protein. Guar protein is deficient in methionine and marginally deficient in lysine. The anti-nutrients present are trypsin inhibitors, HCN, haemagglutinins and residual gums. Trypsin inhibitors can be inactivated by proper heat treatment. The meal is high in molybdenum that interferes with copper metabolism.

Kokum (*Garcinia indica*) seed meal

Kokum meal is a forest byproduct and its seed meal contains 15% protein.

Animal protein sources

i. Animal protein sources in general are high in protein, lysine and methionine, calcium and phosphorus than vegetable protein sources.
ii. Unless properly processed, these are potential sources of pathogenic microorganisms such as coliform, salmonella, fungal toxins, etc.
iii. Material containing high fat is prone to rancidity and may cause fire accidents.
iv. Animal protein sources are liable to be adulterated with sand, urea, rock phosphate, etc.
v. Animal protein sources should not be used as sole sources of protein in poultry diets.

Fish meal

Dried whole fish and fish meal are good sources of crude protein (40 to 60%). The protein of fish meal is a good source of lysine and methionine. Fish is also a good source of available phosphorus, calcium, vitamin B_{12}, iodine and selenium. Many varieties of fish go in the preparation of dried fish or fish meal. The composition as such is variable. Standard processing conditions are not followed in developing countries causing concern in the variability of amino acid composition. Many adulterants such as sand, and fish scales are added to fish. When fish meal contains high fat, fire accidents may occur on long storage time. Rancidity is also a problem due to high fat content. Dry fish and fish meals are a potential source of infection of coliform and salmonella. During processing, if more heat is applied, gizzarosine may be produced, causing gizžard erosion in chicken.

It is advisable to use only good quality fish, if available and economically feasible. Fish is not absolutely essential for poultry. If fish oil is more than 1% of the feed, fishy flavor may be found in the eggs and poultry meat.

Meat meal and Meat-cum-bone meal

Meat meal and meat-cum-bone meal are produced from slaughterhouse wastes and whole carcasses declared unfit for human consumption. Bones, tendons, ligaments, cartilage, intestines, etc. are dried and processed for the preparation of the meals. Hair, hoof, horn, hide trimming, blood and stomach contents are not included in preparation. Meat meal and meat-cum-bone meal are good sources of calcium and phosphorus, but deficient in tryptophan, lysine and methionine. Meat-cum-bone meal contains less protein and more calcium and phosphorus than meat meal. The digestibility of amino acids in meat meals is lower than that of soybean meal and fish meal. These meals are usually adulterated with hide trimming, sand and rock phosphate.

Deoiled Silkworm pupae meal

Deoiled Silkworm pupae meal is a good source of protein (about 65%) and phosphorus. The protein is rich in lysine, methionine, arginine, tryptophan and isoleucine, but low in threonine.

Hatchery byproduct meal

Hatchery byproduct meal is a good source of protein and energy. The protein quality is also good. However if not properly processed, it is a source of pathogenic microorganisms for poultry.

Poultry byproduct meal

Poultry byproduct meal is prepared from inedible parts of carcasses of slaughtered poultry such as head, feet and viscera (without contents). Feathers may be included and in such cases the meal is called poultry offal meal. The composition of poultry byproduct meal is similar to that of meat-cum-bone meal. The protein is low in methionine. The composition of offal meal varies depending on the proportion of various parts of carcass and feathers.

Feather meal

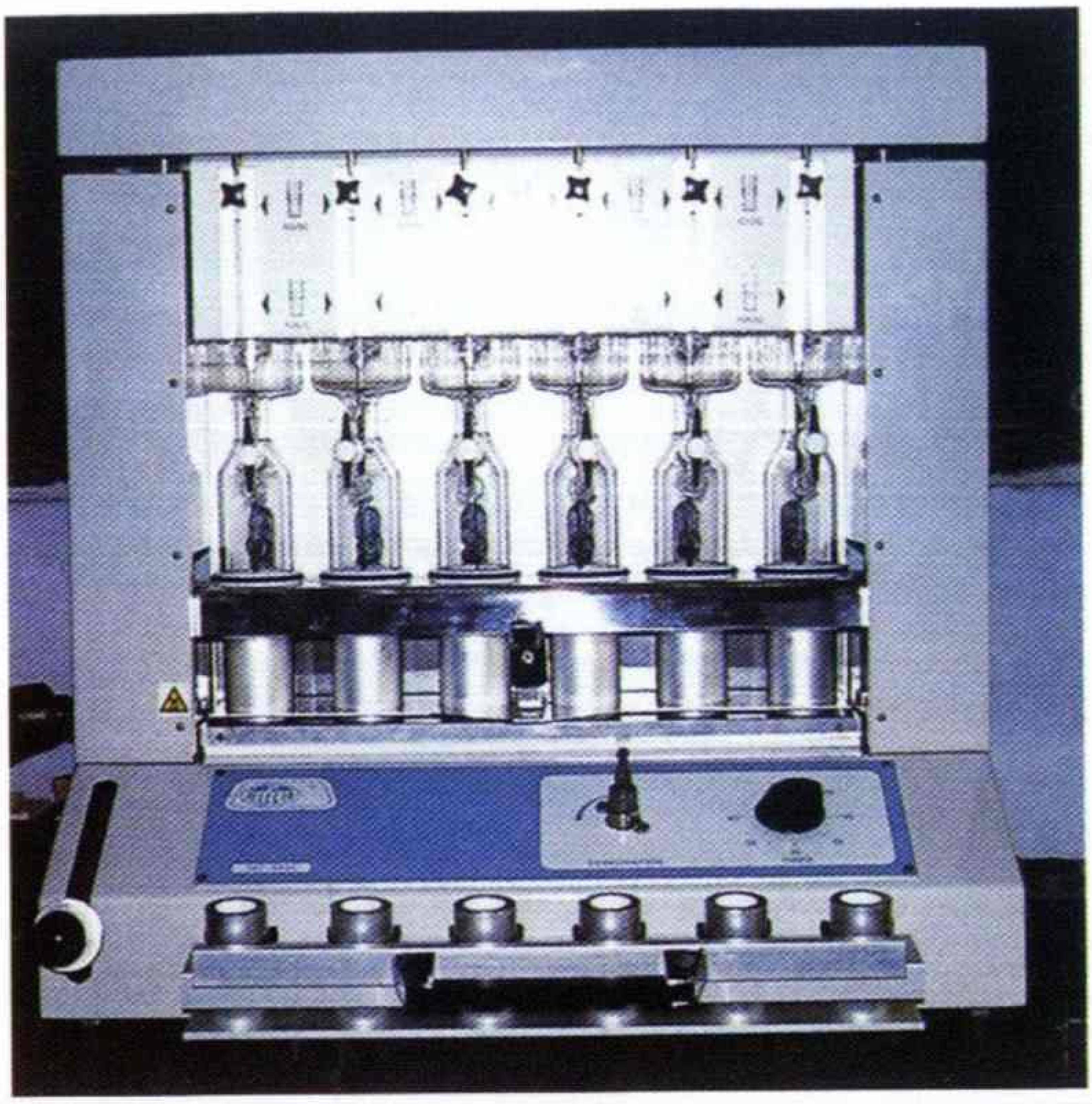
Hydrolyzed feather meal is high in protein (80%) and is low in lysine, methionine and tryptophan. Feather meal is not easily digestible.

33. Calcite - chalky white in colour

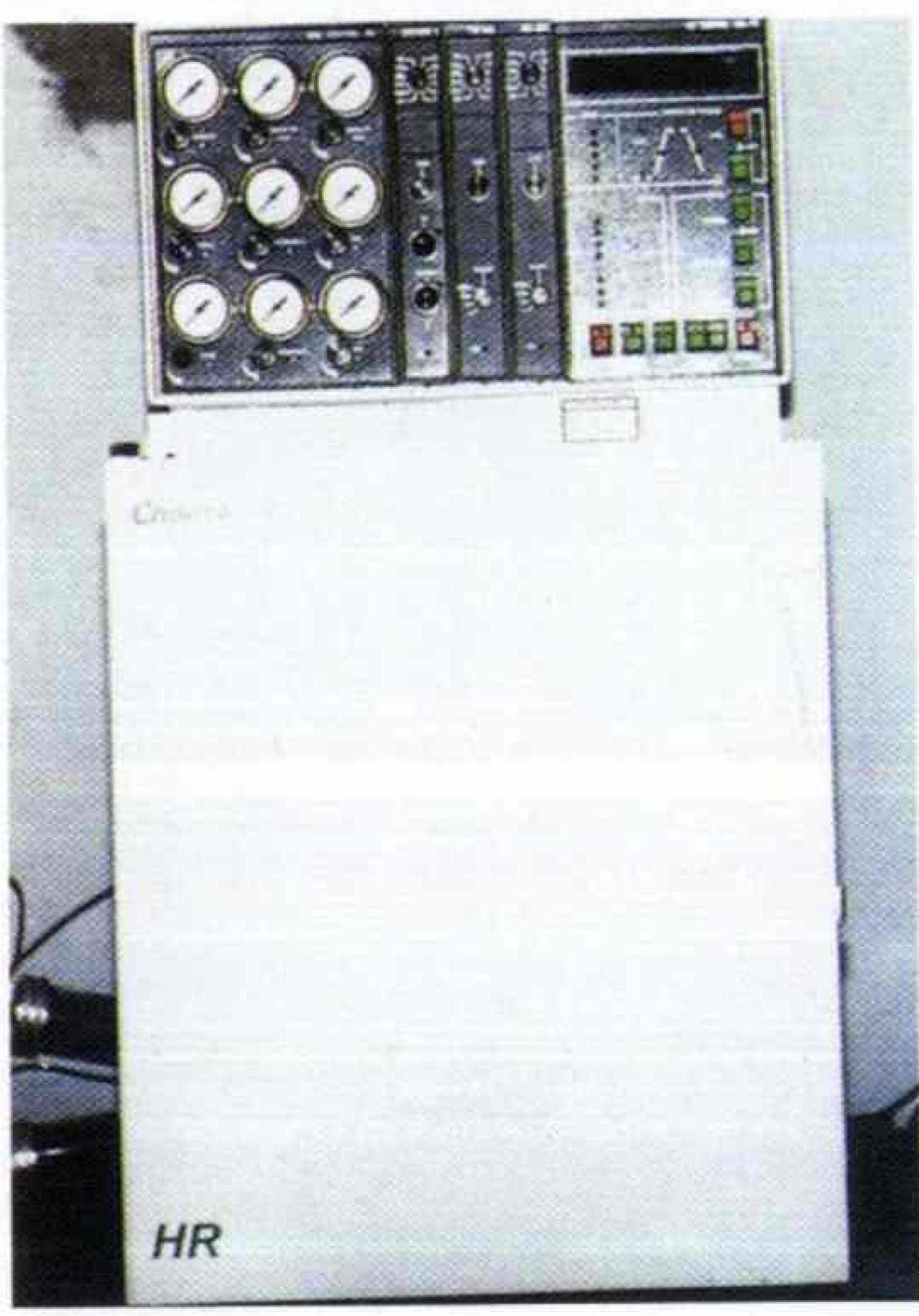
34. Shell Grit - good quality

35. Marble Stones

36. Soft Shell and Grit variable sized

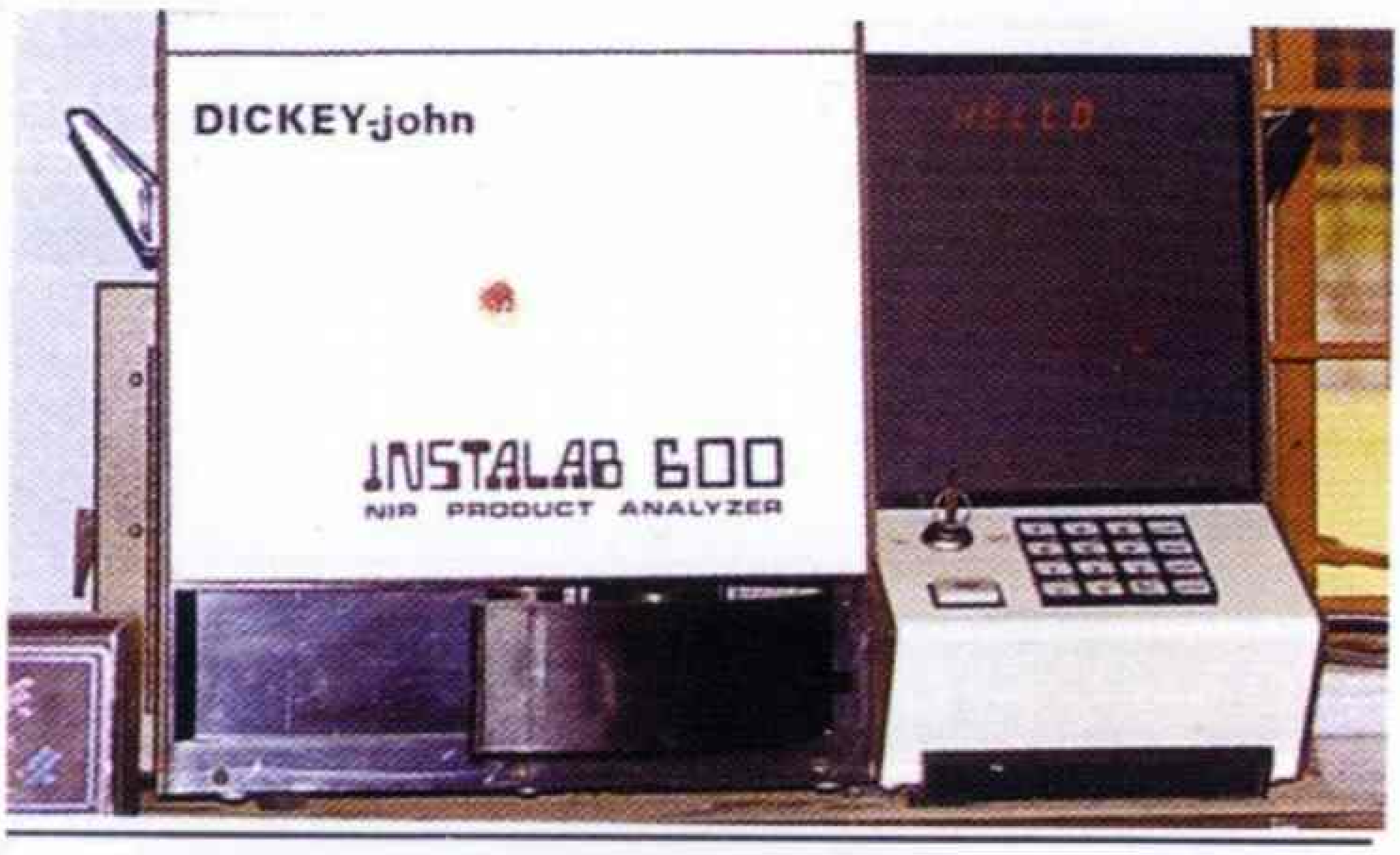


37. Fat estimation (New system)



38. Gas Chromatograph

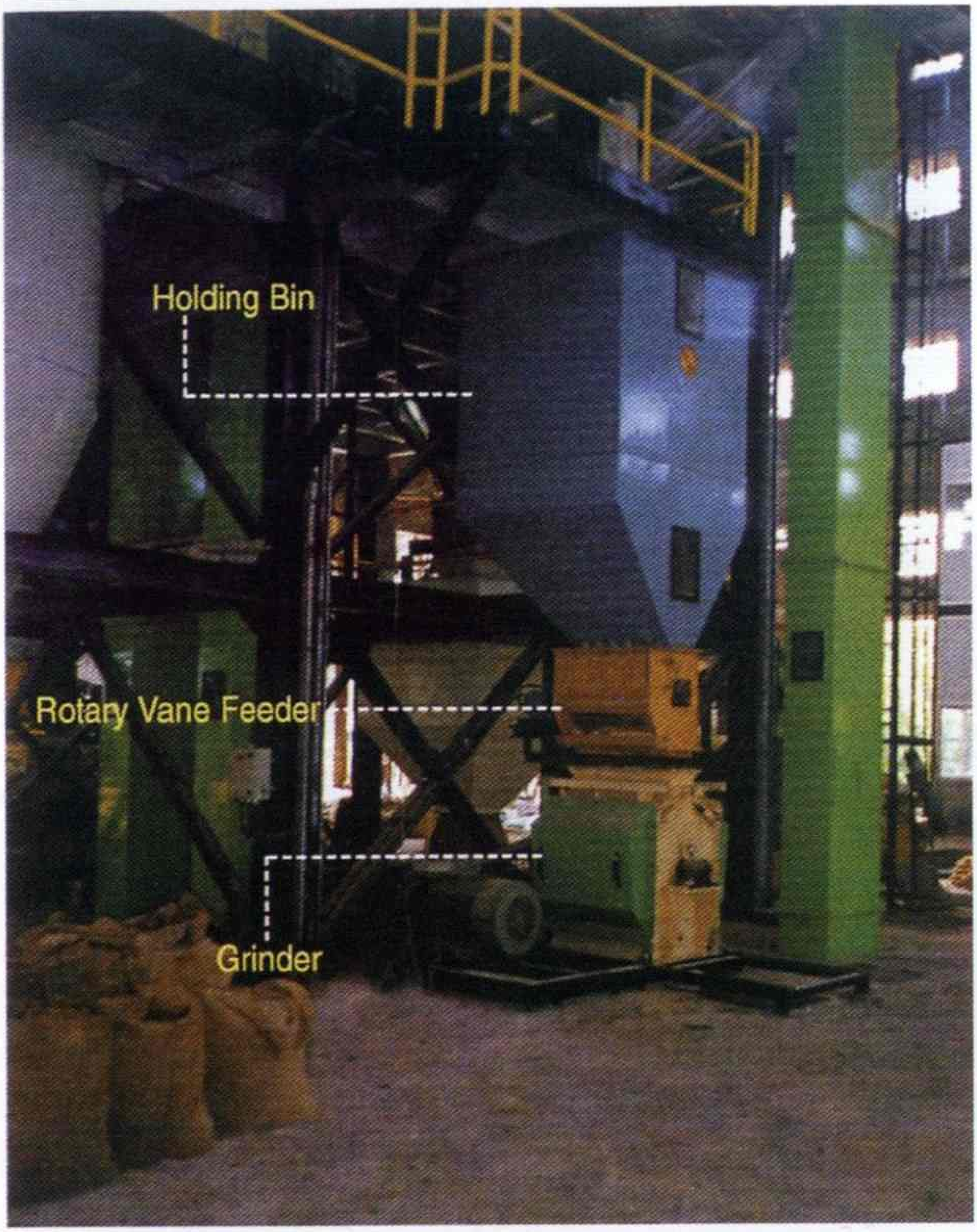
39. *High Pressure Liquid Chromatograph (HPLC)*



40. *NIR analyser*

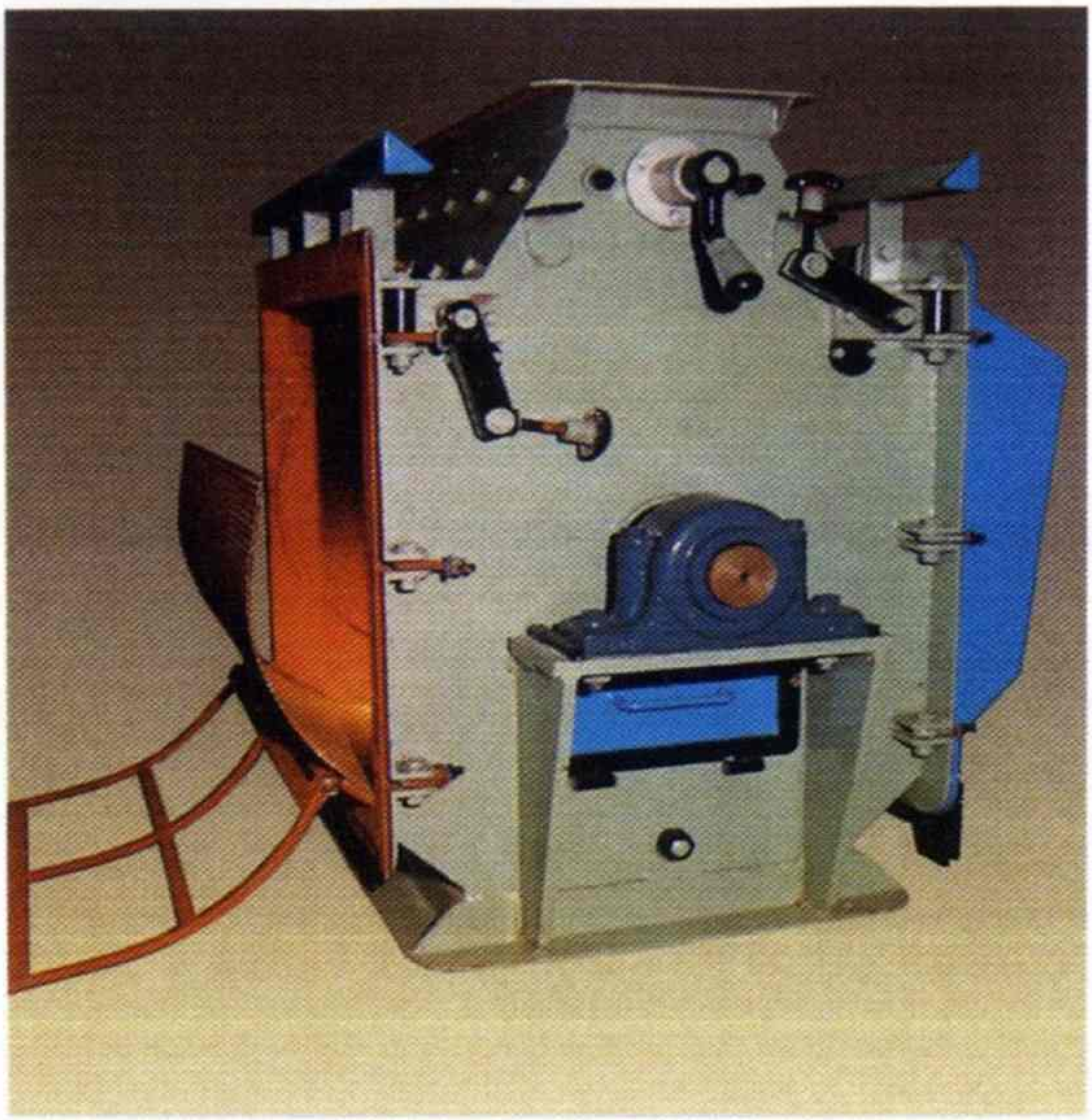
41. *Fibre estimation (New system)*

42. *Typical large feed mill to produce pellet feed*

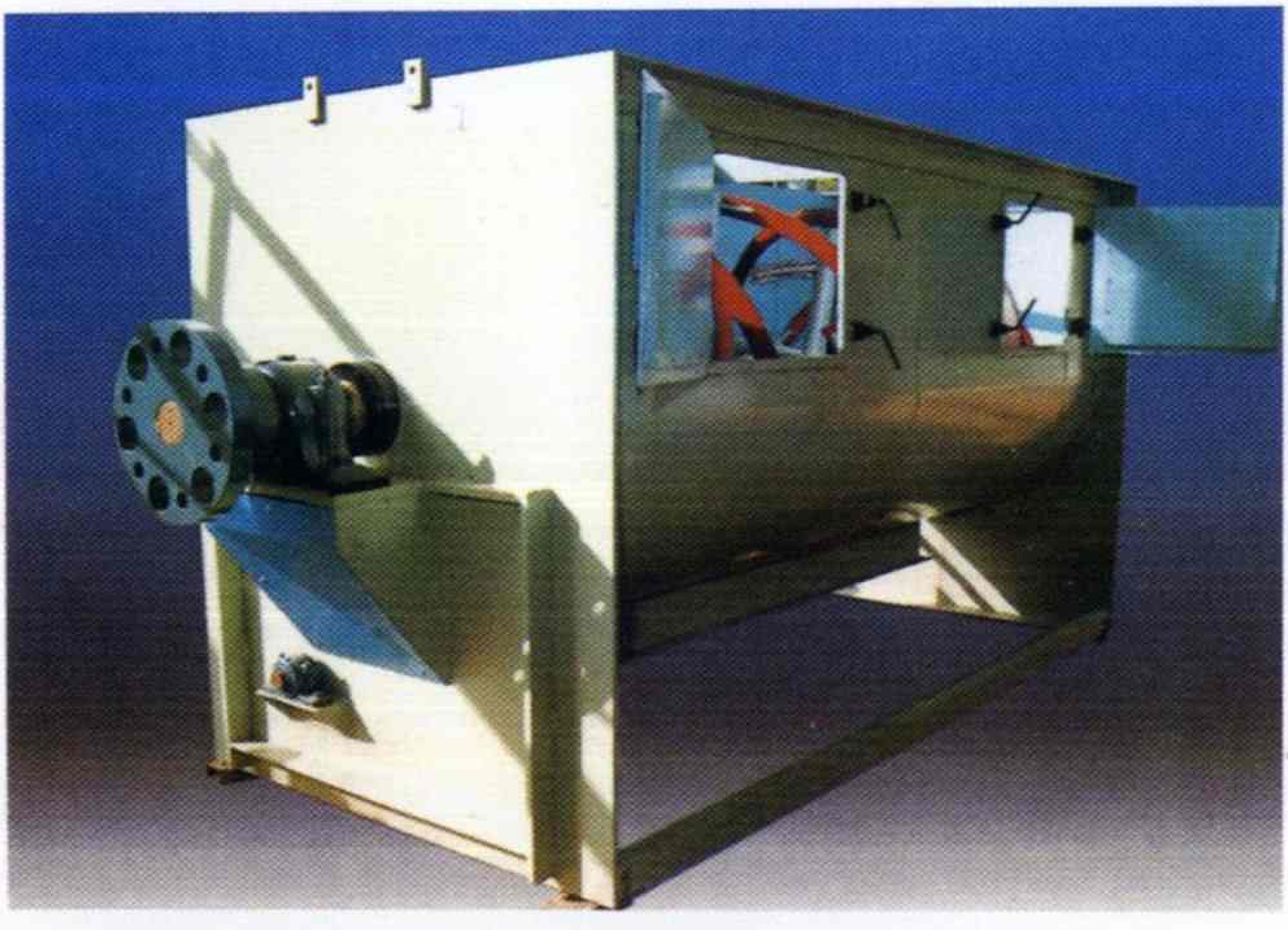


43. Grinding system - consisting of Grinder, Feeder and Holding Bin

44. *Typical small feed mill to produce mash feed*



45. Typical 320⁰ screen Hammer mill/Grinder



46. Typical Ribbon type mixer

Squilla (*Orato squilla nepa*) meal

Squilla is a marine crustacean source. Squilla meal is a moderate source of protein (30%) and is low in lysine, methionine, threonine, tryptophan and arginine. Squilla contains about 14% chitin (linear polymer of anhydro-N-acetyl-D-glucosamine), an indigestible protein for poultry. Squilla meal is also a good source of calcium and phosphorus.

Levels of Inclusion

The level of inclusion of energy sources and vegetable and animal protein sources in poultry diets is shown in Table 1.

Table 1. Level of inclusion of energy sources and vegetable and animal protein sources in poultry diets

S.No.	Ingredient	Chicks and Broilers	Growers and Layer	Remarks
Energy sources				
1	Maize	70	70	Susceptible to mycotoxin contamination
2	Sorghum	30	60	Bird resistant variety may contain tannins
3	Wheat	20	30	Contains arabino-xylans
4	Rice	10	20	
5	Rice broken	10	20	Variable quality
6	Rice param	10	20	Variable quality
7	Barley	10	20	Contains β-glucans
8	Bajra	30	60	
9	Korra	30	60	
10	Ragi	30	60	May not be used in broiler diet
11	Rice bran	20	30	Susceptible for rancidity, add antioxidants while storing
12	Wheat bran	5	10	Low energy
13	Sal seed, deoiled meal	3	6	Contains tannins
14	Molasses, cane	2	5	Wet litter problem at higher levels
15	Mango kernel meal, deoiled	3	5	Contains tannins

S.No.	Ingredient	Chicks and Broilers	Growers and Layer	Remarks
16	Fats and oils	5	5	Cost limits inclusion
17	Tapioca tuber meal	20	30	Contains HCN
18	Leucaena leaf meal	5	10	Contain mimosine
19	Pea nut leaf meal	3	5	Good source of carotenes
20	Poultry manure, dried	0	5	Problem of pathogens
Vegetable protein sources				
1	Soybean meal	35	25	Can be used as sole source of protein
2	Peanut meal	35	25	Prone to contamination with mycotoxins
3	Cotton seed meal	10	10	Iron supplementation is required to bind gossypol
4	Sunflower meal	10	20	High in fibre
5	Coconut meal	3	5	Prone to mycotoxin contamination
6	Rape seed/ mustard meal	3	5	Erucic acid, tannins, glucosinolates are present
7	Safflower meal	5	10	High in fibre
8	Sesame/til cake	10	15	High in phytate and oxalates
9	Linseed meal	3	5	Linatin, linamarin and indigestible mucilage
10	Niger cake	5	10	High in fibre
11	Karanja cake	5	10	Contains Karanjine. Only solvent extracted cake should be used
12	Palm kernel meal	10	20	High in fibre
13	Rubber seed	5	10	May contain HCN, not suitable meal for breeders
14	Ambadi cake	10	20	High in fibre
15	Maize gluten meal	10	20	Prone to mycotoxin contamination
16	Maize gluten feed	10	20	High in fibre and prone to mycotoxin contamination
17	Mahua seed	0	0	Should not be used as feed ingredient
18	Mahua flower residue meal	5	10	May contain mowrin
19	Guar meal,	3	5	Proper heat treatment is required toasted
20	Kokum meal	5	10	

S.No.	Ingredient	Chicks and Broilers	Growers and Layer	Remarks
Animal Protein sources				
1	Fish meal	10	10	Rancidity, fire accidents and pathogenic microbial contamination
2	Meat meal	5	5	Pathogenic microbial contamination
3	Meat-cum-bone meal	5	5	Pathogenic microbial contamination
4	Silkworm pupae meal	2	3	Low in threonine
5	Hatchery byproduct meal	2	3	Pathogenic microbial contamination, rancidity
6	Poultry byproduct meal	5	5	Pathogenic microbial contamination, low in methionine
7	Poultry offal meal	3	3	Pathogenic microbial contamination, low in methionine, low digestibility
8	Feather meal	2	2	Low in lysine, methionine and tryptophan, poorly digestible
9	Squilla meal	5	5	Low in lysine, methionine, threonine, tryptophan and arginine

Mineral Sources

Poultry feeds in earlier days were supplemented with mineral mixture that contained calcium, phosphorus and trace minerals (manganese, zinc, iron, copper, iodine and some times cobalt). Now-a-days, phosphorus in layer feeds is used at lower levels than in the past. Phytase (an enzyme) is being used in broiler and layer diets to reduce supplemental phosphorus source. The mineral content from different sources is given in Table 2.

Table 2. Mineral content (%) from different sources - Calcium and Phosphorus

Compound	Formula	Calcium	Phosphorus
Bone meal		29	12
Calcium carbonate	$CaCO_3$	38	-
Calcium phosphate, dibasic (Dicalcium phosphate)	$CaHPO_4.H_2O$	22	18

Compound	Formula	Calcium	Phosphorus
Calcium phosphate, mono dibasic (Monocalcium phosphate)	$Ca(H_2PO_4)_2$	16	21
Calcium phosphate, tribasic	$Ca_{10}(OH)_2 (PO_4)_6$	32	15
Calcium sulphate	$CaSO_4.2H_2O$	22	-
Lime stone powder	$CaCO_3$	38	-
Meat-cum-bone meal		10	5
Shell grit, ground		38	-
Phosphate, rock, defluorinated		32	18
Phosphate, rock, soft		17	9

Table 2. Mineral (%) content from different sources

Compound	Formula	Mineral	Contents (%)
Copper sulphate	$CuSO_{4,} H_2O$	Copper	35
Copper sulphate	$CuSO_{4,} 5H_2O$	Copper	25
Cupric carbonate	$CuCO_3$	Copper	53
Cupric oxide	CuO	Copper	75
Ferrous carbonate	$FeCO_3$	Iron	43
Ferrous sulphate	$FeSO_{4,} 7H_2O$	iron	21
Potassium iodide	KI	Iodine	76
Potassium iodate	KIO_3	Iodine	59
Manganous carbonate	$MnCO_3$	Manganese	47
Manganous sulphate	$MnSO_{4,} H_2O$	Manganese	25
Manganous sulphate	$MnSO_{4,} 5H_2O$	Manganese	22
Sodium chloride	$NaCl$	Sodium Chlorine	39 60
Sodium selenite	Na_2SeO_3	Selenium	45
Sodium selenate	Na_2SeO_4	Selenium	41
Zinc oxide	ZnO	Zinc	73
Zinc sulphate	$ZnSO_{4,} 7H_2O$	Zinc	22

Vitamin sources

Feed ingredients contain vitamin A, carotenes (precursors of vitamin A), vitamin E, vitamin K and B complex group of vitamins. Supplemental vitamins are required in poultry diets as the feed ingredients do not supply vitamins in required amounts. These are added from synthetic sources. The vitamin content in commonly available synthetic vitamin sources is given in Table 3. Examples of commercial vitamin premixes available are given in Table 4.

Table 3. Vitamin content in commonly available synthetic vitamin sources

Vitamin		Per g
Fat soluble vitamins		
Vitamin A, IU		500,000
Vitamin D_3, IU		200,000
		600,000
Vitamin AD_3, IU	Vitamin A	500,000
	Vitamin D_3	100,000
Vitamin E 50%, mg		500
Vitamin K		
Water soluble vitamins		
Biotin		
Choline chloride 50%		500
Folic acid		
Niacin		
Pantothenate calcium		
Pyridoxine		
Riboflavin		
Thiamin HCl		
Vitamin B_{12}		

Table 4. Commercial vitamin premixes

Vitamin	Per g
Vitamin AB_2D_3	
Vitamin A, IU	40,000
Riboflavin (Vitamin B_2), mg	20
Vitamin D_3, IU	5,000
Vitamin AB_2D_3K	
Vitamin A, IU	80,000
Riboflavin (Vitamin B_2), mg	50
Vitamin D_3, IU	12,000
Vitamin K, mg	10
Vitamin B12, mcg	100
Vitamin B Complex	
Thiamin (Vitamin B_1),mg	4
Pyridoxine (Vitamin B_6), mg	8
Vitamin B_{12}, mcg	40
Vitamin E, mcg	40
Niacin, mg	60
Pantothenate calcium, mg	40

CHAPTER FIVE b

Feed Composition Tables

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The composition of any feed ingredient depends upon the following factors.

i. Variety	ii. Soil conditions	iii. Agroclimatic conditions
iv. Stage of harvesting	v. Processing conditions	vi. Storage method
vii. Storage period	viii. Extrinsic toxic factors	ix. Intrinsic toxic factors
x. Sampling	xi. Method of analysis	xii. Analytical error

It is not practicable to analyse all the ingredients prior to inclusion in feed formulation. Feed composition tables give the nutrient content of ingredients analysed previously. While considering the composition of the ingredients for feed formulation, the analysed values and the table values are considered. Personal judgement also plays a part depending on physical quality of the ingredient and experience of the individual.

In preparing the feed composition tables given in this chapter, it was not possible to get the reported values for all ingredients and data from the following were considered for arriving at the nutrient values.

i. Nutrient values reported in NRC (1994) for conventional feed ingredients, except for data on amino acids of Indian samples, analysed by Degussa, Germany.

ii. Published data on the composition of unconventional feed ingredients for proximate nutrients, calcium and phosphorus.

iii. Data from ICMR (Gopalan et al., 1991) for the content of vitamins, trace minerals and certain amino acids

The feed composition tables are given on as fed basis. For this, a dry matter content of 88% for all ingredients, 75% for molasses, 98% for vegetable fat and 99% for animal fat was considered.

The feed composition tables are given in four tables: Table 1 for proximate principles and acid insoluble ash; Table 2 for minerals; Table 3 for vitamins and Table 4 for amino acids.

Table 1. Feed Ingredient composition – Proximate principles and AIA (On as fed basis)

(Dry matter: Animal fat 99%; vegetable fat, 98%; Molasses 75%; All other ingredients 88%).

Ing No.	Ingredient	DM %	MEn Kcal/kg	Pro %	EE %	LA %	CF %	NFE %	Ash %	AIA %
1	Alfalfa *(Medicago sativa)* leaf meal	88	1148	16.3	2.4	0.45	23.1	44.9	9.1	2.87
	Ambadi *(Hibiscus cannabinus)*									
2	seed meal	88	1826	25.1	5.7	2.73	18.8	31.0	7.4	2.64
3	seed meal, extraction	88	1593	26.0	1.9	0.88	19.6	32.9	7.6	2.64
	Bajra *(Pennisetum typhoides)*									
4	grain	88	3121	10.4	3.8	0.74	2.6	68.9	2.3	0.11
	Barley *(Hordeum vulgare)*									
5	grain	88	2610	10.9	1.9	0.82	5.6	68.0	1.2	0.05
	Coconut *(Cocos nucifera)*									
6	meal	88	1701	22.0	6.2	1.76	13.7	41.2	5.0	1.23
7	meal, extraction	88	1459	23.1	1.8	0.53	14.4	43.4	5.3	1.32
	Cotton *(Gossypium spp)*									
8	seed meal, extraction, undecorticated	88	1256	25.0	0.9	0.33	21.3	36.0	4.8	1.94
	Fat *(Scientific name not used)*									
9	animal	98	7904		97.8					
10	vegetable	99	8800		99.0					
	Fish *(Scientific name not used)*									

Ing No.	Ingredient	DM %	MEn Kcal/kg	Pro %	EE %	LA %	CF %	NFE %	Ash %	AIA %
11	meal 40%	88	1834	39.8	6.2	0.11	0.9	4.4	36.8	22.00
12	meal 54%	88	2464	53.8	7.0	0.12	0.9	4.4	21.9	8.71
	Groundnut (Peanut) *(Arachis hypogaea)*									
13	meal	88	2445	36.2	7.0	1.40	11.4	26.4	7.0	2.20
14	meal, extraction	88	2103	38.8	1.1	0.21	12.2	28.4	7.5	2.2
15	plant meal	88	1426	13.2	1.9	0.39	22.0	37.2	13.6	2.64
	Guar *(Cyamopsis tetragonoloba)*									
16	meal (toasted)	88	1821	37.1	6.7		10.5	27.1	6.6	0.26
	Horse gram *(Dolichos biflorus)*									
17	grain	88	2410	21.9	0.5		5.3	57.1	3.2	0.16
	Karanja *(Pongamia glabra)*									
18	seed meal	88	2042	26.4	0.1		8.8	46.6	6.2	2.20
	Korra *(Setaria italica)*									
19	grain	88	2917	9.3	4.2	0.84	8.0	63.3	3.2	0.16
	Linseed *(Linum usitatissimum)*									
20	meal	88	1452	26.4	3.1	0.62	9.7	41.8	7.0	2.20
21	meal, extraction	88	1276	27.3	0.4	0.09	9.7	43.6	7.0	2.20
	Maize *(Zea mays)*									
22	grain	88	3312	8.6	3.8	2.17	2.2	72.1	1.3	0.07
23	gluten meal 60%	88	3720	60.2	2.5	0.90	1.3	22.2	1.8	0.09
24	gluten meal 42%	88	3237	41.1	2.0	0.88	3.9	38.1	2.9	0.15
25	gluten feed (Maize gluten with bran)	88	1711	21.5	2.5	1.07	7.8	49.1	7.1	0.35
26	hominy feed (Maize grits byproduct)	88	2832	9.8	7.8	3.20	4.9	62.6	2.9	0.15
	Mango *(Mangifera indica)*									
27	kernel meal	88	2084	4.4	8.8		3.5	68.6	2.6	0.88
28	kernel meal, extraction	88	1584	4.8	1.0		3.8	74.4	2.9	0.96
	Meat *(Scientific name not used)*									
29	meal, rendered	88	2100	52.0	6.8	0.26	2.6		26.6	1.76
30	meal (rumen)	88	2728	80.5	3.1				4.4	0.44
	Meat-cum-bone *(Scientific name not used)*									
31	meal	88	2035	48.6	8.6	0.34	2.6		28.2	1.76
	Molasses *(Scientific name not used)*									
32	cane	75	1576	3.0				62.5	9.5	
	Mustard *(Brassica spp)*									
33	meal, extraction, 32%	88	1672	31.7	2.3		11.6	36.1	6.3	2.20

Ing No.	Ingredient	DM %	MEn Kcal/kg	Pro %	EE %	LA %	CF %	NFE %	Ash %	AIA %
34	meal, extraction, 26%	88	1517	26.4	1.9		13.9	38.2	7.6	2.20
	Nahar *(Mesua ferrea)*									
35	seed meal, decorticated	88	3397	11.8	13.2		6.1	52.1	4.8	
	Niger *(Guizotia abyssinica)*									
36	meal	88	2015	33.0	1.7	0.33	15.9	26.7	10.7	1.76
	Oat *(Avena sativa)*									
37	grain	88	2521	11.3	4.1	1.45	10.6	58.7	3.3	0.17
	Okra *(Abelmoschus esculentus)*									
38	seed	88	1799	15.8	11.4		38.5	18.3	4.0	
	Palm *(Elaeis guineensis)*									
39	kernel meal	88	1960	15.2	1.8		16.7	49.5	4.8	
	Poultry *(Scientific name not used)*									
40	byproduct meal	88	2791	56.8	12.3	2.40	1.4			0.95
	Ragi *(Eleusine coracana)*									
41	grain	88	2998	6.4	1.9		3.9	73.3	2.5	0.12
	Rice *(Oryza sativa)*									
42	broken	88	2648	6.9	1.7	0.53	8.9	65.5	5.1	0.26
43	param	88	2437	7.3	3.7	1.07	8.5	53.6	14.9	0.75
44	bran	88	2914	9.7	14.1	3.52	13.2	38.4	12.7	5.28
45	bran extraction (DORB)	88	1808	13.0	1.3	0.31	18.1	40.3	15.2	8.80
46	polishings	88	3021	14.6	14.1	3.52	6.2	44.4	8.8	2.64
	Rubber *(Hevea brasiliensis)*									
47	seed meal	88	1760	15.5	8.4	1.08	22.5	36.4	5.3	1.51
	Rye *(Secale cereale)*									
48	grain	88	2626	12.1	1.5		2.2			
	Safflower *(Carthamus tinctorius)*									
49	meal, extraction	88	1141	22.4	1.3	0.62	28.7	30.3	5.3	1.76
50	meal, extraction, decorticated	88	1837	41.1	1.2	0.62	12.9	25.3	7.5	1.76
	Sal *(Shorea robusta)*									
51	seed meal, extraction	88	2376	9.8	1.8		2.6	70.3	3.5	0.88
	Samai (Little millet) *(Panicum miliare)*									
52	grain	88		7.7	4.7	0.88	7.6	66.5	1.5	0.08
	Sesamum (Til) *(Sesamum indicum)*									
53	meal	88	2228	31.7	12.3	3.31	6.2	26.4	11.4	1.80
54	meal extraction	88	1661	37.6	0.9	0.26	6.5	30.8	12.2	1.92
	Silk worm *(Bombyx mori)* pupae									

Ing No.	Ingredient	DM %	MEn Kcal/kg	Pro %	EE %	LA %	CF %	NFE %	Ash %	AIA %
55	meal	88	3473	44.0	22.0		2.6	13.1	6.3	0.88
56	meal, extraction	88	2404	58.3	2.6		3.5	14.9	8.8	1.32
	Sorghum *(Sorghum vulgare)*									
57	grain	88	3103	10.4	2.6	0.97	2.0	71.1	1.9	
	Soybean *(Glycine max)*									
58	meal, full fat	88	3275	36.5	17.6	8.27	4.6	24.5	4.8	1.47
59	meal extraction	88	2205	44.9	1.1	0.44	7.8	28.0	6.2	
60	meal, extraction, dehulled	88	2297	46.9	1.0	0.39	3.8	30.4	5.9	
	Squilla *(Oratosquilla nepa)*									
61	meal	88	1500	29.5	1.7		12.2	10.5	34.1	
	Subabul *(Leucaena leucocephala)*									
62	leaf meal	88	1502	18.7	6.2		10.4	45.8	7.0	0.38
	Sunflower *(Helianthus annuus)*									
63	seed meal, extraction	88	1543	26.9	1.1	0.44	24.9	28.1	7.0	
	Tapioca *(Manihot esculenta)*									
64	flour	88	2754	2.6	1.0	0.18	2.2	80.1	2.2	0.88
	Triticale *(Triticale hexaploide)*									
65	grain	88	3092	11.8	1.5	0.29	3.9	68.9	1.9	0.10
	Varagu *(Paspalum scrobiculatum)*									
66	grain	88	2499	8.4	1.4	0.28	9.1	66.5	2.6	0.13
	Wheat *(Triticum aestivum)*									
67	bran	88	1286	17.2	3.0	1.68	10.9	50.8	6.2	0.31
68	grain	88	2900	13.3	2.5	0.59	3.0	67.5	1.8	0.09

Ing No = Ingredient number, DM = Dry matter, MEn = Metabolizable energy (nitrogen corrected), Pro = Protein, EE = Ether extract, LA = Linoleic acid, CF = Crude fiber, NFE = Nitrogen free extract, AIA = Acid insoluble ash

Table 2. Feed Ingredient composition – Minerals (On as fed basis)

(Dry matter: Animal fat 99%; vegetable fat, 98%; Molasses 75%; All other ingredients 88%).

