A LABORATORY MANUAL

OF

ANIMAL NUTRITION

(Unit IV: Applied Non-Ruminant Nutrition)

Compiled and Edited by:

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DIVISION OF ANIMAL NUTRITION

FACULTY OF VETERINARY SCIENCES AND ANIMAL HUSBANDRY

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PREFACE

It is the first edition of laboratory manual of “Unit IV: Applied Non-Ruminant Nutrition”. All the exercises have been thoroughly written as per the syllabus of Veterinary Council of India-2016. This manual is designed keeping in mind the basic principles of applied non-ruminant nutrition (poultry, horse, laboratory animals, dogs and cats and zoo animals including wild birds), which are necessary for better livestock health, growth, reproduction and production. In different chapters, feed formulation exercises have been prepared and also given for assignment to the students to keep as record what they have learnt.

We extend our gratitude to Hon’ble Vice-Chancellor, SKUAST-Jammu for moral and Professional support. We are thankful to Dean, Faculty of Veterinary Sciences and Animal Husbandry, R. S. Pura, Jammu for his kind encouragement and support to prepare this manuscript.

— Editors

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Nutrient requirements for different classes of poultry given by various agencies

- Nutrient requirements are the amount of nutrients required by poultry to support normal function.
- Requirements may be expressed in quantities of nutrients or in dietary proportions.
- Statements or quantitative descriptions of the amounts of one or more nutrients needed by poultry have been provided by various agencies or organizations.
    - In India now days we usually follow BIS specification (2007) and ICAR (2013).
    - In USA and in many other nations the NRC specifications are followed.
    - In UK the ARC specifications are followed.
    - Some poultry industry also using Degussa (1996 and 2001) specification.
    - However certain commercial poultry farms follow their own standards.
- Poultry feeds must be formulated and prepared so that it provides all of the bird's nutrient requirements.

The nutrient requirements of poultry are affected by a large number of factors, including:

- Genetics (the species, breed or strain of bird) - Different species, breeds or strains of bird have different average body sizes, growth rates and production levels and will also absorb and utilize nutrients from feed with different levels of efficiency, leading to different nutrient requirements.
- Age - Nutrient requirements are related to both body weight and the stage of maturity.
- Sex - Prior to sexual maturity the sexes have only small differences in their nutrient requirements. Differences in nutrient requirements are larger following the onset of sexual maturity.
- Reproductive state - The level of egg production in hens and sexual activity in males will affect nutrient requirements.
- Ambient temperature - Poultry have increased energy requirements to maintain normal body temperature in cold ambient temperatures and the opposite in hot ambient temperatures.
- Housing system - The type of housing system will influence the level of activity of the birds and therefore their energy requirements.
- Health status - Birds experiencing disease require an increase intake of some nutrients, commonly minerals and vitamins.

Table 1: Nutrient requirements of various categories of chicken as per BIS (2007)

Nutrient	Requirements for various categories of chickens														
	Broiler feed			Layer feed				Broiler breeder feed				Layer breeder feed			
	Pre starter	Starter	Finisher	Chick	Grower	Layer Ph-1	Layer Ph-2	Chick	Grower	Layer	Male	Chick	Grower	Layer	Male
Moisture (%) Max.	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
CP (%) Min.	23	22	20	20	16	18	16	20	16	16	15	20	16	17	16
EE (%) Min	3	3.5	4	2	2	2	2	2.5	2.5	2.5	2.5	2	2	2	2
CF (%) Max.	5	5	5	7	9	9	10	7	9	9	9	7	9	9	9
AIA (%) Min.	2.5	2.5	2.5	4	4	4	4.5	4	4	4	4	2.5	2.5	2.5	2.5
ME (Kcal/kg) Min.	3000	3100	3200	2800	2500	2600	2400	2800	2750	2800	2750	2800	2600	2600	2600
Linoleic acid (%) Min	1.1	1.1	1.1	1	1	1	1	1	1	1	1	1	1	1	1
Lysine (%) Min.	1.3	1.2	1	1	0.7	0.7	0.65	1	0.8	0.85	0.8	0.95	0.7	0.7	0.8
Methionine (%) Min.	0.5	0.5	0.45	0.4	0.35	0.35	0.3	0.45	0.4	0.45	0.4	0.4	0.4	0.4	0.4
Meth + Cys (%) Min.	0.9	0.9	0.85	0.7	0.6	0.6	0.55	0.7	0.7	0.7	0.7	0.7	0.6	0.6	0.6
Salt (%) Max.	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Calcium (%) Min	1	1	1	1	1	3	3.5	1	1	3.5	1	1	1	3.5	1
Total P (%) Min.	0.7	0.7	0.7	0.7	0.65	0.65	0.65	0.7	0.7	0.7	0.7	0.7	0.6	0.6	0.6
Available P (%) Min.	0.45	0.45	0.45	0.45	0.4	0.4	0.4	0.45	0.45	0.4	0.4	0.45	0.4	0.4	0.4

Continue....

Nutrient	Requirements for various categories of chickens														
	Broiler feed			Layer feed				Broiler breeder feed				Layer breeder feed			
	Pre starter	Starter	Finisher	Chick	Grower	Layer Ph-1	Layer Ph-2	Chick	Grower	Layer	Male	Chick	Grower	Layer	Male
Trace Minerals (Min.)															
Mn (%)	100	100	100	70	60	60	60	100	100	100	100	100	100	100	100
Co (%)	12	12	12	12	9	9	9	12	12	12	12	12	12	12	12
Zn (%)	80	80	80	60	60	60	60	80	80	80	80	80	80	80	80
Fe (%)	80	80	80	70	60	60	60	80	80	80	80	80	80	80	80
I (%)	1.2	1.2	1.2	1	1	1	1	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Se (%)	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.20	0.15	0.15	0.15	0.20	0.15
Vitamins (Min.)															
A (IU/kg)	11000	11000	10000	9000	8000	8000	8000	12000	12000	15000	12000	12000	12000	15000	12000
D_3 (IU/kg)	3000	3000	3000	1800	1600	1600	1600	2500	2500	3000	2500	2500	2500	3000	2500
E (ppm)	30	30	30	15	10	10	10	20	20	50	20	20	20	50	20
K (ppm)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	2	2	3	2	2	2	3	2
B1 (ppm)	2.5	2.5	2.5	2	1.5	1	1.5	2	2	3	2	2	2	3	2
B2 (ppm)	6	6	6	6	5	5	5	5	5	6	5	5	5	6	5
Niacin (ppm)	40	40	40	40	20	20	20	40	40	50	40	40	40	50	40
Folate (ppm)	1	1	1	1	0.5	0.5	0.5	3	3	4	3	3	3	4	3
Pan.acid (ppm)	15	15	15	10	9	7	9	15	15	25	15	15	15	25	15
Biotin (ppm)	0.15	0.15	0.15	0.10	0.10	0.10	0.10	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
B_6 (ppm)	5	5	5	3	3	3	3	5	5	6	5	5	5	6	5
B_{12} (ppm)	0.015	0.015	0.015	0.010	0.008	0.008	0.008	0.025	0.025	0.030	0.025	0.025	0.025	0.030	0.025
Chol (ppm)	500	500	500	500	200	400	200	850	850	700	500	850	850	700	500
Afl B1 (ppb)	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20

Table 2: Nutrient requirements of commercial white and coloured broiler chickens (as fed basis) as per ICAR (2013)

Nutrients	White (Age, Days)			Coloured (Age, Days)	
	0-14	14-21	21-42	0-21	21-42
Crude protein (%)	22.00	21.50	19.50	21.60	20.00
Metabolisable energy (Kcal/kg)	3000	3050	3100	2950	3050
Linoleic acid (%)	1.00	0.90	0.90	1.00	0.90
Lysine (%)	1.2	1.07	0.94	1.07	0.98
Methionine (%)	0.52	0.48	0.41	0.48	0.40
Methionine + Cysteine (%)	0.86	0.76	0.70	0.87	0.71
Threonine (%)	0.80	0.78	0.67	0.77	0.72
Tryptophan (%)	0.20	0.19	0.17	0.19	0.18
Arginine (%)	1.35	1.22	1.63	1.22	1.08
Isoleucine (%)	0.80	0.78	0.69	0.78	0.72
Calcium (%)	1.00	0.95	0.85	1.00	0.85
Available Phosphorus (%)	0.45	0.40	0.38	0.45	0.38
Sodium (%)	0.19	0.19	0.14	0.19	0.14
Chlorine (%)	0.19	0.19	0.14	0.19	0.14
Manganese (mg/kg)	55.00	55.00	50.00	55.00	50.00
Iodine (mg/kg)	1.00	1.00	1.00	1.00	1.00
Iron (mg/kg)	75.00	60.00	50.00	75.00	60.00
Zinc (mg/kg)	60.00	60.00	60.00	50.00	40.00
Copper (mg/kg)	10.00	10.00	8.00	10.00	8.00
Selenium (mg/kg)	0.15	0.15	0.15	0.15	0.15
Chromium (mg/kg)	0.20	0.20	0.20	0.20	0.20
Vitamin A (IU/kg)	5000	5000	5000	5000	5000
Vitamin D3 (IU/kg)	2400	2400	2400	2400	2400
Vitamin E (mg/kg)	15.00	15.00	15.00	15.00	15.00
Vitamin K (mg/kg)	1.00	1.00	0.80	0.80	0.80
Thiamine (mg/kg)	5.00	4.00	4.00	5.00	4.00
Riboflavin (mg/kg)	6.00	6.00	6.00	5.00	4.00
Pyridoxine (mg/kg)	5.00	5.00	5.00	5.00	5.00
Pantothenic acid (mg/kg)	12.00	10.00	10.00	10.00	9.00
Nicotinic acid (mg/kg)	35.00	35.00	30.00	35.00	30.00
Biotin (mg/kg)	0.15	0.15	0.15	0.15	0.15
Vitamin B12 (mg/kg)	0.015	0.015	0.015	0.015	0.015
Folic acid (mg/kg)	0.50	0.50	0.50	0.50	0.50
Choline (mg/kg)	1300.00	1200.00	900.00	1200.00	900.00

Table 3: Daily requirement during starting (0-3 weeks) and finishing (4-6 or 7 weeks) periods

Nutrients	Type of activity	Requirements
Starting period (0-3 weeks)		
CP	Maintenance	2.403 g CP/kgW$^{0.75}$
	Gain	0.292 g CP/g gain
ME	Maintenance	43.25 kcal/kgW$^{0.75}$
	Gain	3.994 kcal/g gain
Lysine	Maintenance	117 mg/ kgW$^{0.75}$
	Gain	14.53 mg/g gain
Methionine	Maintenance	41.63 mg/kgW$^{0.75}$
	Gain	6.6 mg/g gain
Threonine	Maintenance	80.4 mg/kgW$^{0.75}$
	Gain	10.44 mg/g gain
Finishing period (3-6 or 7 weeks)		
CP	Maintenance	8.637 g CP/kgW$^{0.75}$
	Gain	0.195 g CP/g gain
ME	Maintenance	124.442 kcal/kgW$^{0.75}$
	Gain	3.06 kcal/g gain
Lysine	Maintenance	408 mg/ kgW$^{0.75}$
	Gain	9.632 mg/g gain
Methionine	Maintenance	173 mg/kgW$^{0.75}$
	Gain	3.81 mg/g gain
Threonine	Maintenance	307 mg/kgW$^{0.75}$
	Gain	6.923 mg/g gain

Table 4: Nutrient requirements of broiler breeders (as fed basis) as per ICAR (2013)

Nutrients	Chicks	Growers	Pre-breeder	Breeder	Male
	0-4 wk	5-8 wk	19-23 wk	24 wk onwards	24 wk onwards
Crude protein (%)	20.00	10.00	16.50	16.00	14.00
Metabolisable energy (Kcal/kg)	2800	2650	2700	2700	2750
Lysine (%)	1.1	0.80	0.80	0.75	0.60
Methionine (%)	0.45	0.40	0.36	0.35	0.30
Threonine (%)	0.70	0.60	0.52	0.52	0.48
Tryptophan (%)	0.20	0.16	0.17	0.16	0.14
Calcium (%)	1.00	1.00	1.50	3.00	0.90
Available Phosphorus (%)	0.45	0.45	0.38	0.35	0.30
Manganese (mg/kg)	100.00	120.00	120.00	100.00	120.00
Iodine (mg/kg)	2.00	3.00	3.00	2.50	2.50
Iron (mg/kg)	80.00	80.00	80.00	80.00	80.00
Zinc (mg/kg)	100.00	100.00	120.00	100.00	100.00
Copper (mg/kg)	20.00	20.00	20.00	20.00	20.00
Selenium (mg/kg)	0.30	0.30	0.30	0.30	0.35
Vitamin A (IU/kg)	12000	20000	18000	15000	12000
Vitamin D3 (IU/kg)	3000	4500	4000	3500	2000
Vitamin E (mg/kg)	80.00	100.00	100.00	100.00	200.00
Vitamin K (mg/kg)	3.00	5.00	5.00	5.00	5.00
Thiamine (mg/kg)	4.00	5.00	5.00	4.00	4.40
Riboflavin (mg/kg)	20.00	20.00	20.00	20.00	20.00
Pyridoxine (mg/kg)	5.00	8.00	6.00	6.00	6.00
Pantothenic acid (mg/kg)	30.00	30.00	30.00	10.00	9.00
Nicotinic acid (mg/kg)	60.00	80.00	75.00	66.00	60.00
Biotin (mg/kg)	0.25	0.30	0.30	0.25	0.25
Vitamin B12 (mg/kg)	0.03	0.03	0.04	0.03	0.03
Folic acid (mg/kg)	4.00	4.00	4.80	4.00	4.00
Choline (mg/kg)	1200.00	1200.00	1200.00	1200.00	1200.00

Table 5: Nutrient requirements of starting and growing egg type pullets and cockerels (as fed basis) as per ICAR (2013)

