Important Notes AN-602

Feed evaluation, Formulation and Processing Technology

Department of Animal Sciences

Edited by

Dr. Muhammad Arif

1. Maize Normal

2. Maize medium sized

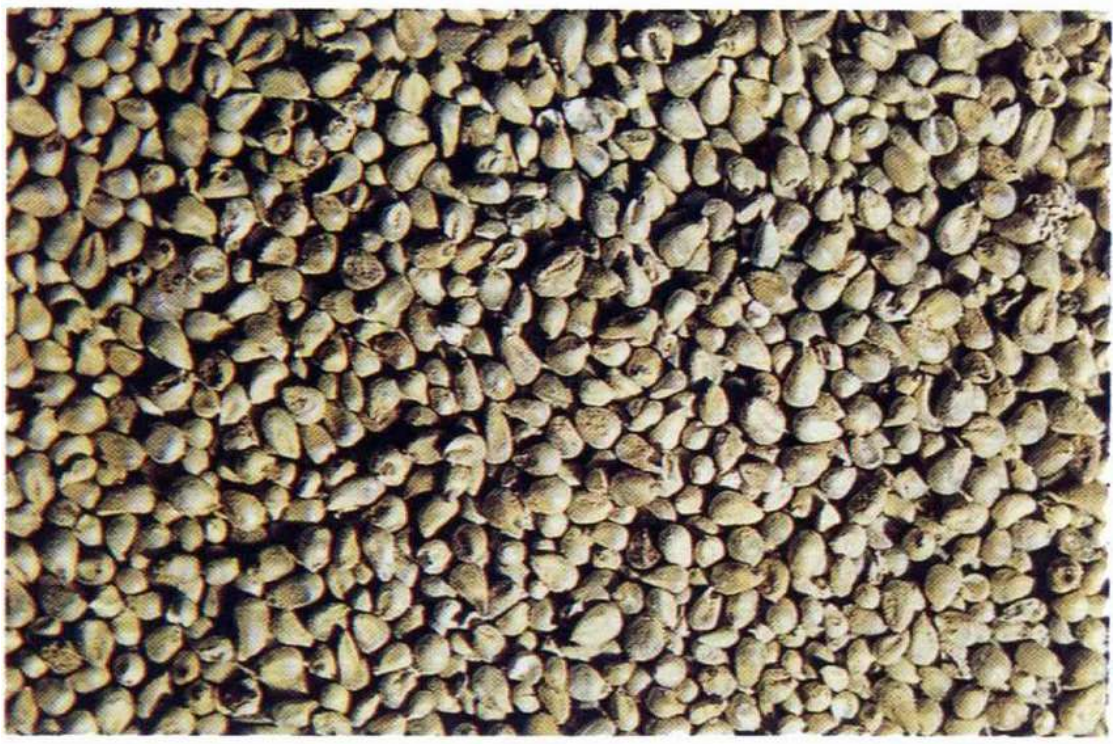