I No.	Ingredient	Ca %	TP %	NPP %	Na %	Cl %	K %	Mg %	S %	Fe mg/kg	Mn mg/kg	Cu mg/kg	Se mg/kg	Zn mg/kg
	Alfalfa *(Medicago sativa)*													
1	leaf meal	1.38	0.21	0.07	0.09	0.45	2.06	0.34	0.16	459	29	10	0.33	23
	Ambadi *(Hibiscus cannabinus)*													

I No.	Ingredient	Ca %	TP %	NPP %	Na %	Cl %	K %	Mg %	S %	Fe mg/kg	Mn	Cu	Se	Zn
2	seed meal	0.35	0.59	0.18										
3	seed meal, extraction	0.36	0.57	0.18										
	Bajra *(Pennisetum typhoides)*													
4	grain	0.04	0.26	0.09	0.01	0.04	0.31	0.14	0.15	80	11	11		31
	Barley *(Hordeum vulgare)*													
5	grain	0.03	0.35	0.17	0.04	0.15	0.57	0.14	0.15	77	18	10	0.10	30
	Coconut *(Cocos nucifera)*													
6	meal	0.16	0.62	0.18	0.04	0.03	1.34	0.29			51			
7	meal, extraction	0.17	0.65	0.19	0.04	0.03	1.41	0.31			54			
	Cotton *(Gossypium spp)*													
8	seed meal, extraction, undecorticated	0.18	0.72	0.22	0.04	0.04	1.41	0.46	0.33	148	23	14	0.14	42
	Fat *(Scientific name not used)*													
9	animal													
10	vegetable													
	Fish *(Scientific name not used)*													
11	meal 40%	5.39	2.99	2.99	0.65	0.60	0.62	0.16	0.45	439	33	7	2.11	147
12	meal 54%	4.45	2.47	2.47	0.54	0.49	0.52	0.13	0.37	363	27	5	1.76	121
	Groundnut (Peanut) *(Arachis hypogaea)*													
13	meal	0.16	0.55	0.17	0.06	0.03	1.13	0.33	0.28	152	25	15	0.27	29
14	meal, extraction	0.17	0.59	0.18	0.07	0.03	1.21	0.35	0.30	164	26	16	0.29	31
15	plant meal	1.65	0.26	0.08										
	Guar *(Cyamopsis tetragonoloba)*													
16	meal (toasted)	0.41	0.50	0.15										
	Horse gram *(Dolichos biflorus)*													
17	grain	0.29	0.31	0.11	0.01		0.76	0.16	0.18	68	16	19		28
	Karanja *(Pongamia glabra)*													
18	seed meal	0.55	0.44	0.13										
	Korra *(Setaria italica)*													
19	grain	0.03	0.26	0.07	0.01	0.04	0.22	0.07	0.15	25	5	12		21
	Linseed *(Linum usitatissimum)*													
20	meal	0.39	0.78	0.24	0.11	0.04	1.21	0.56	0.38			25	0.49	129
21	meal, extraction	0.35	0.75	0.23	0.14	0.04	1.38	0.6	0.39			26	0.5	132
	Maize *(Zea mays)*													
22	grain	0.02	0.27	0.08	0.02	0.04	0.30	0.11	0.08	44.5	7	3	0.03	18
23	gluten meal 60%	0.02	0.50	0.14	0.02	0.05	0.35	0.15	0.43	400	4	26	1	33
24	gluten meal 42%	0.16	0.39	0.25	0.10	0.08	0.03	0.05	0.59	391	7	27	0.98	
25	gluten feed (Maize gluten with bran)	0.39	0.78	0.26	0.15	0.21	0.55	0.28	0.21	450	24	47	0.1	69

No.	Ingredient	Ca %	TP %	NPP %	Na %	Cl %	K %	Mg %	S %	Fe mg/kg	Mn mg/kg	Cu mg/kg	Se mg/kg	Zn mg/kg
26	hominy feed (Maize grits byproduct)	0.05	0.51		0.08	0.05	0.58	0.24	0.03	66	15	13	0.1	3
	Mango *(Mangifera indica)*													
27	kernel meal	0.37	0.04											
28	kernel meal, extraction	0.40	0.04											
	Meat *(Scientific name not used)*													
29	meal, rendered	7.91	3.92	3.92	1.10	0.87	0.57	0.55	0.47	421	10	10	0.4	99
30	meal (rumen)													
	Meat-cum-bone *(Scientific name not used)*													
31	meal	9.77	4.82	4.82	0.66	0.65	1.37	1.06	0.48	464	13	2	0.24	88
	Molasses *(Scientific name not used)*													
32	cane	0.8	0.08	0.04		3.10	3.40		0.46					30
	Mustard *(Brassica spp)*													
33	meal, extraction 32%	0.58	0.82	0.26	0.08		1.14	0.45		158	38	6	0.86	58
34	meal, extraction 26%	0.48	0.69	0.22	0.07		0.95	0.38		132	32	5	0.72	48
	Nahar *(Mesua ferrea)*													
35	seed meal, decorticated	1.14	0.40	0.12										
	Niger *(Guizotia abyssinica)*													
36	meal	0.42	0.31	0.11						792				
	Oat *(Avena sativa)*													
37	grain	0.06	0.26	0.05	0.08	0.11	0.45	0.16	0.20	84	42	8	0.29	37
	Okra *(Abelmoschus esculentus)*													
38	seed													
	Palm *(Elaeis guineensis)*													
39	kernel meal													
	Poultry *(Scientific name not used)*													
40	byproduct meal	2.84	1.61	1.61	0.38	0.51	0.52	0.21	0.48	416	10	13	0.71	114
	Ragi *(Eleusine coracana)*													
41	grain	0.35	0.28	0.09	0.01	0.04	0.31	0.14	0.15	39.6	12	11		31
	Rice *(Oryza sativa)*													
42	broken	0.04	0.26	0.09	0.07	0.09	0.40	0.11	0.05	9	18	2	0.26	17
43	param	0.04	0.48	0.11	0.06	0.08	0.62	0.26	0.07	43.6	62	4	0.26	18
44	bran	0.07	1.49	0.22	0.07	0.2ô	1.71	0.94	0.18	187	247	13	0.4	29
45	bran extraction (DORB)	0.05	1.19	0.18	0.05	0.05	1.36	0.76	0.14	150	198	11	0.32	23
46	polishings	0.05	1.29	0.14	0.10	0.11	1.05	0.64	0.17	158	12	3	0.09	26
	Rubber *(Hevea brasiliensis)*													

I No.	Ingredient	Ca %	TP %	NPP %	Na %	Cl %	K %	Mg %	S %	Fe mg/kg	Mn mg/kg	Cu mg/kg	Se mg/kg	Zn mg/kg
47	seed meal	0.34	0.64	0.19										
	Rye *(Secale cereale)*													
48	grain	0.06	0.32	0.06	0.02	0.03	0.46	0.12	0.15	60	58	7	0.38	31
	Safflower *(Carthamus tinctorius)*													
49	meal, extraction	0.33	0.72	0.35	0.04	0.14	0.73	0.33	0.12	473	17	10		39
50	meal, extraction, decorticated	0.33	1.23	0.37	0.04	0.15	1.06	0.98	0.19	463	37	9		32
	Sal *(Shorea robusta)*													
51	seed meal, extraction	0.19	0.15	0.04										
	Samai (Little millet) *(Panicum miliare)*													
52	grain	0.02	0.19	0.06	0.01	0.01	0.13	0.13	0.15	92	7	10		37
	Sesamum (Til) *(Sesamum indicum)*													
53	meal	1.88	1.29	0.33	0.04	0.05	1.14	0.73	40.7	88	45			95
54	meal extraction	2.02	1.38	0.34	0.04	0.05	1.21	0.77	43.5	94	49			101
	Silk worm *(Bombyx mori)* pupae													
55	meal	0.66	1.13	1.13	0.26		0.73	0.31		198	128			245
56	meal, extraction	0.88	1.50	1.50	0.33		0.97	0.4		264	171			326
	Sorghum *(Sorghum vulgare)*													
57	grain	0.04	0.26	0.09	0.01	0.08	0.31							
	Soybean *(Glycine max)*													
58	meal, full fat	0.25	0.58	0.19	0.04	0.03	1.66	0.20	0.29	73	29	15	0.1	34
59	meal extraction	0.29	0.64	0.26	0.01	0.05	2.02	0.26	0.42	119	29	22	0.1	40
60	meal, extraction, dehulled	0.26	0.61	0.21	0.02	0.05	1.94	0.29	0.43	166	42	15	0.1	54
	Squilla *(Oratosquilla nepa)*													
61	meal	6.41	1.51	1.51				0.50		880	42	88		396
	Subabul *(Leucaena leucocephala)*													
62	leaf meal	2.73	1.50	0.45	0.02		0.99		0.2	242	66	22		26
	Sunflower *(Helianthus annuus)*													
63	seed meal, extraction	0.21	1.07	0.35	0.19	0.10	0.94	0.67	0.29	137	33	34		98
	Tapioca *(Manihot esculenta)*													
64	flour													
	Triticale *(Triticale hexaploide)*													
65	grain	0.05	0.29	0.10			0.35	0	0.15	43	42	8		31
	Varagu *(Paspalum scrobiculatum)*													
66	grain	0.03	0.18	0.05	0.01	0.01	0.12	0.13	0.12	4	10	14		6
	Wheat *(Triticum aestivum)*													
67	bran	0.14	1.14	0.20	0.05	0.06	1.18	0.51	0.22	168	112	14	0.84	99
68	grain	0.05	0.37	0.13	0.04	0.05	0.45	0.17	0.12	60	32	6	0.2	34

Ca = Calcium, TP = Total phosphorus, NPP =\ Nonphytin phosphorus, Na = Sodium, Cl = Chloride, K = Potassium, Mg = Magnesium, S = Sulfur, Fe = Iron, Mn = Manganese, Cu = Copper, Se = Selenium, Zn = Zinc.

Table 3. Feed Ingredient composition – Vitamins (On 88% Dry matter)

(Dry matter: Animal fat 99%; vegetable fat, 98%; Molasses 75%; All other ingredients 88%).

I No.	Ingredient	Biot	Cho mg/kg	Folic	Nia	Pant	Pyri	Ribo	Thia	E	B_{12} mg/kg
	Alfalfa *(Medicago sativa)*										
1	leaf meal	0.3	1340	4.0	36.3	23.9	6.2	13.0	3.3	120	3.8
	Ambadi *(Hibiscus cannabinus)*										
2	seed meal										
3	seed meal, extraction										
	Bajra *(Pennisetum typhoides)*										
4	grain	3.3		0.5	22.9			2.6			
	Barley *(Hordeum vulgare)*										
5	grain	0.2	979	0.1	54.6	7.9	2.9	1.8	1.9	19.4	
	Coconut *(Cocos nucifera)*										
6	meal		1035	0.3	22.6	6.2	4.1	3.3			
7	meal, extraction		1089	0.3	23.8	6.5	4.4	3.5			
	Cotton *(Gossypium spp)*										
8	seed meal, extraction, undecorticated	0.3	1434	0.9	17.6	5.3	2.9	1.9	2.8	9.7	
	Fat *(Scientific name not used)*										
9	animal									7.9	
10	vegetable									56.4	
	Fish *(Scientific name not used)*										
11	meal 40%	0.1	2152	0.2	38.7	6.3	2.8	3.4	0.4	4.9	73.0
12	meal 54%	0.2	2953	0.3	53.2	8.7	3.9	4.7	0.5	6.8	100
	Groundnut (Peanut) *(Arachis hypogaea)*										
13	meal	0.3	1618	0.4	162	45.8	9.8	5.1	7.0	2.9	
14	meal, extraction	0.4	1738	0.4	174	49.3	10.5	5.5	7.5	3.1	
15	plant meal										
	Guar *(Cyamopsis tetragonoloba)*										
16	meal (toasted)										
	Horse gram *(Dolichos biflorus)*										
17	grain				15.0			2.0	4.2		
	Karanja *(Pongamia glabra)*										

I No.	Ingredient	Biot	Cho	Folic mg/kg	Nia	Pant	Pyri	Ribo	Thia	E	B_{12} mg/kg
18	seed meal										
	Korra *(Setaria italica)*										
19	grain			0.1	28.2			1.0	5.2		
	Linseed *(Linum usitatissimum)*										
20	meal	0.3	1635	2.8	36.2	16.1	5.4	4.0	2.5	7.5	
21	meal, extraction	0.3	1760	1.3	33.0	16.5	5.5	4.1	6.6	5.8	
	Maize *(Zea mays)*										
22	grain	0.1	613	0.4	23.8	4.0	6.9	1.0	3.5	21.7	
23	gluten meal 60%	0.2	330	0.2	55.0	3.0	6.2	2.2	0.3	24.0	
24	gluten meal 42%	0.2	323	0.2	53.3	9.4	3.5	1.5	0.2	19.4	
25	gluten feed (Maize gluten with bran)	0.3	1485	0.3	64.5	16.6	14.7	2.4	2.0	14.7	
26	hominy feed (Maize grits byproduct)	0.1	1129	0.3	45.9	8.0	10.7	2.1	7.9		
	Mango *(Mangifera indica)*										
27	kernel meal										
28	kernel meal, extraction										
	Meat *(Scientific name not used)*										
29	meal rendered	0.2	1987	0.3	54.6	4.8	2.9	5.3	0.2	1.0	65.0
30	meal (rumen)										
	Meat-cum-bone *(Scientific name not used)*										
31	meal	0.1	1888	0.3	43.6	3.9	12.1	4.2	0.8		66.3
	Molasses *(Scientific name not used)*										
32	cane	0.7	749	0.1	3.1	37.5	4.2	2.9	0.9	5.3	
	Mustard *(Brassica spp)*										
33	meal, extraction 32%	0.8		2.0	141	8.4		3.3	4.6		
34	meal, extraction 26%	0.7		1.7	117	7.0		2.7	3.8		
	Nahar *(Mesua ferrea)*										
35	seed meal, decorticated										
	Niger *(Guizotia abyssinica)*										
36	meal				117			13.5	1.0		
	Oat *(Avena sativa)*										
37	grain	0.3	935	0.3	11.4	7.7	1.0	1.1	5.9	19.4	
	Okra *(Abelmoschus esculentus)*										
38	seed										
	Palm *(Elaeis guineensis)*										
39	kernel meal										
	Poultry *(Scientific name not used)*										
40	byproduct meal	0.3	5632	1.0	37.8	11.6	4.2	10.4	1.0	1.9	293
	Ragi *(Eleusine coracana)*										

I No.	Ingredient	Biot	Cho	Folic mg/kg	Nia	Pant	Pyri	Ribo	Thia	E	B_{12} mg/kg
41	grain			0.2	11.2			1.9	4.2		
	Rice *(Oryza sativa)*										
42	broken	0.1	785	0.2	28.2	7.8	4.4	0.9	2.6	8.7	
43	param	0.1	774	0.6	77.6	9.9	5.8	1.1	6.3	17.9	
44	bran	0.4	1122	2.2	290	22.0	13.8	2.5	22.2	59.0	
45	bran extraction (DORB)	0.3	898	1.7	231	17.6	11.1	2.0	17.8	47.2	
46	polishings	0.6	1223	0.2	514	45.8	10.6	1.8	19.5	88.9	
	Rubber *(Hevea brasiliensis)*										
47	seed meal										
	Rye *(Secale cereale)*										
48	grain	0.1	419	0.6	19.4	7.9	2.6	1.6	3.6	15.0	
	Safflower *(Carthamus tinctorius)*										
49	meal, extraction	1.4	784	0.5	10.6	32.4	10.8	2.2	4.3	1.0	
50	meal, extraction, decorticated	1.6	3106	1.5	21.0	37.4	10.8	2.3	4.3	1.0	
	Sal *(Shorea robusta)*										
51	seed meal, extraction										
	Samai (Little millet) *(Panicum miliare)*										
52	grain			0.1	31.7			0.9	2.9		
	Sesamum (Til) *(Sesamum indicum)*										
53	meal	0.3	1448	0.0	28.4	5.7	11.8	3.4	2.7		
54	meal extraction	0.3	1547	0.0	30.4	6.1	12.7	3.6	2.8		
	Silk worm *(Bombyx mori)* pupae										
55	meal										
56	meal, extraction										
	Sorghum *(Sorghum vulgare)*										
57	grain										
	Soybean *(Glycine max)*										
58	meal, full fat	0.3	2366	3.4	21.5	15.3	10.6	2.6	10.7	39.1	
59	meal extraction	0.3	2762	1.3	29.0	15.8	6.0	2.9	4.5	2.0	
60	meal, extraction, dehulled	0.3	2670	1.3	21.1	15.0	4.9	2.8	3.2	2.9	
	Squilla *(Oratosquilla nepa)*										
61	meal										
	Subabul *(Leucaena leucocephala)*										
62	leaf meal										
	Sunflower *(Helianthus annuus)*										
63	seed meal, extraction	1.4	3707	0.0	258	29.0	10.8	2.9	2.9		
	Tapioca *(Manihot esculenta)*										
64	flour										
	Triticale *(Triticale hexaploide)*										

I No.	Ingredient	Biot	Cho	Folic mg/kg	Nia	Pant	Pyri	Ribo	Thia	E	B_{12} mg/kg
65	grain		451					0.4			
	Varagu *(Paspalum scrobiculatum)*										
66	grain			0.2	17.6			0.8	2.9		
	Wheat *(Triticum aestivum)*										
67	bran	0.5	1218	1.2	184	30.6	7.0	4.6	7.8	13.8	
68	grain	0.1	1090	0.4	48.0	9.9	3.4	1.4	4.5	13.0	

Biot = Biotin, Cho = Choline, Folic = Folic acid, Nia = Niacin, Pant = Pantothenic acid, Pyri = Pyridoxine, Ribo = Riboflavin, Thia = Thiamin, E = Vitamin E, B_{12} = Vitamin B_{12}

Table 4. Feed Ingredient composition – Amino acids (On 88% Dry matter)

(Dry matter: Animal fat 99%; vegetable fat, 98%; Molasses 75%; All other ingredients 88%).

	Ingredient	Pro %	Arg %	His %	Ile %	Leu %	Lys %	Met %	Cys %	Phe %	Tyr %	Thr %	Trp %	Val %
	Alfalfa *(Medicago sativa)*													
1	leaf meal	16.3	0.66	0.55	0.64	1.14	0.70	0.23	0.18	0.77	0.77	0.66	0.22	0.80
	Ambadi *(Hibiscus cannabinus)*													
2	seed meal	25.1	2.53	0.72	0.77	2.20	1.03	0.32		1.28	0.44	1.05	0.48	1.33
3	seed meal, extraction	26.0	2.62	0.75	0.80	2.29	1.07	0.33		1.34	0.46	1.09	0.50	1.38
	Bajra *(Pennisetum typhoides)*													
4	grain	10.4	0.50	0.23	0.43	1.25	0.32	0.25	0.18	0.48	0.33	0.40	0.18	0.55
	Barley *(Hordeum vulgare)*													
5	grain	10.9	0.51	0.26	0.37	0.75	0.40	0.18	0.24	0.55	0.34	0.37	0.14	0.51
	Coconut *(Cocos nucifera)*													
6	meal	22.0	1.20	0.47	0.65	1.27	0.34	0.23	0.23	0.89		0.58		1.04
7	meal, extraction	23.1	1.26	0.49	0.69	1.34	0.36	0.25	0.25	0.93		0.61		1.09
	Cotton *(Gossypium spp)*													
8	seed meal, extraction, undecorticated	25.0	2.14	0.59	0.81	1.45	0.95	0.38	0.38	1.25		0.80		1.11
	Fat *(Scientific name not used)*													

Ingredient	Pro %	Arg %	His %	Ile %	Leu %	Lys %	Met %	Cys %	Phe %	Tyr %	Thr %	Trp %	Val %
9 animal													
10 vegetable													
Fish (*Scientific name not used)*													
11 meal 40%	39.8	1.90	0.62	1.49	2.46	2.27	0.87	0.37	1.65		1.29	0.35	1.76
12 meal 54%	53.8	2.54	0.95	2.03	3.52	3.29	1.30	0.53	1.98		1.89	0.48	2.42
Groundnut (Peanut) *(Arachis hypogaea)*													
13 meal	36.2	3.86	0.82	1.21	2.24	1.29	0.36	0.50	1.85		0.98	0.37	1.49
14 meal, extraction	45.0	4.79	1.01	1.50	2.79	1.61	0.44	0.62	2.29		1.22	0.46	1.85
15 plant meal	13.2												
Guar *(Cyamopsis tetragonoloba)*													
16 meal (toasted)	37.1	5.90	2.09			2.58	0.39					0.39	
Horse gram *(Dolichos biflorus)*													
17 grain	21.9	1.86	0.67	1.29	1.89	1.82	0.25	0.46	1.33		0.81	0.25	1.36
Karanja *(Pongamia glabra)*													
18 seed meal	25.1												
Korra *(Setaria italica)*													
19 Grain	9.3	0.33	0.19	0.71	1.55	0.21	0.27	0.15	0.62		0.28	0.09	0.64
Linseed *(Linum usitatissimum)*													
20 meal		2.54	0.59	1.66	1.86	1.07	0.46	0.55	1.37		1.07	0.46	1.47
21 meal, extraction		2.70	0.70	1.80	2.00	1.10	0.48	0.58	1.50		1.20	0.48	1.60
Maize *(Zea mays)*													
22 grain	8.6	0.43	0.26	0.28	0.99	0.26	0.18	0.19	0.45		0.31	0.06	0.39
23 gluten meal 60%	60.2	1.82	1.20	2.45	10.0	1.03	1.49	1.10	3.56	3.07	2.00	0.36	2.78
24 gluten meal 42%	41.1	1.37	0.88	2.25	6.45	0.78	0.98	0.59	2.83	1.66	1.37	0.19	2.15
25 gluten feed (Maize gluten with bran)	21.5	0.99	0.70	0.63	1.85	0.62	0.44	0.50	0.76	0.56	0.87	0.10	0.05
26 hominy feed (Maize grits byproduct)	9.8	0.46	0.19	0.39	0.82	0.39	0.12	0.12	0.34	0.48	0.39	0.10	0.48
Mango *(Mangifera indica)*													
27 kernel meal	4.4												
28 kernel meal, extraction	4.8												
Meat *(Scientific name not used)*													
29 meal rendered	52.0	3.56	1.24	1.53	3.18	2.87	0.72	0.63	1.63	0.80	1.66	0.34	2.20

Ingredient	Pro %	Arg %	His %	Ile %	Leu %	Lys %	Met %	Cys %	Phe %	Tyr %	Thr %	Trp %	Val %
30 meal (rumen)	80.5	5.29	1.30	2.46	4.64	4.10	1.36	0.67	2.53		2.48		3.19
Meat-cum-bone *(Scientific name not used)*													
31 meal	48.6	3.40	0.74	1.21	2.56	2.32	0.62	0.31	1.47		1.36		1.88
Molasses *(Scientific name not used)*													
32 cane													
Mustard *(Brassica spp)*													
33 meal, extraction 32%	31.7	2.95	0.80	1.00	1.99	1.37	0.51	0.73	1.32		0.99	0.40	1.34
34 meal, extraction 26%	26.4	2.46	0.67	0.84	1.65	1.14	0.42	0.61	1.10		0.83	0.33	1.12
Nahar *(Mesua ferrea)*													
35 seed meal, decorticated	11.8												
Niger *(Guizotia abyssinica)*													
36 meal	33.0	3.48	0.74	1.33	2.01	1.21	0.48	0.53	1.58	0.75	1.11		1.69
Oat *(Avena sativa)*													
37 grain	10.0	0.78	0.24	0.51	0.88	0.49	0.18	0.22	0.58	0.53	0.42	0.16	0.67
Okra *(Abelmoschus esculentus)*													
38 seed	15.8												
Palm *(Elaeis guineensis)*													
39 kernel meal	15.2	1.48	0.26	0.49	0.91	0.33	0.25	0.16	0.61		0.42		0.73
Poultry *(Scientific name not used)*													
40 byproduct meal		3.73	1.01	20.1	3.78	2.93	0.93	0.92	2.16	1.59	2.05	0.35	2.72
Ragi *(Eleusine coracana)*													
41 grain	6.4	0.29	0.15	0.25	0.58	0.19	0.21	0.14	0.31		0.26		0.37
Rice *(Oryza sativa)*													
42 broken	6.9	0.57	0.20	0.28	0.57	0.33	0.17	0.16	0.37	0.26	0.28	0.08	0.41
43 param	7.3	0.58	0.21	0.28	0.57	0.34	0.17	0.16	0.37	0.26	0.28	0.08	0.41
44 bran	12.6	0.88	0.33	0.41	0.84	0.55	0.24	0.25	0.55	0.39	0.44	0.11	0.62
45 bran extraction (DORB)	13.0	1.02	0.28	0.51	1.00	0.44	0.31	0.28	0.67		0.43		0.72
46 polishings	14.6	1.09	0.37	0.54	1.03	0.64	0.32	0.31	0.68		0.52	0.18	0.76
Rubber *(Hevea brasiliensis)*													
47 seed meal	15.5	1.13	0.72	1.00	0.61	0.49	0.18	0.08	0.61	0.27	0.49	0.55	0.34
Rye *(Secale cereale)*													
48 grain	12.1	0.53	0.26	0.47	0.70	0.42	0.17	0.19	0.56	0.26	0.36	0.11	0.56
Safflower *(Carthamus tinctorius)*													

Ingredient	Pro %	Arg %	His %	Ile %	Leu %	Lys %	Met %	Cys %	Phe %	Tyr %	Thr %	Trp %	Val %
49 meal, extraction	22.4	2.11	0.58	0.98	1.66	0.86	0.40	0.43	1.06	0.68	0.81	0.35	1.36
50 meal, extraction, decorticated	41.1	3.49	1.02	1.50	2.35	1.21	0.65	0.67	1.67	1.02	1.24	0.56	2.23
Sal *(Shorea robusta)*													
51 seed meal, extraction	9.8	0.68	0.20	0.34	0.68	0.49	0.16	0.15	0.48		0.28	0.09	0.46
Samai (Little millet) *(Panicum miliare)*													
52 grain	7.7	0.27	0.13	0.40	0.83	0.12	0.19	0.10	0.36		0.20	0.06	0.38
Sesamum (Til) *(Sesamum indicum)*													
53 meal	31.7	3.63	0.77	1.16	2.07	0.71	0.95	0.55	1.50	1.14	1.08	0.48	1.48
54 meal extraction	37.6	4.29	0.91	1.38	2.45	0.84	1.12	0.65	1.77	1.36	1.28	0.57	1.75
Silk worm *(Bombyx mori)* pupae													
55 meal	43.7	2.45	1.32	1.58	2.24	2.51	1.06	0.73	1.98	2.51		0.60	1.79
56 meal, extraction	58.3	3.26	1.76	2.11	2.99	3.34	1.41	0.97	2.64	3.34		0.79	2.38
Sorghum *(Sorghum vulgare)*													
57 grain	10.4	0.47	0.27	0.41	1.25	0.29	0.18	0.19	0.58		0.34	0.09	0.52
Soybean *(Glycine max)*													
58 meal, full fat		2.74	0.99	2.13	2.74	2.35	0.53	0.54	2.05	1.34	1.65	0.51	1.97
59 meal extraction	43.5	3.11	1.16	1.94	3.35	2.66	0.62	0.65	1.21	1.89	1.70	0.73	2.05
60 meal, extraction, dehulled	46.9	3.49	1.24	2.16	3.57	2.79	0.61	0.69	2.49		1.80	0.61	2.22
Squilla *(Oratosquilla nepa)*													
61 meal	29.5	1.04	0.52	1.04	1.64	1.25	0.43	0.28	2.24		0.93	0.20	1.25
Subabul *(Leucaena leucocephala)*													
62 leaf meal	20.8	0.38	0.23	0.38	0.40	0.46	0.12				0.41		0.59
Sunflower *(Helianthus annuus)*													
63 seed meal, extraction	26.9	2.09	0.63	1.09	1.68	0.94	0.59	0.48	1.21		0.97	0.36	1.31
Tapioca *(Manihot esculenta)*													
64 flour	2.5	0.11	0.03	0.09	0.09	0.10	0.01		0.05	0.04	0.06	0.01	0.07
Triticale *(Triticale hexaploide)*													

Ingredient	Pro %	Arg %	His %	Ile %	Leu %	Lys %	Met %	Cys %	Phe %	Tyr %	Thr %	Trp %	Val %
65 grain	11.8	0.57	0.26	0.39	0.76	0.39	0.26	0.26	0.49	0.32	0.36	0.14	0.51
Varagu (*Paspalum scrobiculatum*)													
66 grain	8.4	0.32	0.14	0.42	0.77	0.18	0.21	0.13	0.50		0.24	0.06	0.48
Wheat (*Triticum aestivum*)													
67 bran	17.2	0.15	0.45	0.49	0.96	0.62	0.23	0.35	0.61		0.51		0.75
68 grain	13.3	0.60	0.31	0.44	0.89	0.37	0.21	0.30	0.60	0.43	0.39	0.16	0.57

Pro = Protein, Arg = Arginine, His = Histidine, Ile = Isoleucine, Leu = Leucine, Lys = Lysine, Met = Methionine, Cys – Cysteine, Phe = Phenylalanine, Tyr = Tyrosine, Thr = Threonine, Trp = Tryptophan, Val = Valine.

References

Degussa, 1997. Amino acid values of different Indian feed ingredients. Personal communication. Degussa, A. G. Frankfurt, Germany.

Degussa, 1998. Amino acid values of different Indian feed ingredients. Personal communication. Degussa, A. G. Frankfurt, Germany.

Degussa, 2000. Amino acid values of different Indian feed ingredients. Personal communication. Degussa, A. G. Frankfurt, Germany.

Degussa, 2001. Amino acid values of different Indian feed ingredients. Personal communication. Degussa, A. G. Frankfurt, Germany.

Gopalan, C., Rama Sastri, B. V., Balasubramanian, S. C., Narasinga Rao, B. S., Deosthale, Y. G. and Pant, K. C. 1991. Nutritive value of Indian foods. National Institute of Nutrition. Indian Council of Medical Research, Hyderabad 500007, India.

NRC, 1994. Nutrient requirements of poultry. 9th Ed. National Research Council, National Academy Press, Washington D. C.

CHAPTER SIX

Feed Activities

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Additive is an ingredient or a mixture of ingredients added to the basic feed mix or parts thereof, usually in small quantities, to fulfill a specific function, nutritive or non-nutritive. There are various types of additives.

i. Antibiotics	ii. Anti-oxidants	iii. Aromatics/ Flavourers
iv. Anti-coccidials	v. Emulsifiers	vi. Colouring agents
vii. Pellet binders	viii. Anti-caking agents	ix. Herbal preparations
x. Hormones oligosaccharides	xi. Probiotics	xii. Mannan
xiii. Mineral proteinates	xiv. Arsenicals	xv. Copper sulphate
xvi. Grits	xvii. Pigments	xviii. Adsorbents
xix. Mould Inhibitors	xx. Enzymes	

Antibiotics

Several antibiotics are used as growth promoters or performance improvers. Toxins produced by pathogens in the gut not only affect the digestion but also damage the architecture of the villi, affecting the absorption of nutrients. Antibiotic growth promoters act by suppressing the microbial load in the gut of the birds. Thinning of the intestine walls has been observed due to the addition of antibiotics to the feed, leading to improved efficiency in absorption of nutrients. In addition glucose sparing effect is observed due to the prevention of lactic acid production and amino acid sparing due to the prevention of production of toxic amines, such as putrescine and cadaverine, in the caecum.

The antibiotics commonly used are avilamycin, flavomycin, virginiamycin, zinc bacitracin, lincomycin, oxytetracycline and chlortetracycline. The use of antibiotics as feed additives is now-a-days being discouraged.

Several antibiotics have been banned in several countries for two reasons.

i. Antibiotic residues in the products may affect humans.
ii. Antibiotic resistant strains of microbes may develop.

Reduction in digestibility, feed efficiency and the life of the birds has led to demands in several European countries for reconsidering the legislation on the use of antibiotic feed additives.

Anti-oxidants

Fat in feed ingredients (eg. rice polish, high fat fish meal or oil in the poultry feed) tends to undergo auto-oxidative rancidity. Formation of free radicals initiates rancidity. High ambient temperature favours free radical formation. Iron and copper (prooxidants) present in feed catalyse oxidative rancidity.

The adverse effects of rancidity are:

i. Lowered palatability of feed
ii. Reduced availability of nutrients
iii. Destruction of some nutrients (vitamin A, D, E and biotin, etc.)
iv. Imparting off flavour to feed and poultry meat
v. Reduced pigmentation of broiler skin and egg yolk

Anti-oxidants, synthetic and natural, prevent auto-oxidative rancidity. They are immunostimulatory. Synthetic anti-oxidants spare natural anti-oxidants (eg. vitamin E). The use of anti-oxidants is on the increase.

Anti-oxidant	Quantity/ton feed
Synthetic anti-oxidants	
Butylated hydroxy toluene(BHT)	125 g and above
Butylated hydroxy anisole (BHA)	
Ethoxyquin	
Commercial anti-oxidants (combination of synthetic anti-oxidants)	
Nutrient anti-oxidants	
Vitamin E	15 – 30 g
Vitamin C	100-1000 g
Selenium (Inorganic or organic)	0.1 – 0.15 g

Aromatics/Flavourers

Flavouring agents, in powder or liquid form, miscible with either water or oil, impart flavour or aroma to feed. Several flavours can be given to feed. They may be used to improve natural aroma or to mask the original flavour (usually unpleasant), or to give a new flavour.

Anti-coccidials

Coccidiosis is a major economic parasitic infestation affecting birds. In layer type chicken, coccidiosis is not a major problem with the change in housing system from deep litter to cages. Anti-coccidial vaccines are being used in broiler breeders maintained in cages. In growing chicken and broilers, which are reared on deep litter, anti-coccidials are used as a preventive measure.

Chemicals (3,5-dinitro-toluamide (DOT), clopidol, robenidine), ionophores (salinomycin or madhuramycin, monensin), herbal preparations and a natural occurring anti-coccidial (a steroidal sapogenin) are used for prevention of coccidiosis. Diclauzuril is a new entrant. Development of resistance is a major problem with coccidiostats. Amprolium, sulpha drugs and p-toluene-sulphonyl-beta-methoxyethylurethane (codrinal) are used for treatment purpose. Layers require immunity to be developed for coccidiosis. Therefore, coccidiostats (eg. DOT) are used. Outbreaks of coccidiosis or sub-clinical infections may occur in spite of DOT being used. In broilers, anti-coccidiostats (ionophores more frequently, some times chemicals) are used. Alternating the coccidiostats is suggested in shuttle programmes to prevent the development of resistance.

Emulsifiers

Emulsifiers increase the surface area of fat for digestion and absorption by dispersing it as droplets in water. Chicks in the first week of their life may not digest fat properly. Fat (animal or vegetable) is added at 0.5-2% in broiler starter diets and even up to 6% in finisher diets now-a-days. These situations may require emulsification of fats. Soya lecithin is a good emulsifier.

Colouring agents

Colouring agents for poultry feeds are important to attract the customers. Some feed manufacturers now add colours to their feeds.

Pellet binders

Bentonites and lignin sulphonate may be used as pellet binders.

Bentonites are naturally occurring trilayered aluminum silicate, montmorillonite. They may contain calcium or sodium. Sodium bentonite has swelling properties. Bentonite may be used at not more than 2% in feed. It can be used in medicated feeds, provided it does not interfere with availability of medicaments.

Lignin sulphonate is derived from sulphite wood pulping industry. It is used at 0.5 to 2.5 %. Attapulgite clay may be used at not more than 0.25%.

Anti-caking agents

Bentonites at not more than 2.5% and attapulgite clay at not more than 0.25% may be used as anti-caking agents.

Herbal preparations

Several herbal preparations are available. They may act differently and may be useful for several purposes.

i. Protection of liver against mycotoxins
ii. Improvement in performance
iii. Protection against nephro-toxicity
iv. Improving utilisation of minerals like calcium and phosphorus
v. Stimulation of immune response

Hormones

Hormones like stilbesterol and somatotropic hormone (STH) have been tried as performance enhancers in poultry with beneficial results. However, the problem of residues has restricted their use and, in fact several countries have banned the use of hormones as feed additives.

Probiotics (Direct-fed Microbials)

The gut of a newly hatched chick is sterile. Only later does it get microbes from the environment. In normal conditions, with the increase in age of the chick, the gut microflora stabilises to a native state, i.e. a balance exists between host favourable and host harmful microflora. The microflora in certain parts of the intestinal tract of chicken is of the order of 10^9 to 10^{11} per gram of tract contents. Harmful microbial population increases due to stress, disease conditions and antibiotic treatment. Direct-fed microbials, administered through water or feed, helps maintain host favourable bacteria and prevents harmful bacteria in the gut.

Several organisms can be used as direct-fed microbials. The commonly used ones are *Aspergillus oryzae, Bifidobacterium bifidium, Lactobacillus acidophilus, Lactobacillus bulgaricus, Lactobacillus casei, Lactobacillus plantarum, Streptococcus diacetylactis, Streptococcus faecium, Streptococcus lactis* and *Saccharomyces cerevisiae.*

Direct-fed microbials may act in tandem with adhesion receptors on the gut epithelium, with nutrients, produce antibacterial substances and stimulate of immunity.