Nutrients	Laying pullets			Cockerels	
	0-8 wk	8-16 wk	16-18 wk	0-4 wk	4-10 wk
Crude protein (%)	18.50	15.50	15.00	19.00	17.50
Metabolisable energy (Kcal/kg)	2600	2600	2700	2600	2600
Linoleic acid (%)	1.00	0.80	0.80	1.00	0.80
Lysine (%)	0.85	0.65	0.50	0.98	0.90
Methionine (%)	0.32	0.29	0.27	0.35	0.33
Methionine + Cysteine (%)	0.65	0.59	0.54	0.70	0.67
Threonine (%)	0.68	0.58	0.50	0.78	0.70
Calcium (%)	1.00	0.80	2.00	1.00	0.85
Available Phosphorus (%)	0.40	0.35	0.32	0.41	0.38
Sodium (%)	0.15	0.15	0.15	0.15	0.15
Chlorine (%)	0.15	0.15	0.15	0.15	0.15
Manganese (mg/kg)	55.00	55.00	50.00	55.00	50.00
Iodine (mg/kg)	0.35	0.35	0.35	0.35	0.35
Iron (mg/kg)	60.00	60.00	60.00	60.00	60.00
Zinc (mg/kg)	64.00	35.00	35.00	40.00	40.00
Copper (mg/kg)	8.00	5.00	5.00	8.00	8.00
Selenium (mg/kg)	0.15	0.10	0.10	0.15	0.15
Vitamin A (IU/kg)	3000	2500	3000	3000	2500
Vitamin D3 (IU/kg)	300	250	300	300	250
Vitamin E (mg/kg)	10.00	10.00	10.00	10.00	10.00
Vitamin K (mg/kg)	0.50	0.50	0.50	0.50	0.50
Thiamine (mg/kg)	1.00	1.00	1.00	1.00	1.00
Riboflavin (mg/kg)	3.60	1.80	1.80	3.60	3.00
Pyridoxine (mg/kg)	3.00	3.00	3.00	3.00	3.00
Pantothenic acid (mg/kg)	10.00	10.00	10.00	10.00	10.00
Nicotinic acid (mg/kg)	25.00	11.00	11.00	25.00	25.00
Biotin (mg/kg)	0.15	0.10	0.10	0.15	0.15
Vitamin B12 (mg/kg)	0.009	0.009	0.009	0.009	0.009
Folic acid (mg/kg)	0.55	0.25	0.25	0.55	0.55
Choline (mg/kg)	1300.00	900.00	500.00	1300.00	1000.00

Table 6: Nutrient requirements of Leghorn type hens and breeder males (as fed basis) as per ICAR (2013)

Description	Age (wk)		Age (wk)		Breeder male
	18-30	18-30	>30	>30	>20 wk
Live wt (g)	1300	1400	1400	1500	-
Egg Mass (g)	42.5	45	45	50	-
Shed Temp (^{0}C)	25	25	25	25	-
Feed Intake (g)	90	100	100	110	-
Nutrient					
Crude protein (%)	20.00	18.00	16.50	15.00	16.50
Metabolisable energy (Kcal/kg)	2750	2600	2600	2550	2600
Linoleic acid (%)	1.10	1.00	1.00	0.85	1.00
Lysine (%)	0.90	0.82	0.76	0.68	0.76
Methionine (%)	0.40	0.36	0.34	0.32	0.34
Methionine + Cysteine (%)	0.78	0.70	0.65	0.60	0.65
Threonine (%)	0.63	0.56	0.52	0.47	0.52
Arginine (%)	0.93	0.84	0.77	0.70	0.77
Tryptophane (%)	0.21	0.19	0.18	0.16	0.18
Calcium (%)	3.80	3.61	3.60	3.40	1.00
Available Phosphorus (%)	0.36	0.28	0.32	0.30	0.32
Sodium (%)	0.17	0.15	0.15	0.14	0.15
Chlorine (%)	0.17	0.15	0.15	0.14	0.15
Manganese (mg/kg)	50.00	45.00	45.00	40.00	45.00
Iodine (mg/kg)	0.04	0.035	0.035	0.032	0.035
Iron (mg/kg)	55.00	50.00	50.00	45.00	50.00
Zinc (mg/kg)	50.00	45.00	45.00	40.00	45.00
Copper (mg/kg)	8.00	5.00	5.00	8.00	8.00
Selenium (mg/kg)	0.08	0.06	0.06	0.05	0.06
Vitamin A (IU/kg)	5000	4500	4500	4000	4500
Vitamin D3 (IU/kg)	500	450	450	400	450
Vitamin E (mg/kg)	15.00	10.00	10.00	10.00	10.00
Vitamin K (mg/kg)	0.60	0.50	0.50	0.45	0.50
Thiamine (mg/kg)	0.85	0.70	0.70	0.65	0.70
Riboflavin (mg/kg)	3.50	3.00	3.00	2.80	3.00
Pyridoxine (mg/kg)	3.50	3.00	3.00	2.80	3.00
Pantothenic acid (mg/kg)	2.50	2.00	2.00	1.80	2.00
Nicotinic acid (mg/kg)	12.00	10.00	10.00	9.00	10.00
Biotin (mg/kg)	0.12	0.10	0.10	0.09	0.10
Vitamin B12 (mg/kg)	0.004	0.004	0.004	0.004	0.004
Folic acid (mg/kg)	0.30	0.28	0.28	0.25	0.28
Choline (mg/kg)	1200.00	1050.00	1050.00	950.00	1000.00

Table 7: Nutrient requirements and specifications from different agencies- Broiler Starter

Nutrient Age (Weeks)	Degussa (2001) 0-3	ARC (1975) 0-4	NRC (1994) 0-3
Moisture%	-	-	10.00
Protein%	18.70	17.00	20.10
ME kcal/kg	2800	2800	2800
Arginine%	1.19	0.93	1.09
Histidine%	-	0.44	0.31
Isoleucine%	-	0.77	0.70
Leucine%	-	1.33	1.05
Lysine%	1.14	0.99	0.96
Methionine%	0.50	0.43	0.44
Methionine + Cystine%	0.85	0.83	0.79
Phenylalanine%	-	0.77	0.63
Phenylalanine + Tyrosine%	-	1.43	1.17
Threonine%	0.75	0.67	0.70
Tryptophane%	0.19	0.19	0.18
Valine%	-	0.89	0.79
Linoleic acid%	-	0.90	0.88
Calcium%	-	1.08	0.88
Phosphorus% (non-phytin)	-	0.42	0.39
Sodium%	-	0.14	0.18
Chlorine%	-	0.13	0.18

Table 8: Nutrient requirements and specifications from different agencies- Broiler Finisher

Nutrient Age (Weeks)	Degussa (2001) 4-7	ARC (1975) 4-8	NRC (1994) 3-6
Moisture%	-	-	10.00
Protein%	18.10	14.60	18.10
ME kcal/kg	2900	2900	2900
Arginine%	1.16	0.71	1.00
Histidine%	-	0.34	0.291
Isoleucine%	-	0.60	0.66
Leucine%	-	1.00	0.99
Lysine%	1.11	0.75	0.91
Methionine%	0.47	0.34	0.34
Methionine + Cystine%	0.83	0.63	0.65
Phenylalanine%	-	0.60	0.59
Phenylalanine + Tyrosine%	-	1.11	-
Threonine%	0.73	0.50	0.67
Tryptophane%	0.18	0.14	0.16
Valine%	-	0.66	0.74
Linoleic acid%	-	0.94	0.91
Calcium%	-	0.70	0.82
Phosphorus% (non-phytin)	-	-	0.32
Sodium%	-	0.11	0.14
Chlorine%	-	0.10	0.14

Table 9: Nutrient requirements and specifications from different agencies- Chick Starter

Nutrient	Degussa (1996)	ARC (1975)		NRC (1994)
Age (Weeks)	Up to 6	0-4	4-8	0-6
Moisture%	-	-	-	10.00
Protein%	17.80	16.40	13.60	17.10
ME kcal/kg	2700	2700	2700	2700
Arginine%	0.95	0.90	0.66	0.95
Histidine%	-	0.42	0.31	0.25
Isoleucine%	-	0.74	0.56	0.57
Leucine%	-	1.28	0.93	1.04
Lysine%	0.83	0.96	0.70	0.81
Methionine%	0.38	0.42	0.31	0.28
Methionine + Cystine%	0.73	0.80	0.58	0.59
Phenylalanine%	-	0.74	0.56	0.51
Phenylalanine + Tyrosine%	-	1.38	1.01	0.95
Threonine%	0.57	0.65	0.46	0.64
Tryptophane%	0.15	0.18	0.13	0.16
Valine%	-	0.85	0.62	0.59
Linoleic acid%	-	0.87	0.87	0.95
Calcium%	-	1.05	0.65	0.85
Phosphorus% (non-phytin)	-	0.41	-	0.38
Sodium%	-	0.13	0.11	0.14
Chlorine%	-	0.12	0.10	0.14

Table 10: Nutrient requirements and specifications from different agencies- Grower

Nutrient	Degussa (1996)		ARC (1975)	NRC (1994)	
Age (Weeks)	7-12	13-20	9-20	7-12	13-18
Moisture%	-	-	-	10.00	10.00
Protein%	14.70	13.00	10.70	14.00	14.00
ME kcal/kg	2700	2700	-	2700	2700
Arginine%	0.79	0.69	0.60	0.70	0.70
Histidine%	-	-	0.28	0.16	0.16
Isoleucine%	-	-	0.49	0.47	0.42
Leucine%	-	-	0.84	0.81	0.65
Lysine%	0.69	0.60	0.63	0.57	0.42
Methionine%	0.32	0.30	0.28	0.24	0.19
Meth. + Cystine%	0.64	0.57	0.52	0.49	0.39
Phenylalanine%	-	-	0.49	0.43	0.34
Phen. + Tyro%	-	-	0.90	0.79	0.62
Threonine%	0.47	0.41	0.42	0.54	0.34
Tryptophane%	0.13	0.12	0.12	0.13	0.10
Valine%	-	-	0.56	0.49	0.38
Linoleic acid%	-	-	1.00	0.95	0.93
Calcium%	-	-	0.40	0.76	0.74
Phosphorus%	-	-	-	0.33	0.28
Sodium%	-	-	0.07	0.14	0.14
Chlorine%	-	-	0.06	0.11	0.11

Table 11: Nutrient requirements and specifications from different agencies- Layer

Nutrient	Degussa (2001)	ARC (1975)	NRC (1994)
Moisture%	-	-	10.00
Protein%	16.00	16.50	13.64
ME kcal/kg	2500	-	-
Arginine%	0.85	0.51	0.64
Histidine%	-	0.17	0.16
Isoleucine%	-	0.55	0.59
Leucine%	-	0.68	0.75
Lysine%	0.80	0.75	0.63
Methionine%	0.38	0.35	0.27
Methionine + Cystine%	0.71	0.47	0.53
Phenylalanine%	-	0.39	0.43
Phenylalanine + Tyrosine%	-	0.70	0.76
Threonine%	0.52	0.36	0.43
Tryptophane%	0.15	0.17	0.15
Valine%	-	0.55	0.64
Linoleic acid%	-	1.20	0.91
Calcium%	-	3.50	2.96
Phosphorus% (non-phytin)	-	0.35	0.23
Sodium%	-	0.10	0.14
Chlorine%	-	0.09	0.12

Calculation of nutrient requirements for maintenance, growth, reproduction and production (like meat and egg production)

Protein (Amino acids) requirements

Proteins are complex organic compounds made up of amino acids. They are essential for living bodies in a more important way than either lipids or carbohydrates. They are needed for maintenance (body tissue wear and tear), growth, meat and egg production. Transformation of dietary proteins into meat, eggs and other body proteins are very important parts of chickens. They are essential as catalysts such as enzymes and hormones in the ion transport mechanism, muscular contractions, antigen-antibody reactions and acid base homeostasis. The correct balance of amino acids is required in the diet to meet the requirements of birds. The requirements of amino acids depend upon the type of proteins; feed containing specific level of amino acids i.e. essential amino acids.

Various factors affect the amino acid requirements are:

1) Rate of growth and egg production: If the growth is more rapid and egg production is higher than amino acid requirement is also higher.
2) Protein level: Amino acid requirement tend to increase with dietary protein.
3) Strain: Even within species like body size, growth rate, egg production, they may be different among strains.
4) Amino acid relationship/ interactions:
    i) Methionine and cystine: The requirement for methionine can be met only by methionine supplementation while the requirement for cystine may be met by cystine or methionine. Methionine is converted into cystine during metabolism.
    ii) Phenylalanine and tyrosine: The requirement for phenylalanine can be met by phenylalanine supplementation while the requirement for tyrosine may be met by tyrosine or phenylalanine.
    iii) Glycine and serine: Glycine and serine can be used interchangeably in poultry diet.
5) Amino acid antagonism: Amino acids like valine, leucine, isoleucine, arginine and lysine etc., they are specific antagonistic among each other that may be structurally related, therefore, increasing of such a group may raise the need of another of same group.
6) Amino acid imbalance: In supplementary diet, with limiting amino acids, it is important to supplement first with the most limiting amino acid followed by second most limiting amino acid.
7) Conversion of certain amino acids to vitamins: High level of methionine may partly be compensate for a deficiency of choline or vitamin B12 by providing needed methyl groups and high levels of tryptophan may alleviate niacin deficiency through metabolic conversion to niacin.
8) Amino acid availability: The usual assumption that amino acids are 80-90 percent available is not necessarily valid.

Calculation of amino acid requirement

The requirement for amino acids depends upon the individual bird's need for live weight or egg production. The requirement of an individual can be estimated by calculating using coefficients given in the table 12.

Table 12: Coefficients for calculating the requirements of two limiting amino acids

Amino acids	Broiler chicken		Laying chicken	
	A	**B**	**a**	**B**
Lysine	14.86	82	9.09	73
Methionine + Cystine	11.59	41	10.15	13
Amino acid requirement (mg/day) = a X productive output (g/day) + b X Live weight (kg)				

Example: A flock of laying hens have a mean live weight of 2.05 kg and there is no overall weight gain or loss. Their mean egg output is 58.7 g/day with standard deviation of egg output 4.18 g/day. An initial study of the possible diet indicates that methionine plus cystine are the first limiting amino acids and the economic level of addition is to meet 95% of the flock's requirement. The birds are eating 114 g/day. Calculate the methionine and cystine requirement using the coefficients from table 12.

Maintenance requirement (mg/day) = 13.0 X 2.05 = 26.7 mg (2.05 kg body weight)

Production requirement (mg/day) = 10.15 X 65.40 = 663.8 mg (an egg output of 1.6 standard deviation above the mean is required to meet 95% of individual potentials. This is calculated as 58.7 + (1.6 X 4.18) = 65.4 g/day).

Total = 690.5 mg.

Level in feed: The laying hens need 690.5 mg in 114 g of feed = 690.5/ 114 = 6.06 g/kg of feed.

Table 13: Ideal balance of amino acids for poultry (relative to lysine = 1.00)

Amino acid	Growing chicken	Layers
Lysine	1.00	1.00
Arginine	1.05	1.06
Methionine + Cystine	0.75	0.86
Histidine	0.40	0.25
Threonine	0.63	0.69
Tryptophan	0.18	0.24

Calculation for other amino acids

Lysine

Table 13 indicates the ideal ratio of methionine plus cystine to lysine is 0.86.

Level of lysine in feed = 6.06 X (1.0/ 0.86) = 7.05 g/kg of feed.

Arginine

Table 13 indicates the ideal ratio of arginine to lysine is 1.06.

Level of arginine in feed = 7.05 X 1.06 = 7.47 g/ kg of feed.