3. Maize Weevil attacked

4. Maize with cob and dust

5. Maize Normal

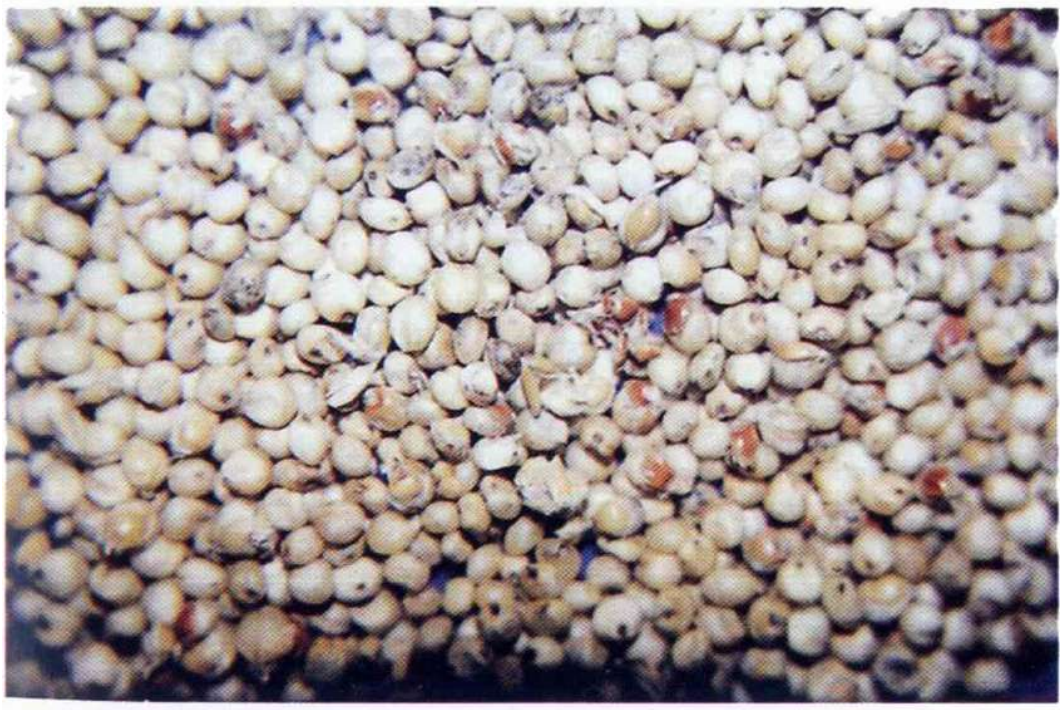
6. Maize Normal and Moldy

7. Bajra (pearl millet) Normal and large sized

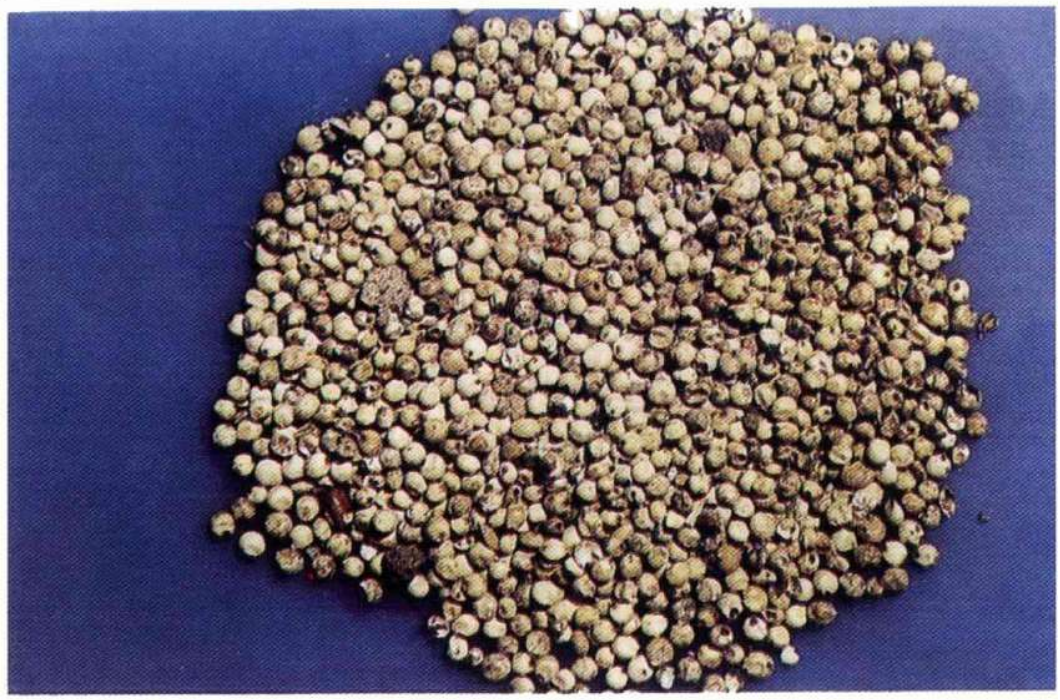