Mannan oligosaccharides

Specific nonstarch polysaccharides, not digested by chickens, help in improving intestinal health. The microbes attach through lectins on their walls to oligosaccharide receptors containing D-mannose in the intestinal mucosa. The bacterial attachment can be inhibited through mannose or similar sugars e.g. mannan oligosaccharides (MOS) in the feed. This decolonisation of bacteria is not uniform. Salmonella may be decolonised more efficiently than coliforms.

Mineral proteinates

The absorption and availability of inorganic trace minerals varies depending upon the nature of the minerals (sulphate, oxide, carbonate), their solubility, ionization, etc. Trace minerals can be attached to an amino acid of a protein and they are more bioavailable to animals. Commercial preparations of proteinated selenium and chromium are used in poultry.

Arsenicals

Arsenicals (0.01% or less) are used for improvement in performance of poultry, e.g. Roxarsone (3-nitro-4-hydroxyphenylarsonic acid)). Arsenic accumulates in the liver but is not dangerous to a consumer, a five-day withdrawal period allows the arsenic levels in liver to drop to normal levels.

Copper sulphate

Copper (20 ppm) as copper sulphate is used in diets, especially for broiler diets. It may give beneficial responses in health and can also be useful as a mould inhibitor.

Grits

Stone grits when fed gets lodged in gizzard and help in grinding of feed particles. Either stone grits or shell grits or marble grits can be added. The last two can also contribute calcium to the birds. Grit in gizzard may prevent the appearance of undigested maize and soya in excreta of broilers and chicks.

Pigments

Naturally occurring xanthophylls pigments impart yellow orange colour to egg yolk, body fat, skin, shanks, feet and beak of birds. The most common xanthophylls are zeaxanthin in maize and lutein in alfalfa. The pigments have no nutritional value. The colouration due to pigments is eye appealing. Naturally occurring xanthophylls are susceptible to oxidation. The xanthophylls and lutein content in few ingredients is shown in Table 1.

Table 1. Xanthophylls and lutein content in few ingredients (NRC, 1994)

Ingredient	**Xanthophyll** mg/kg	**Lutein** mg/kg
Alfalfa leaf meal	220	143
Algae meal	2000	-
Maize	17	0.12
Maize gluten meal (60%)	290	120
Marygold petal meal	7000	-

In times of necessity, synthetic or natural extracts of the pigments can be used to improve colouration of egg yolk, fat, skin, shanks, feet and beak of birds. These include synthetic canthaxanthin and ß-apo-8-carotenoic acid (ethyl ester).

Adsorbents

Addition of adsorbents to the poultry feed is becoming routine with the increase in the prevalence of mycotoxins and pesticide residues. Commonly used adsorbents are activated charcoal, zeolites, alumino silicates and bentonites. The most commonly used adsorbent is hydrated sodium calcium aluminum silicate (HSCAS). It is very useful in binding aflatoxins. HSCAS have been seen to bind aflatoxins in the laboratory up to 500 ppb level, but only up to 100 ppb in field conditions due to various factors like the needed time for binding, the release of bound aflatoxins during peristalsis and due to the variable release of the aflatoxins which are deeply embedded inside the ingredient. Further, HSCAS are unable to bind other mycotoxins like ochratoxin, citrinin, sterigmatocystin, pesticide and fungicide residues in feed. Activated charcoal can be effectively used to bind these other mycotoxins, pesticide and fungicide residues. A combination of HSCAS and activated charcoal can be more beneficial. These binders may also bind nutrients. HSCAS has high affinity for calcium. Activated charcoal may bind vitamins. Additions of overages of vitamins appears to be essential. Reports indicate that mannan oligosaccharides (MOS) are able to bind toxins and are also able to eliminate pathogens in the gut. Currently, binders with a combination of organic acids, HSCAS, activated charcoal and MOS are available and are being used in feed as a prophylactic measure.

Mould Inhibitors

Stocking of feed ingredients is unavoidable. Sometimes, feed ingredients may contain more moisture. Fungal infestation and consequent mycotoxin production in stored grains can be inhibited with organic acids like propionic acid, formic acid, acetic acid and benzoic acid. These have to be mixed with the grains before they are stored in silos. These organic acids are corrosive in nature. Copper sulphate may also be used to inhibit moulds.

Enzymes

Non-starch polysaccharides (NSPs) content of a typical corn-soya-DORB layer mash ranges between 20 and 25% and that of broiler from 16 to 20%. The NSPs in the feed are cellulose (9 to 11%), hemi-cellulose (10 to 12%), pectin, galactosides, b-glucans, etc. The cellulose is 100% glucose while hemi-cellulose contains not less than 50% glucose. The total glucose bound in cellulose and hemi-cellulose comes to about 15 to 16% of the mash. These are unavailable as the birds do not posses the enzymes to break these substances.

NSPs are also constituents of the cell walls of plant materials. The cell walls are broken down during soaking and grinding in the gizzard and the nutrients are released for digestion. The process of breaking down of the cell wall constituents cannot be said to be complete hence the possibility of some nutrients being trapped. Some NSPs like pectin, b glucans have the power to imbibe water and consequently swell there by increasing the viscosity of the gut contents, interfering with the activity of the enzymes and with the absorption process.

Plant ingredient sources contain nearly two-thirds of the phosphorus in the phytate, which is a hexaphosphoric acid ester of inositol. The phosphorus in the phytate is unavailable to birds as they do not have the enzyme phytase to break it down. The phytate is also considered an anti-nutritional factor because it binds proteins, amino acids and minerals like calcium, magnesium, manganese, zinc, copper and iron.

Addition of external enzymes capable of breaking down NSPs and phytate will help in reducing the anti-nutritional effects of the NSPs and phytate, and in enhancing nutrient availability. The enzyme cocktail targeting the NSPs should be able to contribute at least 200 units of cellulase, 1000 units of xylanase, 400 units of pectinase for one kg of feed. Phytase is added in practical diets at 500 –700 FTU/kg feed for broilers and 400-600 FTU/kg feed for layers to substitute 0.1 to 0.12% phosphorus.

Benefits of using enzymes

i. Enhances nutrient availability by digesting hitherto indigestible nutrients
ii. Enhances capabilities of local enzymes by reducing the viscosity
iii. Releases bound minerals
iv. Reduces moisture content of the excreta
v. Reduces fecal volume and nutrient content, thereby improving farm hygiene
vi. Reduces feed cost

Characteristics of an effective enzyme

i. Should be able to function at a pH range between 2 and 7
ii. Should be able to withstand high temperatures of processing
iii. Should have a good keeping quality after mixing in the feed
iv. Should have optimal potency to be able to digest the target nutrient in the time
v. Should be economical

CHAPTER SEVEN

Anti-nutrients in Feed Ingredients

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Introduction

Before using any feed ingredient it is essential to know about the anti-nutrients present in it. Every vegetable protein sources contain one or other anti-nutrients and most of them are destroyed during processing prior to use in feeds. Anti-nutritive substances are deleterious substances (toxic substances) present in certain feed ingredients. They arise during the normal growth and metabolism of a plant. They reduce the performance of poultry.

Types of anti-nutritive substances

Several anti-nutrients are present in feed ingredients, particularly in plant feed ingredients. They affect the digestion, absorption and metabolism of nutrients. Some important anti-nutrients are given in Table 1.

Table 1. Important anti-nutrients present in feed ingredients

S No.	Anti-nutrient substance	Occurrence
1	Protease inhibitors, e.g. Trypsin inhibitors	Soybean seeds
2	Haemagglutinins (lectins)	Legume seeds (Castor bean, kidney bean, soybean)
3	Glucosides	

	a. Saponins	Soybean seeds, Lucern leaf meal
	b. Cyanogens	Cassava (tapioca) root, linseed meal
	c. Glucosinolates	Rape and mustard seed
	d. Estrogens	Soybean seeds
4	Phenols	
	a. Gossypol	Cotton seed meal
	b.Tannins	Sorghum, rape and mustard meal, salseed meal, mango seed kernel, leucaena leaf meal, tamarind seed meal
5	Phytate	All vegetable feed ingredients
6	Erucic acid	Rape and mustard seed
7	Argemone*	Rape and mustard seed meal
8	Mimosine	Subabul (Leucaena) leaf meal
9	Nimbidins	Neem seed meal
10	Nitrates and Nitrites	
11	Oxalates	Vegetable and animal feed sources
12	Antivitamins	
	Antivitamin A	Lipoxygenase in soybean seeds
	Antivitamin D	Soybean seeds
	Antivitamin E	Kidney bean
	Antivitamin K (Dicumarol)	Sweet clover
	Antivitamin B_6 (Linatin)	Linseed meal
13	Non-starch polysaccharides	Cereal grains and vegetable protein sources

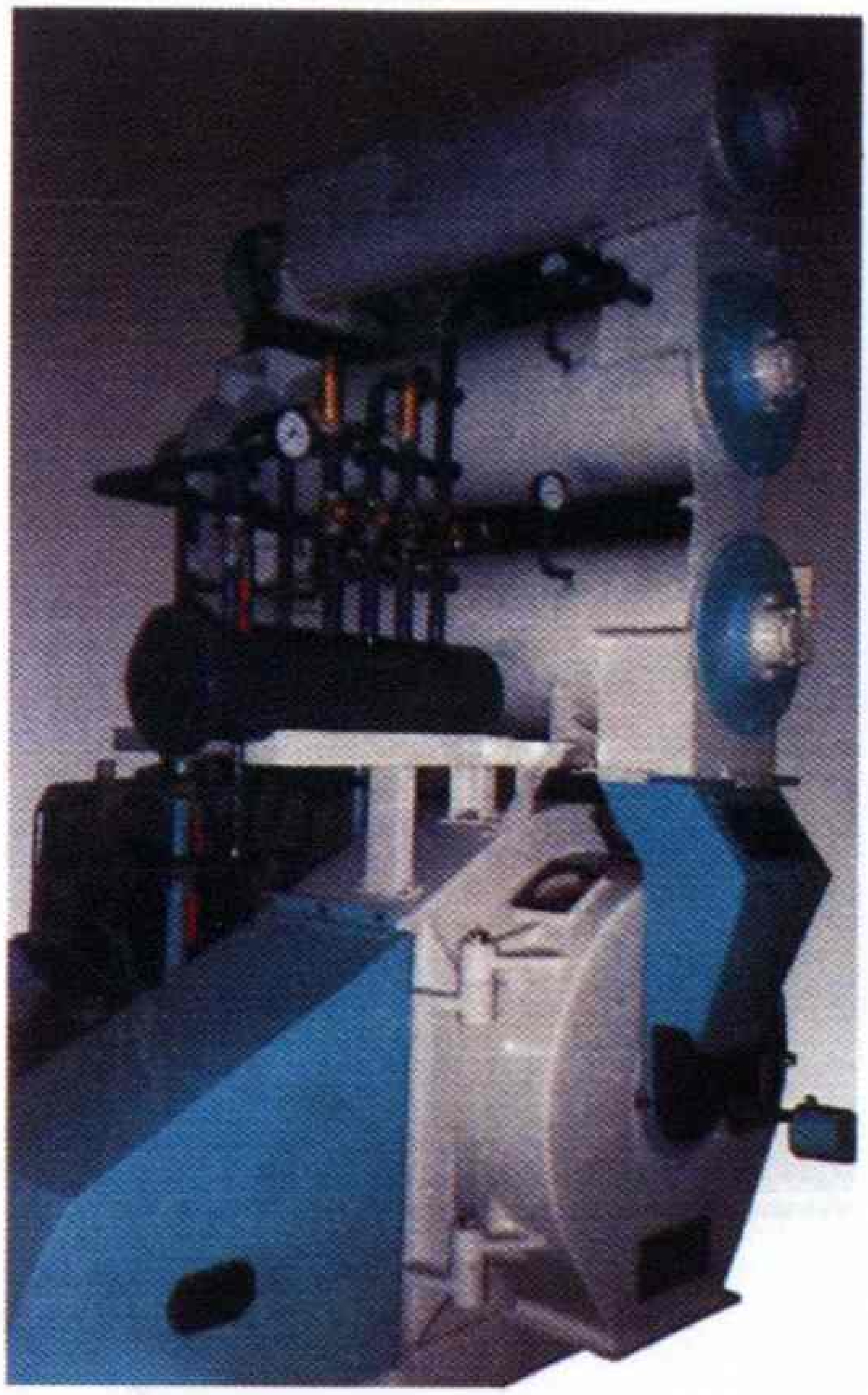
** Argemone is on adulterant and not anti-nutrient.*

Effects of anti-nutrients and detoxification methods

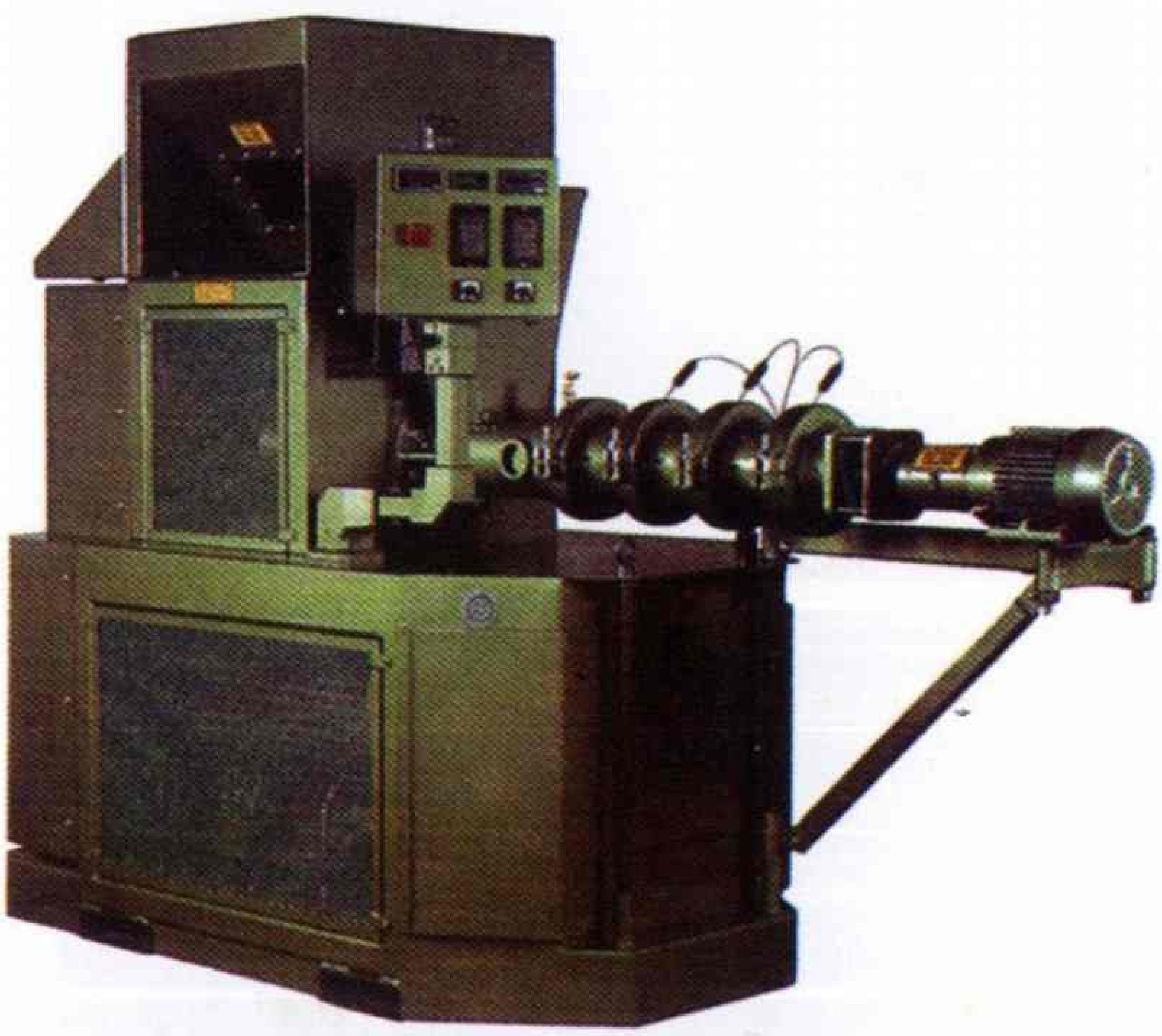
The deleterious effects and detoxification methods of anti-nutrients are presented in Table 2.

Table 2. Deleterious effects and detoxification methods of anti-nutrients present in plant feed ingredients

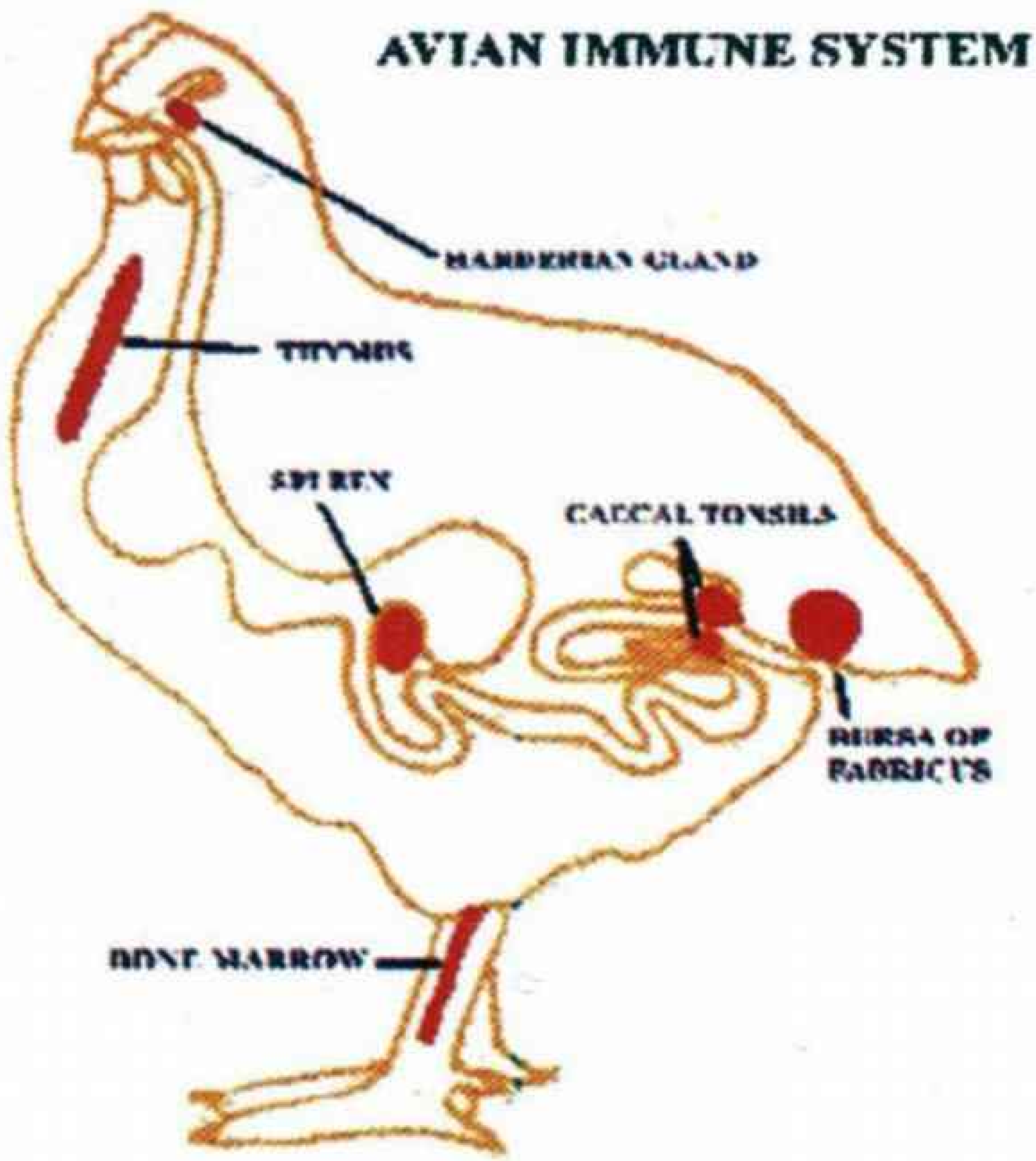
Mechanism of action	Deleterious effects	Detoxification
1. Trypsin inhibitors (Protese inhibitor) in soybean seeds		
i. Trypsin inhibitors form a complex with trypsin	i. Reduced growth	i. Heat treatment



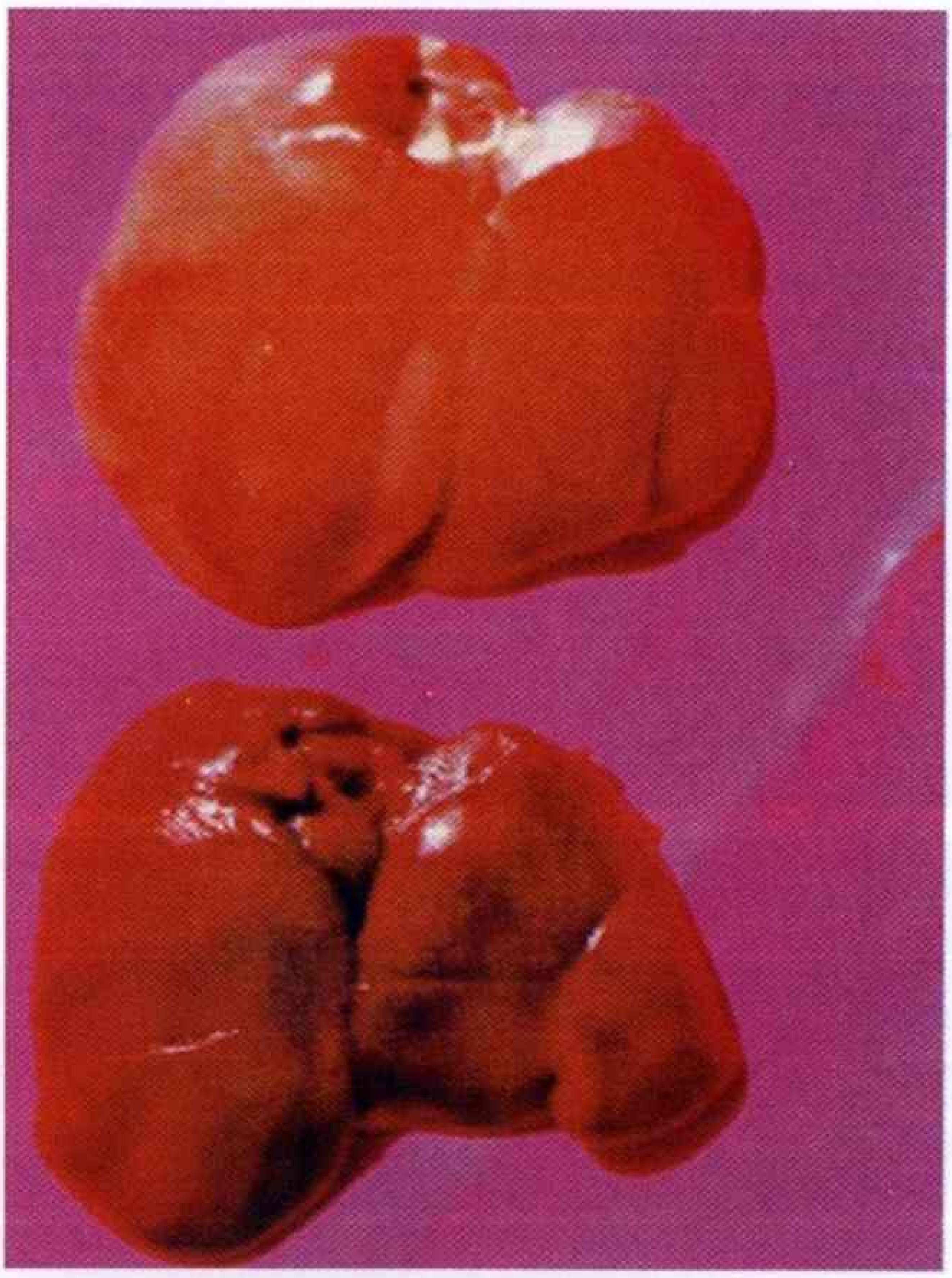
47. *Typical Pellet Mill with double conditioner*



48. *Typical Dry Extruder*



49. Avian Immune system



50. Pale liver (top) and normal liver (below)

47. Typical oral lesions of T2 toxin in poultry

ii. Pancreas produces more proteases (rich in methionine) iii. Endogenous loss of methionine	ii. Low production iii. Pancreatic hypertrophy	ii. Flowing steam for 60 min iii. Autoclaving 5 Lb/in^2 for 45 min iv. Autoclaving 10 Lb/ in^2 for 30 min iv. Autoclaving 15 Lb/ in^2 for 20 min vi. Autoclaving 20 Lb/ in^2 for 10 min
2. Haemagglutinins (lectin) in legume seeds (castor bean, kidney bean, soybean)		
i. Binds with mannose (glycoproteins) of cells ii. Binds to mannose of RBC and causes agglutination iii. Attach to the intestinal cell lining resulting in poor absorption of nutrients iv. Impairs immune system	i. Decrease in protein utilisation ii. Poor growth	i. Cooking in water for 30 min ii. Autoclaving for 30 min iii. Soaking in water overnight iv. Ammoniation
3. Glucosides - a. Saponins in soybean seeds, lucern leaf meal		
i. Lower surface tension and forms stable foam with proteins and cholesterol ii. Haemolysis of RBC iii. Alter cell permeability	i. Increases respiratory rate ii. Inhibits the activity of certain enzymes (chymotrypsin) iii. Low growth iv. Low egg production	i. Extraction with hot water or organic solvents (ethanol, methanol)
3. Glucosides - b. Cyanogens in cassava (tapioca) root, linseed meal		
i. Intact glucosides not toxic. On hydrolysis release HCN. HCN inactivates cytochrome oxidase system		i. Closed steam distillation with HCl at 100 °C for 3 hours ii. Cooking followed by discarding of cooked water iii. Peeling of skin from tapioca tubers
3. Glucosides - c. Glucosinolates or thioglucosinolates (Goitrogens) in rape and mustard seed		
i. Glucosinolates are hydrolyzed to 2-OH-3-butenyl isothiocyanate and 5-venyloxazolidinine –2-thione-goitroin, which suppresses iodine uptake by thyroid.	i. Goitre ii. Poor growth iii. Low egg production iv. Liver haemorrhages v. Fatty liver	i. Extraction of glucosinolates with hot water, dilute alkali or acetone ii. Decomposition of glucosinolates with iron salts or soda ash iii. Extraction of goitrogens with acetone or water or steam
3. Glucosides - d. Estrogens in soybean seeds		
i. Genistein (an isoflavone) in soybean seeds	i. Poor growth ii. Increased zinc in liver and bone iii. Increased deposition of Ca, P and Mn in bones	i. Dry or moist heat treatment ii. Solvent extraction

4. Phenols - a. Gossypol in cotton seed meal		
i. Free gossypol at more than 150 mg/kg diet is toxic. ii. Binds with protein (lysine)	Chicks i. Poor growth ii. Low feed intake iii. Ascites iv. Cardiac irregularity v. Reduced oxygen carrying capacity of the blood. Layers i. Olive green discoloration of yolk	i. Cotton seed meal containing less than 0.04% free gossypol may be used for poultry. ii. If it contains more free gossypol, use iron salts at 4:1 ratio (iron and gossypol) iii. Solid substrate fermentation with certain fungi (*Aspergillus oryzae, Aspergillus janus*)
4. Phenols - b. Tannins (Polyphenolic compounds) in sorghum, rape and mustard meal, salseed meal, mango seed kernel, leucaena leaf meal, tamarind seed meal		
i. Binds with proteins ii. Inhibits enzymes (trypsin, amylase, lipase, etc.) in intestines	i. Reduced growth ii. Poor egg production	i. Cold water processing ii. Boiled water processing iii. Treatment with dilute acid, alkali and salt iv. Extraction with ether, acetone, ethanol and methanol v. Autoclaving
5. Phytate (Salt of phytic acid) - in all vegetable feed ingredients		
i. Six phosphate molecules are bound in one phytic acid molecule. Calcium, magnesium salts of phytic acid is phytate. Trace minerals (manganese, zinc) are also bound to phytate. ii. Phosphorus present in phytate is not available to poultry iii. Phytase, which hydrolyzes phytate, is not produced in bird's intestine.	i. Increased requirement of phosphorus and trace minerals.	i. Microbial phytase hydrolyzes phytate and releases phosphorus, calcium and trace minerals. ii. One phytase unit (FTU, FYT, PTU) is the amount of phytase that releases 1 _mol inorganic phosphorus per minute from an excess of sodium phytate at 37°C and pH 5.5. iii. 500 FYT/kg feed releases 0.12% phosphorus from phytate.
6. Erucic acid in rape and mustard seeds		
i. Erucic acid is a polyenoic fatty acid, present in rape and mustard oil.	i. Poor growth ii. Low feed intake iii. Poor feed efficiency	i. Erucic acid up to 0.06% in diet is tolerated. ii. Solvent extraction removes oil and so erucic acid.
7. Argemone in adulterated rape and mustard seed meal		
i. Seeds from *Argemona maxicana* are high in oil. Adulterated withrape and mustard seed meal.	i. Swelling of leg ii. Diarrhoea iii. Atrophy of optic nerve iv. Edema	i. Heating at 240°C for 15 min

8. Mimosine in subabul *(Leucaena)* leaf meal		
i. Inhibits biosynthesis of thyronine	i. Reduced growth ii. Weight loss iii. Enlarged thyroid gland iv. Poor reproductive efficiency	
9. Nimbidins (Nimbine, nimbinin and nimbidine) in neem seed meal		
i. Low feed intake ii. Poor growth iii. Low egg production iv. Toxicity of internal organs	i. Urea treatment at 2.5% of neem seed meal	
10. Nitrates and nitrites		
i. Accumulation of nitrates from soil to crops. Nitrates get converted to nitrites.	i. Conversion of hemoglobin to methaemoglobin	
11. Oxalates in vegetable and animal feed sources		
i. Soluble oxalates (Sodium and potassium oxalates) ii. Insoluble oxalates (Calcium and magnesium oxalates)	i. Poor growth ii. Decreased serum calcium iii. Rickets	
12. Antivitamins - a. Antivitamin A (Lipoxygenase in soybean seeds)		
i. Lipoxygenase of soybean seed oxidizes carotene, a precursor of vitamin A	i. Destruction of carotene	i. Heat treatment of soybean seed or meal
12. Antivitamins - b. Antivitamin D in soybean seeds		
i. Increased requirement of vitamin D	i. Heat treatment of soybean seed or meal	
12. Antivitamins - c. Antivitamin E in kidney bean		
i. Increased requirement of vitamin E	i. Autoclaving	
12. Antivitamins - d. Antivitamin K (Dicumarol) in sweet clover		
i. Dicumarol in sweet clover	i. Reduced utilisation of vitamin K	
12. Antivitamins - e. Antivitamin B_6 (Antipyridoxine, Linatine) in linseed meal		
i. Linatine (A peptide containing 1-amino –D-prolone in combination with glutamic acid)	i. Reduced utilisation of pyridoxine	i. Extraction of linseed meal with water ii. Autoclaving

13. Non-starch polysaccharides in cereal grains and vegetable protein sources		
i. Arabinoxylans : Wheat, Rye, Triticale	i. Soluble NSPs increase digesta viscosity which impairs uptake of nutrients.	i. Xylanase may be used in wheat, rye, triticale based diets.
ii. (1 - 3, 1 - 4) - B-glucans: Barley, Oats	ii. Increased viscosity promotes bacterial multiplication	ii. B-glucanase may be used in barley and oat based diets.
iii. Pectic polysaccharides (Galacturonans and associated arabinogalactans) : Soybean meal	iii. Pectic (Galactouronase) enzymes and a-galactosidase to break sucrose and galactose containing oligosaccharides in soybean meal may be used.	
iv. Water soluble carbohydrates (sucrose and galactose containing oligosaccharides): Soybean meal		

Practical methods of detoxification

The practical methods of detoxification of anti-nutrients are given in Table 3.

Table 3. Practical methods of detoxification of anti-nutrients

S NO.	Anti-nutrient substance	Practical method of detoxification
1	Protease inhibitors, e.g. Trypsin inhibitors	Heat treatment is effectively used in industry to destroy protease inhibitors, haemagglutinins and saponins in production of soybean meal.
2	Haemagglutinins (lectins)	
3	Glucosides	
	a. Saponins	
	b. Cyanogens	Only sun drying of cassava tubers is followed.
	c. Glucosinolates	Rapeseed and mustard seed meal is being used in limited quantity.
	d. Estrogens	Heat treatment is being effectively used in industry to produce soybean meal.
4	Phenols	
	a. Gossypol	Cotton seed meal is rarely used in limited quantity in poultry feed.
	b.Tannins	Indian sorghum does not contain tannins. Other ingredients are used in restricted quantity.
5	Phytate	Phytase enzymes are commercially available and are being used.

S N0.	Anti-nutrient substance	Practical method of detoxification
6	Erucic acid	Rapeseed and mustard seed is used in limited quantity.
7	Argemone	Detect argemone and avoid argemone containing rape and mustard seed meal.
8	Mimosine	Subabul (*Leucaena*) leaf meal is used rarely and in restricted quantity.
9	Nimbidins	Neem seed meal is not used for poultry.
10	Nitrates and Nitrites	Not a noticeable problem.
11	Oxalates	Not a noticeable problem.
12	Antivitamins	
	Antivitamin A	Heat treatment is being effectively used in industry to produce soybean meal.
	Antivitamin D	Heat treatment is being effectively used in industry to destroy rachitogenic property of soybean meal.
	Antivitamin E	Kidney beans are not used in poultry feeds.
	Antivitamin K (Dicumarol)	Sweet clover not used in poultry.
	Antivitamin B_6 (Linatin)	Linseed meal is not used much in poultry. If used, supplemental B_6 may be used.
13	Non-starch polysaccharides	Commercial poly enzymes may be beneficial.

CHAPTER EIGHT

Nutrient Requirements and Specifications for Poultry

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Nutrient Requirements

A normal chicken requires about 50 nutrients. Nutrient requirements can be expressed on as fed basis or dry matter basis. In this book, they are expressed on as fed basis, unless otherwise specified.

i. Water
ii. Energy (the nutrient function)
iii. Protein, amino acids (20)
iv. Fatty acid (1)
v. Minerals (at least 13)
vi. Vitamins (13)

Figures in parentheses are the number of nutrients required.

Water

The water requirement is dependent on

i. Age
ii. Functional status
iii. Environmental temperature
iv. Other factors

Water is given to the birds *ad libitum*. Usually, birds drink water double the quantity of feed. In summer, this can be more than three times the quantity of feed. Water is not restricted to the birds, except under special circumstances, i.e. for initiation of molt in certain programmes.

Energy

The intake of energy by a chicken is governed by

i. Energy content of the diet
ii. Productive state
iii. Nutritional adequacy
iv. Other factors

The nutrients (protein, amino acids, fatty acids, minerals and vitamins) can be expressed at any energy content of the diet, practically feasible. Broilers are given high energy feeds (2700-3100 kcal ME/kg feed). The feed for chicks and growers contains about 2600-2900 kcal ME/kg feed and layers about 2300-2700 kcal ME/kg in India. Different agencies have given nutrient requirements at different energy concentrations. The nutrient requirement data given is converted to the following energy content for different categories of chicken.

Broiler starter	2800 kcal ME/kg	Broiler finisher	2900 kcal ME/kg
Chicks and growers	2700 kcal ME/kg	Layers	2500 kcal ME/kg

Protein (amino acids), Fatty acid, Minerals and Vitamins

The requirements for these nutrients differ depending on

i. Bird type
ii. Functional status of the bird
iii. Energy content of diet.

Protein (amino acids)

Some amino acids have to be provided in diet as the chicken cannot synthesize them or they do so inadequately. Such amino acids are called essential amino acids. Amino acids required but synthesized in the body adequately are known as non-essential amino acids. Among the essential amino acids, certain amino acids are likely to be low in practical feeds and these are known as critical amino acids. Among the critical amino acids, lysine and methionine are the most deficient amino acids and are known as limiting amino acids.

Non-essential amino acids	Essential amino acids		
	Essential amino acids	*Critical amino acids*	*Limiting amino acids*
Alanine	Lysine	Lysine	Lysine
Asparatic acid	Methionine	Methionine	Methionine
Glutamic acid	Methionine + cystine[1]	Methionine + Cystine[1]	Methionine + Cystine[1]
Hydroxyproline	Tryptophan	Tryptophan	
Proline	Threonine	Threonine	
Glycine + Serine	Arginine	Arginine	
	Isoleucine	Isoleucine	
	Leucine		
	Valine		
	Histidine		
	Phenylalanine		
	Phenylalanine + tyrosine[2]		

[1]*The requirement for cystine can be met by cystine or methionine.*
[2]*The requirement for tyrosine can be met by tyrosine or phenylalanine.*

Fatty acid

Linoleic acid is considered in practical diet formulation.

Minerals

Several factors influence the requirements of minerals. These are:

i. Breed of the chicken
ii. Age of the chicken
iii. Animal adaptation
iv. Level of production
v. Chemical form
vi. Interrelation with other elements

The essential minerals are given in following table. Usually, calcium, nonphytin phosphorus, sodium and chlorine requirements are met from the contribution from the diet as well as mineral supplements. Trace minerals are added, as trace mineral mixture, well above the requirement ignoring the contribution from the ingredients. The minerals to be supplied in diet are known as critical minerals.

Essential minerals*	Critical minerals	Remarks
Major minerals		
Calcium (Ca)	Calcium (Ca)	
Phosphorus (P)	Phosphorus (nonphytin) (NPP)	
Sodium (Na)	Sodium	
Chlorine (Cl)	Chlorine	
Magnesium (Mg)		Not deficient in practical diet
Potassium (K)		Not deficient in practical diet
Sulphur (S)		Not deficient in practical diet
Trace minerals		
Manganese (Mn)	Manganese (Mn)	
Zinc (Zn)	Zinc (Zn)	
Iron (Fe)	Iron (Fe)	
Copper (Cu)	Copper (Cu)	
Iodine (I)	Iodine (I)	
Selenium (Se)	Selenium (Se)**	

** Many more minerals are now considered as essential.*

*** Few nutritionists don't put selenium under critical mineral category.*

Vitamins

The vitamins A, B_2, D_3, K and B_{12} are to be supplemented in the feed disregarding their contribution from the feed ingredients. The B complex group of vitamins are supplied at different levels for different categories of chicken. Usually, the diets of broilers and chicks are supplemented with thiamin, niacin, pyridoxine, pantothenic acid, choline and vitamin E. Folic acid and biotin are supplemented occasionally. Layer diets are not always supplemented with the above vitamins.

The list of vitamins to be supplemented in diet is shown in following table.

Essential Vitamins	Critical Vitamins		Remarks
	Chicks	Layers	
Fat soluble vitamins			
Vitamin A	Vitamin A	Vitamin A	
Vitamin D_3	Vitamin D_3	Vitamin D_3	

Essential Vitamins	Critical Vitamins		Remarks
	Chicks	Layers	
Vitamin E	Vitamin E		Improves immunity. Addition may be beneficial under stress conditions.
Vitamin K	Vitamin K		
Water soluble vitamins			
Thiamine (Vitamin B_1)			Not deficit in practical diets
Riboflavin (Vitamin B_2)	Riboflavin (Vitamin B_2)	Riboflavin (Vitamin B_2)	
Pyridoxine (Vitamin B_6)	Pyridoxine (Vitamin B_6)	Pyridoxine (Vitamin B_6)	Feed ingredients may not supply adequate amounts.
Pantothenic acid	Pantothenic acid	Pantothenic acid	
Niacin	Niacin	Niacin	
Biotin			Feed ingredients supply sufficient biotin and folic acid for growth and egg production.
Folic acid			
Choline	Choline		Supplemental choline may be necessary to mobilise fat.
Vitamin B_{12} (Cyanocobalamin)	Vitamin B_{12} (Cyanocobalamin)	Vitamin B_{12} (Cyanocobalamin)	
Vitamin C			Improves immunity Beneficial under stress

Practical considerations in Feed Formulation

Energy, amino acids (protein), calcium, nonphytin phosphorus, sodium and chloride are given consideration in practical feed formulation. Nutrient requirements and specifications are discussed in relation to these nutrients. Trace minerals and vitamins are supplemented in the diets (See Tables 11 and 12).

Nutrient Requirements – Commercial Chickens

Agencies for the nutrient requirement data

The following agencies in India, UK and the USA, have given the standards for chickens and specifications for chicken feed (Table 1). The requirements and specifications set by the Bureau of Indian Standards, Agricultural Research Council (UK), National Research Council (USA) and Degussa (Germany) for important nutrients for chickens are given in Tables 2 to 6. These may have to be modified for some nutrients, depending on the experience, product desired and local environmental conditions.