For growing chicken

Growing laying chicken is only 61% efficient in utilisation of dietary protein, while broiler chicken of the same age are approximately 67% efficient in the retention of dietary protein. The daily protein requirements of growing chicks can be categorized into three parts:

1) Protein required for tissue growth

Carcass of chicken contains approximately 18% protein, daily protein requirements for tissue growth is calculated by multiplying the daily gain in body weight (in grams) by 0.18

(18% protein) and divided by 0.61 (i.e. in growing laying chicken 61% is the efficiency of feed utilization).

Protein for tissue growth = (Daily gain in g x 0.18)/0.61

2) Protein for maintenance

The endogenous nitrogen loss in chicken has been determined approximately 250 mg of nitrogen per kg body weight. Nitrogen is multiplied by 6.25 indicated that 1600 mg of nitrogen is lost per kg body weight per day. The dietary protein requirement for maintenance may be calculated by multiplying the body weight in grams by 0.0016 and divided by 0.61.

Maintenance requirement = 250 mg nitrogen/ kg body weight/day

= 1600 mg (or 0.0016 g) protein/kg body weight/day

= (Bodyweight in g x 1.6/1000) / 0.61

3) Protein for feather growth

At 3 weeks of age the feathers represent about 4% of body weight. Thus increase to 7% at 4 weeks of age and remains relatively constant thereafter. The protein content of feathers is 82%. Daily protein required for feather production is calculated by% of feather weight (0.04/ 0.07) multiplied by daily gain in weight (grams) multiplied by 0.82 (protein of feathers) divided by 0.61.

= (Daily gain in g x 0.07 x 0.82) / 0.61

Calculation of protein requirement (grams) for growing chicken

= [(Bodyweight in g x 1.6/1000) + (Daily gain in g x 0.18) + (Daily gain in g x 0.07 x 0.82)] / 0.61 (% efficiency of protein utilization)

Same formula may be used for calculating the daily protein requirement of broiler chicks by substituting 0.67 (67% efficiency of protein efficiency of protein in broilers)

Protein requirements for laying hens

Various factors influence the feed consumption and protein requirements in laying hens which are:

1) Size and breed of hen
2) Environmental temperature
3) Stage of production
4) Housing system
5) Feeding space for hen
6) Depth of feed in feeders
7) Whether the hens are de-beaked or not
8) Floor space per hen in cage or deep litter
9) Availability of ample, cool, fresh drinking water
10) Health condition
11) Energy content of diet

If all these managemental factors are controlled, the feed consumption depends up to a great extent upon the size, breed of hen, environmental temperature, energy content of feed, stage of production.

1) Size and breed of hen: Heavy breeds consume more feed than lighter ones, therefore, heaver chicken requires more energy for maintenance and higher daily protein intake.
2) Environmental temperature: A white leghorn hen fed diet containing approximately 3000 Kcal ME per kg diet and consumes about 110 g of feed while in the summer season the

bird consumes 90 g of feed per bird per day. Thus in winter a protein level of 15.5% would provide 17 g of protein per bird per day while in summer dietary protein level of 19% would be needed for providing 17 g of protein per bird per day.

3) Stage of production: Egg production in laying hens usually remains for 15 months and egg production commencing at 22 weeks of age, reaching at peak on 28-30 weeks of age and gradually declines at zero level of 65% after 15 months of laying when the hens are about 82 weeks of age. Therefore, the production cycle of layer is divided into 2 phases.

1) In phase I, at the onset of laying (21-42 weeks of age) a white leghorn hen weighing 1350 g (1.35 kg) consumes about 75 g of feed per hen per day. There is an increase in egg production from 0-80th level i.e. 85-90% and also increase in body weight from 1.35 kg to approximately 1.80 kg and also increase in egg size from 40 g to 56 g per egg. Therefore, phase I period is most critical in production cycle of hen.

2) In phase II (period after 42 weeks onwards) when the hens have attained the body weight more than 1.8 kg and protein requirement of hens can be divided into 3 portions.

   i) Protein required for egg production

   ii) Protein required for maintenance

   iii) Protein required for body tissue and feather growth

Digestibility of protein in the diet of hens

The digestibility ranges from 75-90% with an average 85% for a mixed layer ration. The digestible amino acids are those that are absorbed from the gut lumen and they are calculated as the difference between the amount of amino acids of feed and excreta.

Calculation of protein requirement for egg production

Maintenance requirement of white leghorn hen = 3 g / day

Protein content of one egg = 6 g / day

Total requirement = 9 g / day

Efficiency of protein utilization for maintenance and egg production – 55%

Therefore, the protein requirement of laying hen = 9 x (100/55) = 16.36 g /day.

NB: If hen eats 120 g diet per day, then the protein content of the diet should be 13.6%. If hen eats 100 g diet only, then the protein content of the diet should be 16.4%.

Energy requirement for chicken

The birds consume feed largely to satisfy their inner need for energy and it is not possible to express the energy requirement in terms of specific number of kcal of diet. The energy requirement in case of poultry should be expressed into number of kcal of metabolisable energy (ME) which are approximately 18% higher than net energy (NE) requirement. This is due to the specific dynamic action of the nutrients. Consumption of protein causes about 30% increase in heat production whereas consumption of carbohydrate and fat produce 15 and 10% heat, respectively. In a well balanced ration containing 20% protein, 5% fat and 65% carbohydrate, the average heat production is 18%. Thus the net energy for maintenance (NEm) is 82% of metabolisable energy for maintenance (MEm) since chickens have high body temperature than mammals; therefore, energy expenditure for maintenance is higher.

Energy requirement for growth (in broilers)

The energy requirement ranges from 1.5-3 kcal/g of body weight gain. This depends upon the amount of fat in relation to protein in the body weight gain. The energy requirements for growing cockerels are higher than in pullets.

Calculation of energy requirement for broilers

Weight of broiler breeder= 2.5 kg

Age= 25 weeks

NEm= 83 x $2.5^{0.75}$= 83 x 1.99= 165 kcal/day

MEm requirement= 165/0.82= 201 kcal/ day

Activity= 50% of MEm = 101 kcal/ day

MEm + activity = 201 + 101 = 302 kcal/ day

Egg production is 85%

MEm egg = 86 kcal x 0.85 = 73 kcal/day

These pullets are still growing and body weight gain is approximately 500 g over 10 weeks period i.e. 7.14 g gain/day

Energy requirement for gain (18% protein and 15% fat) = 7.14 x 0.18 = 1.285 g protein

1.285 g protein x 4 kcal (1 g protein = 4 kcal) = 5.14 k cal

(7.14 g gain x 0.15 = 1.07 g fat)

1.07 g fat x 9 kcal (1 g fat = 9 kcal) = 9.64 kcal

Total ME for gain = 5.14 + 9.64 = 14.78 kcal

Total ME required (for the period of 25-30 weeks of age)

= MEm + ME activity + ME egg + ME gain

= 201 + 101 + 73 + 14.78

= 389.78 or 390 kcal/ hen / day.

Energy requirements for maintenance of layers

On the basis of basal metabolism studies,

NEm requirement of adult hen = 83 x body weight $Kg^{0.75}$ kcal/day

NEm requirement of 1.75 kg adult hen = 83 x $1.75^{0.75}$

= 83 x 1.56 = 126 kcal/day

MEm requirement = 126 x 82% = 126/0.82 = 154 kcal/day

Activity allowance is 50% of the energy needed for basal metabolism and 37% for caged hens.

Therefore, total ME requirement for non-laying hens = 154 + 57 = 211 kcal/day

(kept in cage; 154 x 0.37= 57)

The energy content of a large egg =86 kcal

Then total ME requirement of a laying hen (white leghorn) (in 100% production at 21^0C)

= 211 + 86 = 297 kcal/day.

Ration formulation for different classes of poultry and swine by using different methods

Ration can be defined as the total amount of feed given to the animals on daily basis.

Animal feed formulation can be defined as the process by which different feed ingredients are combined in a proportion necessary to provide the animal with proper amount of nutrients needed at a particular stage of production.

As the world population increases, one of the major problem facing developing countries of the world is their ability to cope with protein requirement for the growing population. Poultry, which offer meat and egg on account of its short generative interval and handy size is expected to play a major role in the bid to provide protein of animal source. It is reported that the most commonly kept livestock is poultry and that over 70% of those farmers kept chickens. Feed formulation is very important in raising animals because feed cost between 65% and 70% of the total cost of production in poultry production as identified by literatures.

Livestock feed formulation methods

There are about six conventional livestock feed formulation methods:

Pearson Square method

This method is relatively simple and easy to follow.

Advantages

1) Its simplicity of use and
2) Its usefulness for balancing protein requirement.

Disadvantages

1) Its usability for only two requirements at the same time,
2) Its reduced consideration given to other nutritive requirements especially, vitamins and minerals.

Simultaneous Equation Method/ Algebraic method

This is an alternative method for the square method using a simple algebraic equation. Here, a particular nutrient requirement is satisfied using a combination of two feed ingredients.

Advantages

1) The system is easy to use both by beginners and the experienced feed millers. It is used to introduce feed formulation to students in teaching classes.
2) Farmer can balance for both protein and energy.
3) It is useful in considering more than two feed ingredients at once when balancing more complex ration. Finally, as the requirement increases, the system of equation increases.

Disadvantages

1) It satisfies only one nutrient requirement and uses only two feed ingredients.
2) Level of the nutrient being computed should be intermediate between the nutrient concentrations of the two feed ingredients being used.

Two-By-Two Matrix Method

This method solves two nutrients requirement using two different feed ingredients. A 2 by 2 matrix is formed a set and a series of equations are solved to come up with the solution to the problem.

Trial and Error Method

This is the most popular method of formulating ration for the swine and poultry. It is a

type of feed formulation used in many developing nations of the world.

Advantages

1) As the name implies, the formulation is manipulated until the nutrient requirements of the animal are met.
2) This method makes possible the formulation of a ration that meets all the nutrient requirements of the animal.

Disadvantages

1) In poultry feed formation, various cases of mineral deficiency such as osteomalacia, rickets and shellessness or soft shell formation may not be properly addressed.
2) If care is not taken to comprehensively analyze or calculate the level of calcium and phosphorus of the ration in question.

Imami Method

This is an educational way to describe and balance simple rations by a common calculator with a high accuracy for farmers who do not have access to the computer.

Linear Programming (LP) Method

This is otherwise called, least cost computerized feed formulation. This method of determining the least cost combination of ingredients using a series of equations which employs Linear Programming methods. This least cost can employed in feed formulation takes seven basic steps.

Advantages

1) Scientific Approach to Problem Solving: It is the application of scientific approach to problem solving. Hence it results in a better and true picture of the problems which can then be minutely analyzed and solution ascertained.
2) Quality of Decision: LP provides practical and better quality of decisions that reflect very precisely the limitation of the system i.e; the various restrictions under which the system must operate for the solution to be optimal. If it becomes necessary to deviate from the optimal path, LP can quite easily evaluate the associated costs or penalty It guaranteed the finding of optimal solution.
3) Evaluation of All Possible Alternatives: Majority of the problems in animal feed formulation are somehow complicated. LP method ensure that all possible solutions are generated, out of which the optimal solution is selected.

Disadvantages

1) Absence of risk
2) Linear Relationship: It can only be applied to situations where the given problem can be represented in the form of linear relationship. Hence it is based on implicit assumption that the objective as well as all the constraints or the limiting factors can be stated in the form of linear expression. Many practical problems like feed mix problem can be better expressed with a minimum of quadratic equation.
3) Constant Value of objective and Constraint Equations: Before a LP technique could be applied to any feed mix problem, the values or the coefficients of the objective and constraints functions must be completely known and be constant over a period of time. If the values changed during the period of study, the LP would loose its effectiveness and may fail to provide optimal solution to the problem. However, in practical sense it is not possible to determine the coefficients of objective function and the constraint equations with absolute certainty.
4) Fractional solutions often have no meaning: There is absolutely no certainty that the solution to a LP feed mix problem can always be quantified as an integer quite often. It

can give fractional answers which are rounded off to the next integer. Hence, the solution would not be the optimal one.

5) Flexibility Limitation: Once a problem has been properly quantified in terms of objective function and constraint equations and the tools of Linear Programming are applied to it, it becomes very difficult to incorporate any changes in the system arising on account of any change in decision parameter. Hence, it lacks the desired operational flexibility. Reducing the world to a set of linear equations is usually very difficult.
6) Multiplicity of Goal: The long term objectives of any farm are not confined to a single goal. Any farm, at any point of time in its operations has a multiplicity of goals or the goals hierarchy- all of which must be attained on a priority wise basis for its long term growth.

A ration is the feed allowed for a given animal or bird during a period of 24 hours. The feed may be given at a time or in portions at intervals. Ration formulation is a process by which different feed ingredients are combined in a proportion necessary to provide the animal or bird with proper amount of nutrients needed at a particular physiological stage or for stage of production. Ration formulation requires the knowledge about nutrients, feedstuffs and livestock including poultry.

The basic objective of ration formulation for different categories of poultry and swine is to provide the correct amount of nutrients and their intake at a lower possible cost. A mixture of 4-5 feed ingredients could probably meet all nutrient requirements for various classes of poultry and swine. Formulation of commercially prepared poultry and swine diets tend to low in fibre and are cereal based. Cereals and their by-products often comprises between 50-75 percent in poultry and swine diets. They supply high proportion of starch i.e. frequently the lowest cost form of available dietary energy. Animal fats or vegetable oils may also be used as a source of dietary energy up to their inclusion level. Cereals and their by-products may also contribute up to 50% of the crude protein required in feed but this protein is usually deficient in essential amino acids. Lysine is particularly deficient in protein of cereals and their by-products. Concentrated source of protein must therefore, be used.