8. Bajra (pearl millet) small uneven sized

9 . Jowar (sorghum) normal, white



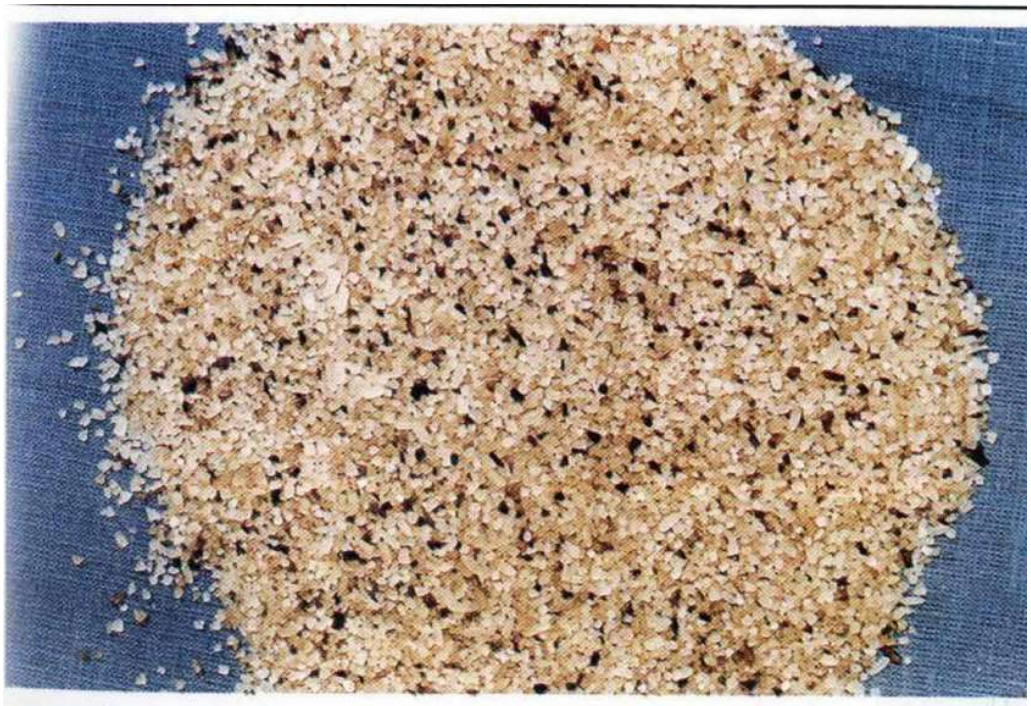
10. Jowar (sorghum) with husk



11. Jowar (sorghum) poor quality

12. Rice full grains