Table 1. Nutrient requirements and specifications for chicken from different agencies

S No	Standard	Organisation	Remarks
1	ICAR (1985) Nutrient requirements of poultry	Indian Council of Agricultural Research nutrients to be useful	To be modified in respect of some for practical chicken feeding
2	IS: 1374 (1992) Specifications for poultry feeds	Bureau of Indian Standards (BIS)	
3	IS: 9863 (1992) Nutrient requirements of poultry	Bureau of Indian Standards (BIS)	
4	CLFMA (1995) Standards for chicken feeds	Compound Livestock Feed Manufacturers Association	
5	ARC (1975) The nutrient requirements of farm livestock No. 1 Poultry	Agricultural Research Council	Very old. May be considered
6	NRC (1994) Nutrient Requirements of Poultry	National Research Council	Widely practiced in the USA and elsewhere
7	Amino Dat 1.0 Total amino acids and true fecal digestible amino acids for broilers, turkeys and laying hens	Degussa (1996) Degussa. (2001)	Recent ones. Deals with amino acid requirements only. May be considered

Table 2. Nutrient requirements and specifications from different agencies – **Broiler Starter**

Nutrient	IS 1374:1992	ARC (1975)*	NRC (1994)*	Degussa (2001)*
Age (weeks)	0-6 week	0-4 week	0-3 week	Up to 3 weeks
Feed intake, g/b/d				
Moisture, %	11		10	
Metabolizable energy, kcal/kg	2800	2800	2800	2800
Protein, %	23.0	17.0	20.1	18.7
Arginine, %		0.93	1.09	1.19
Histidine, %		0.44	0.31	
Isoleucine, %		0.77	0.70	
Leucine, %		1.33	1.05	
Lysine, %	1.20	0.99	0.96	1.14
Methionine, %	0.50	0.43	0.44	0.50
Methionine + Cystine, %	0.90	0.83	0.79	0.85
Phenylalanine, %		0.77	0.63	
Phenylalanine + tyrosine, %		1.43	1.17	
Threonine, %		0.67	0.70	0.75
Tryptophan, %		0.19	0.18	0.19
Valine, %		0.89	0.79	
Linoleic acid, %	1.00	0.90	0.88	
Calcium, %	1.20	1.08	0.88	
Phosphorus, nonphytin, %	0.50	0.42	0.39	
Sodium, %		0.14	0.18	
Chlorine, %		0.13	0.18	
Sodium chloride, %	0.60			

**Calculated to the energy content of 2800 kcal ME/kg.*

Table 3. Nutrient requirements and specifications from different agencies – **Broiler Finisher**

Nutrient	IS 1374:1992 BIS (1992)	ARC (1975)*	NRC (1994)*	Degussa (2001)*
Age (weeks)	From 6 week	4-8 week	3-6 week	4-7 week
Feed intake, g/b/d				
Moisture, %	11		10	
Metabolizable energy, kcal/kg	2900	2900	2900	2900
Protein, %	20.0	14.6	18.1	18.1

Nutrient	IS 1374:1992 BIS (1992)	ARC (1975)*	NRC (1994)*	Degussa (2001)*
Age (weeks)	From 6 week	4-8 week	3-6 week	4-7 week
Arginine, %		0.71	1.00	1.16
Histidine, %		0.34	0.29	
Isoleucine, %		0.60	0.66	
Leucine, %		1.00	0.99	
Lysine, %	1.00	0.75	0.91	1.11
Methionine, %	0.35	0.34	0.34	0.47
Methionine + cystine, %	0.70	0.63	0.65	0.83
Phenylalanine, %		0.60	0.59	
Phenylalanine + tyrosine, %		1.09	1.11	
Threonine, %		0.50	0.67	0.73
Tryptophan, %		0.14	0.16	0.18
Valine, %		0.66	0.74	
Linoleic acid, %	1.00	0.94	0.91	
Calcium, %	1.20	0.70	0.82	
Phosphorus, nonphytin, %	0.50		0.32	
Sodium, %		0.11	0.14	
Chlorine, %		0.10	0.14	
Sodium chloride, %	0.60			

**Calculated to the energy content of 2900 kcal ME/kg.*

Table 4. Nutrient requirements and specifications from different agencies – **Chick Starter**

Nutrient	IS 1374:1992* BIS (1992	ARC (1975)*		NRC (1994)*	Degussa (1996)*
Age (weeks)	0- 8 weeks	0-4 wk	4-8 wk	0-6 week	Up to 6 week
Feed intake, g/b/d					
Moisture, %	11			10	
Metabolizable energy, kcal/kg	2700	2700	2700	2700	2700
Protein, %	20.8	16.4	13.6	17.1	17.8
Arginine, %		0.90	0.66	0.95	0.95
Histidine, %		0.42	0.31	0.25	
Isoleucine, %		0.74	0.56	0.57	
Leucine, %		1.28	0.93	1.04	
Lysine, %	0.93	0.96	0.70	0.81	0.83
Methionine, %	0.31	0.42	0.31	0.28	0.38
Methionine + cystine, %	0.62	0.80	0.58	0.59	0.73
Phenylalanine, %		0.74	0.56	0.51	
Phenylalanine + tyrosine, %		1.38	1.01	0.95	

Nutrient	IS 1374:1992* BIS (1992	ARC (1975)*		NRC (1994)*	Degussa (1996)*
Age (weeks)	0- 8 weeks	0-4 wk	4-8 wk	0-6 week	Up to 6 week
Threonine, %		0.65	0.46	0.64	0.57
Tryptophan, %		0.18	0.13	0.16	0.15
Valine, %		0.85	0.62	0.59	
Linoleic acid, %	1.04	0.87	0.87	0.95	
Calcium, %	1.04	1.05	0.65	0.85	
Phosphorus, nonphytin, %	0.52	0.41		0.38	
Sodium, %		0.13	0.11	0.14	
Chlorine, %		0.12	0.10	0.14	
Sodium chloride, %	0.62				

**Calculated to the energy content of 2700 kcal ME/kg.*

Table 5. Nutrient requirements and specifications from different agencies – **Grower**

Nutrient	IS 1374:1992* BIS (1992)	ARC (1975)⁺	NRC (1994)*		Degussa (1996)*	
Age (weeks)	9- 20 weeks		7-12 wk	13-18 wk	7-12 wk	13-20 wk
Feed intake, g/b/d		75				
Moisture, %	11		10	10		
Metabolizable energy, kcal/kg	2700		2700	2700	2700	2700
Protein, %	17.3	10.7	15.2	14.0	14.7	13
Arginine, %		0.60	0.79	0.70	0.79	0.69
Histidine, %		0.28	0.21	0.16		
Isoleucine, %		0.49	0.47	0.42		
Leucine, %		0.84	0.81	0.65		
Lysine, %	0.65	0.63	0.57	0.42	0.69	0.60
Methionine, %	0.27	0.28	0.24	0.19	0.32	0.30
Methionine + cystine, %	0.54	0.52	0.49	0.39	0.64	0.57
Phenylalanine, %		0.49	0.43	0.34		
Phenylalanine + tyrosine, %		0.91	0.79	0.62		
Threonine, %		0.42	0.54	0.34	0.47	0.41
Tryptophan, %		0.12	0.13	0.10	0.13	0.12
Valine, %		0.56	0.49	0.38		
Linoleic acid, %	1.08	1.00	0.95	0.93		
Calcium, %	1.08	0.40	0.76	0.74		
Phosphorus, nonphytin, %	0.54		0.33	0.28		
Sodium, %		0.07	0.14	0.14		
Chlorine, %		0.06	0.11	0.11		
Sodium chloride, %	0.65					

**Calculated to the energy content of 2700 kcal ME/kg. ⁺On feed intake of 75 g/b/d*

Table 6. Nutrient requirements and specifications from different agencies – **Layer**

Nutrient Age (weeks)	IS 1374:1992* BIS (1992)	ARC (1975)+	NRC (1994)+	Degussa (2001)+
Feed intake, g/b/d		110	110	110
Moisture, %	11		10	
Metabolizable energy, kcal/kg	2500			
Protein, %	17.31	16.5	13.64	16
Arginine, %		0.51	0.64	0.85
Histidine, %		0.17	0.16	
Isoleucine, %		0.55	0.59	
Leucine, %		0.68	0.75	
Lysine, %	0.63	0.75	0.63	0.80
Methionine, %	0.29	0.35	0.27	0.38
Methionine + cystine, %	0.53	0.47	0.53	0.71
Phenylalanine, %		0.39	0.43	
Phenylalanine + tyrosine, %		0.7	0.76	
Threonine, %		0.36	0.43	0.52
Tryptophan, %		0.17	0.15	0.15
Valine, %		0.55	0.64	
Linoleic acid, %	0.96	1.2	0.91	
Calcium, %	2.88	3.5	2.96	
Phosphorus, nonphytin, %	0.48	0.35	0.23	
Sodium, %		0.10	0.14	
Chlorine, %		0.09	0.12	
Sodium chloride, %	0.58			

** Calculated to the energy content of 2500 kcal ME/kg. + On feed intake of 110 g/b/d*

The nutrient requirement values from different agencies are highly variable. Therefore, it is difficult to arrive at any fixed set of nutrient levels for diet formulation.

Nutrient Specifications

Several factors influence nutrient requirements. These include

i. Breed and strain
ii. Bird type
iii. Sex
iv. Age
v. Productive state of the bird
vi. Energy concentration

vii. Digestibility of nutrients	viii. Management	ix. Environmental temperature
x. Anti-nutritional factors and toxins in feed	xi. Feed density	xii. Feed processing
xiii. Feed form	xiv. Deficiencies or excesses of nutrients	xv. Nutrient interrelationships and interactions
xvi. Water quality		

The requirement figures are the minimum requirements established under experimental conditions and do not include margins of safety. The nutrient requirements have to be increased by including safety margin to take care of the factors influencing the requirements. The safety margin may be more for certain nutrients that are relatively not expensive and which do not interfere with utilisation of other nutrients and performance of the animal and less for the costly amino acids and major minerals. The nutrient requirements plus safety margin may be termed as nutrient specifications.

Amino acids – Ideal amino acid profile

Amino acid interactions may exist, if consideration is given in feed formulation to meet their minimum requirements. Amino acid interactions may be due to amino acid imbalance, amino acid antagonism or amino acid toxicity. Amino acid interactions lower amino acid utilisation i.e. the nitrogen retention in the body.

Amino acid imbalance may be caused in diets formulated with conventional feed ingredients, without supplemental amino acids. In such diets, protein content is high with excess levels of some amino acids. The utilisation of the first limiting amino acid is reduced in poultry. Amino acids in excess compete with the dietary limiting amino acid for transport to the brain, causing reduced feed intake and consequent reduced performance. From a practical point of view, it is suggested to keep each amino acid at a level above the minimum requirement but not exceeding 1.5 times the requirement.

Amino acid antagonism is an interaction between structurally similar amino acids resulting in the precipitation of adverse effects. Lysine-arginine antagonism is well documented. Excess dietary lysine specifically impairs the utilisation of arginine, due to increased arginase activity, resulting in increased catabolism of arginine. The ratio of lysine to arginine may be 1: 0.9-1.5. Excess arginine is not a problem to be considered in practical feed formulation. Fortunately, situations of excess lysine are unlikely unless attempted deliberately or done by a mistake.

Amino acid toxicity is due to an individual amino acid. In practical diets, it is not encountered. Methionine is the most toxic amino acid.

If an amino acid profile is followed, as ideal ratios of essential amino acids to one reference amino acid (ideal protein or amino acid profile), for each category of birds, the ratios of amino acids remain rather stable avoiding interactions. Lysine is chosen as the reference amino acid. Considering the nutrient requirements of NRC (1994) and Degussa (1996, 2001), the ideal amino acid ratios in relation to lysine for different categories of chicken are given in Table 7.

Table 7. Ideal amino acid ratios in relation to lysine for different categories of chicken

Nutrient	Broiler Starter	Broiler Finisher	Chick Starter	Grower		Layer
Age	0-3 weeks	4-7 weeks	0-6 weeks	7-12 weeks	13-18 weeks	From 18 weeks
Metabolizable energy, kcal/kg	2800	2900	2700	2700	2700	2500
Protein, %	20.0	18.0	18.0	15.0	13.0	15.0
Lysine, %	1.10	1.00	0.95	0.70	0.60	0.75
Essential amino acid, % of lysine						
Arginine	110	110	110	110	110	110
Histidine	31	31	31	31	31	25
Isoleucine	73	73	73	73	73	87
Leucine	120	120	120	120	120	118
Methionine	42	42	46	47	48	46
Methionine + cystine	76	76	84	86	87	84
Phenylalanine	64	64	64	64	64	84

Nutrient	Broiler Starter	Broiler Finisher	Chick Starter	Grower		Layer
Age	0-3 weeks	4-7 weeks	0-6 weeks	7-12 weeks	13-18 weeks	From 18 weeks
Phenylalanine + tyrosine	118	118	118	118	118	120
Threonine	65	65	65	67	67	67
Tryptophan	18	18	18	18	18	18
Valine	80	80	80	80	80	101

Digestible amino acids

However, in an ingredient, the digestibility of different amino acids is variable as also is their digestibility in different feed ingredients. It is obvious that feeds are to be formulated on the basis of digestible amino acids rather than on total amino acids . For formulation on digestible amino acid basis, other books may be consulted (NRC, 1994: Haffner et al., 2000).

Crude fibre and acid insoluble ash

In some cases, the maximum levels may be set for crude fibre and acid insoluble ash.

Daily intake of nutrients

It is difficult to set the nutrient requirements on feed intake basis for growing chickens (broilers, chicks and growers), as this keeps on increasing. However, for layers, nutrient allowances can be set taking feed intake into consideration. The energy content is the prime factor that governs the feed intake.

Practical levels of nutrients

Considering the requirement figures given by different agencies, the amino acid ratios, the feeding practices in India and the experience of the author, the practical levels of nutrients in feed are given in Table 8.

Table 8. Practical levels of nutrient allowances for chicken on as fed basis (88% dry matter)

Nutrient	Broiler Starter	Broiler Finisher	Chick Starter	Grower		Layer
Age	0-3 weeks	4-7 weeks	0-6 weeks	7-12 weeks	13-18 weeks	From 18 weeks
Feed intake, g/b/d						115
Moisture, %	12	12	12	12	12	12
Metabolizable energy, kcal/kg	2800	2900	2700	2700	2700	2500
Protein, %	20.0	18.0	18.0	15.0	13.0	15.0
Arginine, %	1.21	1.10	1.05	0.77	0.67	0.83
Histidine, %	0.34	0.31	0.30	0.22	0.19	0.19
Isoleucine, %	0.80	0.73	0.69	0.51	0.44	0.65
Leucine, %	1.32	1.20	1.14	0.84	0.72	0.89
Lysine, %	1.10	1.00	0.95	0.70	0.60	0.75
Methionine, %	0.46	0.43	0.44	0.33	0.29	0.35
Methionine + cystine, %	0.84	0.78	0.80	0.60	0.52	0.63
Phenylalanine, %	0.70	0.64	0.61	0.45	0.38	0.63
Phenylalanine + tyrosine, %	1.30	1.18	1.12	0.83	0.71	0.90
Threonine, %	0.72	0.65	0.62	0.47	0.41	0.50
Tryptophan, %	0.20	0.18	0.17	0.13	0.11	0.14
Valine, %	0.88	0.80	0.76	0.56	0.48	0.76
Linoleic acid, %	0.96	1.00	0.93	0.93	0.93	0.87
Calcium, %	0.90	0.84	0.90	0.80	0.70	3.50
Phosphorus, nonphytin, %	0.45	0.42	0.45	0.40	0.35	0.30
Sodium, %	0.18	0.15	0.18	0.15	0.14	0.14
Chlorine, %	0.18	0.15	0.18	0.15	0.14	0.14
Choline, mg/kg	1300	1300	1300			

Protein *per se* is not important. Essential amino amino acids and sufficient protein or a source of nitrogen for the synthesis of non-essential amino acids in adequate amounts have to be present.

Phase Feeding

Egg type layers are maintained even up to 80 weeks of age. The production cycle of layers may be divided into 3 phases.

Phase (Age)	Egg production	Egg weight	Body weight
Phase I (Up to 36 weeks age)	Rises and reaches the maximum	Gradually increases	Gradually increases
Phase II (37 to 56 weeks age)	Production maintained	Gradually increases	Gradually increases
Phase III (From 57 weeks age)	Production declines	Gradually increases	Slightly increases

Some nutritionists believe that feed requirements are different during the different phases. Requirements of protein and amino acids are reduced particularly in phase 3. However, there is no scientific support for such phase feeding.

It is known definitely that the requirement of calcium increases while that of phosphorus decreases with each succeeding phase.

Nutrient Specifications – Breeder Chicken

Egg cost from a breeder is higher than from a layer. Therefore, breeders are given a more liberal supply of amino acids, essential fatty acids, minerals and vitamins than layers.

The requirements for egg type breeders and broiler breeders are different because of the differences in feed intake, body weight and probably digestibility.

Certain micro-nutrients are required more for breeders (for hatchability) than for layers. These are

Trace minerals	Fat soluble vitamins	Water soluble vitamins
Iodine	Vitamin E	Folic acid
Iron	Vitamin K	Pantothenic acid
Zinc		Pyridoxine
		Riboflavin
		Vitamin B_{12}

Egg type breeders

Egg type breeders are maintained up to 72 - 76 weeks of age, just like commercial layers..

Table 9. Nutrient specifications for egg type breeders on as fed basis (88% dry matter)

Nutrient	Chicks	Growers	Growers	Prebreeder	Female breeders	Male
Age (weeks)	0-6 wk	7-12 wk	13-18 wk	19 wk -		From 19 wk
Feed intake, g/b/d					105	80
Moisture, %	12	12	12	12	12	12
M E, kcal/kg	2850	2850	2850	2850	2700	2850
Protein, %	20.0	16.6	14.4	16.6	17.0	15.0
Arginine, %	1.16	0.85	0.74	0.85	0.94	0.77
Histidine, %	0.33	0.24	0.21	0.24	0.22	0.22
Isoleucine, %	0.76	0.57	0.49	0.57	0.74	0.51
Leucine, %	1.26	0.93	0.80	0.93	1.01	0.83
Lysine, %	1.05	0.78	0.67	0.78	0.85	0.70
Methionine, %	0.49	0.37	0.32	0.37	0.40	0.33
Methionine + cystine, %	0.89	0.67	0.58	0.67	0.71	0.60
Phenylalanine, %	0.68	0.50	0.42	0.50	0.71	0.44
Phenylalanine + Tyrosine, %	1.24	0.92	0.79	0.92	1.02	0.82
Threonine, %	0.69	0.52	0.45	0.52	0.57	0.47
Tryptophan, %	0.19	0.14	0.12	0.14	0.16	0.13
Valine, %	0.84	0.62	0.53	0.62	0.86	0.55
Linoleic acid, %	1.00	1.00	1.00	1.00	1.10	1.10
Calcium, %	0.90	0.80	0.7	2.00	3.5	0.6
Chloride, %	0.18	0.15	0.14	0.15	0.17	0.14
NPP, %	0.45	0.40	0.40	0.40	0.27	0.30
Sodium, %	0.18	0.15	0.15	0.15	0.16	0.15

Broiler breeders

Broiler breeders become obese and egg production would be less on *ad lib* feeding. Restricted or limited feeding is practiced in growers, female and male breeders. The limited quantity of feed is given based on body weight during growing period, and production; body weight and feed clean up time during laying period.

Broiler breeders are maintained up to about 68 weeks age.

Table 10. Nutrient specifications for broiler breeders on as fed basis (88% dry matter)

Nutrient	Chicks	Growers	Growers	Prebreeder	Female breeders	Male breeders
Age (weeks)	0-6 wk	7-12 wk	13-18 wk	19 wk -		Fm 19 wk
Moisture, %	12	12	12	12	12	12
Metabolizable energy, kcal/kg	2850	2850	2850	2850	2700	2850
Protein, %	19	16	14	16	16	14
Arginine, %	1.11	0.89	0.78	0.89	0.78	0.72
Histidine, %	0.30	0.24	0.21	0.24	0.21	0.20
Isoleucine, %	0.73	0.58	0.51	0.58	0.61	0.48
Leucine, %	1.29	1.03	0.90	0.96	0.85	0.78
Lysine, %	1.00	0.80	0.70	0.80	0.70	0.65
Methionine, %	0.46	0.37	0.32	0.37	0.32	0.32
Methionine + cystine, %	0.84	0.67	0.59	0.67	0.60	0.56
Phenylalanine, %	0.65	0.51	0.45	0.51	0.50	0.41
Phenylalanine + Tyrosine, %	1.19	0.95	0.83	0.95	0.83	0.77
Threonine, %	0.67	0.53	0.47	0.54	0.47	0.44
Tryptophan, %	0.19	0.15	0.13	0.15	0.13	0.13
Valine, %	0.78	0.62	0.55	0.63	0.65	0.51
Linoleic acid, %	1.00	1.00	1.00	1.00	1.10	1.00
Calcium, %	0.90	0.80	0.70	1.20	3.00	0.60
Chloride, %	0.18	0.15	0.14	0.15	0.17	0.14
Phosphorus, nonphytin, %	0.45	0.40	0.40	0.40	0.27	0.30
Sodium, %	0.18	0.15	0.15	0.15	0.16	0.15

References

ARC, 1975. The nutrient requirements of farm livestock No.1 Poultry. Agricultural Research Council, London, UK.

CLFMA, 1995. CLFMA standards for compound animal feeds. The Compound Livestock Feed Manufacturers' Association of India. 111, Mittal Chamber, 11th Floor, Nariman Point, Mumbai, 400 021, India.

Table 11. Supplemental Trace mineral allowances for poultry

Mineral	Commercial				Egg type Breeders	Broiler Breeders
	Broilers	Chicks	Growers	Layers		
Copper, mg/kg	8	8	8	8	12	10
Iodine, mg/kg	0.8	0.8	0.8	0.8	1.2	1
Iron, mg/kg	40	40	40	40	60	50
Manganese, mg/kg	80	80	60	60	120	100
Selenium, mg/kg	0.15	0.15	0.1	0.1	0.24	0.2
Zinc, mg/kg	60	60	60	60	90	75

Added to diet, ignoring the contribution from feed ingredients.

Table 12. Supplemental Vitamin allowances for poultry

	Commercial				Egg type Breeders	Broiler Breeders
	Broilers	Chicks	Growers	Layers		
Fat soluble vitamins						
Vitamin A, IU/kg	8000	8000	6400	8000	15000	10000
Vitamin D_3 ICU/kg	1200	1200	960	1200	3000	2000
Vitamin E, IU/kg	8	8	4	4	50	50
Vitamin K, mg/kg	1	1	0.8	1	3	2
Water soluble vitamins						
Biotin, mg/kg	-	-	-	-	0.2	0.2
Choline, mg/kg	250	250	-	-	500	500
Folic acid, mg/kg	-	-	-	-	2	2
Niacin, mg/kg	12	12	6	6	60	40
Pantothenic acid, mg/kg	8	8	4	4	20	20
Pyridoxine, mg/kg	1.6	1.6	0.8	0.8	5	5
Riboflavin, kg	5	5	4	5	15	10
Thiamin, mg/kg	0.8	0.8	0.4	0.4	3	2
Vitamin B_{12} mg/kg	0.02	0.02	0.02	0.02	0.03	0.03

Added to diet, ignoring the contribution from feed ingredients.

Degussa, 1995. Amino acid recommendations for poultry. Degussa AG.

Degussa, 1996[a]. Ideal protein in broilers: A new concept to optimise amino acid nutrition. IC-FA-AT/Feedb.Sp./P-6e/MP/03.96 Degussa AG.

Degussa, 1996[b]. The amino acid composition of feedstuffs. 4th rev edition. Degussa Feed Additives. Degussa AG.

D'Mello, J.P.F. 1994. Amino acid imbalances, antagonisms and toxicities. In: "Amino acids in Farm Animal Nutrition". Edit D'Mello, J.P.F. CAB International.

Feed Industry Red Book, 1998. Feed Industry Red Book. Zaworski, F. (Edit). Moffatt Publishing Inc. 200 N. Chestnut Street, Suite 100, Chaska, MN 55318, USA.

Haffner, J., Kahrs, D., Limper, J., de Mol, J., Peisker, M. and Williams, P. 2000. Amino acids in animal nutrition. Agrimedia GmbH, Spithal 4. D-29468 Bergen/Dumme, Germany.

ICAR, 1985. Nutrient requirements of livestock and poultry. Indian Council of Agricultural Research, New Delhi, India.

IS: (1374), 1992. Indian standard specifications for poultry feeds. Fourth revision. Bureau of Indian Standards, Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi, 110 002, India.

IS: (9863), 1992. Indian standard nutrient requirements for poultry. First revision. Bureau of Indian standards, Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi, 110 002, India.

Leeson, S. and Summers, J. D. 1991. Commercial Poultry Nutrition. University Books, Guelph, Ontario, Canada NH 6N8.

NRC, 1994. Nutrient requirements of poultry. National Research Council, National Academy Press, Washington, D.C., USA.

Ramasubba Reddy, V. 1996. Nutrient requirements of chicken – work done in India. Proc. World's Poultry Cong. New Delhi, India. pp 75-91.

Scott, M. L., Nesheim, M. C. and Young, R. J. 1982. Nutrition of the chicken. M. L. Scott & Associates, Ithaca, New York, USA.

CHAPTER NINE

Feed Formulation

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Introduction:

Feed millers and poultry farmers have following alternatives for feeding their birds:

1. Purchase of commercially prepared, complete compound feed
2. Purchase of commercially prepared protein supplement, mixed with vitamins and minerals, to be blended with locally available cereal grains
3. Purchase of commercially prepared vitamin – mineral premix, which may be blended with oilseed meals and cereal grains
4. Purchase of individual ingredients (including minerals and vitamins) and mixing the feed at farm

It is necessary to see that balanced feed formulae will supply all the essential nutrients for good health and production.

Feed formulation requires following information:

1. Composition of feed ingredients commonly used

2. Nature or type of feed
3. Cost and availability of feed ingredients
4. Ingredient inclusion levels and anti-nutritional factors
5. Acceptability and physical condition of ingredients
6. Nutrient requirements of poultry
7. Average daily feed consumption of birds
8. Interaction of nutrients
9. Environmental temperature
10. Cost of final products i.e. eggs and poultry meat

Following methods can do feed Formulation:

By hand calculation

It is possible to design simple diet by hand. The fewer nutrients such as metabolizable energy, crude protein, calcium, phosphorus, etc. taken into consideration. Limited number of feedstuffs can be used. But it is still long and tedious process to formulate a diet. This is because substituting one feedstuff for another changes all the nutrients in the diet. For a commercial diet with more than fifteen feedstuffs and ten nutrients to take into consideration, the possible number of combinations becomes almost infinite. If we then wish to make it least cost diet it becomes quite clear that we need to apply computers for this task.

By using Pearson square

If it is desired to achieve a set percentage of a nutrient in final feed using two ingredients only, Pearson square can be used. It is simple, direct and easy method. It permits quick substitution of feed ingredients in keeping price fluctuations, without disturbing protein content. It is a method of balancing protein requirement, with no consideration given to mineral, vitamin and other nutrient requirements. This technique can not be used for more than one nutrient and certainly cannot be used to formulate least cost rations.

By trial and error method

Feeds are interchanged by trial and error until the right combination is reached.

Simultaneous equation method

Rations are formulated by using two sources and one nutrient quickly through the solving of simultaneous equations. Two nutrients can be used.

The 2 x 2 matrix method

Matrix algebra provides quick and accurate way of solving for two nutritional parameters – like energy and protein – through use of two feed ingredients.

Computerized feed formulations

Advantages of using computer for feed formulation are as follows:

1. It helps to formulate a diet, which within the constraints given meets all the nutrient requirements at the least possible cost.
2. It rejects costly ingredients and tells us how much we can afford to pay for rejected ingredient.
3. It informs us about the constraint raising the price of the diet. It also shows how much price can be altered if these constraints are changed.
4. It gives complete picture of nutrient content of the ration, thus saving laborious calculation.
5. Diet can be compounded which do not meet 100 kg but meets all nutritional constraints. Filler can be added to make the total 100.

Trial and error formulation and **linear programming** are commonly used with computers for formulating the rations. The objective of trial and error method is to confirm the nutrient values for the ration based on the specific ingredients used by the feed manufacturer. The number of ingredients for specific ration are may be limited so that this technique is just as fast as linear programming to arrive at the desired nutrient levels in the ration. Spreadsheets are used for this purpose.

Many times, linear programming is refereed as least cost feed formulation. Maximizing net profit is the only true objective of this technique. In LP program large number of simultaneous equations are solved in such a way as to meet the minimum and maximum levels of nutrients and levels of feed ingredients specified by user at the lowest possible cost. It is necessary to understand the inner workings of computer program to use LP, but it will advantageous to avoid certain pitfalls.

For computerized feed formulation by linear programming, we will need to take following steps:

1. Enter tables of nutrient content of commonly used feed ingredients
2. Enter nutrient requirements of birds of different ages
3. Enter prices of feed ingredients
4. Enter limitations for usage of feed ingredients – both maximum and minimum
5. Submit all of the above information to the matrix building and solving portion of the LP software program
6. Examine solution provided by the program
7. Reprocess formulae with LP at periodic intervals depending on changes in ingredient costs, availability, FCR and nutrient requirements

Normally constraints for vitamins and trace minerals are not used, as it is possible to add a mineral-vitamin supplement to the final diet. It saves the time to compute the diet and will not result in any major saving to final cost of feed.

Effects of applied constraints while doing feed formulation are as follows:

- The main problem while considering constraints on individual feed ingredients is to achieve a compromise between using too many or too few constraints. When too many constraints are applied, the diet might as well have been compiled by hand as the computer is given too little scope. It may result in non-formulation of diet because specifications cannot be met. When too few constraints are used, diet may meet the nutritional requirements but would not be nutritionally acceptable.

- Consideration is given to individual amino acids (lysine, methionine, tryptophan), protein, ME, Calcium, phosphorus, CF, etc. Maximum and minimum levels should be used especially for cheaper nutrients like calcium or computer would select far too much of cheap ingredients which may not be nutritionally desirable.

- Normally diets are computed in mixes of one tonne but it is possible to provide nutrients within smaller mix and filler can be used to make sum total to one tonne.

- The next decision should be taken – are we interested in cheapest ration or the one, which will give greatest efficiency per unit cost? A high-energy ration will give better FCR as compared to low energy ration and high protein till certain level will be better than low protein diet. This is not easy to achieve, as individual animals will respond differently to diets fed.

- Generally the percentages or amounts of final feed formulation are rounded off which results in slightly increase or decrease in the cost of diet.

Selection of computer software and hardware package for feed formulation

Many companies market feed formulation software programs which ranges from simple to complex packages intended for feed manufacturers. It may include additional packages for inventory control,

control of use of ingredients in limited availability, production of feed tags, etc. These programs may be generalized so that can be used for all species of livestock or it may be designed for specific species. Computers are not able to assess effect of many variables like ingredient quality, environment or management.

Following are few examples of software programs available for Indian poultry farmers and feed manufacturers:

1. Simple excel based feed formulations from Central Avian Research Institute (CARI) and from Dr. D. Chandrasekaran, Veterinary College, Namakkal – suitable for poultry farmers
2. Sri Ayyaappa software program, Hyderabad – suitable for poultry farmers, hatcheries and small & medium feed manufacturers
3. Brill and Mixit software programs with add-on versions – suitable for medium & large feed manufacturers

Feed Formulation with Computer Software Program

Several software programmes are available for least cost feed formulation in India. The essentials of a software programme are the master files on the ingredients and feeds, and operational files. The master files on ingredients can be modified to add/delete the ingredients and their composition, and on feeds to add/delete the type of feeds and their specifications.

Steps in least cost feed formulation

Step	Activity
1	Open the nutrient requirements file.
2	Select the nutrient requirements of desired category of chicken.
3	Modify the nutrient requirements, if desired. For some nutrients, minimum levels have to be fixed: e.g. ME, CP, lysine, methionine, TSAA, sodium, chloride, Ca, P, etc. For some, the maximum level has to be fixed: e.g. Fibre, acid insoluble ash, sodium, chloride, etc.

4 Fix the levels of certain feed additives like antibiotic, coccidiostat, vitamins, trace minerals, growth promoters, and enzymes.

5 Select the feed ingredients available and set their maximum and minimum levels ingredients. Modify the price of ingredients.

6 Execute the formulae.

7 Check the nutrient content of the formulae in relation to the desired levels. Modify if necessary. Round off the ingredient content, if it is a fraction.

8 Save and/or print the out put.

Feed formulation with Microsoft Excel programme

In MS Excel programme, the feed ingredients and their composition are entered. The nutrient content and cost can be calculated. It can be compared with the specifications and may be modified. The critical nutrients may also be highlighted.

Feed formulation with Calculator

Steps in formulating feed manually by calculator are described briefly.

Step	Activity	Ingredient(s)/Additive(s)	Levels (%)		
1	Fix the nutrient requirements for the feed to be formulated				
2	Slack space for additives	Trace minerals, vitamins, antibiotics, coccidiostat, liver tonic, toxin binders etc	Broilers Chicks	Growers	Layers
			0.50	0.50	0.50
3	Slack space for	L-lysine HCl	Broilers Chicks	Growers	Layers
			0.05	0.05	0.05
4	Slack space for	DL-methionine	Broilers Chicks	Growers	Layers
			0.15	0.05	0.1
5	Slack space for	Common salt	Broilers Chicks	Growers	Layers
			0.4	0.4	0.4

Step	Activity	Ingredient(s)/Additive(s)	Levels (%)		
6	Slack space for	Phosphorus and calcium	Broilers Chicks	Growers	Layers
			3	2	10-12
7	Fix the level of animal protein (if included)	Dried fish, fish meal, meat meal, meat and bone meal, etc	Broilers Chicks	Growers	Layers
			Up to 10	Up to 10	Up to 10
8	Fix the levels for cereal by product(s) (May not be necessary for broilers)	Rice bran Deoiled rice bran Wheat bran	Broilers Chicks	Growers	Layers
			5-15	Up to 25	Up to 20
9	Calculate the nutrient contribution from ingredients in step 7 and 8 for	ME CP - lysine, methionine and TSAA Minerals – Calcium, Phosphorus and Sodium			
10	Calculate the levels of nutrients to be met from cereals and vegetable protein sources by subtracting the nutrients arrived in step 9 from the nutrient requirements fixed in step 1 for	ME CP - lysine, methionine and TSAA Minerals – Calcium, Phosphorus and Sodium			
11	Calculate the level of cereals and vegetable protein sources to meet the requirements by Pearsons square / algebraic equation / trial and error method for	ME and lysine	Broilers Chicks	Growers	Layers
			Cereals		
			50-65	Up to 50	Up to 55
			Vegetable proteins		
			Broilers Chicks	Growers	Layers
			30-35	20	25
12	Make adjustments in the level of cereal byproduct and lysine HCl for	ME and lysine			
13	Calculate the nutrients contributed from all ingredients for	ME CP - lysine, methionine and TSAA Minerals – Calcium, Phosphorus and Sodium			
14	Calculate the levels of DCP required and supplement it to meet the allowances for	Phosphorus			

Step	Activity	Ingredient(s)/Additive(s)	Levels (%)
15	Calculate the levels of calcium required and supplement LSP/shell grit to meet the allowances for	Calcium	
16	Calculate the levels of sodium required and supplement common salt to meet the allowances for	Sodium	
17	Calculate the levels of methionine and TSAA required and supplement it to meet the allowances for	Methionine and TSAA	
18	Supplement trace minerals, vitamins, antibiotics, coccidiostat, liver tonic, toxin binders etc		
19	Adjust the formulae by making slight changes in cereals / cereal byproduct to make the desired weight (usually 100)		
20	Calculate all the nutrients and cost of feed		

Broiler Starter Feed Formulation – Example:

Step 1 Fix the nutrient requirements for the feed to be formulated

Nutrient	Broiler Starter
Age	0- 3 weeks
Feed intake, g/b/d	
Moisture, %	12
Metabolizable energy, kcal/kg	2800
Protein, %	20.0
Arginine, %	1.21
Isoleucine, %	0.80
Lysine, %	1.10
Methionine, %	0.46
Methionine + cystine, %	0.84
Threonine, %	0.72
Tryptophan, %	0.20

Nutrient	Broiler Starter
Age	0- 3 weeks
Linoleic acid, %	0.96
Calcium, %	0.90
Phosphorus, nonphytin, %	0.45
Sodium, %	0.18
Chlorine, %	0.18

Step 2	Slack space for additives	0.50
Step 3	Slack space for L-lysine HCl	0.05
Step 4	Slack space for DL-methionine	0.15
Step 5	Slack space for common salt	0.40
Step 6	Slack space for Phosphorus and calcium	3.00
Step 7	Fix the level of animal protein (if included)	0.00
Step 8	Fix the levels for cereal byproduct: Rice bran	5.00

Step 9 Calculate the nutrient contribution from ingredients in step 7 and 8 for

Ingredient	ME	CP %	Lysine %	Methionine %	TSAA %	Calcium %	Nonphytin Phosphorus %	Sodium %
Rice bran 5%	140	0.645	0.030	0.013	0.027	0.004	0.011	0.004
Total	140	0.645	0.030	0.013	0.027	0.004	0.011	0.004

Step 10 Calculate the levels of nutrients to be met from cereals and vegetable protein sources by subtracting the nutrients arrived in step 9 from the nutrient allowances fixed in step 1 for

Ingredient	ME Kcal/kg	CP %	Lysine %	Methionine %	TSAA %	Calcium %	Nonphytin Phosphorus %	Sodium %
Cereals & vegetable protein sources (100-9.1=90.9)	2660	19.36	1.070	0.447	0.813	0.896	0.439	0.176

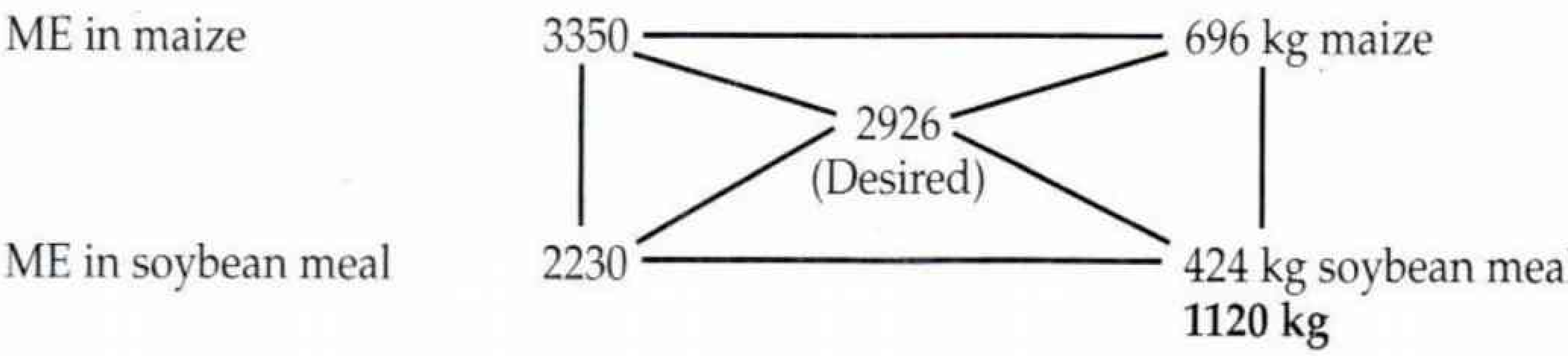
Step 11 Calculate the level of cereals and vegetable protein sources to meet the requirements by Pearsons square / algebraic equation / trial and error method for ME

Pearsons square method:

Total of cereals and vegetable protein sources = 90.9

ME (kcal/kg): 2660

ME as kcal/kg in cereal and vegetable protein mixture = (2660/90.9) * 100:2926



Enter the desired ME in the centre of square, the ME of maize and vegetable protein (soybean meal) in the left corners. The difference between ME of ingredients and desired ME is the ratio of maize and soybean meal to be mixed.

For 90.9 = 696/1120*90.9 = 56.5 kg maize
424/1120*90.9 = 34.4 kg soybean meal

Algebraic equation:

Total of ingredients	90.9 kg
Desired ME	2660 kcal

Let X represents maize and Y soybean meal.

X + Y	=	90.9	Equation 1.
33.50 X + 22.30 Y	=	2660	Equation 2.
22.30 X + 22.30 Y	=	2027	Equation 3 (Multiply the equation 1 with 22.3 or 33.5).

11.20 X = 633 Equation 4 (Subtract equation 3 from equation 2).

X = 633/11.20 = 56.5 kg maize

Y = 90.9 – 56.5 = 34.4 kg soybean meal

Step 12 Make adjustments in the level of cereal byproduct and lysine HCl for lysine and ME

Step 13 Calculate the nutrients contributed from all ingredients for

ME Kcal/kg	CP %	Lysine %	Methionine %	TSAA %	Calcium %	Phosphorus %	Sodium %
2800	21.31	1.126	0.318	0.664	0.115	0.149	0.018

Step 14 Calculate the levels of DCP required and supplement it to meet the allowances for Phosphorus. Calculate the calcium supplied from DCP

Phosphorus requirement to be met = 0.45% – 0.149% = 0.301%
DCP required = 0.301/17% = 1.77 kg
Calcium supplied from DCP = 1.77*22% = 0.389%

Step 15 Calculate the levels of calcium required and supplement LSP/ shell grit to meet the allowances for Calcium

Calcium met from ingredients and DCP = 0. 115 + 0.389 = 0.504%
Calcium requirement to be met = 0.90 – 0.504 = 0.396%
LSP/shell grit powder required = 0.396/35% = 1.13 kg

Step 16 Calculate the levels of sodium required and supplement common salt to meet the allowances for Sodium

Sodium met from ingredients = 0.02%
Sodium requirement to be met = 0.18 – 0.02 = 0.16%
Salt required = 0.16/37% = 0.43 kg

Step 17 Calculate the levels of methionine and TSAA. Supplement methionine in quantity to meet the requirements of methionine or TSAA, which ever is to be met in higher proportion?