Basic inputs/ Prerequisites are required for ration formulation before formulating rations

1) To know the nutrient requirements of various classes of livestock and poultry to which the ration is formulated.
2) To know the nutrient composition of feedstuffs/ feed ingredients used for ration formulation. A wide variety of feed ingredients are used for formulation of rations. They are cereals and cereal by-products, animal fats and vegetable oils (energy source), plant proteins and animal protein feed ingredients (protein source), mineral and vitamin supplements (source of minerals and vitamins) and feed additives (performance and production enhancer), etc.
3) To know the current market price of selected feed ingredients. The requirement of the animals or birds can be met through several combinations of feed ingredients. However, when the costs of these ingredients are considered, there can only be one least-cost formulation. The least-cost ration should ensure that tile requirements of the animas or birdsl are met and the desired objectives are achieved.
4) Easy accessibility and availability of feed ingredients in local market.
5) Physical condition of the available feed ingredients
6) Acceptability and palatability of feed ingredients.
7) Knowledge about nutrient digestibility. The nutrients in the feed should be digestible and released into the gastrointestinal tract to be utilized by the animals or birds. Rations with high fiber content cannot be tolerated by poultry and swine. The most important feed factors that affect digestibility of feed are feed composition, ration composition, formulation and preparation of the feed. The digestibility of a feed is closely related to its chemical composition. The crude fiber fraction of feed has greater influence on its digestibility and both the amount and chemical composition of the crude fibre are important. The digestibility of feed is influenced not only by its own composition, but also by the composition of other feeds consumed with it. This is known as associative effect. Feed formulation and preparation also influences its digestibility. The commonest treatment applied to the feeds are crushing or grinding and cooking. In order to obtain maximum digestibility cereal grains should be crushed for horses and ground for pigs and poultry: otherwise they may pass through the gut intact. Feed processing such as pelleting and extrusion cooking also enhances feed digestibility.
8) Maximum inclusion level of feed ingredients. Each ingredient has its maximum level of inclusion in the diet. Inclusion of an ingredient beyond the maximum level may induce imbalance of nutrients, difficulty in feed formulation, and may reduce the performance of the birds or animals due to the presence of anti-nutritional factors beyond tolerance level. Cost is one of the factors imposing an upper limit on the inclusion of feed ingredients.
9) Interactions or interrelationship of various nutrients present in feed ingredients.
10) Presence of any anti-nutritional factors or toxins in the feed ingredients. The presence of anti-nutritional factors in the feed affects the digestion of some nutrients and makes them unavailable to the animals or birds. The inclusion of these feed ingredients should therefore be limited in the formulation. If the feedstuffs are having better nutrient profile and having anti-nutritional factors, thus it should be processed before incorporating in the ration so that the processing detoxified the anti-nutritional factors and nullify its detrimental effect.
11) Knowledge about proper dose of feed additives / feed supplements in formulated rations.

Table 14: Calcium and Phosphorus content (%) from different sources

Sources	Formula	Calcium	Phosphorus
1. Bone meal	-	29	12
2. Calcium carbonate	$CaCO_3$	38	-
3. Di-calcium phosphate (DCP)	$CaHPO_4.H_2O$	22	18
4. Mono-calcium phosphate	$Ca(H_2PO_4)_2$	16	21
5. Calcium sulphate	$CaSO_4.2H_2O$	22	-
6. Limestone powder (LSP)	$CaCO_3$	38	-
7. Meat cum bone meal	-	10	5
8. Shell grit, ground	-	38	-
9. Rock phosphate, de-fluorinated	-	32	18
10. Rock phosphate, soft	-	17	9

Table 15: Mineral (%) content from different sources

Compound	Formula	Mineral	Content (%)
1. Sodium chloride	NaCl	Sodium	39
		Chlorine	60
2. Sodium selenite	Na_2SeO_3	Selenium	45
3. Sodium selenate	Na_2SeO_4	Selinium	41
4. Potassium iodide	KI	Iodine	76
5. Potassium iodate	KIO_3	Iodine	59
6. Copper sulphate	$CuSO_4. H_2O$	Copper	35
7. Copper sulphate	$CuSO_4. 5H_2O$	Copper	25
8. Cupric carbonate	CuCO3	Copper	53
9. Cupric oxide	CuO	Copper	75
10. Ferrous sulphate	$FeSO_4.7H_2O$	Iron	21
11. Ferrous carbonate	$FeCO_3$	Iron	43
12. Zinc oxide	ZnO	Zinc	73
13. Zinc sulphate	$ZnSO_4.7H_2O$	Zinc	22
14. Magnous sulphate	$MnSO_4.H_2O$	Manganese	25
15. Magnous sulphate	$MnSO_4.5H_2O$	Manganese	22
16. Magnous carbonate	$MnCO_3$	Manganese	47

Table 16: Commercially available various vitamin premix

Vitamin	Per gram
1. Vitamin AB_2D_3	-
2. Vitamin A, IU	40,000
3. Riboflavin (B2), mg	20
4. Vitamin D3, IU	5000
5. Vitamin AB_2D_3K	-
6. Vitamin A, IU	80,000
7. Riboflavin (Vit. B_2), mg	50
8. Vitamin D3, IU	12,000

9. Vitamin K, mg	10
10. Vitamin B_{12}, µg	100
11. Vitamin B-complex	-
12. Thiamin (B_1), mg	4
13. Vitamin B_{12}, µg	40
14. Niacin, mg	60
15. Pantothenate calcium, mg	40
16. Pyridoxine (B_6), mg	8

Table 17: Nutrient composition of various feed ingredients used for poultry rations

Feed ingredients	Crude protein (%)	ME (Kcal/kg)
Maize	10	3450
Wheat	10	3300
Barley	10	3000
Sorghum	10	3350
Pearl millet	10	3300
Finger millet	9.5	3000
Broken rice	7.5	3250
Rice bran	12	3400
De-oiled rice bran	14	2550
Wheat bran	13	2750
Cassava	2.5	3500
Sweet potato	6	3400
Banana fruit	5	3000
Mango kernel meal	7.5	2400
Sal seed meal	9	2400
Molasses	3	2480
Palm oil	-	8800
Coconut oil	-	8400
Animal fat	-	8800
De-oiled sal seed cake	45	2300
Soybean seed	38	3100
Soybean meal	45-48	2600
Groundnut cake	45	2800
Groundnut cake (solvent extracted)	48	2450
Cotton seed meal	38	2000
Rapeseed meal	40	2320
Sunflower meal	36	2130
Coconut meal	21	1900
Sesame meal	40	2000
Linseed meal	34	1660
Neem kernel meal	38	2550

Alfalfa meal	20	1600
Leucaena meal	22	900
Fish meal	45-50	2850
Blood meal	73	1420
Meat meal	56	2310
Meal cum bone meal	45	2110
Liver residue meal	65	3000
Silkworm pupae meal	48	2900
House fly pupae meal	60	2500
Earthworm meal	66	2400
Poultry feather meal	73	1850

Table 18: Maximum level of inclusion of various conventional and un-conventional feed ingredients in poultry rations

Ingredients	Chicks and Broilers	Growers and Layers	Remarks
A. Energy Sources			
1. Maize	60-70	60-70	Susceptible to Mycotoxin contamination
2. Sorghum	30	50-60	Bird resistant variety may contain tannins
3. Wheat	20	30	Contains Arabinoxylans, Avidin
4. Rice	10	20	-
5. Broken Rice	10	20	Variable quality
6. Barley	10	20	Contains β-glucans
7. Bajra	30	60	-
8. Ragi	30	60	May not be used in broiler diet.
9. Rice bran	20	30	Susceptible for rancidity while storing.
10. Wheat bran	5	10	Low energy
11. Sal seed deoiled meal	3	6	Contains tannins
12. Cane molasses	2	5	Wet litter problems at higher levels.
13. Mango kernel meal	3	5	Contains tannins
14. Fats and oils	5	5	Cost limits inclusion
15. Tapioca tuber meal	20	30	Contains HCN
16. Leucaena leaf meal	5	10	Contains Mimosine
17. Alfalfa leaf meal	3-5	5-6	Good source of Carotenoides
18. Peanut leaf meal	3	5	Good source of Carotenes
19. Poultry manure meal	0	5	Problems of Pathogens
B. Veg. Protein Sources			
1. Soybean meal	35	25	Trypsin inhibitors
2. Peanut / Ground nut cake	35	25	Prone to contamination with Mycotoxins
3. Cotton seed meal	10	10	Iron suppl^{n} is required to bind Gosypol
4. Sunflower meal	10	20	
5. Coconut meal	3	5	
	3	5	

6. Rape seed/ Mustard cake	5	10	High in fibre
7. Safflower meal	10	15	Prone to Mycotoxin contamination.
8. Sesame/ Til cake	3	5	Erucic acid, tannins, glucosinolates
9. Linseed meal	5	10	High in fibre
10. Niger cake	5	10	High in Phytate and Oxalate
11. Karanj cake	10	20	Linatin/Linamarin&indigestible mucilage.
12. Ambadi cake	10	20	
13. Maize gluten meal	3	5	High in fibre
14. Guar meal			Contains Karanjin.
C. Animal Protein Sources	10	10	High in fibre
	3-5	3-5	Prone to Mycotoxin contamination.
1. Fish meal	6	6	Proper heat treatment is required, toasted.
2. Meat meal	2	3	
3. Meat cum bone meal	2	3	
4. Silk worm pupae meal	5	5	Rancidity, microbial contamination.
5. Hatchery by-product meal	3	3	Pathogenic microbial contamination.
	2	2	″
6. Poultry by-product meal			Low in threonine
7. Poultry offal meal			Pathogenic microorganism, rancidity.
8. Feather meal			Source of microorganism, low in methionine.
			Source of microorganism, low in methionine.
			Low in lysine, methionine, tryptophane

Table 19: Important Anti-nutritional factors (Anti-nutrients) present in feed ingredients

Anti-nutritional factors/ Anti-nutrients	Occurrence in feed ingredients
1. Protease inhibitors eg. Trypsin inhibitors	Soybean seeds
2. Haemagglutins (Lectins)	Castor bean, kidney bean, soybean)
3. Glucosides	
a. Saponins	Soybean seeds, Lucerne 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, meals of Rape and Mustard, Sal seed, Mango seed kernel, Leucaena and Tamarind seed
5. Phytate	All vegetable feed ingredients
6. Erucic acid	Rape and Mustard seed meal
7. Mimosine	Subabul (Leucaena) leaf meal
8. Nimbidines	Neem seed meal
9. Oxalates	Vegetable and animal feed sources
10. Anti-vitamins	

a. Anti-vitamin A	Lipoxygenase in Soybean seeds
b. Anti-vitamin D	Soybean seeds
c. Anti-vitamin E	Kidney bean
d. Anti-vitamin K (Dicumarol)	Sweet clover
e. Anti-vitamin B_6 (Linatin)	Lin seed meal
11. Non-starch Polysaccharides	Grains and vegetable protein sources.

Table 20: Practical methods of detoxification of Anti-nutritional factors/ Anti-nutrients

Anti-nutrients substance	**Practical method of detoxification**
1. Protease inhibitors/ Trypsin inhibitors	Heat treatment (Moist /dry heat treatment)
2. Haemagglutinins (Lectins)	Heat treatment (Moist /dry heat treatment)
3. Glucosides	
a. Saponins	Heat treatment (Sun drying)
b. Cyanogens	Only sun drying of Casava tuber
c. Glucosinolates	Water washing
d. Estrogens	Heat treatment is being effectively used
4. Phenols	
a. Gossypol	Used in restricted amount, Iron supplement
b. Tannins	Sun drying, used in restricted quantities.
5. Phytate	Phytase enzymes supplementation
6. Erucic acid	Rape and Mustard meal in limited quantity.
7. Argemone	Avoid argemone containinationeed meal.
8. Mimosine	Sun drying, used in restricted quantity.
9. Nimbidines	Water washing, used in restricted quantity.
10. Nitrates and Nitrites	Not a noticeable problem
11. Oxalates	Water washing, used in limited quantity
12. Anti-vitamins	
a. Anti-vitamin A	Heat treatment is being effectively used
b. Anti-vitamin D	Heat treatment (Moist / dry heat treatment).
c. Anti-vitamin E	Need vitamin E supplementation.
d. Anti-vitamin K (Dicumarol)	Need vitamin K supplementation.
e. Anti-vitamin B6 (Linatin)	Supplemental B6 may be used.
13. Non-Starch Polysaccharides	Commercial poly enzymes may be beneficial.

Various important steps involved in ration formulation and preparation of balanced ration

The ration formulation should be carried out in a step-wise manner. For formulation and preparation of 100 Kg ration for broilers, the essential steps are as follows:

Steps I- The minor ingredients are fixed and or slack space may be left to include them later. These are added in limited quantities based on cost or to provide a specific nutrient or non-nutrient feed additive or to balance a nutrient usually deficient. Trace mineral, vitamins and feed additives can be fixed because the contribution of major feed ingredients for these nutrients is little. Slack space may be left for addition of common salt, calcium and phosphorus sources, supplemental amino acids and fats at a later stage to balance the diet.

Fixed minor ingredients: Trace minerals, vitamins, Coccidiostats, Antibacterial agents

Slack space for– Fat, phosphorus source, calcium source, salt, amino acids and mineral mixture

Fixed minor ingredients and slack space – 5kg

Step II- The levels of animal protein sources are fixed as 8-10 kg. These are added at fixed levels because of cost. These provide the limiting amino acids (lysine and methionine + cystine) at higher levels than other feed ingredients.

Animal protein sources – Fish meal: 7 kg

Meat meal: 3 kg

Step III: The level cereal by-products like rice polish, rice bran/ deoiled rice bran, wheat bran if to be added may be fixed as 8-10 kg. Alternatively the cereal by-products and cereals can be fixed in certain ratio and can be added.

Cereal by-products – Rice polishing/ rice bran: 6-7 kg

De-oiled rice bran: 3-4 kg

Step VI: Vegetable protein sources (soybean meal/ groundnut cake, etc) and energy sources (cereal grains like maize, wheat, sorghum, barley, millets etc.) are added to provide the required amount of protein.

Step V: The metamolozable energy content of the diet has to be balanced. Any shortfall of ME can be met by supplementation of animal fats. However the addition of fat is the question of economics and may be practical in all circumstances then it should be met by energy concentrate.

Step VI: The phosphorus content of the diet is calculated in terms of available phosphorus. Phosphorus from animal and inorganic sources is considered completely available whereas that from plant sources is considered to be 30% available.

Step VII: The limiting amino acids in synthetic form can be met by supplementation of limestone powder, di-calcium phosphate and bone meal.

Step VIII: The limiting amino acids in synthetic form can be supplemented to meet the requirement. Supplementation of synthetic amino acids is the question of economics. The requirement of these limiting amino acids can be met by increasing level of inclusion of animal protein sources.

Step IX: A check is made for the total of the ingredients and also for all the nutrients if desired. If the total is still below 100 kg, cereal or cereal by-products can be added to make the ration 100 kg.

Using the above information rations can be formulated and prepared by several methods that include:

Algebraic method, Pearson square method, Trial and error method, Two-by-two matrix method, Computer operated MS Excel method and Linear programming, etc

Q.1: Formulate a balanced ration for pre-starter chicks (CP: 23% amd ME 3000 Kcal) as per BIS (2007) by using **Algebraic method** from various feed ingredients and their nutrient composition given below:

S. No.	Feed ingredients	Crude protein (CP%)	Metabolizable energy (ME Kcal / kg)
1	Crushed maize	10	3450
2	Broken wheat	10	3300
3	Rice polish	12	3400
4	Wheat bran	15	2750
5	Soybean meal	45	2600
6	Ground nut cake	45	2800
7	Fish meal	45	2850
8	Meat meal	56	2310
9	Mineral mixture	-	-
10	DCP	-	-
11	LSP	-	-
12	Common salt	-	-
13	Vitamin premix	-	-
14	Feed additives	-	-
15	Animal/ vegetable fat	-	7600-8800

Solution;

Steps involved in feed formulation: Pre-starter chick feed

A 100 kg of least cost feed is formulated to provide the nutrients as per the specifications.