13. Rice - broken grains



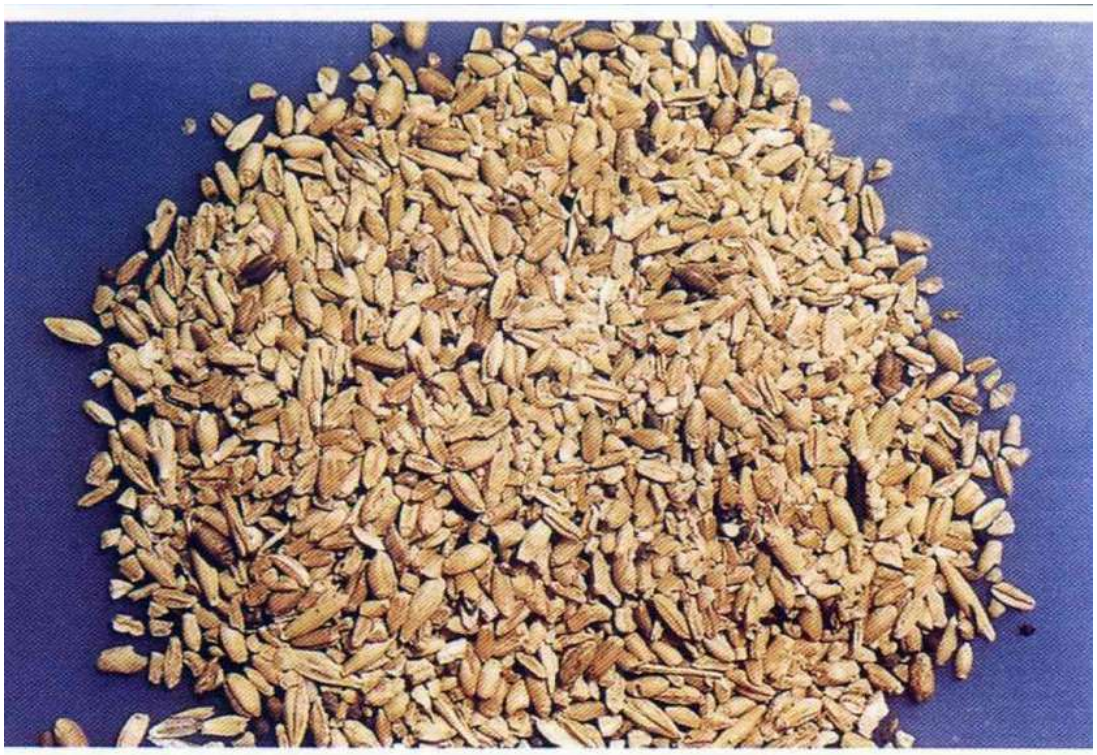
14. Rice broken - moderate quality

15. Rice broken - Very poor quality

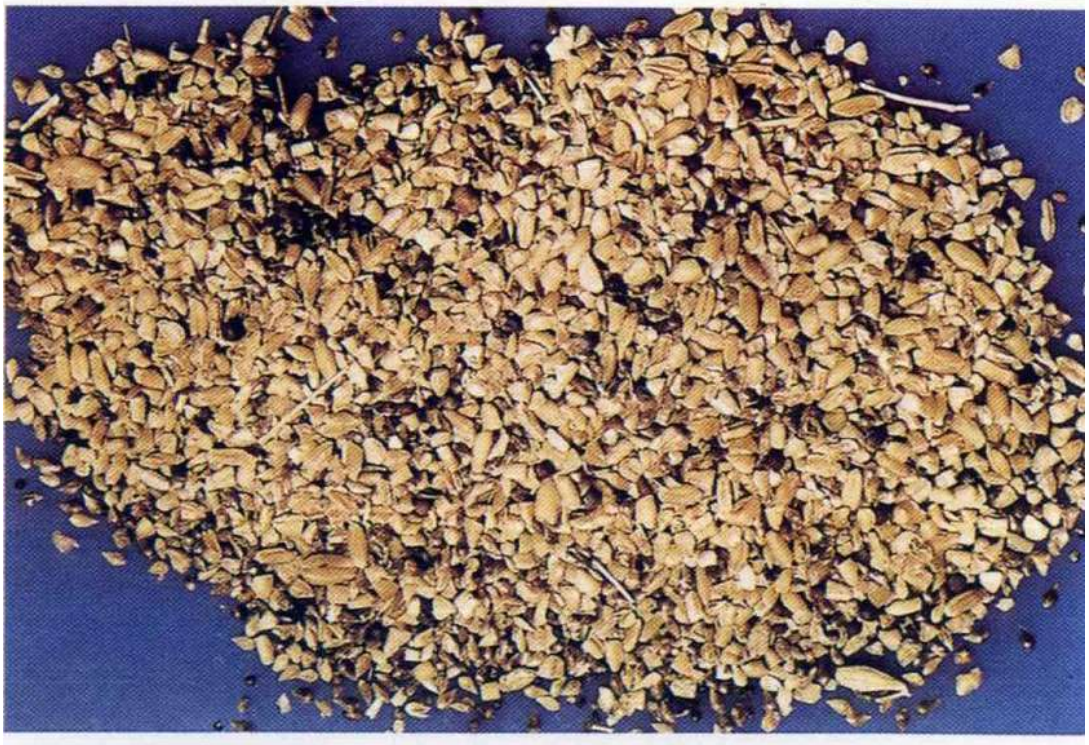
16. Rice polish - A good quality rice polish