In the case given, methionine is supplemented to meet the requirements of TSAA

	Methionine %	TSAA %
Met from ingredients	0.318	0.664
Requirement to be met by supplemental methionine	0.46 – 0.318 = 0.142	0.84 – 0.664= 0.176

TSAA met from ingredients = 0.664%
TSAA requirement to be met = 0.84 – 0.664 = 0.176%
Methionine required = 0.176/98% = 0.180 kg

Step 18 Supplement trace minerals, vitamins, antibiotics, coccidiostat, liver tonics, toxin binders etc

Additives	**Quantity, kg/100kg**
Trace minerals	0.100
Vitamin mixture (AB2D3K+Bcomplex+E+C+B12	0.060
Coccidiostat	0.050
Antibiotic	0.050
Liver tonic	0.050
Toxin binder	0.200
Enzymes	0.050
Total	0.560

Step 19

Adjust the formulae by making slight changes in cereals/cereal byproducts to make the desired weight (usually 100). The total weight came to 99.74. Adjust to 100 by increasing rice bran from 5.0 to 5.26%

Step 20

Calculate all the nutrients and cost of feed

Ingredient	kg/ 100 kg	ME Kcal/ kg	CP %	Lysine %	Methi- onine %	TSAA %	Calcium %	NPP %	Sodium %	Rate Rs/kg	Cost Rs/ 100 kg
Rice bran	5.03	141	0.649	0.030	0.013	0.027	0.004	0.011	0.004	4.00	20.12
Maize	56.50	1893	4.80	0.147	0.102	0.203	0.011	0.045	0.011	5.00	282.50
Soybean meal	34.40	767	15.86	0.949	0.203	0.433	0.100	0.093	0.003	10.50	361.20
DCP	1.77						0.389	0.301		16.00	28.32
LSP/shell grit	1.13						0.396			1.00	1.13
Salt	0.43								0.159	2.00	0.86
Methionine	0.18				0.176	0.176				200.00	36.00
Trace minerals	0.10									28.00	2.80

Ingredient	kg/ 100 kg	ME Kcal/ kg	CP %	Lysine %	Methi- onine %	TSAA %	Calcium %	NPP %	Sodium %	Rate Rs/kg	Cost Rs/ 100 kg
Vitamin mixture (AB2D3K+B Complex+E+C+ B12	0.06									450.00	27.00
Coccidiostat	0.05									250.00	12.50
Antibiotic	0.05									100.00	5.00
Liver tonic	0.05									60.00	3.00
Toxin binder	0.20									30.00	6.00
Enzymes	0.05									200.00	10.00
Total	100	2801	21.309	1.126	0.494	0.839	0.90	0.449	0.177		796.43

CHAPTER TEN

Feed Milling Technology

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Introduction

Feed milling plants of higher capacity and innovative technology are now available to serve the increased livestock population. Today, developed countries are using high technology feed milling plants of capacities up to 200 tons per hour to produce livestock feed. The word "Livestock" includes dairy cattle, beef cattle, fishes, horses, pigs, poultry, etc. However this is mainly on poultry feed in the Indian context.

Going Ahead

Before a decision is taken actually to establish a feed mill, the promoter will need to carry out a SWOT analysis, i.e. Strength-Weakenss-Opportunity-Threat analysis, in the business environment. More specifically, the promoter will need to conduct a study of

i. Geometric boundary of operation
ii. Volume of market within the geometric boundary to arrive at the plant size
iii. Customer profile
iv. Competitors' activity
v. Availability of raw material in and around the location of the plant
vi. Availability of workforce
vii. Availability of infrastructure facilities like power, water, roads
viii. Economic feasibility given the investment, interest, operation costs and contributions from sale

Feed Milling Technology

Feed milling technology is essentially a combination of the following.

i. Nutritionally balancing feed using various ingredients
ii. Selection of machinery to process the feed, and
iii. The processing parameters

This implies that feed manufacturing technology is a balance between a nutritionist, an engineer and a process technologist.

Role of Nutritionist

The role of a nutritionist is to offer a balanced diet keeping in mind that the number of ingredients in a feed formulation should be as low as possible. Though economics is important, the numbers of ingredients need to be restricted. Use of too many ingredients may cause

i. Delay in batch weighing, eventually leading to errors in batch weighing.
ii. Difference in particle size after grinding arising out of different physical character of each ingredient eventually enhancing the possibility of segregation after mixing.
iii. Longer mixing time in the batch mixer.
iv. Non-uniform conditioning of feed when feed is being pelleted.
v. Larger space requirement for ingredient storage.

Also, selection of ingredients influences the output from the plant and the life of the machinery. For example when whole fish is used, grinding is difficult thus affecting output. Another problem in using fish is wear or tear because in whole fish (available in India) the sand silica content is high, because fish catch is sun dried on sea shores. Sand silica is a known abrasive material thus leading to heavy wear and tear on the machinery. Instead, soya in combination with synthetic amino acids can be used. Moisture also, may it be in fish or maize or any other ingredient, puts pressure on the output and on the wear.

Quality control both at the ingredient level and at the finished feed level is entirely in the scope of the nutritionist. A full fledged laboratory is inevitable to effectively manage quality control. The facilities required for the establishment of a laboratory are given in the chapter "Feed analytical laboratory".

Role of Engineer

The role of an engineer is to

i. Size the plant in terms of capacity/output
ii. Define the type of plant and the level of automation
iii. Define warehousing and storage
iv. Select the appropriate machinery and other infrastructure
v. Select an appropriate location keeping in mind the infrastructural requirements and the utilities required
vi. Install, run and maintain the plant and machinery

It is important that the engineer is conversant with different disciplines of engineering, like

i. Electrical: Maintenance and replacement of motors, switchgear equipment and cables
ii. Boiler: Water treatment, boiler operation and maintenance, steam line operation and maintenance of steam traps, pressure regulating valves, etc.
iii. Compressed air: Compressor maintenance, pneumatic cylinder maintenance and replacement, filter, regulator, lubricator maintenance and replacement
iv. Mechanical: Machinery and pumps maintenance and replacement
v. Electronic: Hardware and software of the batch weighing system and bag weighing machine
vi. Safety within the plant

It is essential to have a small workshop in the plant with some minimum machine tools like drilling machine, grinding machine, bench vice and a full set of hand tools.

Role of Process Technologist

A process technologist balances between the nutritionist and the engineer. The role of the process technologist is to

i. Aid the engineer in sizing the plant
ii. Aid the engineer in selecting the plant and making the plant layout
iii. Decide the capacity utilisation percentage of the plant
iv. Decide processing parameters like particle size reduction, mixing time, type of conditioning if feed being pelleted, quality of steam, type of pellet cooling
v. Quantity and quality of workforce
vi. Controlling costs like in electrical energy, steam, spares consumption
vii. Sanitation and pest control
viii. Inventory control
ix. Production planning
x. Environmental management and pollution control

Essentials of Feed Milling

The primary minimum requirements to establish a feed mill are as follows.

i. Developed and fenced land
ii. Buildings for warehousing
iii. Buildings for plant
iv. Building for laboratory and workshop
v. Buildings for boilers, power generating sets
vi. Housing facilities for workforce
vii. Weigh Bridge
viii. Plant and machinery

The primary minimum requirements to operate a feed mill are as follows.

i. Electric power
ii. Water

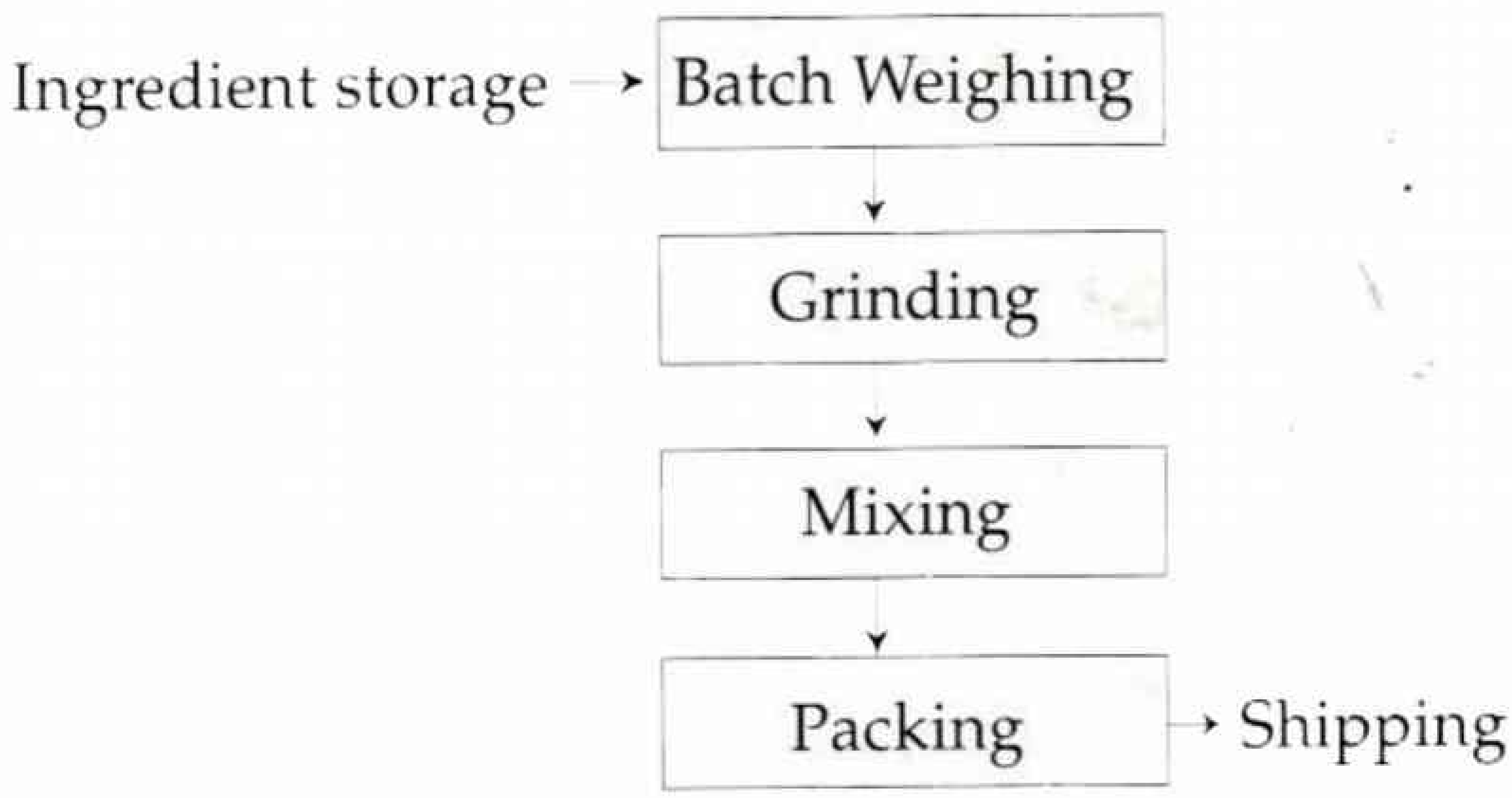
iii. Workforce men and material (skilled, semi-skilled, unskilled, clerical, managerial and technical)
iv. Canteen
v. Proper tools and tackles for maintenance
vi. Proper transport facilities to move
vii. Security staff
viii. First aid kit

Feed Form

Feed is produced and consumed all over the world in mash and pellet forms.

Mash Feed

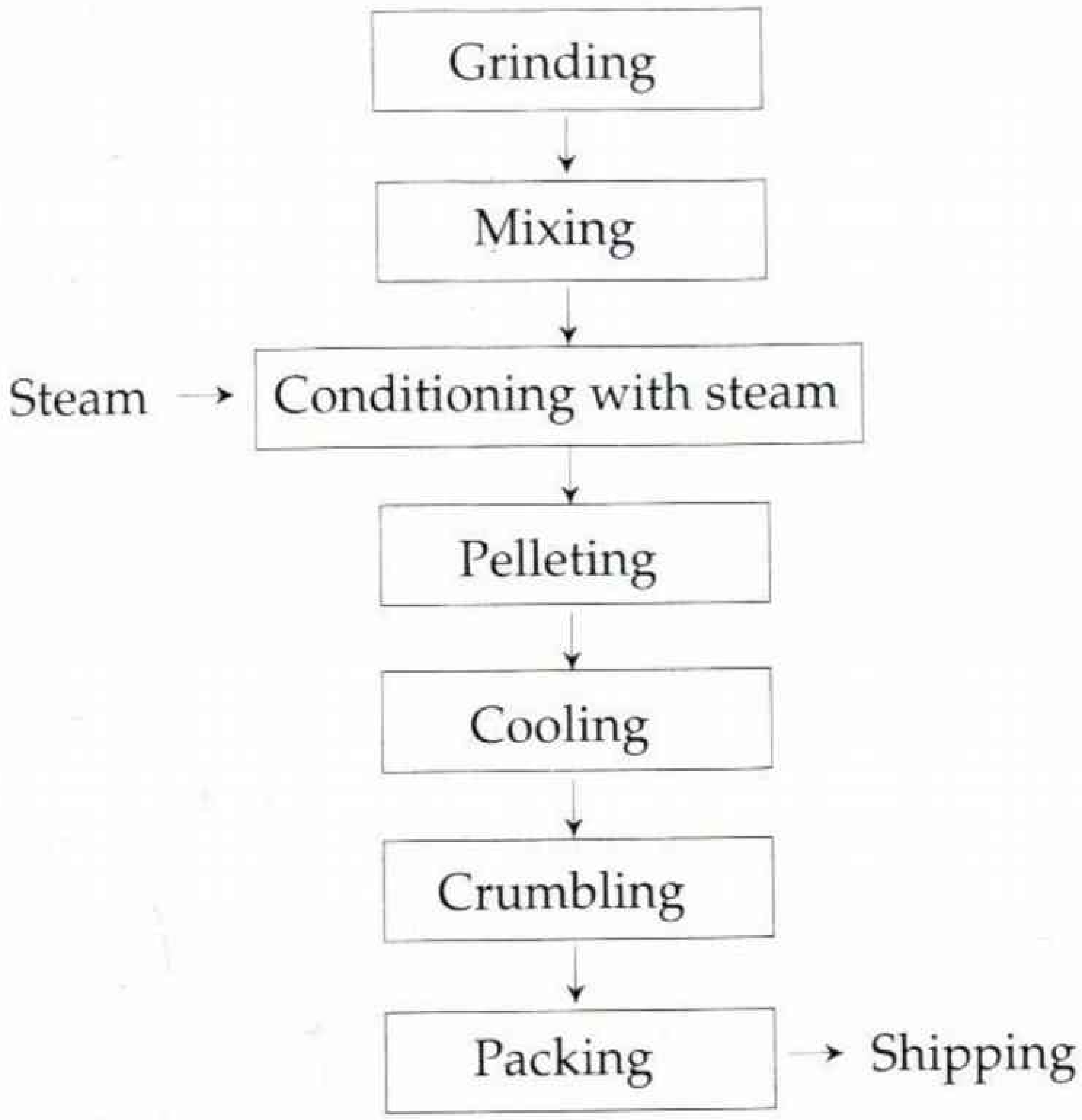
Mash feed is generally in the form of coarse powder. Mash feed production is a fairly simple process and involves.



The desired output governs the plant layout and level of automation.

Pellet Feed

Pellet feed is in the form of pellets of 3 and 5mm diameter for poultry. The pellet may be "crumbled" to reduce particle size to feed poultry in chick stage. Pellet feed production process is not as simple as mash feed production. The process primarily is the following.



Feed Milling Process

Primarily, the feed milling process consists of batch weighing, grinding, premixing and mixing.

Batch Weighing

Feed milling in a plant is a batch process. Batch weighing is weighing each ingredient as per formulation to constitute one batch of 1 ton (small plants) or 2 tons (large plants). In small plants, this may be manually done while in large plants, the weighing is done by an auto batch weighing system.

Grinding

Grinding is done to reduce particle size of ingredients. Particle size reduction helps digestive enzymes to act effectively. Grinding is to be coarse for mash feed while it is fine for pellet feed.

Pre-Mixing

In feed formulations there is often use of vitamins, medicines, growth promoters, etc. in very small or trace quantities. If these trace materials are added to the mixer as it is, there is always a chance of these not getting properly disbursed in the feed. To avoid this, the trace materials are first "pre-mixed" separately in an efficient small batch mixer to form a "pre-mix" and again mixed with another feed ingredient to form a larger portion of pre-mix. The pre-mix is then added to the main batch mixer to achieve uniform disbursement.

Mixing

In this process, all ingredients are properly mixed to provide a balance diet. Mixing is done in batches of one or two tons commonly. In certain cases, liquids are also mixed with dry, ground ingredients. Mixing time of each batch is a function of

a. Number of ingredients
b. Fineness of particles

While preparing mash feed, the mixed batch directly goes for packing.

Pelleting

Pelleting consists of conditioning and compaction.

Conditioning

Live steam is directly injected into feed to condition the mash feed. Poultry feeds contain almost 50% of maize (corn) and other cereal grains. By conditioning, the following effects are obtained.

i. Partial sterilization because feed reaches a temperature of about 85∞ to 90∞C
ii. Pre-digestion of feed: Maize starch is gelatinized because of steam cooking.
iii. Gelatinized starch is gummy, desirable to form a pellet as a binding agent.

Compaction to form pellet

The conditioned mash is compacted by forcing feed through a die by a set of rollers. The compacted feed while leaving the die is a cylindrical mass of desired diameter and is cut to desired lengths to form feed pellets.

Cooling

While leaving the die, the pellet has a temperature of about 90∞C and about 13% moisture. The temperature needs to be reduced to near about ambient temperature and the moisture to about 10% before packing. This drop in temperature, termed as cooling, is achieved through evaporation of moisture caused by drafts of air.

Packing

Packing is normally in bags of 50 to 70 kg. In certain cases, feed is directly loaded into bulk carrier without packing

Selection of Process

Before going for selection of machinery, it is necessary to freeze the capacity of plant and the process. The process is dependent on the ingredients and the type of finished feed desired.

If liquids are to be added, necessary arrangements need to be made in the machinery.

If feed is to be produced in pellet form, a provision for steam needs to be made available in the process.

Similarly depending upon capacity, the level of automation needs to be frozen. For output capacities up to 50 tons per shift (of 8 hours), batch weighing and bag packing can be manual. But beyond this, it is advisable to have automatic batch weighing and bag weighing.

Once it has been decided that auto batch weighing is required, then it becomes essential also to decide the number of storage silos required and the capacity of each storage silo. The number of silos depends on the maximum number of ingredients at any given time. Capacity of each silo depends upon the quantity of each ingredient in a formulation. Batch size (one or two tons commonly) also depends on the output capacity.

Selection of Plant and Machinery

Once the capacity, types of end products to be produced, level of automation and process have been frozen, one can commence selection of machinery.

For selection of machinery it is best to go by previous experience. When there is no previous experience, one may turn to the experience of other producers. Visits to exhibitions and fairs help a great deal. Various international magazines in the market can give an excellent insight into the latest machinery, their pros and cons. Dependence on consultants in this aspect may be kept at a minimum. Last but not the least, one may zero in on a reliable and experienced machinery/plant builder and give sufficient weightage to his advice. First preference can be given to indigenous plant builders. Only in case of non-availability of desired machinery in the local market, one may turn to imports. Some of the core machines in a feed plant are listed below with some tips on selection process.

Grinder – Hammer Mill

Grinding is a process to reduce particle size of feed ingredients. In poultry feed, the most commonly used grinder is the hammer mill with swinging hammers. Raw material is broken into smaller particles through the impact of the swinging hammers on them. Particle size of raw material leaving the hammer mill is dependent on the hole size of the screen used. Rating of motor on the hammer mill depends on the output capacity and the desired particle size. Power transmission from motor is either through a set of "V" belts or by direct coupling. Proper balancing of the hammer mill rotor is important to achieve vibration-free operation. Important aspects to be considered while selecting a grinder are:

i. Consistency of grinding fineness
ii. Output to power ratio
iii. Life of wearing parts
iv. Ease of changing screens, hammers and other frequently wearing out parts

v. Linear speed of hammers in terms of meters per second
vi. Vibration and noise levels

Consistency of fineness is more a function of uniform feeding into the grinder while output to power ratio is a design aspect. Therefore, one has to select an appropriate mechanism to uniformly feed the hammer mill. A vibratory feeder and a rotary vane feeder are commonly used mechanisms in combination. This mechanism is employed along with an infinitely variable device to vary the rate of flow from the feeding mechanism into the grinder.

Tips on Selection of Grinder and it's Feeding System

i. Grinder should preferably be at least 320^0 screen. A larger screen area will help in improving power to throughput ratio.
ii. Hammers should have a hardness of around 60 HRC to have better abrasion resistant properties.
iii. Motor directly coupled with grinder through a flexible coupling reduces power transmission losses, thus improving power to throughput ratio.
iv. Against this, a "V" belt power transmission "slips" and prevents motor damage in case of starting "on load".
v. Bearings should be preferably "spherical roller".
vi. The rotor should be perfectly balanced through dynamic or static balancing method to restrict vibrations to minimum.
vii. Feeding mechanism should be able to feed uniformly and continuously and not intermittently.
viii. Use preferably three phase, frequency variation type variable speed device.

Mixer

An efficient mixer is an acid test for a nutritionist's formulation. Only when all ingredients as per the formulation of a nutritionist are thoroughly mixed, the feed will prove worthy. A mixer is essentially a batch mixer. Various types of mixers are available in the market: vertical, horizontal paddle type, horizontal ribbon type, horizontal double shaft paddle type, etc. The most commonly used mixer is a ribbon type. Power rating of the motor depends on the batch capacity, design of internals and type of speed reduction during power transmission. The important factors to be considered while selecting a mixer are:

i. Power rating of prime mover
ii. Mixing time per batch
iii. Co-efficiency of mixing or co-efficiency of variance (CV)
iv. Clean out efficiency

Clean out means that there should be as less mixed feed as possible left in the mixer after emptying out the batch of feed.

Configuration of ribbons/paddles, RPM, method of speed reduction to achieve desired RPM, gap between moving piece and shell of mixer are some of the primary design aspects.

Type of mixer, mixing time per batch and CV is shown in Table 1.

Table 1. Type of mixer, mixing time per batch and CV

S No.	Mixer Type	Mixing time per batch (Minutes)	Typical CV
1	Vertical	20	>20
2	Paddle	08	12 to 15
3*	Ribbon (Double)	03	08 to 10
4	Double Shaft – Paddle	01	02 to 05

Tips on selection of Mixer

i. Only when two materials of similar densities are to be mixed, a vertical type mixer can be selected. A vertical mixer is comparatively inexpensive. It should not be selected only on this point.
ii. When multiple dry materials with varying densities and coarseness are to be mixed, it is preferable to select a ribbon type mixer.
iii. Though a double shaft paddle mixer is the best for mixing, it should be restricted for mixing of "pre-mixes" where very finely ground

multiple materials, sometimes even a liquid, need to be thoroughly mixed. Cost of this type of mixture is very high because it is practically a twin mixture. The mixing chamber is also much taller because space is required to fluidize the feed. The chamber of the entire mixer itself is more than two times that of a ribbon type mixer.

iv. In vertical mixers, only a "V" belt transmission is possible while in a double shaft paddle mixer, only a roller chain transmission is possible. However, in a ribbon type mixer, power transmission direct from the gearbox to mixer is preferable to reduce transmission losses. It is also preferable to incorporate a "on load" mixer starting mechanism, like a fluid coupling, when frequent power breakdowns occur.

v. Clean out of mixer is the best in a double shaft mixer because it has two, full length "bomb bay" type discharge doors

Pellet Mill with conditioner

In the pellet mill, the mixed feed is conditioned with steam in a conditioner and formed into pellets by pressing the conditioned feed through a die. Perfect mixing of steam with feed results in a consistent pellet. Power rating of the motor for the pellet press depends on the output capacity. Transmission of power from the motor to the pellet press can either be through "V" belts or through direct coupling with a gear box. However, majority of pellet presses today use "V" belts. To achieve an optimum output from the pellet press, it is important to have a well conditioned feed and a mirror finished hole in the die. Power rating of conditioner depends on its design. Design of conditioner is important to achieve proper mixing of steam with feed.

The important factors to be considered while selecting a pellet mill are:

i. Output to power ratio

ii. Design of conditioner

iii. Material of construction of die and rollers

iv. Process of manufacture of die, particularly method of hole drilling and hardening

v. Percentage of unpelleted feed (percentage of mash feed not converted to pellets)

vi. Stability or durability of pellets delivered

vii. Life of wearing out parts which directly corresponds to material of construction of each of these wearing out parts

viii. Ease of making roll to die gap adjustments

ix. Ease of lubricating all bearings

x. Ease of replacing die, roll shells, rolls, main bearings

Stability is a function of compaction capability and ingredients going in the feed formulation. Percentage of unpelleted feed is more a function of design of conditioner. Conditioning of feed with steam (a pelleting process) is very important. It has been proved that a good, experienced, operator only can extract the best out of a pellet mill. Some important factors influencing pellet quality and output that the operator needs to evaluate and implement are

i. Ratio of steam to feed

ii. Pressure and dryness of steam at entry

iii. Residence time in conditioning

iv. Gap between roller and die

v. Nutrient content of feed formulation (Starch percentage, fiber percentage, etc.)

Whenever pellet quality is in doubt, first point to the operator quality, then to the feed formulation and lastly to the machine.

Tips on selection of Pellet Mill

i. Good pre-conditioning of feed with steam is a very important factor to produce a uniform, good quality feed. Therefore, the conditioner design is very important. Design is a combination of conditioner diameter, angle of paddles and rpm of the paddles. The idea is to uniformly mix the steam with feed. To cope up with changes and feed formulations pellet diameter changes, it is preferable to have a paddle whose angle can be changed and a variable speed drive to vary rpm of the paddles. Material of construction of the entire pre-conditioner should essentially be stainless steel.

ii. Construction of the pellet mill should be very sturdy. A welded construction is preferable.

iii. Linear speed of the die should be around 7 m/sec.

iv. Die used should be made preferably from chromium steel and vacuum hardened to achieve longer life.

v. Die holes should preferably be "gun drilled" with mirror finish. This improves throughput dramatically.

vi. Adjustment between roller and die should be simple. This is a critical parameter to achieve good quality pellet.

vii. Mechanical over load protection, like shear pin is most essential.

viii. Automatic lubrication system to all bearings is preferable.

Pellet Cooler

The three types of coolers in the market are

i. Vertical column type
ii. Counter flow type
iii. Horizontal type

Cooling is achieved by passing draft of air through the pellets to evaporate moisture resulting in temperature reduction. In a counter-flow type cooler, air flows counter to the flow of pellets. This type of cooler is now in common use. The vertical column type cooler is an older version where air passes side to side through a vertical column of pellets. In a horizontal cooler, pellets move on a perforated belt within a long enclosure and air circulates in the enclosure.

In a cooler, warms feed pellets are expected to be cooled to a temperature about 2-3 ^{0}C above ambient. It is, however, very important to cool the pellets to the core. If the pellet is cool on the surface and the core is not cool, then the moisture from the core surfaces after a period of time. This phenomenon is called "sweating". Therefore, rapid cooling is not desirable.

As pellets entering the cooler are warm and moist, it is desirable to construct the cooler in stainless steel to prevent corrosion.

The selection of a cooler is to be done jointly by a process technologist and an engineer. While selecting a cooler, the factors to be considered are:

i. Residence time of pellets in the cooling chamber recommended by the manufacturer
ii. Quantity of air being used
iii. Material of construction
iv. Design of discharge mechanism, design of cyclone and efficiency of airlock
v. Design of the entire cooling chamber, particularly sturdiness and provision for internal cleaning
vi. Mechanism to automatically operate periodic discharge of cooled pellets from cooling chamber.

In India the most commonly used cooler in the feed milling industry is the counter-flow type cooler.

Pellet Crumbler

A crumbler is a machine used to crumble a whole pellet into smaller portions. Very young chicks cannot pick up and consume a whole pellets due to it sheer size. It is also not advisable to directly produce very small diameter pellet because of the economics of production costs. Therefore, a 4 mm diameter pellet is produced and crumbled. In a crumbler, pellets are passed through a pair of rolls, spaced at a certain distance and moving in opposite directions.

While selecting a crumbler, the design aspects to be considered are:

i. Material of construction of rolls
ii. Consistency of output in terms of size
iii. Percentage of fines generated during the process of crumbling.

However, percentage of fines can be directly attributed to fineness of grinding and level of compaction in the pellet mill.

Sifter

A sifter is a machine to *grade* the pellets by size. Sifters are available in various types like reciprocating, vibrating, etc. Typically, a sifter is fitted with a sieve of a desired opening size. The pellets/crumbs are let into the sifter from top of the sieve. Particles that pass through the sieve are diverted to one direction and those, that do not pass are diverted to another direction. Say the opening in the sieve is 2mm on which pellets of 3 mm dia are passed. Particles more than 2mm are *accepted* size and are diverted for packing while the particles that pass through the sieve are *not accepted* and are sent back to the process for pelleting once again. There can be a number of decks in a sifter, each deck having a sieve. In a single deck there is one sieve and can grade the feed pellets in two grades. Similarly, in a double deck, there are two sieves and can segregate feed in three grades.

While selecting a sifter, the factors to be checked are:

i. Sturdiness of construction because a vibrating motion or a reciprocating motion will subject the sifter to heavy shocks and uneven loads.
ii. Ease of sieve change and of cleaning
iii. Facility to increase/decrease vibration levels
iv. Efficiency levels

Material Handling Equipment or Conveying Equipment

Bucket Elevators

Buckets elevators handle feed and feed ingredients while conveying them vertically, even up to 40 mtrs. Typically, bucket elevators are buckets of around 250 mm wide fitted on a 300 mm wide belt or chain. Width of buckets varies depending on capacity of the elevator. Bucket elevators can be either single trunk or double trunk. Single trunk is a design where the up and down travel buckets/belt are enclosed in one single enclosure while double trunk is where these are enclosed separately. Each has it's own pros and cons.

Tips on selection of Bucket Elevator

i. Select a belt type bucket elevator and not a chain type.
ii. Select a centrifugal discharge type bucket elevator. However, ensure that linear speed is correct to minimise fall back of material during discharge.
iii. Belt tensioning unit should be at the bottom.
iv. Drive consisting of motor and gear box should be on top and power transmission through roller chain.
v. Pulleys to be rubber lined to reduce slip.
vi. At least one pulley should be crowned to ensure self centering of belt.
vii. Insist on a "U" trough type wear plate in the bottom boot to restrict accumulation of material in the boot.

Screw Conveyors

Screw conveyors handle feed and feed ingredients while conveying horizontally. Typically, a screw conveyor is a spirally formed sheet metal say to 300 mm diameter, welded on a central pipe. Diameter varies depending on capacity. A screw conveyor is used when horizontal conveying distance is not more than 5 meters.

Tips on selection of Screw conveyor:

i. Trough filling factor should never exceed 75%.
ii. Proper sheet thickness is used to construct the "U" trough, screw flights and central pipe.
iii. Hard facing of screw flights on the wear side to reduce rate of wear is preferable.

iv. Avoid any intermittent bearing between the two ends. Only ends should be rotating in bearings.

Chain Conveyors

Chain conveyors also handle feed and feed ingredients while conveying horizontally. A chain conveyor is preferred over a screw conveyor when horizontal conveying distance is beyond 5 meters. A chain conveyor can convey material horizontally even upto 100 meters. It can also convey material at an inclination when required. Typically, a chain conveyor is a series of flights welded on a chain link. The chain links are pinned together and rotate around sprockets provided on either ends. The flights move the material ahead in its linear motion.

Tips on selection of Chain conveyor:

i. Ensure that the chain conveyor is working on en-masse principle
ii. Use a good alloy steel forged chain.
iii. Specify construction parameters because wear and tear could be high.

Bins

Bin is equipment to hold feed or ingredients at various locations within the processing plant. Design of a bin and its hopper are very important aspects. The angle of inclination of the hopper should be calculated and constructed correctly to ensure that the material easily flows out of the bins without bridging. The angle of inclination is a function of angle of repose of the material being held in the bin.

Batch Weighing and Processing Control

A batch weighing and process control system consists of:

i. Weigh hopper mounted on load cells to physically weigh the produce

ii. A programmable logic controller (PLC) programmed to monitor and control batch weighing and the entire process

iii. A computer (CPU, monitor and key board). In the CPU, all data is stored for use during batch weighing using different types of feed formulations. Any changes in weighing and process control parameters are seen on the computer. The PLC serves as an interphase between computer and field.

In batch weighing the raw material is drawn from each of the silos, one at a time, and loaded into the weighing hopper, through a conveyor. When the batch weighing is triggered, the conveyor from the first silo starts loading the feed into the weighing hopper until 90% of the set weight is achieved (fast feed). After this, the conveyor automatically is switched into a "slow feed" rate (trickle feed) to ensure accurate weighing. Once the set weight is reached, the conveyor motor is cut off. After the conveyor of the first silo is switched off, the conveyor of the second silo in the set sequence starts, weighs and switches off. This process continues until the last silo as per the set sequence is switched off. At this point, the entire batch is considered to be weighed. The auto system now commands the weighing hopper to empty itself. Once empty, the weighing hopper is ready to weigh the next batch.

While selecting a batch weighing system, it is important to confirm the accuracy of weighments. This depends on the type and make of load cells being used. Also, it has to be ensured that the system has an auto "in flight" correction.

Process control is essentially the controls and checks at various points in the plant to operate discharge gates to check levels in bins etc.

Bag Weighing machine

Bag weighing machines are available in two types.

i. Mechanical machine using the conventional counter-weight method. In this machine, the numbers of moving parts are many.
ii. Electronic machine using load cells. These can be for either gross or net weighing.

In all weighing machines, feed is loaded into a weighing hopper from a feed bin, through a belt conveyor. When the weighing machine is triggered, the belt conveyor starts loading the feed into the weighing hopper until 90% of the set weight is achieved (fast feed). After this, the belt automatically is switched into a slow feed rate (trickle feed) to ensure accurate weighing. Once the set weight is reached, the belt conveyor motor is cut off.

While selecting a bag weighing, the accuracy of weighments have to be confirmed, which primarily depends on the type and make of load cells in case of a electronic machine. In a mechanical machine, the life of the moving parts has to be confirmed. Also, ensure that the system has an auto in flight correction. A net weigher is always preferred over a gross weigher.

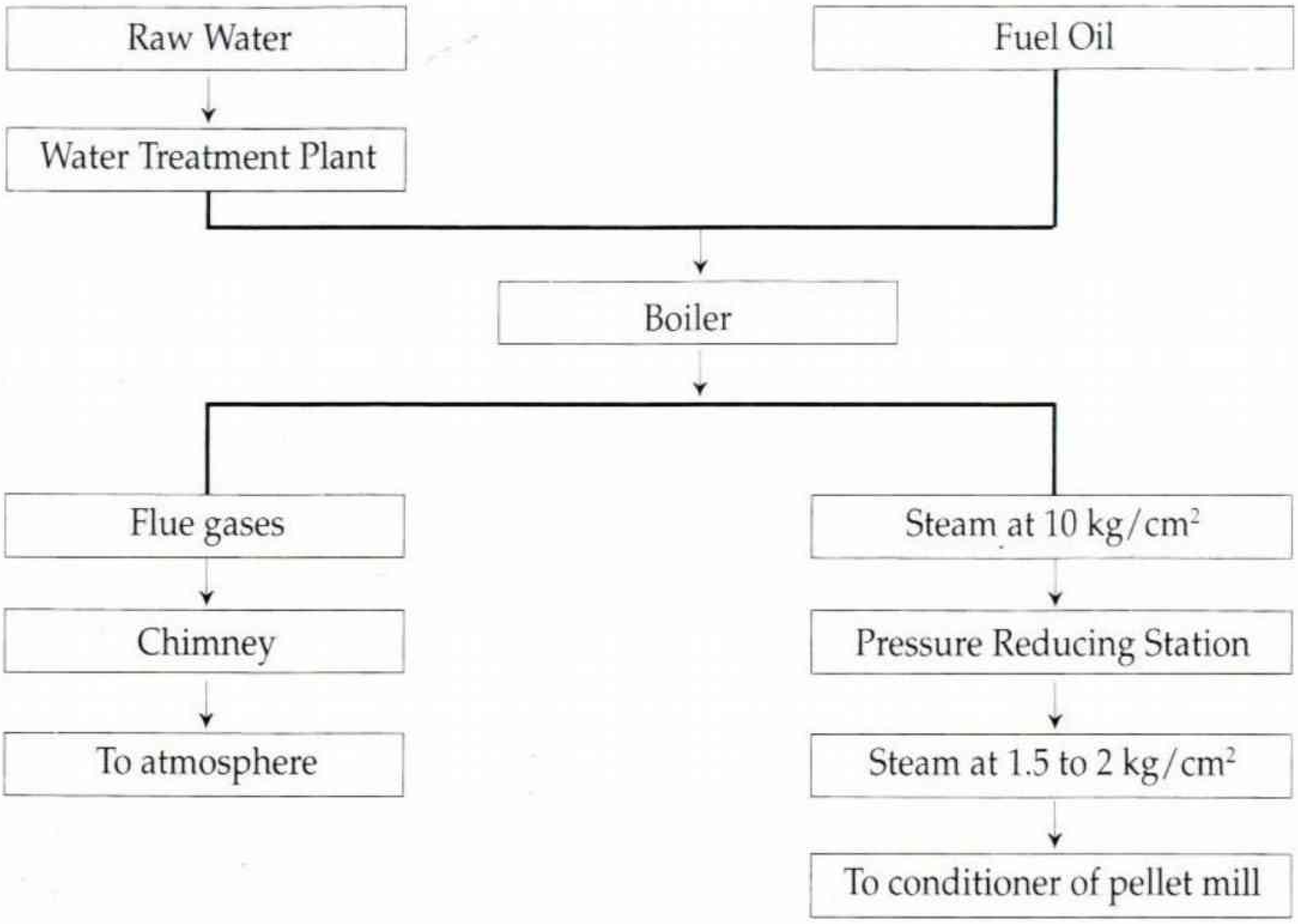
Boiler to produce steam

Boiler is an equipment to produce steam from water by boiling. Heating/boiling energy can be from oil, husk, coal, gas, etc. Types of boilers available are coil type, shell and tube type etc. Steam required in the pellet mill for conditioning of feed should normally be at 2 to 3 bar pressure with more than 95% dryness. While selecting a boiler, check the fuel availability and price in the vicinity of the plant. A coil type boiler is less expensive but may not be able to consistently deliver dry steam. Ensure that the boiler manufactures can guarantee the required dryness. Quality of steam and life of boiler will largely depend on the quality of water, particularly its hardness. The desirable water quality for boiler is given in Table 2.

Table 2. Desirable water quality for boiler

S.No.	Characteristics	Desirable
1	pH	8.5 - 9.5
2	Dissolved solids (mg/l)	400
3	Total Hardness as $CaCO_3$ (mg/l)	<5*
4	Alkalinity of methyl orange as $CaCO_3$ (mg/l)	<250
5	Chloride as $CaCO_3$	<30 ppm
6	Sulphate as $CaCO_3$	<300 ppm
7	Silica as $Si0_2$	<25 ppm
8	Iron as Fe	<0.1 ppm
9	Turbidity (NTU)	mg/1 (in silica scale)

Typical steam generation line



Accessories

Magnetic Separators

In feed ingredients, several ferrous impurities of various sizes are likely to enter. Ferrous materials are likely to damage machinery, and thus need to be separated. Logical and most effective locations in the feed mill need to be identified to locate the magnetic separators. The locations most essential to locate magnetic separators are

a. just before the grinder and b. just before the pellet mill.

A cascading hump type magnetic separator, using two or three permanent magnets is very effective. The magnets need to be cleaned out at regular intervals depending upon the quantity of ferrous impurities. Cleaning can be manual or automatic at regular intervals.

Fluid Coupling

This type of coupling is to transmit power (torque) gradually. This type of coupling is most commonly used in a batch mixer when starting of mixer on full load becomes necessary, for example, starting the mixer after a power failure which could have occurred during the process of mixing a batch of feed.

Variable speed drive

This drive is used when the speed of a particular machine needs to be varied regularly. It is typically used in the feeding equipment (grinder and pellet mill) to vary the quantity of feed entering. Feed output from a grinder varies depending upon the type of feed and the size of screen opening. Similarly, throughput from pellet mill varies depending on the type of feed and the hole diameter in the die. The drive can be mechanical or electronic. The most commonly used drive to day is a frequency variator type drive.

Dust Extraction equipment

In a feed mill, dust emission into the environment can some times be a major concern. At various dust generating points, it may become essential to install a dust extraction system. Typically, a dust extraction system is an air blower sucking fine dust from a defined area and passing it into a filter bag arrangement where the dust is filtered and clean air is released. Though this appears to be simple, the whole equipment needs to be properly designed to achieve desired results.

Storage

Storage in a feed milling operation is emerging as one of the important aspects of planning a feed mill. As quantities of feed from a single plant are increasing, the demand for storage space is also increasing. Storage can broadly be categorised into two parts: Raw material and finished product.

Within the category of raw material, a further categorisation can be grains, oil cakes, liquids (mostly viscous liquids like molasses and vegetable oil), and others. Of these, only grains can be stored in silos. Oil cakes and materials like rice bran cannot be stored in silos because of their combustible properties. Combustible items require being stored in places with good ventilation. Liquids can be stored either in over ground metal tanks or in under ground sumps made of brick and mortar.