Step I: **Fixed the minor ingredients and slack space: 5% or 5 kg**

These include nutrient and non-nutrient feed additives and natural feed ingredients added at a later stage to balance the diet.

Step II: Fixed the animal protein source: 10 kg, These (Fish meal; 7 kg and meat meal; 3 kg) are added to the diets since they are rich source of limiting amino acids (lysine and methionine or methionine + cystine).

Animal protein sources	Parts	CP	ME
Fish meal	7	(45/100) x 7 = 3.15	(2850/100)x7=199.5 kcal
Meat meal	3	(56/100) x3 = 1.68	(2310/100)x3=69.3 kcal
Total	10	3.15 + 1.68 = 4.83	199.5 + 69.3 = 268.8 kcal

Step III: The level of cereal by-products may be fixed: 8-10 kg. Theses (here we use 8 kg) (Rice polish: 6 kg and wheat bran: 2 kg) are used as filler, cheaper sources of energy, protein and B complex group of vitamins.

Cereal by-products	Parts	CP	ME
Rice polish	6	(12/100) x 6 = 0.72	(3400/100) x 6 = 204 kcal
Wheat bran	2	(15/100) x 2 = 0.30	(2750/100) x 2 = 55. 0 kcal
Total		8 = 1.02	= 259 kcal

Step IV: Vegetable protein sources and energy sources are added to provide the required amount of protein.

Out of 100 kg total part fixed as slack space + animal protein sources + cereal by products

= 5 + 10 + 8 = 23 parts (fixed)

= 100 – 23 = 77 kg

Amount of protein from 23 fixed parts provide = 0 + 4.83 + 1.02 = 5.85 kg

That is the remaining 77 kg of ingredients are to provide (23 – 5.85) = 17.15 kg

Soybean meal and ground nut cake are considered as vegetable protein sources, while crushed maize and broken wheat are considered as vegetable energy sources.

Considered average protein value of vegetable protein source (soybean; SBM + ground nut cake; GNC)/ 2

= (45 + 45)/ 2 = 45

Average protein value of vegetable energy source (crushed maize + broken wheat)/ 2

= (10 + 10)/ 2 = 10

The required protein level can be calculated by algebraic equation

Algebraic equation: Total of ingredients = 77 kg

Protein = 17.15 kg

Let X represents the vegetable protein source (SBM + GNC) and Y represents vegetable energy source (Maize + Wheat). The average protein content of vegetable protein source (SBM + GNC) is 45% and of vegetable energy source (maize + wheat) is 10%.

X + Y = 77 kg - (1)

0.45 X + 0.1 Y = 17.15 kg - (2)

Equation 1 is multiply with 0.10

0.10 X + 0.10 Y = 77 x 0.10 = 7.70 - (3)

Now equation 3 is subtracted from equation 2.

0.45 X + 0.10 Y = 17.15 kg - (2)

0.10 X + 0.10 Y = 7.70 - (3)

\- - = -

0.35 X = 9.47

Vegetable protein source (SBM +GNC), X = 9.47/ 0.35

= 27.06 kg

(SBM + GNC) /2 = 27.06/2 = 13.53 kg each i.e. 13.53 kg SBM and 13.53 kg GNC

Equation 1, X + Y = 77 kg

Here X value is = 27.06 kg

27.06 + Y = 77

Y = 77 – 27.06

Y = 49.94 kg

(crushed maize + broken wheat)/2 = 49.94 /2 = 24.97 kg each i.e. 24.97 kg maize and 26.93 kg wheat.

Feed ingredients	CP (%)	ME (Kcal/kg)	Parts	Calculated CP	Calculated ME
Crushed maize	10	3450	24.97	(10/100) x 24.97 = 2.497	(3450/100) x 24.97 = 861.465
Broken wheat	10	3300	24.97	(10/100) x 24.97 = 2.497	(3300/100) x 24.97 = 824.01
Rice polish	12	3400	6	(12/100) x 6 = 0.72	(3400/100) x 6 = 204
Wheat bran	15	2750	2	(15/100) x 2 = 0.30	(2750/100) x 2 = 55
Soybean meal	45	2600	13.53	(45/100) x 13.53 = 6.09	(2600/100) x 13.53 = 351.78
Groundnut cake	45	2800	13.53	(45/100) x 13.53 = 6.09	(2800/100) x 13.53 = 378.84
Fish meal	45	2850	7	(45/100) x 7 = 3.15	(2850/100) x 7 = 199.50
Meat meal	56	2310	3	(56/100) x 3 = 1.68	(2310/100) x 3 = 69.30
Mineral mixture	-	-	1	-	-
DCP	-	-	0.825		-
LSP	-	-	1.50		-
Common salt	-	-	0.5	-	-
Vitamin premix	-	-	0.025	-	-
Feed additives	-	-	0.5	-	-
Animal/veg. fat	-	8800	0.65	-	(8800/100) x 0.65 = 57.2
Total			**100**	**23.02**	**3001.095**

Requirement of CP = 23% and ME 3000 Kcal for pre-starter chicks as per BIS (2007) and

Formulated Ration provide CP = 23.02% and ME 3001.1 Kcal.

Q. 2: Formulate a balanced ration for pre-starter chicks (CP: 23% amd ME 3000 Kcal) as per BIS (2007) by using **Pearson's square method** from various feed ingredients and their nutrient composition given below:

S.No.	Feed ingredients	Crude protein (CP%)	Metabolizable energy (ME Kcal / kg)
1	Crushed maize	10	3450
2	Broken wheat	10	3300
3	Rice polish	12	3400
4	Wheat bran	15	2750
5	Soybean meal	45	2600
6	Ground nut cake	45	2800
7	Fish meal	45	2850
8	Meat meal	56	2310
9	Mineral mixture	-	-
10	DCP	-	-
11	LSP	-	-
12	Common salt	-	-
13	Vitamin premix	-	-
14	Feed additives	-	-
15	Animal/ vegetable fat	-	7600-8800

Solution;

Steps involved in feed formulation: Pre-starter chick feed

A 100 kg of least cost feed is formulated to provide the nutrients as per the specifications.

Step I: **Fixed the minor ingredients and slack space: 5% or 5 kg**

These include nutrient and non-nutrient feed additives and natural feed ingredients added at a later stage to balance the diet.

Step II: Fixed the animal protein source: 10 kg, These (Fish meal; 7 kg and meat meal; 3 kg) are added to the diets since they are rich source of limiting amino acids (lysine and methionine or methionine + cystine).

Animal protein sources	Parts	CP	ME
Fish meal	7	(45/100) x 7 = 3.15	(2850/100)x7=199.5 kcal
Meat meal	3	(56/100) x3 = 1.68	(2310/100)x3=69.3 kcal
Total	10	3.15 + 1.68 = 4.83	199.5 + 69.3 = 268.8 kcal

Step III: The level of cereal by-products may be fixed: 8-10 kg. Theses (here we use 8 kg) (Rice polish: 6 kg and wheat bran: 2 kg) are used as filler, cheaper sources of energy, protein and B complex group of vitamins.

Cereal by-products	Parts	CP	ME
Rice polish	6	(12/100) x 6 = 0.72	(3400/100) x 6 = 204 kcal
Wheat bran	2	(15/100) x 2 = 0.30	(2750/100) x 2 = 55. 0 kcal
Total		8 = 1.02	= 259 kcal

Step IV: Vegetable protein sources and energy sources are added to provide the required amount of protein.

Out of 100 kg total part fixed as slack space + animal protein sources + cereal by products

= 5 + 10 + 8 = 23 parts (fixed)

= 100 – 23 = 77 kg

Amount of protein from 23 fixed parts provide = 0 + 4.83 + 1.02 = 5.85 kg

That is the remaining 77 kg of ingredients are to provide (23 – 5.85) = 17.15 kg

Soybean meal and ground nut cake are considered as vegetable protein sources, while crushed maize and broken wheat are considered as vegetable energy sources.

Considered average protein value of vegetable protein source (soybean; SBM + ground nut cake; GNC)/ 2

= (45 + 45)/ 2 = 45

Average protein value of vegetable energy source (crushed maize + broken wheat)/ 2

= (10 + 10)/ 2 = 10

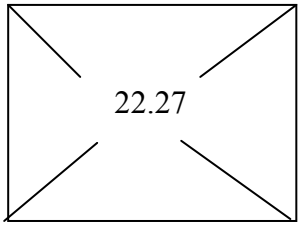
The required protein level can be calculated by Pearson's square method

Total of ingredients = 77 kg

Protein = 17.15 kg

Protein as percent = (17.15 x 100) / 77 = 22.27%

Energy source 10 22.73 Energy Source (maize + wheat)



Protein source 45 12.27 kg Protein source (SBM + GNC)

= 35. 0 kg

Now vegetable protein source (SBM + GNC) and vegetable protein source (Maize + wheat) are proportioned for 77 kg.

Protein source (SBM + GNC) = (12.27 x 77) / 35 = 26.994 kg (SBM + GNC) / 2

SBM = 13.497 kg

GNC = 13.497 kg

Energy Source (Maize + Wheat) = (22.73 x 77) / 35 = 50.006 kg /2

Maize = 25.003 kg

Wheat = 25.003 kg

Feed ingredients	**CP (%)**	**ME (Kcal/kg)**	**Parts**	**Calculated CP**	**Calculated ME**
Crushed maize	10	3450	25.00	(10/100) x 25 = 2.50	(3450/100) x 25.0 = 862. 50
Broken wheat	10	3300	25.00	(10/100) x 24.97 = 2.50	(3300/100) x 25.0 = 825.00
Rice polish	12	3400	6	(12/100) x 6 = 0.72	(3400/100) x 6 = 204
Wheat bran	15	2750	2	(15/100) x 2 = 0.30	(2750/100) x 2 = 55
Soybean meal	45	2600	13.50	(45/100) x 13.50 = 6.075	(2600/100) x 13.50 = 351.00
Groundnut cake	45	2800	13.50	(45/100) x 13.50 = 6.075	(2800/100) x 13.50 = 378.00
Fish meal	45	2850	7	(45/100) x 7 = 3.15	(2850/100) x 7 = 199.50
Meat meal	56	2310	3	(56/100) x 3 = 1.68	(2310/100) x 3 = 69.30
Mineral mixture	-	-	1	-	-
DCP	-	-	0.835		-
LSP	-	-	1.50		-
Common salt	-	-	0.5	-	-
Vitamin premix	-	-	0.025	-	-
Feed additives	-	-	0.5	-	-
Animal/veg. fat	-	8800	0.64	-	(8800/100) x 0.64 = 56.32
Total			**100**	**23.00**	**3000.62**

Q. 3: Formulate a balanced ration for broiler starter chicks (CP: 22% and ME 3100 Kcal) as per BIS (2007) by using **Algebraic method** from various feed ingredients and their nutrient composition given below:

S.No.	Feed ingredients	Crude protein (CP%)	Metabolizable energy (ME Kcal / kg)
1.	Crushed maize	10	3450
2.	Sorghum	10	3350
3.	Rice bran	12	3400
4.	De-oiled rice bran	14	2550
5.	Soybean meal	45	2600
6.	Ground nut cake	45	2800
7.	Fish meal	45	2850
8.	Meat meal	56	2310
9.	Mineral mixture	-	-
10.	DCP	-	-
11.	LSP	-	-
12.	Common salt	-	-
13.	Vitamin premix	-	-
14.	Feed additives	-	-
15.	Animal fat	-	8800

Solution;

Steps involved in feed formulation: Pre-starter chick feed

A 100 kg of least cost feed is formulated to provide the nutrients as per the specifications.

Step I: **Fixed the minor ingredients and slack space: 5% or 5 kg:** These include nutrient and non-nutrient feed additives and natural feed ingredients added at a later stage to balance the diet.

Step II: Fixed the animal protein source: 10 kg, These (Fish meal; 7 kg and meat meal; 3 kg) are added to the diets since they are rich source of limiting amino acids (lysine and methionine or methionine + cystine).

Animal protein sources	Parts	CP	ME
Fish meal	7	(45/100) x 7 = 3.15	(2850/100) x 7=199.5 kcal
Meat meal	3	(56/100) x 3 = 1.68	(2310/100) x 3=69.3 kcal
Total	10	3.15 + 1.68 = 4.83	199.5 + 69.3 = 268.8 kcal

Step III: The level of cereal by-products may be fixed: 10 kg. Theses (here we use 10 kg) (Rice bran: 8 kg and de-oiled rice bran (DORB): 2 kg) are used as filler, cheaper sources of energy, protein and B complex group of vitamins.

Cereal by-products	Parts	CP	ME
Rice bran	8	(12/100) x 8 = 0.96	(3400/100) x 8 = 272 kcal
DORB	2	(15/100) x 2 = 0.30	(2550/100) x 2 = 51. 0 kcal
Total		10 = 1.26	= 323 kcal

Step IV: Vegetable protein sources and energy sources are added to provide the required amount of protein.

Out of 100 kg total part fixed as slack space + animal protein sources + cereal by products

= 5 + 10 + 10 = 25 parts (fixed)

= 100 – 25 = 75 kg

Amount of protein from 25 fixed parts provide = 0 + 4.83 + 1.26 = 6.09 kg

That is the remaining 75 kg of ingredients are to provide (22 – 6.09) = 15.91 kg

Soybean meal and ground nut cake are considered as vegetable protein sources, while crushed maize and sorghum are considered as vegetable energy sources. Considered average protein value of vegetable protein source (soybean; SBM + ground nut cake; GNC)/ 2

= (45 + 45)/ 2 = 45

Average protein value of vegetable energy source (crushed maize + sorghum)/ 2

= (10 + 10)/ 2 = 10

The required protein level can be calculated by algebraic equation

Algebraic equation: Total of ingredients = 75 kg

Protein = 15.91 kg

Let X represents the vegetable protein source (SBM + GNC) and Y represents vegetable energy source (Maize + sorghum). The average protein content of vegetable protein source (SBM + GNC) is 45% and of vegetable energy source (maize + sorghum) is 10%.

X + Y	=	75 kg	-	(1)
0.45 X + 0.1 Y	=	15.91 kg	-	(2)

Equation 1 is multiply with 0.45

0.45 X + 0.45 Y	= 75 x 0.45 = 33.75	-	(3)

Now equation 2 is subtracted from equation 3.