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

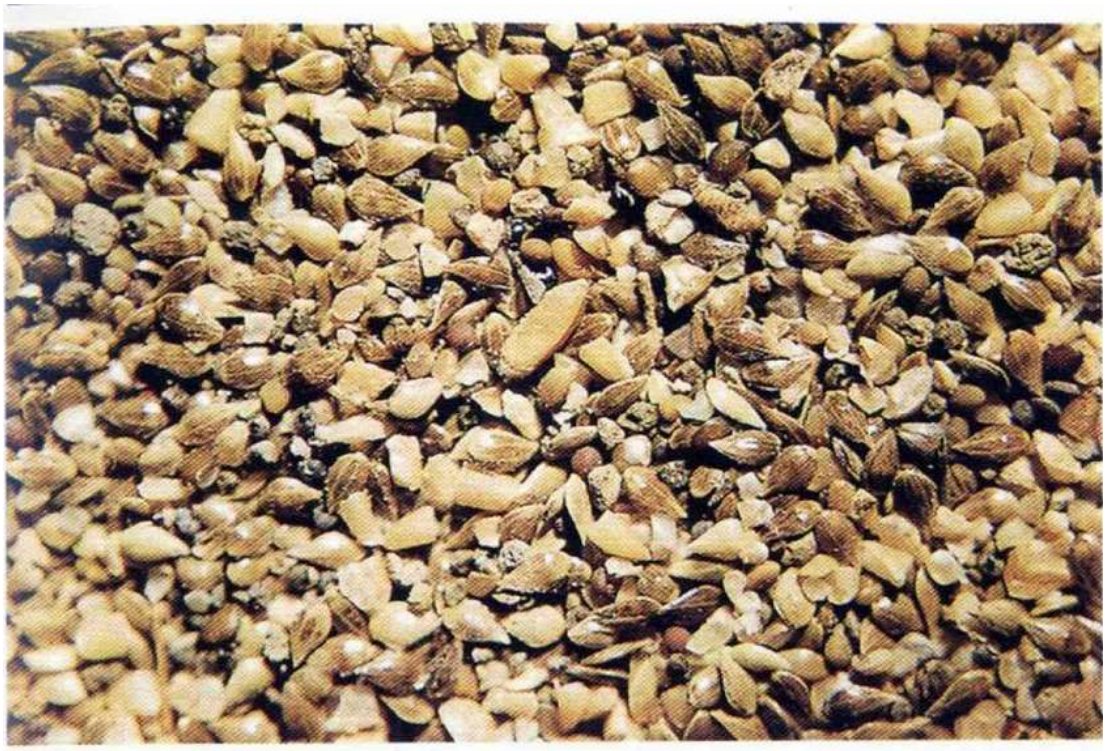
18. Deoiled Rice bran



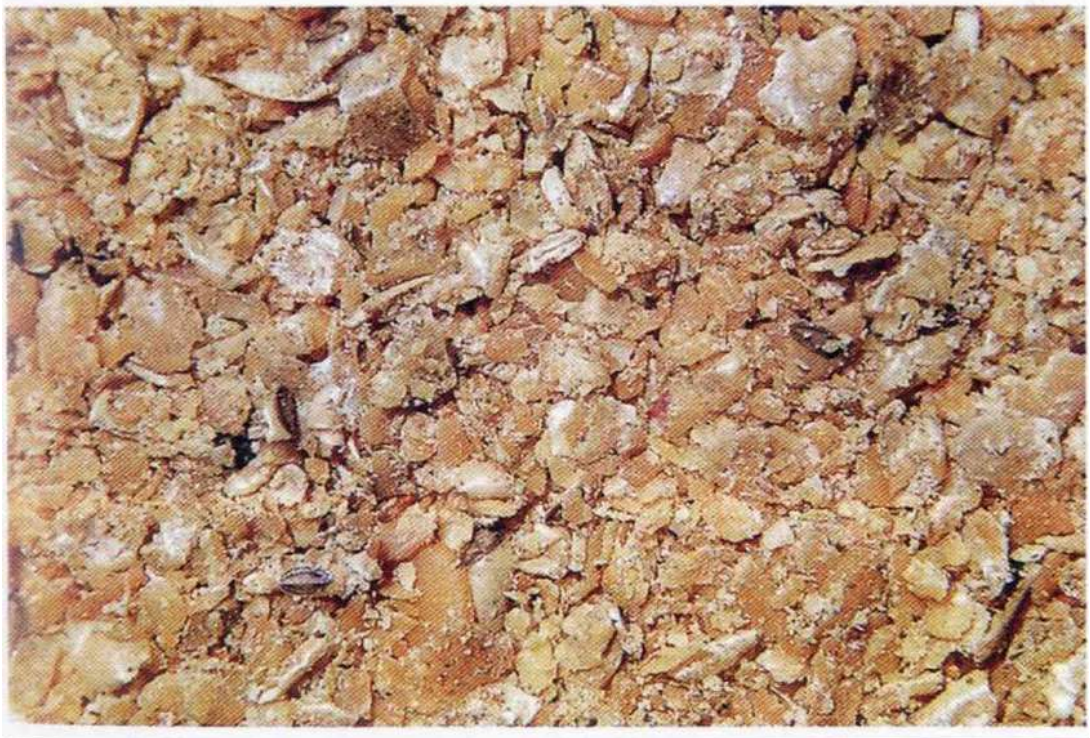
19. Wheat full but with immature grains



20. Wheat broken with weed seed

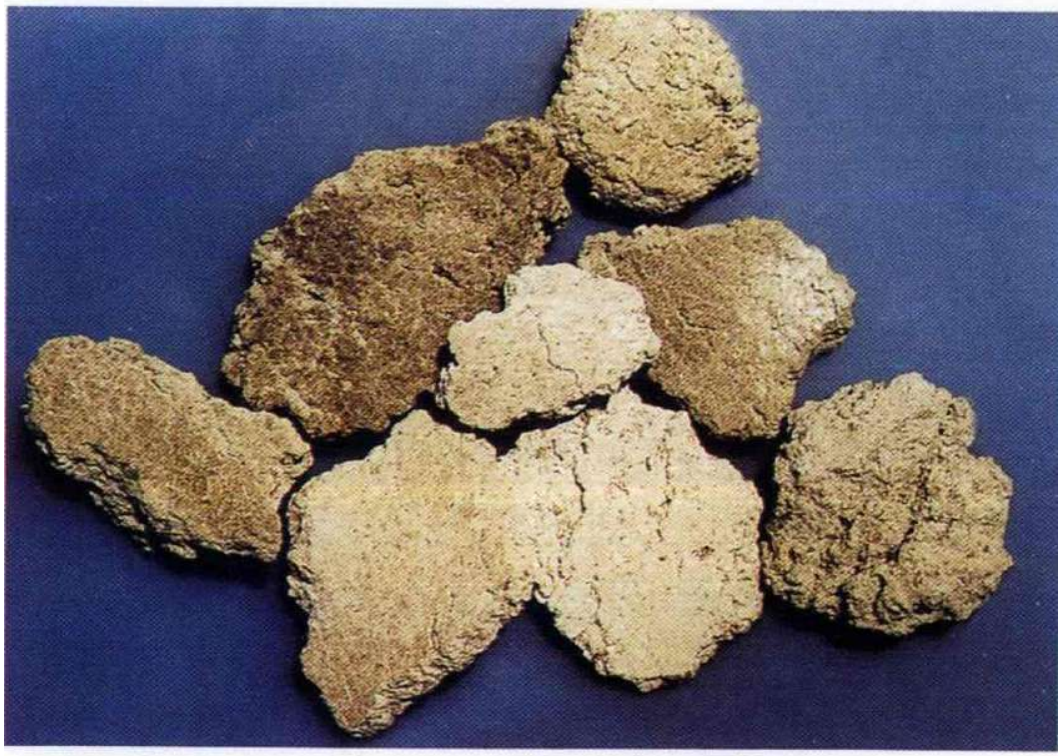


21. Wheat broken majority of portion is weed seed



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

33. *Calcite - chalky white in colour*

34. *Shell Grit - good quality*

35. *Marble Stones*

36. *Soft Shell and Grit variable sized*

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.

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	

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

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)

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.

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 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

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

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.*

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.*

Table 3. Practical methods of detoxification of anti-nutrients

S N0.	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.

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.*

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	-

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

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

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		

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)	$CaHPO_4H_2O$	22	18
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

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

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

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

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

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	

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*

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

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

Table 2. Species susceptibility to mycotoxins

Mycotoxins	Poultry	Dairy	Pig	Horse
Aflatoxin	++	++	++	++
Zeralenone	+	+	++	+
Vomitoxin	+	+	++	+
Ochratoxin	++	-	++	+
Fumonisin	+	+	++	++
T-2 toxin	++	+	+	+

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*)

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	