In Indian conditions, all raw materials are received in bags. Therefore, storage in godowns is the most common and most preferred systems. Maize is also received in bags but as its quantities needed are huge and price fluctuations are enormous, may sometimes make economic sense to store maize in silos.

As silos are always in the open, these have to be constructed to withstand all weather conditions. The options available are steel and cement. The speediest construction undoubtedly is with steel while the most economic solution depends on the capacity of the silo. The most common material, however, is steel. Thin corrugated steel sheets are used to reduce steel tonnage and are galvanized to withstand all weather conditions. These are commonly identified as galvanized, iron, corrugated (GIC) silos.

Silos, both GIC and cement, are either hopper bottom or flat bottom. Normally small capacity silos of up to 50 tons are hopper bottom while larger capacity silos are of flat bottom. Silos are also provided with aeration facilities to improve storage life.

Godowns on the contrary can be constructed to desired length and width depending upon the desired storage capacity and space availability. Height may be decided based on number of stacks possible. High density raw material may be restricted to eight stacks while for low density raw material, which is comparatively easier to handle, the number of stacks can be higher.

For finished feed, normally a minimum storage period is recommended and thus preferable to have just sufficient stocks to last for about two-three days. In most Indian plants, feed is packed in jute bags and stored in godowns. In this type of storage, bags should not be stacked more in than four stacks. However in many advanced countries feed from plant is conveyed to a hopper bottom silo for loading into a bulk carrier. Here the capacity of each silo is normally restricted to 50 tons.

Prime Mover and Power Transmission equipment

Prime mover is always an electric motor. In India, a motor operates on 415 Volts, 50 Hz, 3 phase A.C. power. The rating of a motor is in terms of Kilo Watt (KW) of Horse Power (HP)

From the prime mover, power is to be transmitted to machinery. A large number of choices are available to transmit power, viz.

a. "V" belts – Normally used on higher rpm power transmission. Grinder, pellet mill and crumbler - all, use "V" belt transmission.
b. Roller chain – Normally used at lower rpm, high torque. Bucket elevators, screw conveyors, and chain conveyors – all, use roller chain power transmission.
c. Flexible coupling – Normally used where power transmission losses are to be minimised. Can be used in ribbon type mixers, grinders, etc.
d. Fluid coupling – Normally used where equipment needs a "soft start", for example when a mixer needs to be started "on load".

An important power transmission equipment is a "gear box". A gear box is a piece of equipment used to reduce speeds while transmitting power. The two types of gear boxes most commonly used in the feed milling industry are

a. Worm gear box b. Helical gear box.

In higher ratios of speed reduction, a helical gear box is used as transmission losses are very low. Transmission losses in worm gear boxes are higher, purely because of gear geometry. As a thumb rule, power transmission efficiency in a worm gear box is 100–ratio/2. Thus if the reduction ratio is 60 the 100-60/2=70 which simply means that if the prime mover is 10 HP the HP received after the reduction is only 7, a loss of 3 HP (30%)

On the contrary, a helical gear box is always more than 95% efficient that is transmission losses are only 5% for reduction ratios even up to 100.

Electrical Switchgear equipment

Switchgear equipment includes the following.

i. Switch fuse unit (SFU) which is used to switch electric power "on and off". The unit has a set of replaceable fuses, which blow in case of "excess" load.

ii. Circuit breaker is similar to the SFU but is used in higher power ratings.

iii. Motor starter. Broadly, there are three different type of motor starters, viz.

1. Direct–On–Line (DOL)– Used only up to 7.5 HP motor rating as current drawn on starting is extremely high (up to eight times of full load current rating of motor) thus exerting high load on an incoming line. Only one contactor is used in a DOL starter

2. Star-Delta – Used in motors of 10 HP and above even up to 150 HP. In this starter, the electrical circuit is initially in "star" and after a period of time switches over to "delta" circuit. This is primarily a two-stage starter to restrict initial high starting current to five-six times. In a star-delta starter, three contactors are used along with a delay timer to time gap between switching over from "star" to "delta".

3. Soft – Used in motor power rating 100 HP and above, sometimes even for 50 HP. In this type of starting current used is restricted to 2 to 3 times. The soft starter is essentially an electronic starting device.

iv. Overload initial. This is an instrument to "trip" the motor in case of an overload.

Pneumatics

Pneumatic means *operated by compressed air*. In a feed mill, pneumatic cylinders are used to operate diverter valves, discharge gates, etc. A cylinder consists of a piston rod moving in a bore. The rod is connected to the gate or valve that needs to be moved back and forth. The length that the gate or valve needs to be moved is the length of a stroke of the cylinder. The cylinder normally operates at 7 kgs/cm^2 pressure. As the piston rod is moving in a bore, there is heavy friction and thus the bore needs to be lubricated during every stroke of operation. The most common pneumatic line of operation is

Compressor Compressed air → Moisture separator → Air Filter → Line Lubricator →

Pressure regulator → Solenoid valve → Cylinder

Pneumatics can also be used in conveying materials. Pneumatic conveying can be of *dense* phase or *lean* phase. A typical pneumatic conveying system consists of a blower fan, a cyclone and an airlock.

Hydraulics

Hydraulic means operation by movement of liquids. A hydraulic cylinder is sometimes used in certain applications in place of pneumatic cylinder. Every aspect in a hydraulic system is similar to a pneumatic system except that here "oil pressure" is used in place of "air pressure". A power pack develops oil pressure like air pressure is developed in an air compressor. The line of operation is also more or less similar to a pneumatic line.

Plant Maintenance

This is probably the most important aspect in any process of plant operation. The primary requirements are

i. Trained personnel to handle all disciplines of engineering.
ii. Proper and accurate manuals for the entire plant and their parts, sub-assemblies, accessories, etc.
iii. Proper and adequate tools and tackles for access, testing, dismantling and reconditioning.
iv. Small workshop with a vice, drilling m/c, welding m/c etc.
v. Well drawn out maintenance schedule – Daily, weekly, monthly and annually.

vi. Well designed log book and other maintenance recording sheets.

vii. Well planned spares inventory.

Quality Control

Quality is a blend of ingredient selection, processing parameters and operator skills. Quality of feed can well be classified into

i. Nutritional ii. Physical

Nutritional quality in ingredients and in finished feed is commonly estimated by calculations and also by laboratory analysis. Also, in focus is the level in gelatinization in the conditioner of the pellet mill. However, some important physical quality parameters of finished feed and processing parameters are ignored, viz.

i. Uniformity of mesh size measured through a mesh sieve

ii. Uniformity of mixing, sometimes termed as coeffeciency of mixing or coeffeciency of variation.

   This is measured in the laboratory.

iii. Pellet durability. This is measured by a pellet durability tester available in the market.

iv. Dryness factor in steam. Needs to be periodically checked from time to time

v. Uniform conditioning of feed with steam – Uniform mixing of steam with feed helps in to improve durability of pellets. This needs to be periodically assessed from time to time

vi. Motor loading factor in pellet mill – 90% loading helps in improving compaction, resulting in pellet durability

New Trends

The grinding, mixing, conditioning, pelleting, cooling and crumbling is one of the most commonly used feed processing styles.

i. Livestock, poultry and aqua compete with humans for food. There is a need to explore the possibility of using non-conventional feed ingredients.

ii. As power and labour costs are steadily increasing, there is a need to improve output to power ratio and to reduce cost of labour per ton.

With these goals in mind, various new methods, machines and processes are being tried and employed. Some of them are

i. Extrusion ii. Compaction iii. Double pelleting iv. Expansion

Extrusion

Extrusion is a process used to prepare or enhance nutritive values of poultry feed ingredients. In the poultry industry, the extruder can also be put to use for handling hatchery wastes, slaughter-house waste, etc. The purpose of extrusion is to achieve

a. Cooking b. Expansion c. Sterilisation d. Dehydration e. Stabilisation

Operating principle - In this process, material is subjected to high friction and high shear in a short length barrel, through a series of screws and restrictions placed at regular intervals. The screws push the material ahead while the restrictions restrict the flow. The result is a high pressure and high temperature inside the barrel. The material is then released into the atmosphere through a nozzle.

The barrel is short and thus the temperature build up, up to 180 ^{0}C, is for a short period (less than 30 seconds), ensuring no significant destruction of nutrients.

Compaction

The compactor is a typical combination of compaction, shear and thermal treatment of the feed mixture for industrial manufacture of feed. The compactor is used in combination with a pellet mill and is placed before the pellet mill in order to improve pellet quality and hygienic state of the feed. Some feed mills use the compactor to produce sterile, compact, heat-treated mash feed bypassing the pellet mill to go directly to the cooler.

Operating principle - After a short time of conditioning with steam in an angle adjustable paddle mixer, the feed mixture enters the V-gap with a temperature of around 70 °C. The V-gap is created by two, precisely designed friction rings placed in opposing directions. In the V-gap, the mechanical friction and shear increases the temperature of feed. Temperature between 80 °C and 110 °C can be reached in the compactor. A set of three hydraulic cylinders is controlling the V-gap between the friction rings. Automatic adjustment of the gap between the friction rings controls the degree of compacting. The load on the main motor governs this automatic adjustment. As the feed is forced out of the V-gap, an uniform, sterile, thermal-treated, compact feed is received.

Benefits of using a compactor

i. Greatly enhances digestible values for fibre, fat, protein and starch
ii. Helps in controlling harmful organisms
iii. Improves product texture
iv. Better quality and durability of the end product – pellet or mash
v. Considerable reduction in wearing costs in pellet mill when used in combination
vi. Increase in output of pellet mill when used in combination

Double Pelleting

As the name suggests, the feed is passed through a pellet press twice. The idea is to induce frictional heat.

Expansion

This process is a milder form of extrusion. Here, it is also expected to enhance nutritive value of feed. A compaction pelleting combination improves and enhances output from a pellet mill.

Handy Information

Micron dimensions of Standard Sieves

Sieve Designation		**Opening**
Microns	**U.S. Std. Sieve No.**	**Inches**
4760	4	0.187
4000	5	0.157
3360	6	0.132
2830	7	0.111
2380	8	0.0937
2000	10	0.0787
1680	12	0.0661
1410	14	0.0555
1190	16	0.0469
1000	18	0.0394
840	20	0.0331
710	25	0.0280
590	30	0.0232
500	35	0.0197
420	40	0.0165
350	45	0.0138
297	50	0.0117
250	60	0.0098
210	70	0.0083
177	80	0.0070
149	100	0.0059
125	120	0.0049
105	140	0.0041
88	170	0.0035
74	200	0.0029
62	230	0.0024
53	270	0.0021
44	325	0.0017

1 micron = 0.001mm *1 inch = 25.4mm*

Bulk Densities of some commonly used Feed Ingredients

S.No.	Ingredient (Tons/m^3)	Bulk Density*
1	Maize	0.780
2	Soya flakes	0.480
3	Groundnut meal	0.580
4	Sunflower extraction	0.545
5	Rice bran	0.385
6	Deoiled rice bran	0.485
7	Rapeseed meal	0.610
8	Broken rice	0.785
9	Shell grit	1.100
10	DCP	0.730
11	Calcite powder	1.070

Bulk density is actually measured in one of the Indian feed processing company. It varies from place to place and season to season.

Units of Length			
Micron	1m	=	0.001mm
Millimetre	1mm	=	1000u
Centimetre	1cm	=	10mm
Decimetre	1dm	=	10cm
Metre	1m	=	10dm
Kilo metre	1km	=	1000m
Inch	1″	=	25.4mm
Foot	1′	=	0.305m
Yard	1Yd	=	0.914m
Nautical mile	1	=	1852m
Geographical mile	1	=	7420m
Units of Volume and capacity			
Cubic Millimetre	mm^3		
" centimetre	$1cm^3$	=	$1000mm^3$
" decimetre	$1dm^3$	=	$1000cm^3$
" meter	$1m^3$	=	$1000dm^3$
Litre	1 l	=	$1dm^3$
Hecto Litre	1hl	=	100 l
Cubic inch	1cu.in	=	$16.387cm^3$
Cubic Foot	1cu.ft	=	$28317c^3$
Gallon (British)	1	=	4.54 l

Power

Kilogram-force metre/second		
1kgfm/s		= 9.80665W
Kilowatt	1KW	= 1000W = 1000J/s
		= 102 kgfm/s (approx)
Metric horse power	1 HP	= 75kgfm/s
		= 0.748 KW
I.T. Kilocalorie/hour		= 1 $Kcal_{I.T/h}$ = 1.163W

Calculation of power consumption in a feed mill

Presume total connected power is 250 HP
and output capacity of plant 5 tons per hour

Convert HP to KW: 250 x 0.748 = 187 KW

Convert KW to kwh (power units) =187 KW x 1 hr = 187 kwh (units)

Thumb rule:
In actual 80% of total connected load is utilised

Convert calculated power units to 80% = 80% of 187
units = 150 units ie 150 units consumed per hour

Per hour power consumed: 150 units divide by 5 tons
per hour output = 30 units per ton

Pressure

Pascal	1Pa	= 1 N/m^2
Bar	1bar	= 100000 Pa
Atmosphere	1atm	= 1kgf/cm^2
	1atm	= 101325 Pa
Torr		= 101325/760 Pa
1kgf/cm^2		= 735.6mm of mercury

Units of Area

Square Millimetre	$1mm^2$		
" centimetre	$1cm^2$	=	$100mm^2$
" decimetre	$1dm^2$	=	$100cm^2$
" metre	$1m^2$	=	$100dm^2$
Are	1a	=	$100m^2$
Hectare	1ha	=	100a
Square Kilometre	$1km^2$	=	100 ha
" Inch	1 sq.in	=	$6.45cm^2$
" foot	1 sq.ft	=	$0.093m^2$
" yard	1 sq.Yd	=	$0.84\ m^2$
Acre	1	=	40.5 a

Units of Weight

Milligram force	1mgf		
Gram force	1gf	=	1000mgf
Kilogram force	1kgf	=	1000gf
Ton	1 t	=	1000kgf
Ounce	1	=	28.35gf
Pound	1lb	=	0.454 k
Long ton	1	=	1016kgf
Short ton	1	=	907kgf

Densities of some materials of construction

S.No	Material	Density
1	Steel	7.85
2	Aluminum	2.60
3	Brass	8.45
4	Copper	8.96
5	P.V.C.	1.40
6	Acrylic	1.15
7	Teflon	2.20
8	Paper/cloth	1.33

CHAPTER ELEVEN

Physical Evaluation of Feed Ingredients

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In the feed manufacturing process, evaluation of the feed ingredients is important for achieving consistent quality. If the quality of the ingredient can be assessed before it is unloaded from the truck, it would save both trouble and money. There are different types of evaluations.

Types of Evaluation

1. Physical 2. Chemical 3. Biological

Physical Evaluation

This is the easiest method and more rough in nature. All the five senses may be used to identify the changes in the quality of the raw material.

a. Sight

i. Colour

Change in the colour of the material gives an indication of the storage condition, maturity, contamination due to sand, possible use of insecticide or fungicides (dull and dusty appearance) and presence of toxins. In sorghum (jowar), orange to red colour sorghum is high in tannins and is not suitable for feeding birds. Dark varieties of jowar (grown in Maharastra) is lower in ME value than the white jowar. Dark brown variety of rape seed meal is more common than the greenish yellow variety; both varieties have the same nutritive value for poultry.

The fibre and oil content but not the colour (yellow to light brown and dark brown) determines the nutritive value of rice polish. Browning or blackening of the ingredient due to heat damage on improper storage reduces the nutritive value. High oil fish on storage turns black due to heating (oxidative rancidity).

ii. Size

Size of the grain is an indicator of the energy value. The smaller the grain, the lower the ME value, because of the increased proportion of the seed coat. Weight of a fixed number of grains can be used to evaluate the cereals (weight of 100 or a unit volume of grains). This technique is called test weight

iii. Homogeneity

The presence of contaminants like other grains, husks, broken grains, sprouted grains, weed seeds and weevil infested seeds will lower the nutritive value. Also, presence of feathers or fluff or rat or bird excreta may not only reduce the nutritive value but may also be a source of infection. Adulteration of oil seed meals with fibrous materials will lower the nutritive value and can be easily detected on close examination. In rice polish, contamination or adulteration with husk can be visually identified. Exposure to heat either during processing or due to storage can produce toxic products like gizerosine in fish meal or other biogenic amines in meat meal. Clumps or crystals in mineral ingredients are not suitable for premixing.

b. Smell

The mill manager should familiarise himself with the normal smell of the ingredients; any change in the smell should be viewed with suspicion. Sour odour is indicative of fermenting or mouldy grain or insect infestation. Musty odour indicates the presence of boring insects or fungal contamination. Odour similar to petroleum products is suggestive of excess of pesticides or fungicides. Rancidity in oil rich feed ingredients gives a characteristic smell. Heat damaged ingredients can be easily detected by their smell even when there is no visible change in colour. In good quality meat-cum-bone meal, the tallow smell is similar to that of ghee if it is of good quality and fresh. Leathery smell in meat-cum-bone meal indicates contamination or adulteration with leather meal.

c. Taste

Each ingredient has a different taste; any change in taste can be detected. Bitterness in grains, soybean meal, sunflower oil meal and groundnut meal indicates the presence of mycotoxins. The level of salt can be detected by tasting the ingredient and the feed.

d. Touch

Dryness and high moisture in an ingredient can be detected by feeling or touch. Clumps can be due to high moisture content or improper storage or due to packing immediately fresh warm solvent extracted meal. Those clumps due to packing of warm material crumble on application of light pressure, but those formed due to excess of moisture are hard. Rice polish retains the shape of fist if the crude fibre level is below 12%, and disintegrates if the fibre level is high. In broken rice containing bran, if a significant amount of the bran particles adhere to the palm, it is oil containing polish and the ME value will be higher but they cannot be stored for a longer period. If only a few particles are adhering, then the ME value will be lower.

e. Sound

The sound like spilling of coins when grains, especially of maize, are dropped indicates dryness. When the grain is bitten, a characteristic sound will be heard if it is dry.

Simple Physical Methods to Evaluate Feed Ingredients

Simple tests can be performed to evaluate the ingredients before unloading.

i. Test to assess sand level

The common contaminant or adulterant is sand. The percentage of sand can be estimated by mixing a weighed quantity of the grain with water, separating the grain, draining the water and weighing the sand.

ii. Test to assess husk level

Winnowing is the best method to detect husk in the feedstuff. Husk separated from a weighed quantity of the material allowed to fall against blowing light wind can be weighed.

iii. Sieving

Sieving differentiates contaminants based on particle size.

iv. Test Weight

This gives an idea of the bulk density of the ingredient. As bulk density increases, nutrient content also increases. A litre measure of the ingredient is weighed to arrive at the test weight or bulk density. For example in maize, the normal test weight is 725 to 775 kg/ m^3 or 725 to 775 kg/100 litres or one litre weighs 0.725 to 0.775 kg. Oil cakes have to be ground to pass through 1mm or 2mm sieve before performing test weight. The level of moisture also influences the test weight. The test weight of the ingredient estimated can be compared with a standard. The standards for the materials can also be developed in the mill itself by recording the test weights of the best material received in each category.

Commonly used ingredients and their salient features

Feed Ingredient	Checks to be made for	Common Adulterants	Mycotoxin/ANFs Occurrence
Maize	Freshness, Colour, Size, Moisture, Heat, Mouldy odor, Weevils Pesticide – Thiram Bulk density 0.725 to 0.775 kg/litre	Cobs and Cob dust, Sand	Aflatoxin, Citrinin Cyclopiazonic Acid Ochratoxin
Bajra	Freshness, Colour, Size, Moisture, Heat, Weeds, Sand and Silica Pesticide – Thiram Bulk density 0.72 to 0.76 kg/litre	Certified seed contamination, Sand	T2-toxin, Zeralenone NSPs
Jowar	Freshness, Colour, Size, Moisture, Heat, Sand Pesticide – Thiram Bulk density 0.70 to 0.77kg/litre	Certified seed contamination, Sand	T2-toxin, Zeralenone Sterigmatocystin Tannins, NSPs
Ragi	Freshness, Colour, Size, Sand Bulk density 0.70 to 0.75 kg/litre	Sand	NSPs, Mycotoxins

Feed Ingredient	Checks to be made for	Common Adulterants	Mycotoxin/ANFs Occurrence
Rice	Freshness, Colour, Mouldy odour, Sand, husk, Rancid odour Bulk density 0.70 to 0.775 kg/litre	Sand , Bran, husk	Aflatoxins, Ochratoxin
Wheat	Freshness, Mouldy odour, Sand, husk, weed seeds Bulk density 0.70 to 0.77 kg/litre	Weed seeds, husk, Sand	Aflatoxins, Ochratoxin, NSPs
Soybean	Freshness, Moisture, Clumps, Odour, Colour, Mould Growth, Bulk density 0.52 to 0.57 kg/litre	Sand & Silica Hulls (Fiber)	Aflatoxins, Trypsin inhibitors Emerging toxins, NSPs
Groundnut Cake	Freshness, Moisture, Colour, Heat, Odour, Clumps, Mould growth Bulk density 0.65 to 0.70 kg/litre	Hulls (Fibre) Sand, Other Cheaper oil seeds	Potential feed for Aflatoxins infestation, Ochratoxin
Sunflower Meal	Freshness, Moisture, Heat, Odour, Rancidity, Clumps, Mould growth Bulk density 0.50 to 0.53 kg/litre	Hulls (fibre) Sand	Ochratoxin, Aflatoxin B1, T2 toxin, NSPs
Rapeseed Meal	Moisture, Heat, Clumps, Mould growth Bulk density 0.65 to 0.675 kg/litre	Hulls (fibre) Sand	Aflatoxin B1, Glucosinolates
Dry Fish/ Fish Meal	Moisture, Oil, Sand, Other marine products Bulk density 0.725 to 0.775 kg/litre	Sand, Urea Salt, Other Marine products	Gizerosine
Rice Bran – Deoiled	Moisture, Heat, Smell, Roughness, Clumps Bulk density 0.35 to 0.40 kg/litre	Sand Husk, Fibre, Saw dust	Aflatoxin
Rice Polish	Moisture, Rancidity, Coarseness, Oiliness, Odour Bulk density 0.4 to 0.42 kg/litre	Rice bran Husk, Saw dust, Sand	Aflatoxin
Calcite	Moisture, Colour, Coarseness	Sand Magnesium	
DCP (Dicalcium Phosphate)	Moisture, Colour, Odour	Sand, Fluorine	
Mineral Mixture	Moisture, Colour, Odour	Sand, Magnesium	
Meat and Bone Meal	Moisture, Odour, Colour	Sand, Leather meal	Biogenic amines Microbial contamination
Shell Grit	Colour, Uniformity	Sand	

CHAPTER TWELVE

Immuno Modulation ThroughNutrition

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Introduction

Health is an important determinant of the flock performance, uniformity and survivable capacity through disease resistance. A strong immune system improves disease resistance. Many metabolic responses resulting from stress and oxidative damage can be deleterious to disease resistance. Several infections especially viral diseases such as IBD, CAV, MD, LL and REO viruses and mycotoxins, in the feed cause "Immunosuppression".

Effective vaccines are available against most viral diseases and some bacterial diseases. A wide range of anti-microbials, anti-fungal and anti-parasitic drugs are available to control infections caused by bacteria, fungi and parasites, respectively. The impact of chemotherapy and vaccinations on many complex diseases often fail to work because of drug resistance reaching a plateau and failure of vaccines. Immunomodulation (manipulation of immune system) is one of the most important alternatives as a supportive therapy or to induce natural resistance in birds. It may augment or decrease the magnitude of immune responsiveness. The augmentation of immune response is known as "immunostimulation" or "immunopotentiation". The decrease in responsiveness is termed as "immunosuppression". Several compounds are being used as "immunopotentiators or immunostimulants".

The main objectives of the immunomodulation are:

i. To induce effective and sustained immune response both humoral and cell mediated immunity

ii. To speed up the maturation of non-specific and specific immunity.

iii. To enhance local immunity

iv. To overcome the immunosuppressive effects of environmental stress or adverse condition

v. To maintain the immunological surveillance in neoplastic conditions

The immunomodulators are classified based on their origin and their functions into four categories.

i. Physiological Products
ii. Microbial Products
iii. Synthetic Compounds
iv. Herbal products

Physiological Products

These are the biological products derived from neuroendocrine hormones, thymic hormones, cytokines and glucocorticoids (Fig.1). The body response depends on the production capacity of these hormones. There are limitations in the use of these products in poultry.

The neuroendocrine hormones are small peptides, which include three distinct families of endogenous opioid peptides, enkephalins, endorphins from adrenal gland, which have an immunomodulating effect. The lymphocytes bear receptors for a wide variety of these endogenous substances.

Thymic hormones are also small peptides known to act on different subsets of T cells and contribute to maintain the immune functions. These are termed as thymesin a 1, thymesin b 4, thymulin, thymosin factor 5, thymic humoral factor and thymoprotein.

Cytokines, interferons, interleukins act as cellular messengers. These are essential for antibody production, increased cellular cytotoxic responses and altered trafficking.

Glucocorticoides regulate homeostatic mechanism of the body.

Microbial Products

Crude preparations of some microorganisms are used as immunostimulators enhancing both specific and para specific immunity

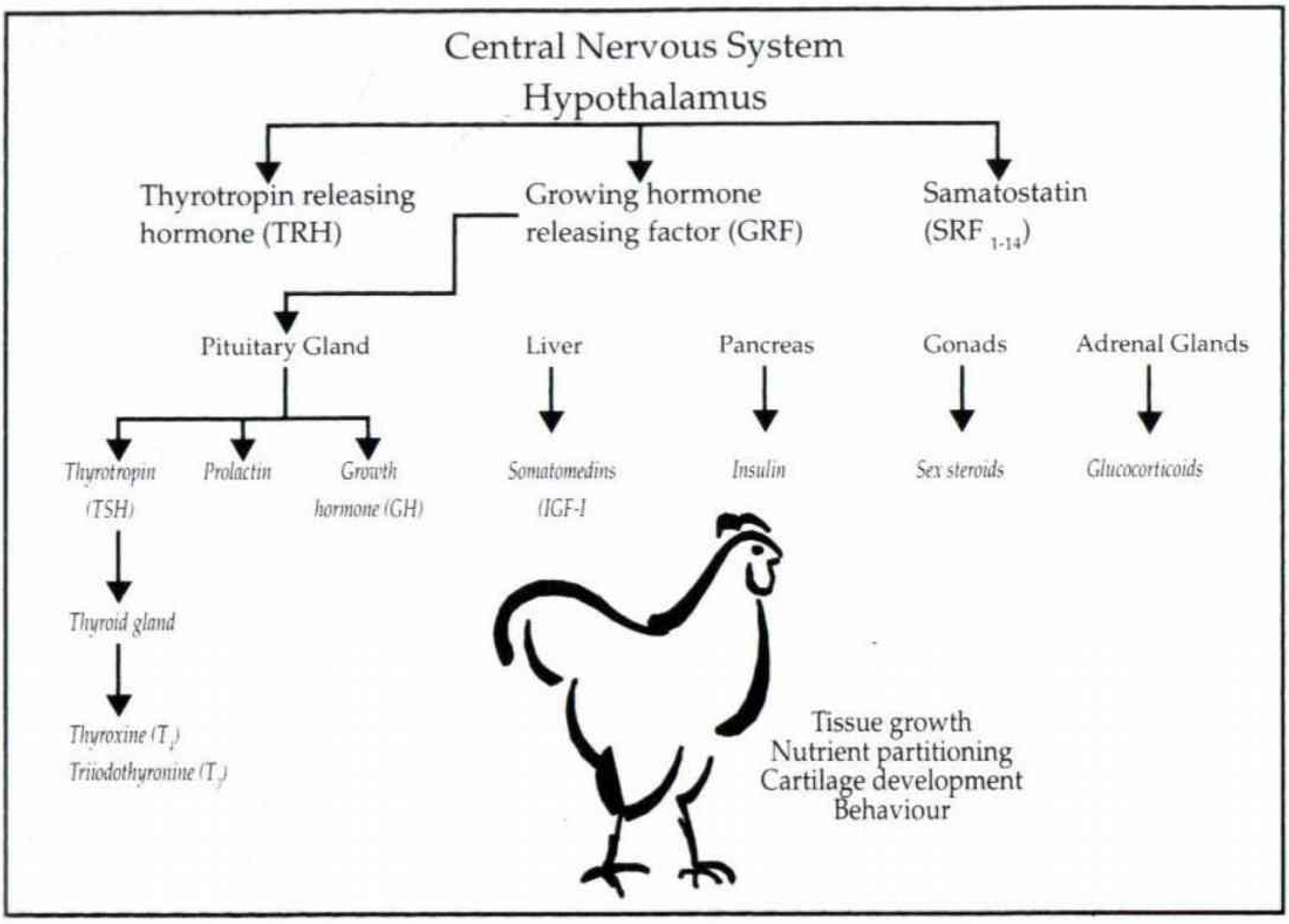

Fig.1: Hormones, growth factors and peptides involved in growth regulation of poultry (Johnson, 1989)

in poultry. Live microbial feed supplements beneficially affect the host by improving its intestinal microbial balance are called "probiotics". The probiotics in poultry feed improve local immunity. Antibiotics can be avoided or minimised by the use of probiotics.

Common probiotic organisms

Lactic acid bacteria	Other probiotic organisms
Lactobacillus acidophilus	*Bacillus subtilis*
L. sporogenes	*Bacillus toyoi*
L. bulgaricus	*Aspergillus oryzae*
L. plantarum	*Torulopsis*
Streptococcus faecium	*Bifidobacterium bifidum*
S. lactis	
S. thermophilus	
S.diacetilactis	

Mechanism of Action

i. Probiotic organisms inhibit the colonisation of pathogenic bacteria, such as coliforms, *Salmonella, shigella* and *Staphylococus* (competitive inhibition).

ii. Lactic acid producing bacteria like *Lactobacillus* acidophilus produce antibiotics like acidolin, acidophilin and lactin are highly effective against poultry pathogens, such as *E.coli, Salmonella, Shigella, Pasteurella* and *Staphylococcus.*

iii. The organisms produce organic acids such as formic acid, lactic acid and acetic acid, which help in decrease of pH and prevent multiplication of pathogenic bacteria in the gut.

iv. The organisms lowers the oxygen tension in the gut and some of the metabolites produced by the *Lactobacillus* organisms render the intestinal tract less conducive for the aerobic pathogenic bacteria.

Another biotechnological product from yeast called "Mannan oligosaccharide" (MOS) is postulated to increase macrophage activation by occupying the macrophage mannose receptor sites in the cell surface glycoproteins, which protrude from the macrophage cell surface membrane. Once three or more such sites are filled, a cascade effect is initiated, resulting in macrophage activation and cytokine release thus signifying the onset of the acquired immune response. These activated macrophages are more efficient in engulfing and destroying invading organisms. Besides, these are significantly more efficient in antigen presentation to antibody producing cells and MOS is thus capable of enhancing specific circulating and secretary in response to antigen exposure.

i. MOS improves disease resistance and maternal antibody transfer by enhancing the extent of uniformity of vaccine response

ii. Prevents gut colonization with enteric pathogens, thus reducing disease challenge

iii. Indirectly improves intestinal morphology and membrane integrity, thus enhancing nutrient digestion, absorption and performance

Synthetic Chemical Compounds

Synthetic chemicals include levamisole, synthetic polynucleotide isoprinosine, vitamin C, vitamin E and selenium. The effects of nutritional immunostimulators is given in Table 1.

i. Levamisole is commonly used as an anthelmentic, but in small doses it acts as an immunostimulant. It is has a marked effect on cellular immunity.

ii. Synthetic polynucleotide is a complex chemical of high molecular weight and found to augment natural killer cell activity, activating macrophage tumoricidal activity and stimulating T cells. It is also has an effect on antibody production.

iii. Isoprinosine is a synthetic immunomodulator having antiviral activity. It enhances lymphocyte proliferative response, augments lymphokine production and increases natural killer cell cytotoxicity.

iv. Nutritional stress is the most significant cause for oxidative damage that can be deleterious to disease resistance. Vitamin E and selenium are able to protect cells from this damage (Fig.2).

v. During stress corticosterone is secreted by pituitary gland and vitamin C levels in plasma fall. Vitamin C modulates corticosterone secretion. Vitamin C acts as an antioxidant by inactivating the highly reactive free radicals, which are associated with damage to both intra- and extra cellular structures. Vitamin C is involved in the regeneration of Vitamin E, the activation of Vitamin D_3 and formation of various hormones.

Herbal Immunomodulators

In ancient Indian Literature many herbs are described for strengthening of the body and to keep away diseases. Herbs, which are known to exert their immunomostimulatory properties, include:

Tinospora cordiofolia (Gudichi, Giloe)	Withania somnifera (Ashwagandha)	Asparagus racemosus (Satavari)	Emblica officinalis (Amla)
Piper Conguran (Pipali)	Terminalia chebula (Haritaki)	Borrhevia diffusia (Punarnava)	Acorus calamus (Vacha)

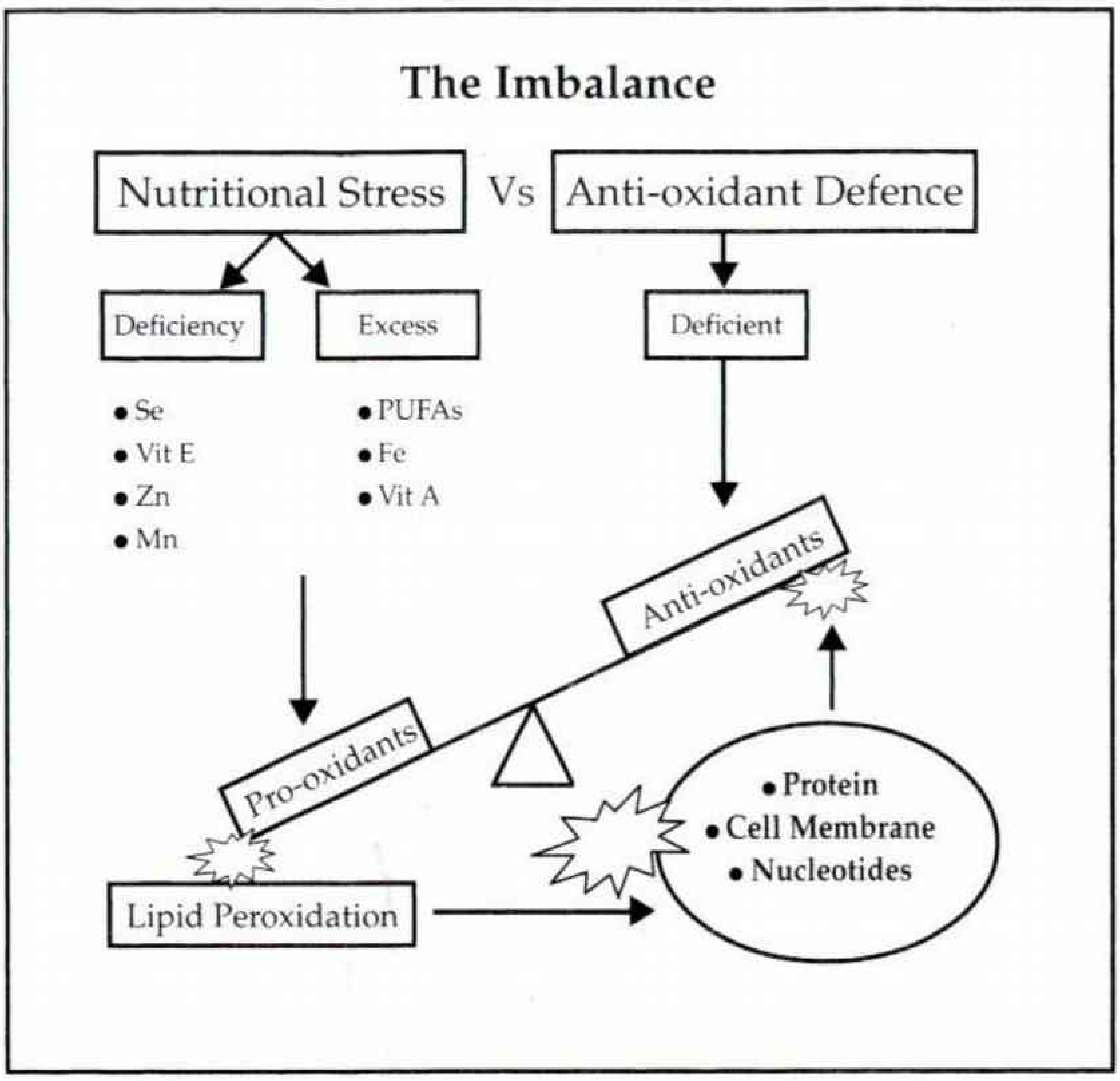

Fig.2. The relationship between nutritional stress and antioxidation (See also, Steve Collett, 2001)

References

Arthur, J, R, and Beckett, G. J. (1994) New metabolic roles for selenium. Proc. Nutr. Soc. 53: 615-624.

Flynn,A; Loftus, M. A. and Finke J.H. (1984) Production of interleukin-1 and IL-2 in alozymic mixed lymphocyte culture under copper, magnesium and zinc deficient conditions. Nutr. Res.4. 673-679.

Johnson, R.J. (1989) Growth physiology and biotechnology. Potential to improve broiler production. Worlds poultry science journal 46:228-240.

Reddy,P.G; and Frey RA (1990) Nutritional modulation of immunity in domestic food animals. Ad. Vet. Se. Comp. Med.35. 255.

Collett, S. (2000) New visions for poultry nutrition in the Asia-Pacific Region. Proc. of Alltech 14th Annual Asia-Pacific lecture tour. PP 19-35.

Table 1. Effects of nutritional immunostimulators

Immunostimulator	Dose	Remarks
Levamisole Hydrochloride	5-10 mg/bird for 1 d	Enhances the production of antibodies by stimulation of T-cells. It increases Bursa body weight ratio
L-lysine HCl	0.5-1.2% over requirement	Helps as an immunopotentiator
DL-methionine	0.1-0.2% over the requirement	
Vitamin C	100-150 mg/kg diet	Acts as an antioxidant by inactivating highly reactive free radicals. Alleviates stress, helps in synthesis of collagen. Maintains membrane integrity
Vitamin E	150-300 mg/kg diet	Vitamin E is a biologic antioxidant and free radical scavenger
Organic and inorganic selenium	0.25 – 0.30 mg/kg diet	The immunosuppressive effect of selenium deficiency appears to involve the response of T-cells, B-cells and macrophage activity. The selenium is also shown to enhance lymphocyte proliferation in response to nitrogen and antigens, T-cells cytotoxicity, natural killer cell activity and lymphocyte response
Zinc	30-60 mg/kg body weight	Zinc helps in enhancement of phagocytic response (CMI). Zinc is associated with enzymes involved in phagocytic oxidative burst, cellular maturation and functioning of B and T-lymphocytes cells and macrophages. Zinc deficiency is also known to alter thymic epithelial function and impair thymic hormone production, which in turn inhibits T-cell production. Zinc deficiency may affect T-cell proliferation by (a) depressing the production of cytokines, (b) interfering with the processing of antigen by accessory cell resulting in a loss of cell function or activation sites.

CHAPTER THIRTEEN

Feeding Management

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Commercial chickens are given complete feed, which is a nutritionally balanced, prepared to meet their nutritional requirements and compounded to feed as a sole source of nutrients, except for water.

Feeding management is dealt under

i. Form of feed
ii. Feeding programmes
iii. Economising feed cost
iv. Reducing feed wastage
v. Feed storage
vi. Feeding chicks
vii. Feeding replacement pullets
viii. Feeding commercial layers
ix. Feeding commercial broilers
x. Feeding egg type breeders
xi. Feeding broiler breeders

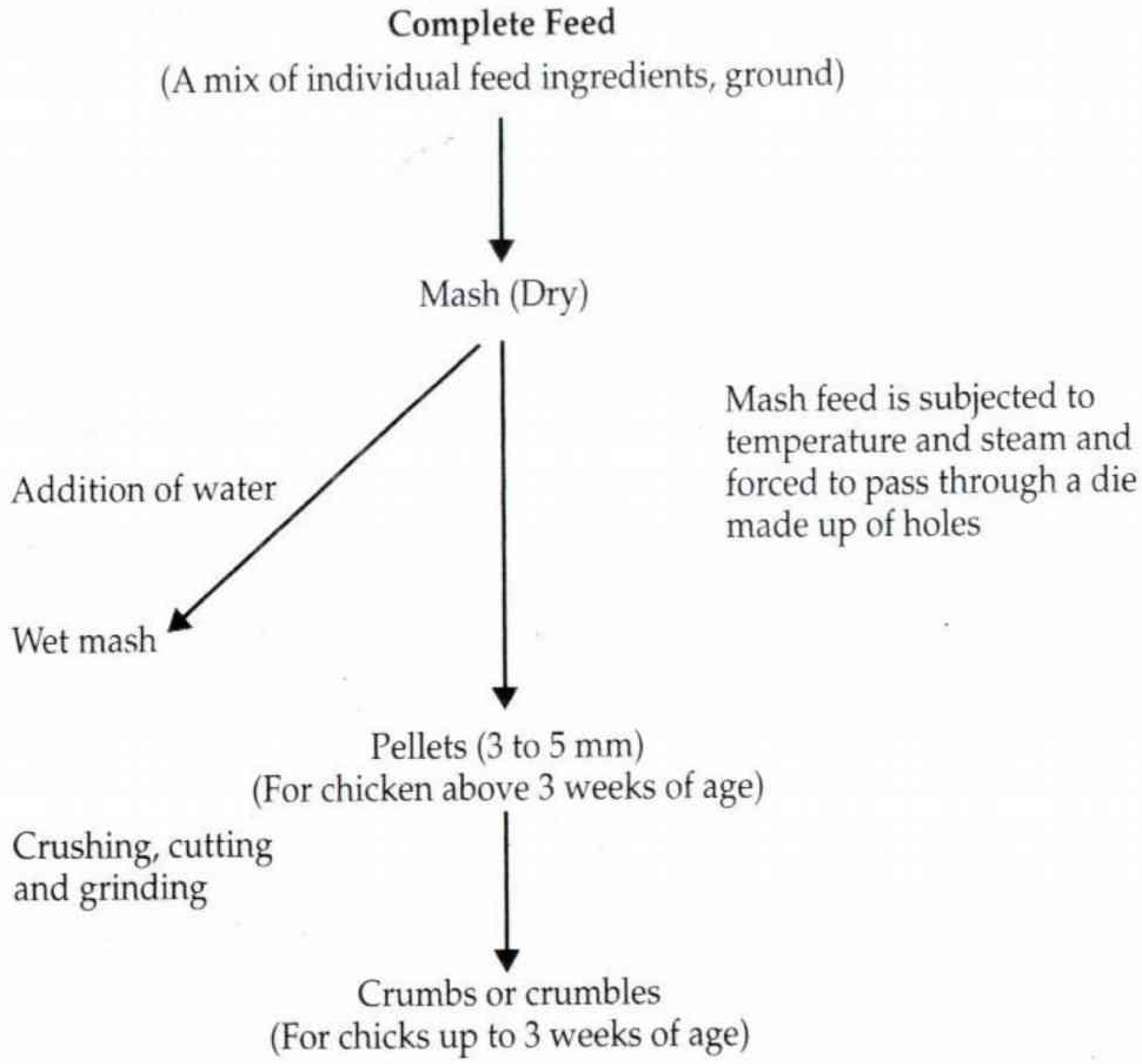
Form of Feed

Feed for poultry may be given in the form of

i. Mash   ii. Wet mash   iii. Pellets   iv. Crumbles

Dry mash and wet mash

Mash feeding is more popular for commercial chickens. Addition of water to mash results in wet mash, which is not popular. On small farms, wet mash feeding is practiced in summer.