0.45 X + 0.45 Y	=	33.75 kg	-	(3)
0.45 X + 0.10 Y	=	15.91	-	(2)
- -	=	-		

0.35 Y	=	17.84

Vegetable energy source (maize + sorghum), Y = 17.84/ 0.35

= 50.97 kg

(maize + sorghum)/2 = 50.97/2 = 25.5 kg each i.e. 25.5 kg maize and 25.5 kg sorghum

But here we use maize 41 kg (25.5 + 15.5) and sorghum 10 kg (25.5-15.5)

Equation 1, X + Y = 75 kg

Here Y value is = 50.97 kg

X + 50.97 = 75

X = 75 – 50.97

X = 24.03 kg

(SBM + GNC)/2 = 24.03 /2 = 12.02 kg each i.e. 12.02 kg SBM and 12.02 kg GNC.

Feed ingredients	CP (%)	ME (Kcal/kg)	Parts	Calculated CP	Calculated ME
Crushed maize	10	3450	41.00	(10/100) x 41.00 = 4.10	(3450/100) x 41.00 = 1414.50
Sorghum	10	3350	10.00	(10/100) x 10.00 = 1.00	(3350/100) x 10.00 = 335.00
Rice bran	12	3400	8	(12/100) x 8 = 0.96	(3400/100) x 8 = 272
DORB	14	2550	2	(15/100) x 2 = 0.30	(2550/100) x 2 = 50.40
Soybean meal	45	2600	12.02	(45/100) x 12.02 = 5.41	(2600/100) x 12.02 = 312.52
Groundnut cake	45	2800	12.02	(45/100) x 12.02 = 5.41	(2800/100) x 12.02 = 336.56
Fish meal	45	2850	7	(45/100) x 7 = 3.15	(2850/100) x 7 = 199.50
Meat meal	56	2310	3	(56/100) x 3 = 1.68	(2310/100) x 3 = 69.30
Mineral mixture	-	-	1.00	-	-
DCP	-	-	0.425		-
LSP	-	-	1.210		-
Common salt	-	-	0.5	-	-
Vitamin premix	-	-	0.025	-	-
Feed additives	-	-	0.5	-	-
Animal/veg. fat	-	8800	1.30	-	(8800/100) x 1.30 = 114.4
Total			**100**	**22.01**	**3104.20**

Requirement of CP = 22% and ME 3100 Kcal for pre-starter chicks as per BIS (2007) and

Formulated Ration provide CP = 22.01% and ME 3100 Kcal.

Q. 4: Formulate a balanced ration for **broiler starter chicks** (CP: 22% and ME 3100 Kcal) as per BIS (2007) by using **Pearson's square and Algebraic method** from various feed ingredients and their nutrient composition given below:

S.No.	Feed ingredients	Crude protein (CP%)	Metabolizable energy (ME Kcal / kg)
1	Crushed maize	10	3450
2	Sorghum	10	3350
3	Rice bran	12	3400
4	De-oiled rice bran	14	2550
5	Soybean meal	45	2600
6	Ground nut cake	45	2800
7	Fish meal	45	2850
8	Meat meal	56	2310
9	Mineral mixture	-	-
10	DCP	-	-
11	LSP	-	-

12	Common salt	-	-
13	Vitamin premix	-	-
14	Feed additives	-	-
15	Animal fat	-	8800

Q. 5: Formulate balanced **chick feed** (CP: 20% and ME 2800 Kcal) as per BIS (2007) by using **Pearson's square method** from various feed ingredients and their nutrient composition given below:

S.No.	**Feed ingredients**	**Crude protein (CP%)**	**Metabolizable energy (ME Kcal / kg)**
1.	Crushed maize	10	3450
2.	Bajra	10	3300
3.	Rice bran	12	3400
4.	De-oiled rice bran	14	2550
5.	Soybean meal	45	2600
6.	Sunflower cake	36	2130
7.	Fish meal	45	2850
8.	Mineral mixture	-	-
9.	DCP	-	-
10.	LSP	-	-
11.	Common salt	-	-
12.	Vitamin premix	-	-
13.	Feed additives	-	-

Solution;

Steps involved in feed formulation: chick feed

A 100 kg of least cost feed is formulated to provide the nutrients as per the specifications.

Step I: **Fixed the minor ingredients and slack space: 5% or 5 kg**

These include nutrient and non-nutrient feed additives and natural feed ingredients added at a later stage to balance the diet.

Step II: Fixed the animal protein source: 6 kg, Fish meal; 8 kg is added to the chick feed since it is rich source of limiting amino acids (lysine and methionine or methionine + cystine).

Animal protein sources	Parts	CP	ME
Meat cum bone meal (MBM)	6	(45/100) x 6 = 2.70	(2850/100) x 6=171.0 kcal

Step III: The level of cereal by-products may be fixed: 10 kg. Here we use DORB: 10 kg as filler, cheaper sources of energy, protein and B complex group of vitamins.

Cereal by-products	Parts	CP	ME
DORB	10	(14/100) x 10 = 1.40	(2550/100) x 10 = 255.0 kcal

Step IV: Vegetable protein sources and energy sources are added to provide the required amount of protein.

Out of 100 kg total part fixed as slack space + animal protein sources + cereal by products

= 5 + 6 + 10 = 21 parts (fixed)

= 100 – 21 = 79 kg

Amount of protein from 21 fixed parts provide = 0 + 2.70 + 1. 40 = 4.10 kg

That is the remaining 79 kg of ingredients are to provide (20 – 4.10) = 15.90 kg

Soybean meal and ground nut cake are considered as vegetable protein sources, while crushed maize and bajra are considered as vegetable energy sources.

Considered average protein value of vegetable protein source (soybean; SBM and Sunflower cake; SFC) = (45 + 36) / 2 = 40.50

Average protein value of vegetable energy source (crushed maize + Bajra)/ 2

= (10 + 10)/ 2 = 10

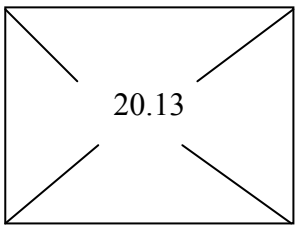
The required protein level can be calculated by Pearson's square method

Total of ingredients = 79 kg

Protein = 15.90 kg

Protein as percent = (15.90 x 100) / 79 = 20.13%

Energy source 10 20.37 Energy Source (maize + bajra)



Protein source 40.5 10.13 kg Protein source (SBM)

= 30. 50 kg

Now vegetable protein source (SBM and SFC) and vegetable protein source (Maize + Bajra) are proportioned for 79 kg.

Protein source (SBM and SFC) = (10.13 x 79) / 30.50 = 26.24 kg (SBM and SFC)

SBM = 13.12 kg

SFC = 13.12 kg

Energy Source (Maize + sorghum) = (20.37 x 79) / 30.50 = 52.76 kg /2

Maize = 40.38 kg

Bajra = 12.38 kg

Feed ingredients	**CP (%)**	**ME (Kcal/kg)**	**Parts**	**Calculated CP**	**Calculated ME**
Crushed maize	10	3450	40.38	(10/100) x 40.38 = 4.038	(3450/100) x 40.38 = 1393.11
Bajra	10	3300	12.38	(10/100) x 12.38 = 1.238	(3300/100) x 12.38 = 408.54
DORB	14	2550	10	(14/100) x 10 = 1.40	(2550/100) x 10 = 255.00
Soybean meal	45	2600	13.12	(45/100) x 13.12 = 5.904	(2600/100) x 13.12 = 341.12
Sunflower cake	36	2130	13.12	(36/100) x 13.12 = 4.723	(2130/100) x 13.12 = 279.46
MBM	45	2110	6	(45/100) x 6 = 2.70	(2110/100) x 6 = 126.60

Mineral mixture	-	-	1	-	-
DCP	-	-	0.835	-	-
LSP	-	-	1.50	-	-
Common salt	-	-	0.5	-	-
Vitamin premix	-	-	0.025	-	-
Feed additives	-	-	0.5	-	-
Total			**100**	**20.003**	**2803.83**

Nutrient requirements for various categories of swine

Nutrient requirements tables given by various agencies (viz. ICAR, BIS, NRC and ARC) serve as guides and are used to calculate and formulate the rations for different categories of swine which provide nutritionally adequate and economically viable practical diets. The ICAR (2013) expressed the nutrient requirements for swine on as fed basis, while NRC (1998) expressed the nutrient requirements for swine on 90 percent DM basis. However, BIS (1986 and 2001) specifications are expressed on 100 percent DM basis for Indian and cross bred swine. As per ICAR (2013) the protein requirement is given in the form of crude protein (CP%) and the energy requirement in the form of digestible energy (DE) and/ or in the form of metabolisable energy (ME) kcal per kg diet.

Table 21: Nutrient requirements (as fed basis) of crossbred pigs having lower to medium growth rate (ICAR, 2013)

Age (weeks)	8-20	21-24	25-32
Body weight (kg)	9-22	23-28	29-43
Bwt gain (g/d)	155	224	263
Avg. Daily feed intake (g/d)	610	1120	1430
Nutrient requirement			
DE (kcal/ kg diet)	3345	2727	2377
ME (kcal/ kg diet)	3210	2617	2282
CP (%)	21.4	15.2	14.1
Lysine (%)	0.91	0.77	0.81
Methionine (%)	0.65	0.48	0.53
Methionine + Cysteine (%)	0.98	0.76	0.77
Threonine (%)	0.68	0.57	0.62
Tryptophane (%)	0.22	0.17	0.23

Table 22: Nutrient requirements (as fed basis) of crossbred pigs having medium to higher growth rate (ICAR, 2013)

Age (weeks)	8-16	17-24	25-32
Body weight (kg)	10-21	22-38	39-56
Bwt gain (g/d)	189	298	323
Avg. Daily feed intake (g/d)	640	1350	1760
Nutrient requirement			
DE (kcal/ kg diet)	3550	2785	2360
ME (kcal/ kg diet)	3400	2670	2270
CP (%)	22.7	15.2	14.0
Lysine (%)	0.91	0.75	0.81
Methionine (%)	0.70	0.47	0.53
Methionine + Cysteine (%)	1.04	0.75	0.77
Threonine (%)	0.74	0.57	0.61
Tryptophane (%)	0.23	0.17	0.22

Table 23: Nutrient requirements (as fed basis) of crossbred pigs having higher growth rate (ICAR, 2013)

Age (weeks)	8-16	17-24	25-32
Body weight (kg)	11.5-44	45-80	81-110
Bwt gain (g/d)	577	640	553
Avg. Daily feed intake (g/d)	1550	2400	3360
Nutrient requirement			
DE (kcal/ kg diet)	3685	3185	2125
ME (kcal/ kg diet)	3537	3058	2040
CP (%)	21.4	16.5	12.6
Lysine (%)	0.70	0.79	0.73
Methionine (%)	0.66	0.51	0.48
Methionine + Cysteine (%)	0.34	0.28	0.20
Threonine (%)	0.77	0.63	0.55
Tryptophane (%)	0.21	0.19	0.20
Calcium (%)	0.70	0.60	0.50
Phosphorus (%)	0.60	0.50	0.45
Available phosphorus (%)	0.30	0.25	0.20
Sodium (%)	0.14	0.11	0.11
Chloride (%)	0.14	0.10	0.10
Potassium (%)	0.26	0.22	0.20
Copper (mg/kg)	5.0	4.0	4.0
Manganese (mg/kg)	3.0	2.5	2.5
Iron (mg/kg)	70	60	50
Zinc (mg/kg)	70	60	55
Selenium (mg/kg)	0.20	0.16	0.16
Iodine (mg/kg)	0.15	0.15	0.15
Vitamin A (IU/kg)	2000	1600	1500
Vitamin D (IU/kg)	200	160	150
Vitamin E (mg/kg)	15	12	12
Riboflavin (mg/kg)	3.0	2.5	2.2
Niacin (mg/kg)	12	10	8.0
Thiamine (mg/kg)	1.2	1.2	1.2
Pyridoxine (mg/kg)	1.5	1.2	1.2
Pantothenic acid (mg/kg)	9.0	8.0	8.0
Folic acid (mg/kg)	0.32	0.32	0.32
Biotin (mg/kg)	0.06	0.06	0.06
Vitamin B_{12} (mcg/kg)	15	10	7.0
Choline (mg/kg)	400	350	350

Table 24: Nutrient requirements (as fed basis) of exotic pigs under Indian agro-climatic conditions (ICAR, 2013)

Age (weeks)	8-16	17-24	25-32
Body weight (kg)	10-25	26-48	49-75
Bwt gain (g/d)	255	410	475
Avg. Daily feed intake (g/d)	960	1560	2170
Nutrient requirement			
DE (kcal/ kg diet)	3000	3180	2600
ME (kcal/ kg diet)	2886	3054	2497
CP (%)	18.40	16.70	15.0
Lysine (%)	0.70	0.65	0.60
Methionine (%)	0.56	0.51	0.50
Methionine + Cysteine (%)	0.29	0.29	0.26
Threonine (%)	0.62	0.62	0.62
Tryptophane (%)	0.19	0.19	0.19

Table 25: Nutrient requirements (as fed basis) of desi (native) pigs (ICAR, 2013)

Age (weeks)	8-20			21-28		29-32	
Body weight (kg)	8-20			21-30		31-40	
Avg. Daily feed intake (g/d)	610	650	700	900	950	1350	1400
Nutrient requirement							
DE (kcal/ kg diet)	3170	2950	2780	3185	3030	2570	2495
ME (kcal/ kg diet)	3040	2830	2670	3060	2900	2470	2395
CP (%)	20	18.65	17.5	18.7	17.8	15.3	14.95
Lysine (%)	0.83	0.77	0.73	0.99	0.94	0.79	0.76
Methionine (%)	0.61	0.57	0.54	0.61	0.58	0.59	0.57
Methionine + Cysteine (%)	0.92	0.86	0.81	0.94	0.89	0.84	0.81
Threonine (%)	0.31	0.60	0.57	0.34	0.65	0.24	0.66
Tryptophane (%)	0.20	0.19	0.18	0.20	0.19	0.25	0.24

Table 26: Nutrient requirements (as fed basis) of crossbred (Landrace x desi) pregnant gilts (ICAR, 2013)

Days of gestation	0-75	75-111/114
Body weight (kg)	78-112.3	120.5-130.6
Avg. Daily feed intake (kg)	2.20	2.50
Nutrient requirement		
DE (kcal/ kg diet)	3440	3420
ME (kcal/ kg diet)	3300	3280
CP (%)	18.84	18.92
Lysine (%)	0.80	0.83
Methionine (%)	0.65	0.70
Methionine + Cysteine (%)	0.99	0.99
Threonine (%)	0.70	0.72
Tryptophane (%)	0.21	0.22

Calculate nutrient requirements for different physiological stages of swine

Nutrient requirements are the statement / amount of nutrient required by the animals that should maintain normal body condition and functions i.e. neither gain nor loss in body weight. Swine require nutrients for maintenance, growth, production, reproduction and lactation.