Advantages of wet mash

i. Increases palatability
ii. Increases feed intake
iii. Reduces dustiness

Disadvantages of wet mash

i. Handling difficulty
ii. Prone to mould growth
iii. Requires cleaning of feeders every day

Mash and Pellets

Pellets have recently become popular for broilers.

Advantages of pellets

i. Higher nutrient density (reduced bulkiness of feed)
ii. Reduction in dustiness of feed
iii. Prevention of selective feeding (feeds are more homogenous)
iv. Higher palatability and increased feed intake
v. Destruction of pathogenic microorganisms
vi. Increased digestibility of certain nutrients due to cooking effect

vii. Improved growth and feed conversion
viii. Uniformity in production
ix. Maintaining feed intake in heat stress
x. Easy handling of feed
xi. Suitability to mechanical conveyance and storage
xii. Reduction in segregation of high density ingredients and micronutrients
xiii. Reduced wastage of feed

Disadvantages of pellets

i. Additional cost
ii. Destruction of vitamins and certain feed additives (enzymes, probiotics)
iii. More susceptibility to mycotoxin formation if not properly dried
iv. Increases water intake and consequent wet litter problem
v. Increases cannibalism
vi. No possibility of further mixing of any ingredient or additive
vii. Higher incidence of ascites

Feeding Programmes

The different practical feeding programmes are

i. Full or *ad lib* feeding
ii. Restricted or controlled feeding
iii. Supplementary feeding

Full or *ad lib* feeding

In this system, chickens are offered feed continuously with no restriction on feeding. Egg type chickens, on nutritionally adequate diets take feed to satisfy energy requirements. It is a problem with egg type chicks and growers to have adequate feed intake to meet the body frame and size as per specifications. On diets marginally deficient in a nutrient, feed intake tends to be higher in order to have adequate intake of the deficient nutrient. If the deficiency is severe, feed intake drops. Broiler breeders on full feeding become too obese with reduced performance.

Restricted or controlled feeding

Broiler breeders, except during the first 2-3 weeks of their life, are fed restricted or limited quantity of feed. The types of feed restriction may be several. In commercial practices, feed is quantitatively restricted every day or every other day (skip a day feeding) to limit energy intake only. The indicator to feed allowance is the body weight during the growing period, body weight, egg productive performance and feed clean up period during laying period.

Even egg type pullets can be maintained to have satisfactory production on about 90% full feeding, i.e. 10% feed (energy) restriction. It becomes difficult to determine the level of feeding and to maintain uniformity in feeding. Some producers are restricting feed to a pre-determined level to reduce egg size in later part of laying cycle.

Supplementary feeding

Supplementary feeding may be practiced with calcium supplements in commercial layers and breeder layers. Calcium supplement (shell grit), may be placed in separate stationary feeders to be available always in litter operations or may be placed in feeders (3 to 5 g/bird/day) in late evening hours in cage or mechanically operated equipment. The calcium source taken in after noon is lodged in the gizzard and it slowly gets dissolved by the action of hydrochloric acid produced in proventriculus. Thus, calcium would be available for shell formation, which takes place in the dark hours when feeding activity is not there.

Economizing Feed Cost

Economisation of feed cost without impairing productive performance can be achieved by

i. Formulating least-cost diets to meet the nutrient requirements / nutrient specifications
ii. Inclusion of unconventional feed ingredients
iii. Home feed mixing
iv. Avoiding feed wastage
v. Increasing efficiency of feed utilisation
vi. Stimulating feed intake in broilers

Formulating least cost diets to meet the nutrient requirements / nutrient allowances

Formulation of diets on least cost basis can be done using specific software programmes in a computer. Where computers are not available, it is not possible to formulate diets on least cost basis. However, attempts may be made with calculators to formulate diets. Experience is an asset in formulating diets with calculators.

Inclusion of unconventional feed ingredients

Unconventional feed ingedients are usually less expensive than conventional feed ingredients and they may be used subject to their availability and limitations in their inclusion level.

Home feed mixing

Mixing feed at the farm is always economical than procurement from a feed manufacturer. However, feed manufacturers have certain advantages. These are

i. Procurement of feed ingredients in bulk at economic rates
ii. Quality evaluation in the laboratory available with them
iii. Formulation of diets by an experienced nutritionist
iv. Processing and mixing in efficient equipment
v. Quality evaluation of finished product
vi. Storage and transport of feed ingredients and feed in a scientific manner

Large farms have some advantages similar to those of feed manufacturers. For small farms, the cost of ingredients is high and quality may not be satisfactory. It is advisable for small farms to procure feeds from reliable feed manufacturing concerns.

Reducing Feed Wastage

It is difficult to avoid feed wastage but it can be reduced. The practical measures to reduce feed wastage are as follows.

i. Formulation of diets to meet nutritional specifications
ii. Proper feed processing
iii. Procuring quality feed equipment
iv. Placing sufficient number of feeders
v. Proper placement of feeders
vi. Proper placement of feed in feeders
vii. Debeaking of chicken
viii. Control of rats and mice

Formulation of diets to meet nutritional specifications

Diets formulated on least-cost basis to meet nutritional specifications result in low cost of product.

Proper feed processing

Proper feed processing (grinding, mixing, etc.) ensures uniform distribution of nutrients.

Procuring quality feed equipment

Chickens have the habit of scratching and billing feed out of the feeder. The feeders are either tubular or linear. In both the cases, the design must be to avoid feed wastage. Proper size of feeders, adequate but not excessive slope from centre to periphery of pan in tubular feeders, and sufficient and raised lip (45^{O}) of the rim of feeders help in prevention of feed wastage from feeders.

Number of feeders

Sufficient number of feeders ensures adequate feed intake and uniform growth, and prevents possibly cannibalism and overcrowding of chickens near a feeder when feed is placed.

Placement of feeders

Chicken take feed properly when feeders are distributed uniformly in a house. Feeders may be placed at a level height so that the height of lip of the feeder is at the level of the back of the bird. This prevents easy billing of feed out of feeder.

Placement of feed in feeders

Placement of more than one-third feed in feeder results in wastage. Feeders may be filled, if necessary, more frequently. At least once a week, feeders may be cleaned to remove caked up feed.

Debeaking of chicken

Debeaking prevents or reduces billing of feed from feeders.

Control of rodents (rats and mice)

Rats and mice are common in poultry houses. A pair of rats produces 3-6 litters of 7-8 young ones per litter. Within a year, about 15,000 rats can be multiplied from a single pair.

Economical losses to poultry farmers due to rodents

i. Eat feed : 30 g/day/rat 2-3g/day/mouse
ii. Carrier of diseases
iii. Contaminate feed with feces (40 droppings/rat/day)

Rats and mice can be controlled by the following methods.

i. Environment control (Rat proof house)
ii. Chemical control (Use safe rodenticides regularly)
iii. Trapping /Hunting of rats
iv. Clean premises
v. Clean poultry houses, feed godown and stores
vi. Pet cat in the farm

Environment control - While constructing a poultry house, care may be taken to prevent rat infestation.

i. Construction of strong floor with cement concrete impregnated with glass pieces of about 2″ below the cement floor.

ii. Providing a concrete wall of about 2 _ and 3″ thick may be constructed all round the walls of poultry house to prevent rats from digging under the floor and entering the poultry house.

iii. Self closing doors

iv. Providing a sheet metal to form edges to doors to prevent rats from entering the house from below.

v. Prompt filling up of all holes

vi. Making feed inaccessible to rats.

Chemical control – Rodenticides (chemicals to kill rats) may be single dose baits and multi-dose baits. All are dangerous to humans, particularly single dose baits.

i. Zinc phosphide is frequently used as a single dose bait.

ii. Bromodiolone is frequently used as multi-dose baits.

iii. Fumigants may be placed in holes and which may be sealed to kill any rats there.

Trapping – Trapping still is an effective method of rat control in poultry farms though it is not generally followed.

Feed Storage

Feed from the point of manufacture until offered to birds has to be stored. During storage, the following effects may occur.

i. Moisture pick up from environment
ii. Nutrient destruction
iii. Oxidation of nutrients
iv. Insect infestation
v. Fungal infestation
vi. Heat generation
vii. Combustion
viii. Rodent effects

Proper storage of feed involves the following.

i. Store has to be constructed away from poultry houses and manure pits.

ii. Store has to be rat proof and damp proof.

iii. Prevent wild bird entry into store house.

iv. Ventilation and light must be adequate.

v. Use disinfectant tub at the entrance of feed store.

vi. Prevent people working in poultry houses from entering into store house.

vii. Maintain feed store clean.

viii. Fumigate store with potassium permanganate and formaline

ix. Fumigate with insecticides (Methyl bromide, Ethylene bromide, Aluminum phosphide etc.) to control insects and their larvae.

x. Spray copper sulphate or any disinfectant on the empty floor inside store.

xi. Store bags of feed or feed ingredients on wooden / iron pallats instead on floor directly.

Duration of storage of feed

i. Purchase and stock feed for 1-2 weeks during rainy season and 3-4 weeks during winter and summer seasons.

ii. Stack feed bags on wooden pallets.

iii. Fresh feed is always better than old one.

iv. Do not use fermented, damp/wet feed under any condition.

v. Never use infected or caked feed.

Freshness of stored depends on

i. Quality of feed ingredient

ii. Quantity and type of antioxidant

iii. Antifungal agents

iv. Moisture of feed ingredient

v. Toxin binders

vi. Climate

vii. Oil content and its quality in feed

Feeding chicks

Chicks are fed starter diet for the first 6 or 8 weeks of age. Chicks are subjected to several stresses (vaccination, debeaking , shifting, infections, etc). Many vaccinations are carried out during this period. It is difficult to obtain body weight as per the standards under these conditions. Probiotics, immmunostimulators, toxin binders, liver tonics, etc. may be included in feed. The performance of chicks may be compared with the standards given by the breeder.

Feeding replacement pullets

Feeding management during growing period is aimed to reach the standard body weight. It is difficult to obtain standard body weights during early growing period. The starter feed may be continued during growing stage also until target body weight of the corresponding week is reached. Low body at 18 weeks age delays sexual maturity with consequent low production and low egg weight.

The grower is susceptible to several infections under Indian conditions. Many vaccinations are carried out during this period. Probiotics, immmunostimulators, toxin binders, liver tonics, etc. may be included in feed. The performance of chicks may be compared with the standards given by the breeder.

Feeding commercial layers

Today, the commercial layer attains sexual maturity by about 18 weeks of age and produces about 310 eggs (hen housed) from 19 to 72 weeks of age. In most cases, maintaining adequate feed intake is a problem. Egg type pullets can be maintained to have satisfactory production on about 90% full feeding, i.e. 10% feed (energy) restriction.

Phase feeding: Some commercial producers follow phase feeding. In phase feeding of layers, protein (amino acid) allowances are reduced with increase in age of layers. Scientific basis for phase feeding is not available. However, calcium content may be increased and phosphorus content may be decreased during later ages.

Feeding commercial broilers

Feed intake stimulation in commercial broilers results in improved body weight gains. Feed intake may be stimulated by

i. High energy diets
ii. Controlled environment
iii. Minimising stress
iv. Immunostimulators
v. Feed additives
vi. Reducing activity of feeding

On high-energy diets, energy intake is slightly higher than on low energy diets. Environmental stress is avoided in controlled environment houses. Minimising stress results in better growth. Immunostimulators and feed additives are dealt in separate chapters. Feeding activity may be reduced by intermittent feeding i.e. allowing feeding for an hour followed by no feeding for about 2-3 hours. Intermittent lighting may be followed in environment controlled houses to minimise activity, including feeding activity.

Ascites may occur during 5-6 weeks of age on high energy diets due to rapid growth. Restriction of feed during second week of age may lessen its incidence.

Feeding egg type breeders

Feeding egg type breeders is similar to feeding commercial layers. However, they are given additional allowances of amino acids, vitamins and trace minerals.

Feeding broiler breeders

Feeding broiler breeders is a challenging task. The feed is fortified with amino acids, vitamins and trace minerals. The broiler breeders become obese on full feeding. In commercial practices, feed is restricted for broiler breeders from about 3 weeks age till culling.

CHAPTER FOURTEEN

Nutrition Management under Adverse Environment

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The productivity of commercial broiler or layer is high. The metabolic dynamics in high producing birds may cause continuous stress to the bird. Chickens developed for maximum production invariably have low disease resistance and poor immune competence.

In day-to-day management, due to economic reasons, managemental conveniences and errors and forced circumstances, the chicken is subjected to stress. Any agent, which causes stress, may be termed as stressor. The different stressors are

i. Adverse environment

ii. Managemental practices
- a) Transportation
- b) Frequent handling
- c) Vaccination
- d) Medication
- e) Beak trimming
- f) Over crowding

iii. Managemental problems
- a) Cannibalism
- b) Wet litter
- c) Ammonia

iv. Poor quality feeds
- a) Imbalanced diets
- b) Feeds containing toxins
- c) Inadequate intake

v. Inadequate measures for health
- a) Lack of minimum biosecurity
- b) Poor sanitation and hygiene
- c) Poor water quality

Stress physiology

In general, the responses of the bird to the stressors are in three stages, depending on the nature and duration of the stressor. The whole sequence of the events is called general adaptation syndrome.

Stage 1	Stage 2	Stage 3
i. Alarm reaction	ii. Stage of resistance	Stage of exhaustion
(If stressor persists)	(If stressor persists and strong enough)	
Adrenal medulla ↓	Adrenal cortex ↓	Adrenal cortex ↓
Epinephrine (adrenaline) ↓	Corticosteroids (glucagon) ↓	Looses ability to produce Corticosteroids (glucagon) ↓
Peripheral vasoconstriction ↓	Accommodates stress	Physical disability ↓
Increased respiration Increased blood pressure Depressed feed intake Low gonadal activity Low immune response		Death

High environmental temperature

Due to metabolic reactions within the body, heat is produced continuously. Heat production decreases as environmental temperature increases from 2 to 30°C. Heat production increases at low temperatures to maintain body temperature and at high temperatures to reduce body temperature. The ideal environmental temperature for broilers is 10-22 °C for high body weight gain and 27 °C for better feed conversion efficiency. In layers, a wider temperature of 10-30 °C is tolerated, but feed efficiency will be better at high temperatures within the range. Higher environmental temperature reduces egg shell quality.

High temperature → Panting (Hyperventilation) → Loss of metabolic CO2 → Hypobicarbonaemia → Reduced buffering capacity of H^+ during egg shell formation → Reduced concentration of carbonic anhydrase → Impairment of production of bicarbonate ion in uterus → **Reduced shell quality** →

High temperature → Reduced feed intake → Bone resorption → Hyperphosphataemia → Reduced capacity of uterus to form calcium carbonate → **Reduced shell quality**

High temperature → Demand to regulate body temperature → More blood flow to periphery of body → Reduced blood flow to uterus → **Reduced shell quality**

Stress and immunity

Stressed birds → Regression of lymphoid organs (bursa, spleen and thymus)
Increasing the ratio of heterophils and lymphocytes in blood
↓
More susceptible to diseases

Amelioration of stress through nutrition

Energy - Increase the energy content of diet by supplemental fat

Requirement of maintenance energy
(WL layers of 1.4 to 1.8 kg body weight)

i. Decreases 2.5-3.0 kcal ME/d/ °C at environmental temperature above 21 °C
ii. More energy is required for dissipation of heat (by panting)
iii. Therefore, the absolute energy requirement may not be less.

Feed intake	Reduced by 1.2% for 1 °C rise in the temperature range of 22 to 32 °C 5 % for 1 °C rise in the temperature range of 32 to 38 °C

Improved by about 15% by supplemental fat (5%)
Fat improves palatability of feed
Reduces heat increment (Heat production after feeding)
Decreases feed passage in gut and increases nutrient absorption
Fats with more saturated fatty acids are preferred in hot-humid climates.

Concentration of other nutrients may be adjusted depending on feed intake.

Protein – Prefer low protein diets with balanced amino acids (proper ratio of amino acids to lysine)

i. Metabolic requirement of protein or amino acid is independent of ambient temperature.

ii. Higher protein level with imbalanced amino acids produce more heat in body (heat increment) than low protein level with balanced amino acids.

iii. Low protein diets with supplemental lysine and methionine (ratio of amino acids to lysine has to be proper) are preferred in summer to reduce heat production from protein (amino acids).

iv. Increase the amino acid levels depending on feed intake at environmental temperatures up to 30°C.

v. Heat stress above 30°C, has a direct effect on production of birds. Increase in the concentration of amino acids may not be useful at temperatures above 30-32 °C.

Broilers

i. Increase in dietary protein (amino acid levels with proper ratio to lysine) is beneficial for growth and feed efficiency during summer.

ii. Diets with balanced amino acids tend to reduce fat deposition in the abdomen, thereby birds may sustain better under heat stress.

Calcium and phosphorus – Increase Ca intake from 4g/b/d to 5g/b/d

Heat stress — Reduces conversion of vitamin D_3 to its metabolically active form i.e., $1{,}25(OH)_2D_3$ (essential for absorption and utilization of Ca in the bird)

Reduced feed intake (Reduced Ca intake)

Increased Ca requirement from 4g/b/d (adequate at 22-30 °C) to 5g/b/d to maintain egg shell quality

i. Provide extra Ca at after noon times

ii. Provide Ca in layer diets of about 1 mm size for retaining in gizzard to provide Ca during the time of shell formation (mostly in night)

iii. Intake of P (see nutrient allowances) should not be increased. Higher levels of P in diet are deleterious at elevated temperature. Hyperphosphataemia is known to inhibit the release of bone calcium and reduce shell quality.

Electrolytes / buffering agents – Supplement electrolytes

Heat stress

i. Alkalosis ⟶ To alleviate alkalosis supplement diet with either of the following

a. Sodium bicarbonate 0.5%
b. Ammonium chloride 0.3 to 0.5%
c. Sodium zeolite

ii. High potassium excretion through urine → Increase potassium allowance from 0.3 to 0.5% when temperature increases from 25 to 38°C

iii. Reduced electrolyte intake due to reduced feed intake → Increase dietary allowances for electrolytes (Na, K and Cl) by 1.5% per 1°C above 20°C considering Na, K and Cl in water

Vitamins

High environmental temperature

↓

Destruction of vitamins in feed depending on temperature and storage period
High moisture, rancid fats, trace minerals and choline, enhance destruction of vitamins.

↓

Incorporate anti-oxidants
Selecting protected vitamins
Maintain optimum storage conditions
Add choline and trace minerals separately as a premix
High environmental temperature

Decreases synthesis of ascorbic acid → Supplement ascorbic acid (up to 200 to 600mg/kg diet)

Reduces absorption of vitamin A → Increase vitamin A allowance by about 1.2 to 1.5 times

Reduces immunity → Supplement vitamin E, zinc, antioxidants

Reduces conversion of vitamin D_3 to $1,25(OH)_2D_3$ → Increase vitamin D allowance by about 1.2 to 1.5 times

Antipyretics and chemotherapeutic agents

High environmental temperature

Increased body temperature →	Salicylic acid, aspirin, acetylsalicylic acid at 3% in diet are antipyretic.
	Magnesium aspartate, zinc sulphate, diazepam, metyrapone or clonidine in the diet minimize catecholamines in blood
Increased loss of carbon dioxide →	eserpine, an alkaloid from *Rauwolfia* plant prevents loss of carbon dioxide
	Flunixin, an anti-inflammatory analgesic drug (0.28 to 2.2 mg/kg body weight per day) increases the water consumption by 150 to 300 ml/bird/day.
Increased mortality coccidiostat, Nicarbazine →	Supplement potassium chloride in due to drinking water.

Change in feeding practices

i. Stored feed only for a week in hot and humid climates to reduce destruction of nutrients.

ii. Feed early and in late hours of the day

Physiologically, the body temperature of bird increases due to the thermogenic effect of feed during its digestion and subsequent utilisation in the body (heat increment). Under regular feeding practices, during the summer, the thermogenic effect coincides with the elevated environmental temperature, which aggravates the ill-effects of heat stress. The thermogenic effect lasts more time (8-10 hours) at higher environmental temperature (>35 °C) compared to at 20 °C (2 hours).

The metabolic heat production is about 20-70% less in starved birds compared to fed birds. Regular practice of feeding the birds in the morning during the summer aggravates the ill-effects of heat stress. Therefore, the ideal feeding practice during temperatures should be to ensure not to coincide the heat increment of feeding with highest temperature of the day and also the birds should be deprived of feed during the maximum day temperature. Feeding the birds during the early and late hours of the day is beneficial and it may increase the weight gain and livability of a broiler.

In layers, feeding during the later part of the day will ensure the availability of ionic calcium while the shell calcification is in active process, i.e. usually midnight to early hours of the day.

iii. Reduce activity of broilers by intermittent light

Intermittent feeding of broilers by providing the light for 30 minutes followed by 3 hours darkness reduces activity (heat production) of the bird. Here, about 20-30% more feeder and water space is required.

iv. Stimulate feed intake

Depression in feed consumption is the major factor limiting the performance of both broilers and layers at higher temperatures.

Feed intake can be increased by the following feeding practices.

a. Wet mash feeding
b. Pellet or crumble form of feed
c. Frequent feeding
d. Stirring of feed in feeder
e. Molasses or fats in feed increases palatability

CHAPTER FIFTEEN

Effect of Feed and Other Factors on Egg and Meat Quality

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Feeding of animals should be governed by the philosophy "Safe feed – Safe food".

Production of quality eggs and meat is essential.

i. Consumer consciousness for quality products is gradually increasing.
ii. Poultry farmers may realise better price for products of higher quality.
iii. Marketing of egg and meat has to be sustained.
iv. Export promotion requires quality products.

Diet is one of the important factors influencing the quality of egg and meat.

Effect of Feed on Egg Quality

Several dietary components influence egg quality

i. by virtue of their transport into the egg
ii. by inducing metabolic changes that result in synthesis of compounds which find their way in to the egg

iii. by changing transport characteristics of the membranes involved in the formation of egg components

Quality of eggs includes the following external and internal characters.

i. Egg size
ii. Shell quality
iii. Tremulous or loose air cell
iv. Albumen quality
v. Yolk quality
vi. Taints in eggs
vii. Blood and meat spots
viii. Drug/chemical residues
ix. Nutritional value
x. Cholesterol content

i. Egg Size

Several factors influence egg size. During 17-20 weeks of age, some producers increase calcium in diet to about 2%. It may not have any effect on subsequent shell quality.

a. Small eggs

i. Breed and strain
ii. Early age at sexual maturity
iii. Early age of the flock
iv. Low body weight of the flock
v. High environmental temperature
vi. Infectious bronchitis disease
vii. Inadequate water intake
viii. Inadequate energy intake
ix. Inadequate protein intake
x. Inadequate methionine intake
xi. Inadequate linoleic acid intake
xii. Mycotoxins in feed

b. Large eggs

i. Breed and strain
ii. Late age at sexual maturity
iii. High body weight of the flock
iv. Older birds of the flock
v. Molted flock

ii. Shell Quality

The shell quality factors are as under.

a. Misshapen eggs
b. Thin, porous or soft shells
c. Rough shell
d. Mottled shell
e. Yellow shell
f. Depigmented shell in brown colored eggs
g. Equatorial bulge (Ridged waist)
h. Corrugated shell
i. Cracked shell

a. Misshapen eggs

i. Breed and strain
ii. Early stage of production (High incidence)
iii. Older birds (High incidence)
iv. Movement of birds
v. Diseases: Newcastle disease Infectious bronchitis
vi. Thiram toxicity

b. Thin, Porous or soft shells

i. Breed and strain
ii. High temperature
iii. Older birds
iv. Disturbance in the night
v. Sulfonamides
vi. Newcastle disease
vii. Infectious bronchitis
viii. EDS76
ix. Thiram toxicity
x. High magnesium
xi. High fluorine
xii. Inadequate feed intake
xiii. Calcium or phosphorus deficiency
xiv. Imbalance of calcium phosphorus ratio
xv. Inadequate vitamin D_3
xvi. Inadequate manganese
xvii. Inadequate zinc
xviii. Inadequate copper
xix. Coffee bean seed (*Cassia occidentalis*)
xx. Chlorinated hydrocarbons
xxi. Malathion

c. Rough shell

i. Breed and strain
ii. Early stage of production
iii. Older birds (High incidence)
iv. Stress
v. High antibiotics treatment
vi. Newcastle disease
vii. Infectious bronchitis
viii. High calcium intake
ix. Thiram toxicity
x. Poor water quality

d. Mottled shell

i. Breed and strain
ii. Rainy days (High humidity)

e. Yellow shell

i. High tetracycline in feed

f. Depigmented shell in brown colored eggs

i. Breed and strain
ii. High production
iii. High temperature
iv. Piperazine
v. Nicarbazine
vi. Diseases: Newcastle disease Infectious bronchitis EDS 76

g. Equatorial bulge (Ridged waist)

i. Stress (Handling)
ii. Activity in early calcification (Disturbance)

h. Corrugated shell

i. Infectious bronchitis
ii. Thiram toxicity
iii. Copper deficiency
iv. Lathyrogen: beta-aminopropionitrile (BAPN)

Copper is necessary for the action of enzyme lysyl oxidase that is found in the hen oviduct. This enzyme is responsible for the production of lysine-derived cross links in the shell membrane protein, which give the membrane fibres their tensile strength. BAPN inhibits this enzyme.

i. Cracked shell

i. Breed and strain
ii. High stock density
iii. Cage design
iv. Collection methods
v. Handling methods
vi. Tray design

Some important nutrient and management factors to improve shell quality are

i. Ca and P content in diet, their source and ratio

ii. Phytase enzyme in diet

iii. Manganese, zinc and copper in diet

iv. Vitamin C (Ascorbic acid) is synthesised in the body of the bird. During stress, the synthesis may be inadequate. Supplemental vitamin C (100 mg/kg diet) may improve shell quality during stress conditions.

v. Increasing Vitamin D_3 in diet up to 2000-3000 IU/kg diet may be beneficial in improving shell quality.

vi. Sodium bicarbonate in diet to reduce chloride level and increase bicarbonate in blood

vii. Probiotics in feed may help to restore intestinal flora and integrity of intestinal structure (villi) for absorption of nutrients, including calcium.

viii. Feeding management

Supplemental calcium may be given as limestone powder, or shell grit, or stone grit. Stone grit is cheaper than shell grit. The calcium supplements should have low magnesium and fluorine. In layer and breeder diets, limestone powder at not more than 4% and hard grit (shell grit or stone grit) at not less than 4 % may be used to maintain shell quality.

It is also known that supplemental shell grit or stone grit in the evening hours improves shell quality. The large particle size causes slow and consistent digestion and absorption of calcium. More calcium is required in the night for shell calcification.

viii. Molting

During the latter part of egg production, shell quality declines probably due to increased egg size and low absorption of calcium. Molting improves shell quality at least during the first 5-6 months of post-molting period.

ix. Lighting

A light period of 13-14 hours is sufficient for maintaining egg production and shell quality. Light periods of more than 17-18 hours may cause reduction in shell quality.

x. Temperature

Higher temperatures (summer) are known to reduce shell quality. Adequate measures of reducing the temperature or effects of increased temperature have to be taken to maintain egg production and egg shell quality.

xi. Disturbance

Disturbance during the night periods is known to reduce shell quality due to premature expulsion of egg from uterus.

xii. Diseases

The effects of diseases are felt on egg production and also on egg quality.

Egg quality	Newcastle disease	Infectious bronchitis	Egg drop syndrome (EDS 76)
General health	Affected	Affected normal	Apparently
Egg production	Reduced	Reduced	Reduced
Egg size	Normal	Small	Small
Eggs shape	Misshapen	Misshapen	Normal
Shell	Rough Thin, porous, soft Loss of colour	Rough Thin, porous, soft Loss of colour	Rough Thin, porous, soft Loss of colour
White (Albumen)	Watery	Watery	
Blood and meat spots		Present	

iii. Tremulous or loose air cell

i. Rough handling
ii. Newcastle disease
iii. Storage condition
iv. Infectious bronchitis
v. Poor shell quality

iv. Albumen quality

Egg albumen (egg white) composition is hardly modified by the diet. Intensity of albumen colour is dependent on riboflavin.

a. Pink white

i. Cotton seed meal (cyclopropane fatty acids - Malvalic and sterculic acids)

ii. Bacteria

b. Watery white

i. Breed and strain
ii. Older birds
iii. Prolonged storage at high temperature
iv. Ammonia
v. Deficiency of copper
vi. Newcastle disease
v. Infectious bronchitis
vi. Lathyrogen beta-aminopropionitrile (BAPN)

v. Yolk Quality

Many nutrients and non-nutrients find their way from food to the yolk.

The intensity of yolk colour is dependent on the intensity of dietary carotenoid pigments. Yellow maize, maize gluten meal, lucerne meal, marigold petals, or their extractions, or synthetic pigments like canthaxanthin, b-apo-8-carotenol, citranaxanthin, astaxanthin are the sources of carotenoid pigments.

Some abnormalities in yolk are as follows.

a. Light colour yolk

i. Less xanthophyll pigments
ii. Coffee bean seed (*Cassia occidentalis*)

b. Abnormal colour

i. Gossypol (cotton seed meal)
ii. Kapok meal

c. Cheesy yolk

i. Chilling of eggs
ii. Cotton seed oil (sterculic acid)

d. Flat yolk

i. Nicarbazine
ii. Storage at high temperature

vi. Taint in eggs

i. Robeinidine (anticoccidial)
ii. Sinapine of Rapeseed meal (Trimethylamine (TMA) responsible)
iii. Detergents (certain types)
iv. Moulds
v. Storage near strong odours
vi. High fish oil (more than 1%) contributed from fish oil or fish meal (Trimethylamine (TMA) responsible)
vii. Capelin meal

vii. Blood and Meat Spots

Blood and meat spots are the internal defects sometimes encountered in eggs and their causes include:

i. Breed and strain
ii. Cold environment
iii. Marked temperature change
iv. Continuous light
v. Older birds
vi. Inadequate vitamin K
vii. Inadequate vitamin A
viii. Stress
ix. Mycotoxins
x. Infectious bronchitis
xi. Disturbance or flightiness

viii. Drug/chemical residues

Several dietary non-nutrients, which are toxic and hazardous to health of birds and man, accumulate in eggs. These include

Chemical/Toxin	Examples
Organochlorines	DDT, BHC, Lindane
Cyclodeines	Aldrin,Endrin, Heptachlor, Toxaphene, Endosulfan
Organophosphorus compounds	Malathion
Carbamates	Carbaryl
Fungicide	Arasan (thiram)
Mercury compounds	Methyl mercury chloride
Mycotoxins	

ix. Nutritive value

The concentrations of several nutrients can be modified in the chicken egg.

i. fatty acid composition
   Unsaturated fatty acids
ii. Fat soluble vitamins
iii. Water soluble B vitamins
iv. Trace minerals
   Iron
   Copper
   Manganese
   Iodine
   Fluorine

x. Cholesterol content

Cholesterol content in egg yolk is blamed for heart problems in humans. Heart surgeons say that even patients can have _ egg per day without any risk. However, the cholesterol in egg can be reduced and polyunsaturated fatty acids (PUFA) can be increased. Flaxseed and flaxseed oil is fed to commercial layers to elevate the concentrations of n-PUFA in eggs (designer eggs).

Influence of feed on meat quality

Meat quality may be characterised in terms of the following components.

i. Tenderness	iv. Flavour	vii. Cholesterol
ii. Juiciness	v. Nutritive value	viii. Drugs or chemical residues
iii. Pigmentation	vi. fat	ix. Stability

i. Tenderness

The effect of diet on the tenderness of meat is not direct.

Chickens fed on high plane diets attain marketable weight early, and, therefore, have soft or tender meat.

ii. Juiciness

Factors that affect the deposition of intramuscular fat and its fatty acid composition determine juiciness of meat.

During the finishing stage, broilers are fed diets to facilitate fat deposition and improve the appearance or finish of the carcass. Such diets increase the juiciness of meat.

iii. Pigmentation

Certain consumers prefer deep yellow pigmentation in broilers.

The dietary pigments arising through lucerne meal, yellow maize, maize gluten meal, xanthophyll concentrate or synthetic carotenoids produce deep yellow pigmentation in the skin and shank of the birds.

iv. Flavour

It is not possible to improve the flavour of meat through dietary manipulation.

Maize oil (2-4 %) in broiler finisher diet produces a satisfactory flavour. When the diet contains fish meal or fish oil at higher levels, offensive flavour may be produced due to trimethylamine. This can be prevented by reducing or avoiding fish or fish oil in finisher diet.

v. Nutritive value

Fat content of carcass is the most variable component. Any increase in fat is accompanied by a parallel decrease in water content and vice versa. Wider calorie protein (amino acid) ratios favour fat deposition in carcass. The concentration of fat soluble vitamins, trace minerals (zinc and copper) in carcass is influenced by their concentration in feed.

vi. Fat

Wider calorie protein (amino acid) ratios favour fat deposition in carcass.

vii. Cholesterol

Deposition of fat containing saturated fatty acids increase cholesterol content in carcass. Garlic powder (30-50g/kg feed) and copper compounds (250 mg/kg feed) may reduce cholesterol content in carcass by about 20%. Garlic powder favours the conversion of cholesterol to bile acids. Copper compounds reduces saturated fatty acid content and so the cholesterol content in carcass.

viii. Drug residues in poultry meat

Drug residues through improper use, not following withdrawal periods and pesticide residues by contamination may accumulate in poultry meat creating health hazards.

ix. Stability

After the birds are killed, poultry body fat of unsaturated type tends to be rancid. The use of supplemental vitamin E in the diets and also of the synthetic antioxidants increases the stability of body fat against rancidity and development of off flavours.

CHAPTER SIXTEEN

Mycotoxins

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Introduction

There are more than 10,000 known species of fungi. Fortunately, most of them are beneficial to humans in the production of bread, cheese, antibiotics, etc. There are about 50 fungi species harmful to poultry, livestock and man known to produce toxins, which are collectively called mycotoxins. Mycotoxins are metabolites produced during metabolism of nutrients present in feeds and feed ingredients.

The formation of mycotoxins may occur when the fungi grows on crops in the field, at harvest, in storage or during the processing of feed when conditions are favourable. No region escapes these silent killers. According to the United Nation's Food and Agriculture organization (FAO), approximately 25% of world's grain supply is contaminated with mycotoxins. The economic loss due to this has been estimated to run into millions of rupees annually. The greatest economic impact of mycotoxin contamination is felt by crop and animal producers, as well as food and feed producers.

Classification of Mycotoxins

The classification of mycotoxins is as follows:

Mycotoxins	Fungi
Aspergillus toxins	
Aflatoxin B_1, B_2, G_1, G_2	*Aspergillus flavus, Aspergillus parasiticus*
Cyclopiazonic acid	*Aspergillus flavus*
Ochratoxins	*Aspergillus ochraceus*

Pencillium Toxins:	
Ochratoxins	*Penicillium viridicatum*
Citrinin	*Pencillium citrinum*
Fusarium Toxins	
T-2 Toxin, HT-2 Toxin, Diacetoxyscirpenol (DAS), Monoacetoxyscirpenol (MAS)	*Fusarium tricinctum* *Fusarium solani*
Deoxynivalenol (DON, vomitoxin)	*Fusarium graminearum (Gibberella zeae)*
Zearalenone	*Fusarium graminearum, Fusarium roseum*
Fumonisins B_1, B_2	*Fusarium moniliforme, Fusarium proliferatum*
Ergot toxins	
Ergopeptines	*Claviceps purpurea*
Ergovaline	*Acremonium coenophialum*

Important mycotoxins in foods and feeds

The important mycotoxins in foods and feeds are as follows:

Mycotoxin	Nature of toxin
Aflatoxins* (Most ubiquitous) and Cyclopiazonic acid	(Hepatotoxins, Immunosuppression)
Ochratoxin* and Citrinin	(Nephrotoxins, Gout)
T-2 toxin* and Diacetoxyscripenol	(Mouth lesions, Loss of appetite, Skin and Gastro-intestinal irritation)
Fumonisins* and Moniliformin	(Neurological disorders, Liver damage)
Vomitoxin* and Fusaric acid	(Feed refusal, Dermatotoxins)
Zearalenone*	(Estrogenic and Reproductive disorders)

**Mycotoxins to occur in feed stuffs significantly.*

Important mycotoxins in forages		
Ergot alkaloids	Sporidesmin	Fescue toxin
Tremorgens	Patulin, Vomitoxin	Zearalenone

Occurrence of mycotoxins

Contamination of feedstuffs with mycotoxins is a global problem. However, in certain geographical areas, some mycotoxins are encountered more often than the others.

Environmental condition	Mycotoxins contaminating feed stuffs
Winter conditions with high moisture	Vomitoxin, Zeralenone, Ochratoxin, Diacetoxyscirpenol (DAS), T-2 toxin, Fumonisins
Warm and humid conditions	Aflatoxins, ochratoxin (produced by *Aspergillus* species only), and fumonisins

Effects on health and production performance

The physical or apparent effects of mycotoxins range from reduced feed intake and poor conversion ratio to a general inability of an animal to thrive. Symptoms vary from toxin to toxin as shown below.

Aflatoxin	Damages liver and causes growth suppression.
T-2 toxin	Oral lesions in poultry
Ochratoxins	Kidney damage
	Poultry and pigs are prone to ochratoxin, whereas dairy animals can tolerate it even at higher levels because of its biotransformation by ruminal microbes.
Vomitoxin (feed refusal factor)	Affects mainly pigs and other animals
Zearalenone	Affects the reproductive organs in pigs, dairy cattle and poultry
Fmonisins	Cause nervous disorders in horses
Ergot alkaloids	Produce nervous system disorders and necrosis of legs and tail in livestock

It is common to observe symptoms of mycotoxin toxicity in field conditions, but an analysis of contaminated feed samples may reveal negligible levels of mycotoxins. This is usually attributed to inadequate sampling of feed, errors of analysis or the presence of other unknown mycotoxins.

Mycotoxins and the immune system

Besides their adverse effects on performance, various mycotoxins damage the immune system and thereby increase susceptibility to diseases. Aflatoxins are the most immunosuppressive mycotoxins, followed by vomotoxin, T-2 toxin, ochratoxins and fumonisins.

In poultry, the bursa of Fabricius, thymus and spleen and to a lesser extent the cecal tonsils and bone marrow constitute the organs contributing to humoral and cellular immunity (Figure 5). In pigs, cows, horses and other mammals, the primary tissues and organs that comprise the immune system are the lymph nodes, thymus, bone marrow, pancreas and spleen. The T-cells, which originate in the thymus, control the cell-mediated immune response. The B-cells originating in the bursa of Fabricius and bone marrow, control the humoral immune response involving the production of antibodies or immunoglobulins, mainly IgM and IgA.

Various mycotoxins adversely affect the immune system by depressing both the cell-mediated and humoral immune response. Aflatoxin-related immunosuppression is due to its direct effect on both cellular and humoral immunity, resulting in lowering of the overall defense mechanism of the animal. Cell-mediated responses appear to be affected by low levels of aflatoxin whereas high levels affect immunoglobulin production and antibody response. Trichothecenes are the second most immunosuppressive mycotoxins next to aflatoxin. They affect primarily the cellular immune response by direct effects on bone marrow, spleen, lymph nodes, thymus and intestinal mucosa where actively dividing cells are damaged. The immunosuppressive effect of ochratoxin in poultry results in the impairment of both cellular and humoral immunity, with atrophy of the thymus accompanied by lower circulating immunoglobulins and phagocytes.