Energy requirement

For maintenance:

The maintenance energy requirement is the amount of feed energy needed to keep the animal at a constant body weight and composition. The ME requirement for maintenance (MEm) includes the needs of all body functions and moderate activity. These requirements are usually expressed on a metabolic body weight basis, which is defined as body weight raised to the power 0.75 (Bwt $Kg^{0.75}$). Thus energy requirement for maintenance of swine is

MEm = 106 x Bwt $kg^{0.75}$ (kcal/day)

DEm = 110 x Bwt $kg^{0.75}$ (kcal/day) (Bwt is in kilogram)

For growth

The DE requirements for growing pigs kept in thermo neutral zone can be estimated by using following equation:

DE = DEm + DEpr + DEfr

Where, DEm, DE pr and DEfr are the requirement for maintenance, protein retention and fat retention, respectively. The daily maintenance requirement of the growing pigs is considered to be 110 kcal of DE/kg Bwt $Kg^{0.75}$ or 106 kcal of ME/kg Bwt $Kg^{0.75}$. Estimates for energy costs of protein retention (MEpr) is 10.6 kcal of ME/ g and that of fat deposition (MEfr) is 12.5 kcal of ME / g as per NRC (1998). One kg of lean muscle tissue contains about 20-23% protein, whereas 1 kg of adipose tissue contains 80-95 percent fat. The requirement for ME is the requirement for DE x 0.96.

For pregnancy

The daily energy requirement is the sum of the requirements for maintenance, for protein and fat accumulation and for thermoregulation. Tissue accretion is the sum of that in the maternal body and the products of conception. The daily maintenance requirement of the gestating sow is considered to be 106 kcal ME / kg bwt $kg^{0.75}$. The energy cost of protein is assumed to be 10.6 kcal of ME / g and that of fat accretion to be 12.5 kcal of ME / g. The daily energy requirement for growth of the products of conception is 35.8 kcal of ME / foetus. Additional energy is required when sows are maintained in a cold environment.

For lactation

Estimation of energy requirements for lactating sows is complicated by the sow's propensity to contribute energy and amino acids retrieved by the sow's from her own body to help support her milk production. The daily energy requirement of lactating sow is the sum of that expended in maintenance plus the gross energy of milk less the contribution made by the mobilize body tissue. The daily maintenance requirement of the lactating sow is considered to be 106 kcal of ME / kg bwt $Kg^{0.75}$ or 0.44 MJ of ME / bwt $kg^{0.75}$. The energy requirement for milk production can be estimated from the growth rate of the suckling pigs in the litter.

Milk energy = (4.92 x litter gain) – (90 x number of pigs)

Where, milk energy is expressed in kcal GE / day and litter gain is in g/ day.

The amount of dietary ME required to produce this amount of milk energy is calculated by dividing the milk energy by 0.72, assuming that the marginal efficiency of use of ME for milk production is 72 percent. The contribution towards milk production from sow's body can be calculated by the equation:

Protein gain = 1.47 + (0.0942 x ADG)

Where protein gain is in g/day and ADG is the sow's average daily gain of body weight in grams. Each gram of protein retrieved from the sow's body is assumed to provide 5.6 kcal of GE toward meeting the energy requirement. The amount of protein is divided by 0.23 to estimate the amount of lean tissue mobilized (assuming lean tissue is 23 percent protein). Subtracting the amount of lean tissue mobilize from the total amount of body weight lost gives an estimate of the amount of adipose mobilized. This adipose tissue is considered to be 90 percent fat, and it is assumed that 9.4 kcal of GE per gram of fat mobilized is available to be applied toward the energy requirement. The total energy from mobilized tissue is used with an efficiency of 0.88 to meet the energy demand of lactation.

Protein requirement

For maintenance

The protein requirements are usually stated for maintenance and production together. The protein requirements in swine are discussed in terms of amino acids requirements as per NRC (1998). The daily tissue ideal digestible lysine requirement for maintenance is assumed to be 36 mg/kg metabolic body weight (Bwt $kg^{0.75}$) for swine.

For growth

For growing-finishing pigs, the daily lysine requirement is the sum of the requirements for maintenance and for protein accretion. The daily true ileal digestible lysine requirement for maintenance is assumed to be 36 mg/kg of metabolic body weight (Bwt$Kg^{0.75}$). The daily amount of lysine needed to support protein accretion i.e. daily amount of protein accreted and the amount of true digestible lysine needed for each gram of protein accreted. The amount of true lysine needed for each gram of protein accreted is 0.122. True ileal digestible lysine required for protein gain for pigs from 20 to 120 kg Bwt (g/day) is 0.12 x whole body protein gains. The true ileal digestible lysine required for maintenance is multiplied by the ratio of each amino acid to lysine for maintenance. The true ileal digestible lysine for gain is multiplied by the ratio of each amino acid to lysine for gain.

For pregnancy

The average daily nitrogen retention is the sum of maternal nitrogen retention and nitrogen in the products of conception.

1) Maternal nitrogen retention (g/day) = [(maternal lean tissue)/ 115] x 0.23 x 0.16
2) Nitrogen in the products of conception (g/day) = No. of pigs x 0.34 g/day
3) True ileal digestible lysine requirement (g/day) for gain is calculated from N retention
   = Total N retention x 0.807
4) True ileal digestible lysine requirement (g/day) for maintenance = 0.036 x Bwt $kg^{0.75}$

For lactation

The amino acid requirement for lactating sows can be calculated as:

1) Apparent digestible lysine for milk production (g)
   = (Daily weight gain x No. of litters x 0.022) – 6.39
2) Apparent digestible lysine for milk production (g/day) is converted to a percentage using
   True digestible lysine (%) = 1.050013 x apparent digestible lysine% + 0.022052
3) The percentage true digestible lysine is converted (g/day) using DE intake and DE concentration.
4) Lysine for maintenance = 0.036 x Bwt $Kg^{0.75}$
5) Lysine from tissue = Change in protein x 0.065

Total true ileal digestible lysine requirement is the sum for maintenance, milk production and tissue change.

Formulation of rations for different categories of swine

Swine is the most prolific (10-12 piglets per farrowing) meat producing animals having very good feed conversion efficiency (1:3) and dressing percentage (60-80 percent). Swine convert inedible feeds, forages, certain grain by-products, meat by products, damaged feeds and kitchen garbage or other garbage's into valuable nutritious meat. Therefore, swine comes under the categories of scavengers and control environmental pollution. Most of these feedstuffs used by swine are not edible or not very palatable to human beings. Moreover, swine is non-ruminant, mono-gastric animal and cannot utilize fibrous feed more efficiently but some part of fibres may be fermented in their hind gut especially in the caecum. Due to its simple stomach, ration must have more of concentrates preferably in ground form.

Nutritionists are mainly concerned with formulation of swine diets by taking the feed ingredients, which will meet protein, essential amino acids, calcium and phosphorus needs and those that will permit maximal rate of body weight gain and increase feed conversion ratio (FCR) and reproductive performance. Since most swine diets in organized farms contains high amount of concentrates and low amount of roughages, insufficient energy in the diet is seldom a problem.

The swine diets are based on sources of energy and a protein supplement. Maize is the key energy feed in swine industry as it is rich in available energy. However, its cost availability poses a problem. Maize can be replaced at least in part of barley. Oat, pearl millet, grain by-products or grain substitutes, but this may mean a reduced efficiency of feed conversion. Groundnut cake alone cannot meet amino acids requirement of swine and therefore 5-10% of fish meal is added to the ration.

The availability and the cost of feed ingredients as well as the convenience and ease of mixing may require the use of different feeds and of small amounts of ingredients other than grains and high protein processed meals. Thus oil is frequently added at the levels of 0.5-2.5% to reduce the dust problems encountered in mixing certain types of diets. Also sugar and milk by-products are added to the diets of young piglets to make the feeds more palatable.

Besides adequate energy and protein, the pigs also need certain vitamins and minerals. Therefore, a complete vitamin mixture, a trace mineral salt, common salt and natural/ synthetic feed additives are also added at specified levels.

Swine diet formulation become easier if some estimate of total needs for the vitamins, minerals, feed additives and common salt are set forth. The maximum percent of Ca-P supplement needed in the diets of swine of different ages and weights are:

Weaning piglets (4.5-18 kg body weight)	-	2.5% (Maximum)
Growing pigs (18-45 kg body weight)	-	2.0% (Maximum)
Finishing pigs (45-100 kg body weight)	-	1.5% (Maximum)
Breeding pigs	-	2.0% (Maximum)

Table 27: Composition of creep/ weaned piglet rations (up to 15 kg Bwt.)

(CP:18-20% & ME: 2950-2975 kcal/kg diet)

Feed ingredients	**Parts**		
	Ration -1	**Ration - 2**	**Ration – 3**
Crushed maize	48.7	48.7	48.7
Maize gluten meal	0	4	5
Soybean meal	9.6	10.2	9.6
Broken rice	3	3	3
Rice bran	9	9	9
De-oiled rice bran	8	10	8
Fish meal	8	4	8
Meat-cum-bone meal	0	4	0
Mustard cake	5	6	5
Pea waste	7.6	-	2.6
Lime stone powder	0.8	0.8	0.8
Salt	0.3	0.3	0.3
Lysine	0.025	0.025	0.025
Total	100	100	100

Table 28: Composition of grower piglet rations (35-60 kg Bwt.)

(CP:15% & ME: 2750 kcal/kg diet)

Feed ingredients	**Parts**		
	Ration -1	**Ration - 2**	**Ration – 3**
Crushed maize	48.5	48.5	52.0
Maize gluten meal	0	0	3
Soybean meal	4.6	6.0	2.5
Broken rice	7	9	7
Rice bran	10.3	12.0	11.4
De-oiled rice bran	10.0	10.0	12.0
Fish meal	6	6	6
Mustard cake	5	5	5
Pea waste	7.5	2.5	0.0
Lime stone powder	0.8	0.8	0.8
Salt	0.3	0.3	0.3
Lysine	0.025	0.025	0.025
Total	100	100	100

Table 29: Composition of finisher pig rations (60 kg and above Bwt.)

(CP: 14% & ME: 2700 kcal/kg diet)

Feed ingredients	**Parts**		
	Ration -1	**Ration - 2**	**Ration – 3**
Crushed maize	48.3	55	51
Maize gluten meal	0	2	0
Soybean meal	3.2	2	3.2
Broken rice	8	8	8
Rice bran	7.4	7.4	5
De-oiled rice bran	15	15	15
Fish meal	4.5	4.5	4.5
Mustard cake	5	5	5
Pea waste	7.5	0	7.5
Lime stone powder	0.8	0.8	0.8
Salt	0.3	0.3	0.3
Lysine	0.03	0.03	0.03
Total	100	100	100

Visit to livestock and poultry farms

Livestock and poultry rearing in the organized farm is an industry. The latest techniques for automatic feeding and watering not only save the labour problems but also providing round the clock uniform supply of feed and fodders to the poultry and livestock. The feed ingredients received at the farm should be got tested from the reputed laboratory to formulate and prepared balanced rations for different categories of poultry and livestock.

Objectives:

1) To acquaint the students with various operations of the poultry and livestock farms.
2) To acquaint the students with feeds, feeding and feed processing techniques in the farms.

Procedure:

The course In-charge and Instructors will arrange a visit to a organized poultry or livestock farm and the students will be writing a report of various types of operation, types of feed offered, the farmers following different feed processing in their farms and also the feed formulations and feeding standards being used by the farmers in their poultry or livestock farms.

Report:

Feeds, feeding and nutrient requirements of Horses

The horses do not possess the rumen but their Caecum is well developed. There is little difference in the digestibility of grains and byproducts concentrate which contain low crude fibre but the digestibility of the roughage s containing high crude fibre is low in horses than in cattle. The digestibility of the feeds in horses is affected by the chemical composition, level of feeding, working intensity and processing of the feeds. The factors like crude protein content and tha nature of crude fibre also affect the OM-digestibilty. The digestibility of the feedstuffs depends upon th e level of feed intake also. Grinding of grains improves the digestion; however, chopping of roughages has no beneficial effect on the digestion. High succulent fodders are less digested since the rate of passage is higher than feeding the fodders in hay form.

Common feedstuffs for the horses

Roughages: Horses should get about 0.6-0.7kg DM per 100 kg body weight through the roughages when doing light work. Working horses may eat up to 80-110kg green fodder. Part of green fodder may be replaced by good quality silage. Feeding of potatoes, sugar beets, carrots etc. which is practiced in western countries is not followed in India. The horses prefer to graze Bermuda grass.

Concentrates: The concentrates which are commonly used for feeding of horses are grams, oats and barley. Gram and oats are the most important and popular grains fed to the horse. Barley and sometimes maize are also used as feed ingredients. Wheat bran and Dal-Chunies are other byproduct concentrates which are used for feeding the horses along with grains. Normally oilseed cakes are avoided for feeding of horses. However, cottonseed cakes, linseed cake and groundnut cakes are the important sources of protein. Molasses and gur are valuable feeds for horses and feeding of these materials is common in India with working horses 1-1.5kg may be given to working hours.

Formulating the ration

The horses consume dry matter at the rate of 1.2% of the body weight when they are at rest> The DM increases to 2% of their body weight when they do medium work and in lactation. During early period of growth upto 100kg body weight, the DM intake may be 3% of the body weight. The roughages are fed @1%of the body weght. A nine month old cot weighing about 225kg should be fed @ 1kg DM per 100 kg body weight. Therefore 2.25 kg DM would be available from 3 kg of hay with 85% DM. The concentrate mixture fed to the growing horses may contain 12-13% DCP and 3.0- 3.2 Mcal of DE. In the concentrate mixture, gram barley oats may be included as main source of energy: wheat bran, rice brawn and chunnies may also be included. Small quantities of groundnut cake, linseed cake and cottonseed cake etc., may be added to the source of protein. Mineral mixture and salt may be added as a source of protein. Mineral mixture and salt may be added to supply all the nutrients. The feeding schedule for different kinds of horses is given in table 13.

The energy requirements of horses are high, that is why a ration should contain about 2.75 Mcal of DE per kg of diet. This is possible only with good quality roughages like barseem, Lucerne, cowpea and oat are harvested at pre-flowering stage. It is possible to maintain horses exclusively on good quality roughages.

Table 30: Feeding schedule for horses

	Dram (Kg)	**Barley (Kg)**	**Wheat bran (kg)**	**Salt (g)**	**Fodder hay (kg)**
Brood Mare	0.91	1.36	0.91	30	5-8
Lactating Mare	1.36	1.81	0.91	30	6-10
Dry Mare	0.50	0.50	0.50	30	4-5

Balanced feeding of laboratory animals

Feeding of Guinea Pigs

The adequacy of the diet as per the specifications of nutrients requirements can be judged by the rate of growth and the breeding performance of the animals. The quality of protein is very important, therefore about 30% of the protein requirements are given through the animal protein sources like skimmed milk powder or fish meal. The guinea pigs have the requirements for the essential fatty acids. If linoleic acid is supplied 4g/kg of diet, it would take care of the essential fatty acid requirement.