Mycotoxin residues in animal products - impact on human health.

The problems with mycotoxins do not, however, end in feed or in reduced animal performance, for many are actually transferred into the meat or milk. The maximum limits of aflatoxin in foods and feeds in USA and India are given in Table 1.

Mycotoxin (In decreasing order of severity) that cause Immunosuppression	Impact of mycotoxins on the immune system
1. Aflatoxin	1. Reduction in size of bursa of Fabricius and thymus
2.. Vomitoxin, T-2 toxin, HT-2 toxin	2.. Reduction in T-lymphocyte, B-lymphocyte and white blood cell counts
3. Ochratoxin	3. Reduction in total serum proteins and immunoglobulin
4. Fumonisins	4. Reduction in antibody titers
	5. Reduction in serum concentration of antibiotics.

Table 1. Maximum limit of aflatoxin level in foods and feeds: U.S, India

Countries	Product	Species
United States (ppb)		
0.5 (Aflatoxin M_1)*	Milk	Humans
20	Any food, except milk	Humans
20	Feed	All species
India (ppb)		
50	Animal feeds	Poultry and livestock

* *A toxic metabolite of aflatoxin B_1, that occurs in milk.*

Co-contamination by mycotoxins

Mycotoxins in combination appear to exert greater negative impact on the health and productivity of livestock and poultry in comparison to their individual effects. This can be attributed to adverse synergistic effect of such combinations of toxins found in mouldy feeds as,

- Aflatoxins and Cyclopiazonic acid
- T-2 toxin and Diacetoxyscripenol
- Vomitoxin and Fusaric acid
- Ochratoxin, Citrinin and Penicillic acid
- Fumonisins and Moniliformin

Species susceptibility to mycotoxins

Susceptibility to mycotoxins by different species of animals varies (Table 2).

Table 2. Species susceptibility to mycotoxins

Mycotoxins	Poultry	Dairy	Pig	Horse
Aflatoxin	++	++	++	++
Zeralenone	+	+	++	+
Vomitoxin	+	+	++	+
Ochratoxin	++	-	++	+
Fumonisin	+	+	++	++
T-2 toxin	++	+	+	+

Brief description of mycotoxins

The most important mycotoxins for poultry and livestock, and their effects are briefly described.

i. Aflatoxins and Cyclopiazonic acid (hepatotoxins)

Aflatoxins cause a variety of effects in livestock and poultry, including poor performance, immunosuppression, adverse effects on egg shells and carcass quality. Livers characteristically are pale and enlarged (Figure 7), including fatty changes, hepatic necrosis, and biliary hyperplasia. Aflatoxins are not considered to be a major problem in cold, temperate regions. However, caution must be exercised in these regions while feeding imported feedstuffs coming from warm and humid countries.

Cyclopiazonic acid is also produced by genus Aspergillus and is commonly found in combination with aflatoxin. Cyclopiazonic acid lesions occur in proventriculus, gizzard, liver and spleen. The proventriculus is dilated and the mucosa is thickened with hyperplasia and ulcerations.

ii. Ochratoxins

The ochratoxins are produced primarily by *Aspergillus ochraceus* and *Pencillium viridicatum*. In tropical and sub-tropical countries, Ochratoxin

A (the most prevalent derivative) is mainly produced by *Aspergillus* species, whereas in temperate countries, *penicillium* species (*Penicillium viridicatum*) is of greater importance.

Ochratoxin primarily affects kidney. Birds which die of this toxin show swollen and abnormally red kidneys due to congestion. Ochratoxin is also known to suppress feed intake, growth and feed conversion efficiency. Loose droppings is another common symptom. Severely affected birds show urate deposits in joints and abdominal cavity. General resistance to disease goes down with consequent increase in mortality. Young chicks in the initial few weeks of age are highly affected. Laying hens show reduced egg production and characteristic yellow staining of eggshells.

iii. Citrinin

Citrinin is produced primarily by *Penicillium citrinum* and some species of *Aspergillus*. Citrinin is responsible for the yellow rice syndrome noticed in animals. Citrinin is often seen along with ochratoxin in cereals like maize, wheat, barely, oats, rice, etc. The major effects are increased water consumption and watery diaorrhea. Body weight is reduced, with post mortem lesions like mottled liver and enlarged kidney. Citrinin has not been shown to affect immunity.

iv. Fusarium Mycotoxins

Fusarium mycotoxins are the most economically significant mycotoxins in foods and feeds on a global scale. The numerous Fusarium mycotoxins include Trichothecenes, [viz., T-2 Toxin, Diacetoxyscirpenol (DAS), Deoxynivalenol (DON)] Zearalenone, fumonisins, moniliformin and fusaric acid.

a. Trichothecenes [T-2 toxin, diacetoxyscirpenol (DAS) and deoxynivalenol (DON)]

The major physiological response to trichothecene mycotoxins is the loss of appetite and hence, these are referred to as " feed refusal toxins". Swine is a more sensitive species to deoxynivalenol (DON) whereas poultry is more sensitive to T-2 toxin and diacetoxyscirpenol (DAS). Most of the trichothecene mycotoxins cause necrosis and inflammation of the oral cavity.

The T-2 toxin is produced primarily by *Fusarium sporotrichoides / tricinctum* frequently contaminating feedstuffs. Mouth lesions (Figure 8) and associated productive losses caused by T-2 toxin have been a major problem for the poultry industry. Mouth lesions are about four-folds more sensitive than growth inhibition as an indicator of T-2 toxicosis. T-2 toxin, apart from causing oral lesions, reduces feed intake and egg production, plasma enzyme changes, loss of body weight and regression of ovary in laying hens and broiler breeders. T-2 toxin is an irritant and it causes gizzard erosion and necrosis of proventicular mucosa.

Diacetoxyscirpenol (DAS) and Monoacetoxyscirpenol (MAS) have been reported to cause mouth lesions and other adverse effects in broilers, laying hens and broiler breeders similar to those caused by T-2 toxin.

b. *Fusarium equiseti* and Tibial dyschondroplasia in poultry

Tibial dyschondroplasia is a common and economically important bone deformation in growing broiler chickens and turkey. The most likely cause of this deformation is a toxin called fusarochromanone produced by *Fusarium equiseti*. This toxin may be largely responsible for the Tibial dyschondroplasia syndrome in poultry; it also kills chick embryos in fertilised eggs.

c. Zearalenone

Zearalenone is produced primarily by *Fusarium graminearum* and *Fusarium roseum*. Zearalenone is responsible for reproductive disorders because of its estrogenic effect. In cattle and sheep the clinical manifestations are udder enlargement, decreased milk yield, vaginal discharge, continuous estrus, infertility and abortions. Pigs, especially young females, are highly sensitive to dietary zearalenone, with severe reproductive disorders including pseudopregnancy, reduced litter sizes, swelling of mammary gland, continuous estrus, and in extreme cases, vaginal and rectal prolapse.

Poultry are relatively more resistant to the effects of zearalenone as compared to pigs and cattle. However, at high dietary concentrations, reproductive disorders may be observed.

d. Fumonisins

Fumonisins are primarily produced by *Fusarium moniliforme* and *Fusarium proliferatum*, the most toxic being fumonisin B_1. Fumonisin mycotoxins are found in a wide range of commodities from millets to grains to banana fruit and they are of major concern to food and feed producers, since they affect human and animal health.

Horses are the most sensitive species to fumonisins. Severe detrimental effects such as "Equine Leukoencepalomalacia" in horses, "Porcine Pulmonary Edemá" in pigs, and in poultry, a condition referred to as " Spiking Mortality or toxic feed syndrome" are observed as a result of fumonisin toxicity.

Clinical signs of spiking mortality include paralysis, extended legs and neck, wobbly gait, gasping and poor growth. It appears that high incidence of human esophageal cancer observed in some countries (South Africa, China, etc.) is due to ingestion of high concentrations of fumonisins over a period of time.

v. Ergot Alkaloids

Ergot toxicity, caused by the *Claviceps purpurea*, differs from other mycotoxicoses. It results from the consumption of considerable amounts of fungal tissue. In other mycotoxicoses, the toxins are secreted into plant tissues in which the fungus is growing and very little fungal material is consumed. The ergot fungus infects the flowers of cereals and many grasses when flowering occurs during predominantly cool, moist weather. Infected florets show characteristic black, spur-like sclerotia that replace the seed. The sclerotia or ergot bodies contain a variety of ergopeptine and clavine alkaloids, which when consumed regularly in small amounts, result in a variety of signs, collectively called ergotism. Symptoms of ergotism in dairy animals, small ruminants and horses are poor hair condition, gangrene or loss of extremities and poor performance.

Safe level of mycotoxins in foods and feeds

Strictly speaking, there is no safe level. The risk directly depends on the level of the major mycotoxins and also on the presence and levels of other mycotoxins in feeds. What is a safe level in one farm may not be safe in another because of difference in managemental conditions and disease prevalence. Some factors that affect the mycotoxin toxicity are: interaction of mycotoxins with pathogens, genetic variability, environmental conditions (high temperature, humidity, ammonia, etc.), sex difference and nutritional status of the poultry and livestock.

Control of mycotoxins

The present concept of mycotoxin control has come beyond the stage where the control of fungal growth is of prime concern. The current emphasis is on reducing the deleterious effects of the pre-formed mycotoxins and thereby enhancing production. Strategies to reduce the impact of mycotoxins include plant breeding for mould resistance, efficient harvesting and storage practices to minimise contamination and the development of potential commercially applicable techniques for decontaminating such commodities. Many decontamination methods have been tried that can be broadly categorised as physical, chemical or biological.

The most effective method of neutralising mycotoxins already in feed is by binding them to an inert compound before they can be absorbed from the intestines. The "ideal" features of a good mycotoxin binder are:

- Ability to bind a wide range of mycotoxins
- Low effective inclusion rate in feed
- Rapid and uniform dispersion in the feed during mixing
- Heat stability during pelleting, extrusion, and during storage
- No affinity for vitamins, minerals or other nutrients
- High stability over a wide pH range and
- Bio-degradability after excretion

i. Nutritional modifications

Nutritional routes for protection against mycotoxins include methionine, selenium and vitamin supplementation of affected diets and some plant and herbal compounds, including chlorophyll derivatives, aspartame, etc. Mycotoxins, upon being absorbed, get detoxified in liver-utilising glutathione (selenium containing compound), which is composed of cystine (derivative of methionine). Thus, the metabolic level of methionine is depleted, leading to poor growth and feed efficiency.

ii. Herbal mould inhibitors

Certain herbs and herbal extracts have been found to exert inhibitory effect on mould growth and toxin production. Aqueous extracts of garlic, onion, turmeric, neem, etc., have been shown to exert anti fungal activity and / or inhibit aflatoxin production. This method, though may be beneficial to some extent, standardisation and practical implementation are not an easy task.

iii. Chemical detoxification

Among the chemicals tested for their ability to detoxify/inactivate mycotoxins ammonia, sodium bisulfite, peroxide acids, bases and gases are effective. However, most chemical methods are not practical and they do not fulfill all the requirements, especially those concerning the safety of reaction products and the palatability of the feed.

iv. Application of mineral clays

Many chemicals have been tested for counteracting mycotoxins, and among those that are successful, very few are used commercially. These include bentonites, zeolites and aluminosilicates. Among these, aluminosilicates are found to be more effective. Hydrated sodium calcium aluminosilicate (HSCAS) at 1.0% of the feed (10 kg per ton) can significantly diminish many of the adverse effects of aflatoxin in chicken and pigs.

However, these clays have some disadvantages, like high inclusion rates and narrow range of binding efficacy. They are mainly effective against aflatoxins and appear to have little or no beneficial effect against zearalenone, ochratoxin and trichothecenes (T -2 toxin, Diacetoxyscirpenol, etc.).

v. Microbial degradation

Ruminal microbes in ruminant animals have the ability to hydrolyze ochratoxin into a non-toxic metabolite. Ensiling is a traditional technique for preserving forages by lactic fermentation. Fungi in ensiled material can produce mycotoxins under aerobic conditions. However, mycotoxins can also be degraded during ensiling.

vi. Natural and organic binder:

Esterified glucomannan has been found to bind different mycotoxins effectively. *In-vitro* Studies have revealed that esterified glucomannan can bind zearalenone up to 75%, aflatoxins up to 92% and fumonisins up to 59%. Esterified glucomannan is also shown to exhibit a moderate binding effect on T-2 toxin and ochratoxin .

Esterified glucomannan supplementation is found to be beneficial in reducing the individual and combined adverse effects of aflatoxin, Ochratoxin and T-2 toxin in broilers In a recent study, esterified glucomannan supplementation was seen improving egg production parameters, serum biochemical and hematological parameters. Broiler trials with diets contaminated by aflatoxin, Ochratoxin A and T-2 toxin have shown that dietary inclusion of esterified glucomannan improved the body weights and antibody titres significantly.

Conclusions

The most appropriate practices for mycotoxin control are:

1. Prevention of fungal growth on crops in the field, at harvest time, during storage of feedstuffs and processing of feed.
2. Not when production is at its lowest but at the time of purchase of raw materials, storage, etc., so that mycotoxin levels can be limited to a minimum

3. Good feed can become contaminated with mycotoxins in livestock and poultry sheds. This can be avoided with proper managemental practices.

4. Application of appropriate mycotoxin binder in order to achieve good productivity and economy.

Bibliography

Ademoyero, A.A., and P.B.Hamilton, 1991. Mouth lesions in broiler chickens caused by Scirpenol mycotoxins. Poultry Sci. **70**: 2082-2089.

Afzali and G. Devegowda, 1999. Ability of modified mannanoligosaccharide to counteract aflatoxicosis in broiler breeder hens. Poultry Sci., **78**: 228 (Suppl. 2).

Bailey, R.H., L.F.Kubena, R.B.Harvey, S.A.Buckley and G.E.Rottinghaus. 1998. Efficacy of various inorganic sorbents to reduce the toxicity of aflatoxin and T-2 toxin in broiler chickens. Poultry Sci. **77**: 1623-1630.

CAST, 1989. Council for Agricultural Science and Technology Task Force Report 16. Mycotoxins: Economic and Health Risks. CAST, Ames, IA.

Charmley, L.L., A.Rosenberg and H.L.Trenholm. 1994. Factors responsible for economic losses due to *Fusarium* mycotoxin contamination of grains, foods and feedstuffs. In: Mycotoxins in Grain, Compounds other than Aflatoxin. J.O. Miller, H.L.Trenholm (Eds) Eagan Press, Ma, U.S.A, 471.

Deo. P., B.J. Blaney and J. G. Dingle, 1999. Effects of mineral and organic adsorbents in meat chicken diets contaminated with sorghum ergot alkaloid. In: Proc. of Queensland Poultry. Sci. Symp. **8.**

Devegowda, G., M.V.L.N. Raju and H.V.L.N. Swamy, 1998. Mycotoxins: Novel solutions for their counteraction. Feedstuffs, **70** (50): 12-17.

Devegowda, G, 1995. Spontaneous combustion in feedstuffs should be prevented. Misset World Poultry. **11** (3) : 45-47.

Devegowda, G., B.I.R. Aravind, K. Rajendra, M.G. Morton, A. Baburatna and C. Sudarshan, 1994. *Saccharomyces cerevisiae* to counteract aflatoxicosis in broilers and ducklings. In : Proc. of the 7th AAAP Animal Science Congress, Bali, Indonesia: 447-449.

Hamilton, P.B., 1984. Determining safe levels of mycotoxins. J. Food Prot. **47**(7): 570-575.

Kubena, L.F., R.B.Harvey, W.E.Huff, M.H.Elissalde, A.G.Yersin, T.D.Phillips and G.E.Rottinghaus, 1993. Efficacy of a hydrated sodium calcium aluminosilicate to reduce the toxicity of aflatoxin and diacetoxyscirpenol. Poultry Sci. **72**: 51-59.

Kubena, L.F, R.B. Harvey, W.E. Huff, D.E. Corrier, T.D. Phillips and G.E. Rottinghaus 1990. Efficacy of hydrated sodium calcium aluminosilicate to reduce the toxicity of aflatoxin and T-2 toxin. Poultry. Sci, **69**: 1078-1086.

Ledoux, D.R., G.E.Rottinghaus, A.J.Bermudez and M.AlonsoDebolt, 1999. Efficacy of a hydrated sodium calcium aluminosilicate to ameliorate the toxic effects of aflatoxin in broiler chicks. Poultry Sci. **78**: 204-210.

Manoj, K.B. and G. Devegowda, 2000. Efficacy of Esterified Glucomannan to ameliorate the toxic effects of T-2 toxin in layer hens. Poultry. Sci. **79**: (Suppl. 1).

Petr Karlovsky 1999. Biological Detoxification of Fungal toxins and its use in Plant Breeding, Feed and Food Production. Natural Toxins **7**: 1-23

Raju, M.V.L.N. and G.Devegowda, 2000. Influence of Esterified glucomannan on performance and organ morphology, serum biochemistry and haematology in broilers exposed to individual and combined mycotoxicosis (Aflatoxin, Ochratoxin and T-2 toxin). British. Poultry. Sci. **41**: 640-650.

Ramakrishna, G.T., G. Devegowda, D. Umesh and Gajendragad, 1992. Evaluation of mould inhibitors in broilers diet and their influence on the performance of broilers. Indian J. Poult. Sci. **27**(2) : 91-94.

Smith, T.K., M. Modirsanei and E.J. Macdonald, 2000. The use of binding agents and amino acid supplements for dietary treatment of Fusarium mycotoxicosis. In: Biotechnology in the Feed Industry (eds: Lyons, T.P and Jacques, K.A), Nottingham University Press, Loughborough, Leics, U.K., pp. 383-390.

Stanley, V.G., R.O.S.Woldesenbet and D.H.Huthinson. 1993. The use of *Saccharomyces cerevisiae* to suppress the effects of aflatoxicosis in broiler chicks. Poultry. Sci. **72:** 1867.

Swamy, H.V.L.N. and G. Devegowda, 1998. Ability of Mycosorb to counteract aflatoxicosis in commercial broilers. Indian J. Poult. Sci., **33** (3): 273-278.

Trenholm, H.L., D.B.Prelusky, J.C.Young and J.D.Miller, 1988. Reducing mycotoxins in animal feeds. Agriculture Canada Publication 1827 E.

Whitlow, L.W., D.E. Diaz, B.A. Hopkins and W.M. Hagler, Jr., 2000. Mycotoxins and milk safety: the potential to block transfer to milk. In : Biotechnology in the feed industry (eds: Lyons, T.P. and Jacques, K.A), Nottingham University Press, Loughborough, Leics, U.K., pp. 391-408.

CHAPTER SEVENTEEN

Feed Analytical Laboratory

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Even a slight variation in quality of feed ingredients or feed affects the performance of poultry. It is difficult to have a general assumption of the published values because of the wide variability observed in the nutrient content of the raw materials. Contamination of raw materials with mycotoxins is not uncommon. A feed analytical laboratory is useful to assess the quality of the raw materials and the finished product.

Feed Analytical Laboratory Model

A feed analytical laboratory may be a small, medium or an advanced one, depending on the feed manufactured and facilities available to analyse the nutrients, toxicants, anti-nutrients and adulterants. The different constituents analysed in a feed analytical laboratory may be as follows:

	Small	**Medium**	**Advanced**
Macro nutrients	Proximate principles (Moisture, Protein, Crude Fibre, Ether extract, Ash) Calcium Phosphorus Salt	Proximate principles (Moisture, Protein, Crude Fibre, Ether extract, Ash) Calcium Phosphorus Salt	Proximate principles (Moisture, Protein, Crude Fibre, Ether extract, Ash) Calcium Phosphorus Salt Amino acids Free fatty acids
Micronutrients		**Minerals** Copper, Zinc Manganese, Iron Magnesium, Fluorine	**Minerals** Copper, Zinc Manganese, Iron Magnesium, Fluorine Vitamins Enzymes

	Small	Medium	Advanced
Extrinsic toxins	Mycotoxins (Aflatoxins)	Mycotoxins (Aflatoxins, Ochratoxin, Citrinin, T2-Toxin, Sterigmatocystin, Zearalenone)	Mycotoxins (Aflatoxins, Ochratoxin, Citrinin, T2-Toxin, Sterigmatocystin, Zearalenone)
Intrinsic toxins	Urease	Urease	Antitrypsins, Urease, Glucosinolates, Gossypol, Tannins and others
Adulterants and contaminants		Urea, leather meal and others	Urea, leather meal and others
Pesticide residues	Thiram	Thiram	Pesticide residues including Thiram and others
Others			Energy, Digestibility (*in vitro and vivo*)

The equipment required for the analyzes are given in Fig 1.

Common Laboratory equipment

i. **Grinder:** Preparation of the sample is important to avoid errors in analysis. The samples should be ground to attain homogeneity and uniform particle size. A hand grinder, which functions like a flour mill, can be used to attain different particle sizes as per need. A blender (mix) can also be used for faster grinding, but variation in the particle size is the problem. A *cyclotec* mill or a similar one may be used to attain fine and uniform particle size.

ii. **Analytical balance**: The mass of a body is determined with the analytical balance. The different types of analytical balances commonly used are:

1. Physical balance
2. Chemical balance
3. Monopan balance

Both physical and chemical balances are mechanically the same but the chemical balance is provided with a rider and the zero resting point is judged by the equal short swings of the pointer. Monopan balance has two knives and single pan balance. A reference mass equal to the mass of the object is selected by operating a dial to keep the balance in equilibrium. The sensitivity of such balances is normally 0.1 mg. Electronic hardware is used in electronic top loading balance for instant weighing.

iii. **Hot air oven:** Hot air oven is used for determination of moisture in substances. This consists of an outer jacket to insulate heat and an inner jacket of aluminum to conduct heat. At the base and on the sides, the heating mantles produce heat, which spreads through air inside the heating chamber. A temperature of 30°C to 250°C can be maintained in a hot air oven.

iv. **Muffle furnace:** A temperature of 200°C to 1200°C can be maintained in a muffle furnace. This consists of an outer insulated cover and a heating chamber, with heat resistant bricks. The sample for ignition is taken in silica basins or crucibles. Normally, graphite pencils are used for labeling sample containers.

Fig 1. Equipment required for small feed analytical laboratory

S. No. Analysis	Equipment required or Methodology
Proximate principles	
a. Moisture	1. Analytical balance with an accuracy of 0.01 mg
	2. Hot air oven (Temperature 100-140°C)
b. Crude protein	1. A digestion room with fume cup boards or with acid vapours removing device, either by water re-circulation or through acid proof material coated exhaust fans
	2. A distilling apparatus
	An auto distillation unit for an advanced laboratory
	An auto distillation unit is optional for a medium-level laboratory
	A micro-kjeldahl apparatus may be enough for a primary feed analytical laboratory
	The accuracy and precision of the results are periodically checked by using a standard reference material for both digestion (Lysine AR Grade) and distillation (Diammonium Hydrogen Phosphate).
c. Crude fibre	1. Fibre digestion and distillation system – Conventional or advanced

	Alkali and acid digestion are done for 30 minutes each. Fibre estimation is done more precisely and accurately by digestion systems like Fibretec (*Tecator,* Sweden).
	2. Hot air oven
	3. Muffle furnace
d. Ether extract (Fat)	1. Soxhlet apparatus – conventional. Time consuming.
	Soxtec (*Tecator*, Sweden or Det Gras by *J.P.Selecta) for quick* (1 1/2 hours) estimation
e. Total ash Sand and Silica	Muffle furnace
f. Nitrogen free extract	Estimated by deducting the above mentioned per cent proximate principles from 100
g. Aflatoxin	1. TLC tools.
	2. UV viewing cabinet

In addition to the above, the following equipments are required for a medium feed analytical laboratory

1 Minerals	
a. Calcium	1. Titrimetric method
	Atomic absorption spectrophotometer in advanced cases for accuracy
b. Phosphorus	1. Titrimetric method
	2. Spectrophotometer or colorimeter in advanced cases for accuracy
c. Salt	1. Titrimetric method
d. Iron	1. Spectrophotometer or colorimeter (Iron is converted to +3 state, complexes with bipyridine)
e. Copper	1. Spectrophotometer or colorimeter (copper is complexed with EDTA and the color is developed with sodium diethyl dithiocarbomate)
f. Manganese	1. Spectrophotometer or colorimeter (Manganese is converted to potassium permanganate by oxidation with potassium periodate)
g. Magnesium	1. By conventional EDTA titration method after removing other metal ions by precipitation.
h. Zinc	1. Gravimetric method
2 Mycotoxins (Aflatoxin, Ochratoxin, citrinin,T2-toxin, sterigmatocystin and zearalenone)	1. TLC method 2. Fluorimetry
3 Urea	1. Spectrophotometer or a colorimeter (Reagent DMAB)

In addition to the above, the following equipments are required for an advanced feed analytical laboratory

4 **Free fatty acids**	Titrimetric method
5 **Enzymes**	
(Cellulase, xylanase, pectinase, phytase etc	1. Centrifuge. 2. Incubator. 3. Spectrophotometer.
6 **Vitamins**	1. High performance Liquid chromatography 2. Spectrophotometer 3. Spectrofluorimeter

v. **Water bath:** A temperature around that of steam can be used for heating samples taken in crucibles, basins or beakers. A thermostat arrangement is fitted with this instrument.

vi. **Hot plate:** This is also used to heat samples.

vii. **Water still:** The water still is used for distilling water. This equipment has a heating coil and a distillation flask. The flask is attached to a condenser through a splash head. The condensed vapour from the condenser is collected as distilled water. For micro-nutrient analysis and precise chemical determinations, double distilled water is used. The iron contamination of the distilled water is eliminated by replacing the coils with glass/ silica covered heating coils.

viii. **pH meter:** This is used to detect pH up to second decimal.

ix. **Colorimeters:** In colorimeter the absorption is measured using glass filters of appropriate wavelength range. If the Bear's Law is obeyed, the absorption represents the degree of light absorbed. It is a common and effective tool used in the quantification of coloured solutions of various analytes.

x. **Incubators:** The operating temperatures should range from 30° to 60° C, within a limit of ± 0.5°C.

xi. **Spectrophotometers:** In this instrument, the coloured glass filter is replaced by diffraction gratings or glass prisms, which ensures monochromatization. Any desired wavelength in the visible and UV region can be selected by switch over of the sources of light i.e., tungsten halogen lamp or deuterium lamp. Using double beam UV-visible Spectrophotometer standard calibration, scanning at different wavelength to get UV visible spectrum of any analyte and even kinetic studies can be performed.

xii. **Rotary shaker:** This instrument is useful for extractions in a slow manner. It has an electrical motor fitted to a shaking device.

xiii. **Magnetic stirrer:** This is an electrical instrument, which has a Teflon-coated iron piece, which rotates constantly and stirs the contents of vessels. The magnetic waves permeate and the iron metal piece, which is put inside the vessel stirs the contents of the vessel.

xiv. **Centrifuge:** This instrument is used to separate the precipitates and insoluble materials using centrifugal force. The speed/ rotation can be controlled depending upon the need.

xv. **Rotary evaporator:** This equipment is used to separate a mixture containing various fractions at low temperature by applying vacuum. This can be used to evaporate the liquid component at a temperature lower than its boiling point.

xvi. **HPLC:** This instrument consisting of four detectors are used to estimate analytes at low concentration (i.e., μg, ng and even pg). The most sensitive part of the HPLC is the column, or its heart, which separates various analytes in the mixture of several analytes. Using this instrument, amino acids, vitamins, antibiotics and any chemical component of non-volatile nature can be estimated accurately and precisely.

xvii. **Gas chromatograph:** This instrument enables to estimate any volatile analytes like pesticides, fatty acids, antibiotics etc. The principle is the same as that for the HPLC except that instead of a liquid mobile phase, a carrier gas.

xviii. **NIR analyzer:** Near Infra Red spectroscopy is currently used in several countries for rapid assay of the ingredients. In India, its use in the animal feed analysis is yet to take a foot hold. The main problem is calibration of the equipment for getting accurate results.

Method Characteristics:

i. **Accuracy:** The accuracy of a value is either exactly equal to the original value or in close proximity to that value. If more than one estimation is made, the mean value is used to test the accuracy of the result.

ii. **Precision:** The precision of a series of results is the reproducibility of the measurements. One can have precise value but inaccurate result (for e.g., if there was an incorrect constant term used for the calculations). Similarly, it is possible to have imprecise value with an accurate result (for e.g., the mean of a large number of imprecise values can be an accurate value). Inaccuracies arise from many sources. Common sources are systematic errors. These are produced by measurement systems like improper calibration, calculation and report generation errors. Errors introduced by interfering compounds are also quite common. Imprecision usually comes from sample variability, sample particle size variability, improper extraction procedures, instrument sources and the analyst's technique or lack thereof. For a routine analysis both accuracy and precision are important.

iii. **Fragility of a method:** In the evaluation of a method if the variation occurs on a day-to-day basis, on analyst-to-analyst basis or on a laboratory-to-laboratory basis, such methods are fragile methods. Methods that yield the same results irrespective of the analyst, day and laboratory are rugged methods. While choosing methods, great care has to be taken.

iv. **Method validation**: Any method should be validated both internally and by reference to another established method. At first, the method should be validated by the study of spike recoveries. Secondly, comparing the results obtained by independent methods using different chemical principles should validate the method. Finally, the method should be validated by inter laboratory collaborative studies.

v. **Data validation:** Method validation alone is not sufficient to obtain a believable data. For routine analysis, an analyst can commit mistake even when using a validated method. The data validation can be achieved by using proper quality control measures. A regular systematic quality control program has to be included in any analysis. For e.g., a standard reference material should be included in each set of samples to be analyzed. The standards ensure that any change in the response of the system will be seen and thus can be taken into account when the calculations are done. The common sources of error are contamination, improper homogenization, and improper calculation procedures. So far as homogenization is concerned in a mixture of samples, each component should have the same particle size. If the particle size differs, a variation will definitely creep in, which will cause erroneous result.

vi. **Safety features:** The safety feature of any method should be carefully evaluated for the potential danger of the analysis. Hazardous, carcinogenic chemicals should be handled with utmost care by wearing safety tools. For e.g., in modern HPLC systems, acetonitrile, which is as toxic as hydrogen cyanide is used as a mobile phase. Safety precautions should be read carefully before handling such chemicals.

vii. **Time factors:** The time factors of a method are very important and crucial. The total time needed for an analysis should be worked out. If in the method, doing some modifications without foregoing the accuracy and precision can shorten a step, such steps should be thought of.

PROJECT FOR ESTABLISHMENT OF FEED ANALYTICAL LABORATORY (as in the year 2002)

Buildings

Description	Area	Approx cost (Rs.)
For Small Feed Analytical Laboratory		
Lab area	30 x 20 sq. ft	180,000
Fume chamber	6 x 4 x 4 ft	5,000
Total		**185,000**
For Medium Feed Analytical Laboratory		
Lab area	30 x 20 sq. ft	180,000
Fume chamber (2No's.)	6 x 4 x 4 ft	10,000
Total		**190,000**
In Addition to the above for Advanced Feed Analytical Laboratory the following building is required for A.C room		
A.C room with 1.5 ton AC	15 x 10 sq. ft	100,000
Fume chamber	10 x 10 x 12 ft	20,000
Total		**120,000**

Furniture

Name	*Qty*	*Approx cost (Rs.)*
For Small and Medium Feed Analytical Laboratory		
Table	1	3,0C..
Chairs	3	1,000
Revolving stool	4	1,500
Total		**5,500**
For Advanced Feed Analytical laboratory		
Chair	2 Nos	650
Revolving stool	4 Nos	1,500
Personnel		
Category	Nos	Salary/month (Rs.)
Laboratory Assistant	1	1,500
Laboratory Attendant	1	1,000

Equipment

Name	*Specification*	*Qty*	*Approx. Cost(Rs.)*
For Small Feed Analytical laboratory			
Electronic top loading balance	0.1 mg sensitivity	1	75,000
Drying oven – with Temp control thermostat (40 to 180 °C)	60 x 60 x 60 cm	1	10,000
Hot air oven - with Digital temp control (40 to 180 ° C)	45 x 45 x 45 cm	1	10,000

Name	Specification	Qty	Approx. Cost(Rs.)
Protein digestion	LPG burner (single unit)	6	4,000
Gas connection		2	6,000
Micro kjeldahl apparatus	(with silver condenser)	1	4,500
Soxhlet heater	(6 heaters) 750 w	1	4,000
Hot plate	25 x 40 cm 1.2 kw	1	1,500
Muffle furnace	23 x 10 x 10 cm 1.6 kw	1	5,000
S.S. Distilled water still	1.5 kW	1	2,500
Erma colorimeter		1	25,000
Electric bunsen		2	2,500
Blender (Mixie)		2	4,500
TLC apparatus (static applicator)		1	4,000
UV cabinet		1	4,000
Total			**162,500**
In addition to the above following equipments are required for Medium Feed Analytical laboratory			
Centrifuge		1	10,000
Incubator		1	10,000
Magnetic strirrer		1	5,000
Rotary shaker		1	5,000
Kjeltec distillation unit		1	250,000
Fibretec unit		1	250,000
Soxtec unit		1	600,000
Cyclotec mill		1	150,000
UV – visible double beam spectrophotometer		1	500,000
Total			**1780,000**
In addition to the above following equipments are required for Advanced Feed Analytical laboratory			
HPLC		1	1000,000
GC		1	600,000
Sonicator		1	10,000
Rotary evaporator		1	125,000
Membrane filter unit with vacuum pump		1	30,000
Total			**1765,000**

Glassware

For Small and Medium Feed Analytical Laboratory

S.No.	Name	Specification	Qty	Approx. cost (Rs.)
1	Dish petri	10 x 17mm	6	750
2	Desiccators			
	Small		1	1,500
	Large		1	4,500
3	Flasks			2,750
	Kjeldahl	(w.o lid) 800 ml	10	1,450

S.No.	Name	Specification	Qty	Approx. cost (Rs.)
	Volumetric	1000 ml	2	
		500 ml	2	1,000
		100 ml	10	3,750
		50 ml	2	700
		25 ml	2	700
4	Bottles	(Tarson)		
	Narrow mouth	125ml LDPE	24	350
	250ml	6	200	
	500ml	6	300	
	1000ml	6	400	
5	Wash bottles	600 ml LDPE	6	250
6	Conical flask	250ml	20	1,500
7	Beaker			
	100ml	20	800	
	250ml	10	500	
	Berzelius	(tall form w.o. spout)	6	800
8	Pipette			
	Volumetric	5 ml	2	100
	10 ml	2	150	
	25 ml	2	175	
	Graduated	5 ml	2	500
	10 ml	2	500	
9	Burette	50 ml	5	2,000
10	Funnel			
		75mm	20	1,500
		100mm	6	750
		75mm pp (Tarson)	6	100
	Separating	250 ml (Tarson)	6	2,500
11	Measuring cylinder (Tarson)			
		100ml pp	6	400
		250ml pp	2	200
		500ml pp	2	300
		1000ml pp	2	650
		10ml Borosil	2	200
		50ml Borosil	2	300
		100ml Borosil	2	400
12	Silica crucible		10	1,500
13	Tongs		2	250
14	Dropping bottle		2	25
15	Glass rod		0.5kg	50
16	Glass tubes		0.5kg	50
17	Pipette stand		1	150

S.No.	Name	Specification	Qty	Approx. cost (Rs.)
18	Burette stand		4	600
19	Clamps		6	300
20	Boss-head		8	400
21	Vacuum desiccator		1	4,000
Total				**40,250**

In addition to the above, the following equipments are required for Advanced Feed Analytical Laboratory

S No.	Name	Specification	Qty	Approx. cost (Rs.)
1	Volumetric flask	1000 ml	2	1,450
		500 ml	2	1,000
		100 ml	10	3,750
		50 ml	2	700
2	Beaker	100ml	20	800
		250ml	10	500
3	Measuring cylinder (Borosil)	10ml	2	200
		50ml	2	300
		100ml	2	400
4	Wash bottles	600 ml LDPE	6	250
5.	Separating funnel (Borosil)	250 ml	6	3,500

Chemicals

S.No.	Name	Quality	Qty	Approx. cost (Rs.)
1	Ammonium ferric sulphate	LR	500 g	120
2	Acetone	LR	2.5 L	400
3	Activated charcoal		100 g	200
4	aflatoxin standard	Sigma	1 mg	2,500
5	Amino napthol sulphonic acid	AR	25 g	200
6	Ammonium hydroxide	LR	2.5 L	240
7	Ammonium molybdate	AR	100 g	270
8	Ammonium oxalate	LR	500 g	110
9	Chloroform	LR	2.5 L	475
10	Copper sulphate	LR	500 g	225
11	Cotton	Adsorbent	1 roll	100
12	Cupric carbonate	LR	500 g	285
13	Dimethyl amino benaldehyde		100 g	385
14	Dipotassium hydrogen phosphate	AR	500 g	450
15	Ethanol		500 ml	250
16	Ferric chloride	LR	500 g	73
17	Hydrochloric acid	LR	2.5 L	230
18	Methyl red		25 g	105

S.No.	Name	Quality	Qty	Approx. cost (Rs.)
19	Nitric acid	LR	2.5 L	270
20	Petroleum ether (60-80 °C)	LR	2.5 L	260
21	Phenolpthalein		50 g	100
22	Potassium chloride	LR	500 g	65
23	Potassium dihydrogen phosphate	AR	500 g	450
24	Potassium ferrocyanide	LR	500 g	280
25	Potassium hydroxide	LR	500 g	135
26	Potassium permanganate	AR	500 g	315
27	Potassium thiocyanate	AR	500 g	675
28	Silica gel for TLC	Acme	1000 g	550
29	Silver nitrate	AR	25 g	460
30	Sodium hydroxide	Flakes	5 Kg	385
31	Sodium hydroxide	AR	500 g	100
32	Sodium meta bisulphite	AR	500 g	100
33	Sodium sulphate	LR	500 g	80
34	Sodium sulphite	AR	500 g	175
35	Sulphuric acid	LR	5 L	350
36	Sulphuric acid	AR	2.5 L	300
37	Thimble		6 Nos	300
38	Urea	AR	500 g	190
39	Whatman no 1 filter paper		100 sheets	1,300
40	Whatman no 1 filter paper	9cm discs	1Pkt	500
41	Zinc acetate	LR	500 g	145
Total				**14,103**

In addition to the above, the following chemicals are required for Medium and Advanced Feed Analytical Laboratory

1	Whatman no 42 filter paper	9cm discs	1Pkt	500
2	Ochratoxin A		1 mg	16,000
3	T2-Toxin		1 mg	16,000
4	Citrinin		1 mg	1,000
5	Zearalenone		1 mg	1,200
6	Sterigmatocystin		1 mg	2,000
7	Sodium sulphate		1x5 kg	420
8	Chloroform (HPLC)		1 L	420
9	Acetonitrile (HPLC)		1 x 2.5 L	1,700
10	Methanol (HPLC)		1 x 2.5 L	420
11	Acetone (HPLC)		1 X 2.5 L	420
12	n. hexane (HPLC)		1 L	1,700
13	TLC aluminum sheet (MERCK)	20x20cm	1 pkt	2,150
14	Formic acid		1 x 500 ml	100
15	Xylanase (SIGMA)		1000 IU	4,112

S.No.	Name	Quality	Qty	Approx. cost (Rs.)
16	Phytase (SIGMA)		2000 IU	3,026
17	Pyridoxal hydrochloride (MERCK)		1 x 10 g	2,200
18	Thiamine chloride (MERCK)		2 x 25 g	2,250
19	Membrane filter paper (HVLP)	47mm (Millipore)	1 pkt	1,200
20	2,2,-Bipyridyl		1 x 5 g	330
21	Vitamin A acetate (MERCK)		1 x 25 g	2,055
22	Vitamin D3 (SIGMA)		1 g	1,567
23	Calcium D.pantothenate (HPLC)		1 x 25 g	452
24	Perchloric acid 70%		1 x 500 ml	550
25	Carboxy methyl cellulose		1x 500 g	950
26	P-DMAB		1 x 100 g	365
27	Acetic acid		1 x 500 ml	1,345
28	Ammonium meta vanadate		1 x 100 g	329
29	Sodium diethyl dithio carbomate		1 x 100 g	177
30	Carbon tetrachloride		1 x 500 ml	82
31	Potassium per iodate		1 x 100 g	330
32	Ortho phosphoric acid		1 x 500 ml	170
33	Ammonium molybdate		1 x 100 g	280
	Total			**65,800**

ABSTRACT

Category of Analytical laboratory	Small	Medium Approximate cost (Rs)	Advanced
Building	1,85,000	1,90,000	305,000
Furniture	5,500	5,500	7,650
Equipment	1,62,500	19,42,500	3707,500
Glass wares	40,250	40,250	43,750
Chemical	14,103	79,903	79,903
Total	**4,07,353**	**22,53,153**	**4068,803**

** Cost of Personnel/month 2,500 2,500*

** Depending on the level and samples received for analysis, the man power is increased in proportion.*

Summary

Establishing a feed analytical laboratory is essential in a feed manufacturing unit. The type depends on the tonnage of the plant. Constant monitoring and upgradation is needed to achieve accuracy and speed.

Handbook of

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There has been considerable increase in the utilization of soybean meal and other soy products like soybean oil, full fat soybeans in poultry feeds in recent years. This handbook on poultry nutrition has been prepared by the American Soybean Association to assist poultry feed millers, nutritionists and poultry farmers to formulate good quality poultry feeds. ASA intends this document to be an easily readable reference manual reviewing each and every aspect of poultry nutrition.

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