The recommended nutrient allowances for growing guinea pigs are given in table 31. Some examples of the natural and purified diets for guinea pigs have been given in table 32. The ISI requirements for compounded feeds for guinea pigs are given in table 33.

Table 31: Recommended Nutrition allowances for growing Guinea pig

S.No.	Nutrient	Amount in diet
1.	Protein	18%
2.	Unsaturated fatty acids	<1%
3.	Digestible energy	3Kcal/g
4.	Fibre	10%
5.	Calcium	0.8-1.0%
6.	Phosphorus	0.4-0.7%
7.	Magnesium	0.1-0.3%
8.	Potassium	0.5-1.4%
9.	Zinc	20 mg/kg
10.	Manganese	40mg/kg
11.	Copper	6mg/kg
12.	Iron	50mg/kg
13.	Iodine	1mg/kg
14.	Selenium	0.1mg/kg
15.	Chromium	0.6mg/kg
16.	Vit A	7mg/kg
17.	Vit D	1000IU/kg
18.	Vit E	50mg/.kg
19.	Vit K	5mg/kg
20.	Vit C	200mg/kg
21.	Thiamin	2mg/kg
22.	Riboflavin	3mg/kg
23.	Niacin	10mg/kg
24.	Pyridoxine	3mg/kg
25.	Pantothenic acid	20mg/kg
26.	Choline	1g/kg
27.	Folic acid	4mg/kg
28.	Biotin	0.3mg/kg
29.	B_{12}	10mg/kg

Table 32: Examples of Natural and Purified Diets of guinea pigs

Ingredients	NIH (%)	Reid & Brigger (1953) (g/Kg)	Everson et al (1959(g/kg)	Navia &Lopez (1973) g/kg
Alfalfa meal	38.15	-	-	-
Ground wheat	28.90	-	-	-
Ground nut	17.75	-	-	-
Soya bean meal	13.25	-	-	-
Ground limestone	1.10	-	-	-
Iodised slat	0.50	-	-	-
Dicalcium phosphate	0.25	-	-	-
Minerals	0.05	-	-	-
Vitamins	0.05	-	-	-
Casein	-	300	-	-
Caesin (vitamin free)	-	-	300	300
Corn starch	-	200	200	-
Sucrose	-	103	100	131.4
Glucose	-	78	106	-
Cellophane	-	15	-	-
Wood pulp	-	-	100	-
Cellulose	-	-	100	130.1
Agar	-	-	-	20
Cottonseed oil	-	-	50	40
Corn oil	-	73	50	-
DL- Methionine	-	-	-	2
L- Arginine	-	3	-	-
Salt mixture	-	60	-	72-2
Potassium acetate	-	25	60	-
Magnesium oxide	-	5	25	-
Vitamin mixture	-	5	5	3.3
Choline chloride	-	-	-	1.0
Inositol	-	2	2	-

Mineral mixture which is contains manganese 12% from mageneous oxide. 10% zinc from zinc oxide, 8% iron from iron sulphate, o.8% copper from copper sulphate, 0.23% iodine from ethylene diamine dihydroiodide, 0.1% cobalt from carbonize and bentonites as an extender is added @ 0.55g kg of diet.

Ascorbic acid is added @ 0.62g/kg of diet, Vit A and D =2000 IU/kg & Vit E at 18 mg/Kg.

Table 33: Requirements for Compounded feeds for guinea pig

S.No	Characteristics	Requirements
1.	Moisture% by weight Max	10
2.	Crude protein% by weight maMin	22
3.	Ether extract% by weight min	4
4.	Crude fiobre% by weight	9-14
5.	Total ash% by weight	9
6.	Acid insoluble% by weight	1.0
7.	Calcium% by weight min.	1.2
8.	Phosphorus% by weight min	0.6
9.	Vitamin C Min.	200 mg/kg

Feeding of rabbits

The NRC (1996) has given the nutritional requirements for meat production. The fat content in the commercial stock diets for rabbits should contain 2-3%. The rabbits require all the essential mineral elements as other animals except cobalt. The vitamin B requirement is partially or completely met through the habititual practice by the rabbit of coprophogy. Rabbits do not require a dietary source of vitamin C.

Rabbits are herbivores and can consume different types of green roughages like barseem, lucerne, cowpea, dub grass etc. They relish leguminous fodders, various types of grasses and weeds are also consumed by the rabbits. Root crops like carrots; turnips etc also are very much relished by these animals.

Rabbits cannot be satisfactory raised on the roughages diets alone. Though barseem and Lucerne are the excellent feed for rabbits but their growth is improved when c rushed barley, maize etc. are fed along with roughage and remaining with concentrate mixture depending upon physiological stage of the rabbits. The feeding schedule for rabbits at IVRI is given in table 34.

Table 34: Feeding schedule for rabbits at IVRI, Izzatnagar.

Body weight (kg)	Concentrate (g)	Green roughage (g)	Remarks
Maintenance Does and Bucks			
2.0	50	200	Equivalent amount of hay can be fed
2.5	60	250	-
3.0	70	300	-
Pregnancy			
2.0	60	250	-
2.5	70	300	-
3.0	80	350	-
Lactating Does			
2.0	140	350	-
2.5	150	350	-
3.0	160	350	-
Growing			
-	40-60	100-200	-

Green roughages like Lucerne, berseem, cowpea etc may be fed either as green or as good quality hay**.**

Enumerate common feeds and feedstuffs for pet dogs

Dogs belong to order carnivore, but domesticated dogs have been well adapted to omnivorous feeding habits. In India, dogs are often reared on vegetarian food items without any health problem, provided milk and milk products are included in their diet. The common feed stuffs used for the computation of balanced and palatable diets may be classified as follows:

1) Feeds of animal origin
2) Feeds of plant origin
3) Feed supplements as additives

Feeds and feedstuffs of animal origin

a) *Meat and meat products/by-products*: Variety meats, bone scrapings, meat-cum-bone, edible glands (like liver, heart and kidneys), cleaned and chopped/minced gut, etc., meat-meal, meat-cum-bone meal.
b) *Milk, milk products and byproducts:* Whole milk, skimmed milk, dried milk powder, casein, cheese-meal, paneer, dahi and matha.
c) *Fish and fish meal*
d) *Poultry and poultry products/ chicken processing byproducts* (head, legs, gizzard and gut, eggs, etc.).
e) Edible fatty tissue and fat.

Feeds and feedstuffs of plant origin

a) Wheat, barley, oat, corn, sorghum, rice, pearl millet, etc.
b) Cereal byproducts: Wheat germ-meal, maize germ meal, maize gluten, broken rice, wheat midlings, wheat bran, etc.
c) Pulses and byproducts: Gram, pea, cowpea, green-gram, black-gram, beans, soybean, kidney-bean and their husk removed grits, etc.
d) Fruits and vegetables: Pomace of apple, tomato, and sweet citrus fruits, carrot, bean pods, leafy vegetable, leaf meals, banana, mango, peaches, etc.

Feed supplements and feed additives

Miscellaneous feed supplements are common salt, mineral mixture, and vitamin supplements. Main feed additives are antioxidants, bacteriostats, colouring agents (permitted edible colours) and flavouring agents.

Some common feedstuffs and their nutritive values used for feeding of dogs

Foodstuff	Moisture (g)	Protein (g)	Fat (g)	Minerals (g)	Fibre (g)	CBH (g)	Energy (kcal)	Ca (mg)	P (mg)	Iron (mg)
Rice (raw, milled)	13.7	6.8	0.5	0.6	0.2	78.2	345	10	160	0.7
Wheat (whole)	12.8	11.8	1.5	1.5	1.2	71.2	346	41	306	5.3
Wheat bread (white)	39.0	7.8	0.7	-	0.2	51.9	245	11	-	1.1
Jowar	11.9	10.4	1.9	1.6	1.6	72.6	349	25	222	4.1
Bengal gram (dal)	9.9	20.8	5.6	2.7	1.2	59.8	372	56	331	5.3

Green gram (dal)	10.1	24.5	1.2	3.5	0.8	59.9	348	75	405	3.9
Lentil	12.4	25.1	0.7	2.1	0.7	59.0	343	69	293	7.58
Rajmah	12.0	22.9	1.3	3.2	4.8	60.6	346	260	410	5.1
Red gram	13.4	22.3	1.7	3.5	1.5	57.6	335	73	304	2.7
Soybean	8.1	43.2	19.5	4.6	3.7	20.9	432	240	690	10.4
Beef (muscle)	74.3	22.6	2.6	1.0	-	-	114	10	190	0.8
Buffalo meat	78.7	19.4	0.9	1.0	-	-	86	3	189	-
Mutton (muscle)	71.5	18.5	13.3	1.3	-	-	194	150	150	2.5
Pork (muscle)	77.4	18.7	4.4	1.0	-	-	114	30	200	2.2
Liver (goat)	76.3	20.0	3.0	1.3	-	-	107	17	279	-
Liver (sheep)	70.4	19.3	7.5	1.5	-	1.3	150	10	380	6.3
Egg (hen)	73.7	13.3	13.3	1.0	-	-	173	60	220	2.1
Milk (buffalo)	81.0	4.3	6.5	0.8	-	5.0	117	210	130	0.2
Milk (cow)	87.5	3.2	4.1	0.8	-	4.4	67	120	90	0.2
Skimmed milk powder	4.1	38.0	0.1	6.8	-	51.0	357	1370	1000	1.4
Whole milk powder	3.5	25.8	26.7	6.0	-	38.0	496	950	730	0.6
Cooking oil	-	-	100	-	-	-	900	-	-	-
Potato	74.7	1.6	0.1	0.6	0.4	22.6	97	10	40	0.48
Cauliflower	90.8	2.6	0.4	1.0	1.2	4.0	30	33	57	1.23
Cabbage	91.9	1.8	0.1	0.6	1.0	4.6	27	39	44	0.8
Beet root	87.7	0.4	0.2	1.4	1.1	11.8	51	25	10	1.1
Carrot	86.0	0.9	0.2	1.1	1.2	10.6	48	80	530	1.03
Radish white	94.4	0.7	0.1	0.6	0.8	3.4	17	35	22	0.4
Brinjal	92.7	1.4	0.3	0.3	1.3	4.0	24	18	47	0.38
Broad beans	85.4	4.5	0.1	0.8	2.0	7.2	48	50	64	1.4
French beans	91.4	1.7	0.1	0.5	1.8	4.5	26	50	28	0.61
Cucumber	96.3	0.4	0.1	0.3	0.4	2.5	13	10	25	0.60
Bottle gourd	96.1	0.2	0.1	0.5	0.6	2.5	12	20	10	0.46
Papaya (green)	92.0	0.7	0.2	0.5	0.9	5.7	27	28	40	0.9
Pumpkin (fruit)	92.6	1.4	0.1	0.6	0.7	4.6	25	10	30	0.44
Tomato (green)	93.1	1.9	0.1	0.6	0.7	3.6	23	20	36	1.8

* All values are per 100 g edible portion

Formulation of balanced diet, feeding schedule and nutrient requirements of pet dogs

Good quality starter pup diet can be easily prepared from milk and other foods at home. It should contain about 30-35% protein, 30-35% edible fat and carbohydrates (Starch, lactose, sugars). Adequate amount of minerals and vitamins may be fed in addition to starter diet. Antibiotics are normally added to provide protection against infections. The dry feed before being given to pups should be mixed with hot water in the ratio of 1:3 and then cooled near to body temperature before feeding.

Feed formulation for young pups

Ingredients (g)	**Diet 1**	**Diet 2**	**Diet 3**	For every 1 kg of liquid diet containing about 25-30% DM added about 2000 IU vitamin A, 500 IU vitamin D and 4 g citric acid. 2) Antibiotics @ 10 mg per kg feed should be mixed.
Dried milk powder	200	-	-	
Liquid whole milk of				
Cow	-	700	-	
Buffalo	-	-	800	
Cream (30% fat)	200	200	100	
Egg-yolk	-	50	50	
Boiling water	400	-	-	
Rice gruel/flour gruel (30% DM)	200	50	50	

Feeding schedule with homemade diet for puppy

Months	**No. of times**
1 - 2	6 times
2 - 3	5 times
3 - 4	4 times
4 - 5	3 times
5 - 7	2 times

Food requirement

A standard balanced dog food should contain:

Crude protein - 20-22 percent
Crude fat/ fat - 4-5 percent
Crude fibre - 5-10 percent
Ash - 4-5 percent
Energy (ME) - 3.3-4.0Mcal/kg (along with minerals and vitamins)

Daily dry matter requirement of dogs for maintenance (on DM basis)

Body weight (kg)	**Dry-matter requirement (g/kg body weight)**		
	3.3 Kcal/g	**3.5 Kcal/g**	**4.0 Kcal/g**
2.5	33	31	27
5.0	28	26	23
7.5	25	23	21
10.0	23	22	19
20.0	18	17	15
30.0	17	16	14
40.0	17	16	14
50.0-60.0	15	14	13
70.0 and above	14	13	12

Recipes for some homemade diets for growing and adult dogs

Feed ingredients	Growth (Puppy)			Maintenance (Adult)		
	Diet 1	Diet 2	Diet 3	Diet 1	Diet 2	Diet 3
Rice	15	-	18	20	16	25
Wheat (ground/flour)	14	22	10	15	26	-
Sorghum (ground/flour)	-	12	-	8	-	-
Soybean meal	16	28	-	14	19	-
Soy nuggets	-	-	20	-	-	-
Lentil	11	-	11	-	-	25
Red gram	14	-	-	16	12	-
Bengal gram	13	5	9	22	-	8
Skimmed milk	10	-	25	-	-	-
Egg	-	-	-	-	22	-
Chicken (whole)	-	29	-	-	-	40
Vegetable oil	7	4	7	5	5	2

Feed requirement chart for dogs

Body weight	Approximate requirement of feed in kg (30% of DM)
2.5	0.30
5.0	0.50
7.5	0.63
15.0	1.20
22.5	1.73
32.0	2.45
50.0	3.83

Requirement of essential nutrients in the diet for dogs

Nutrients	Adult animal	Growing animal
Protein	3.7-4.8 g/kg b.w/day	9.6-10 g/ kg b. w /day
Carbohydrate	17.6 g/kg.b.w/day	32.3 g/kg b.w/day
Fat	1-1.3 g/ kg b.w/day	2.4-2.7 g/ kg b.w/day
Calcium	0.26 g/ kg b.w/day	0.53 g/ kg b.w/day
Phosphorus	0.22 g/ kg b.w/day	0.44 g/ kg b.w/day
Sodium Chloride	0.37 g/ kg b.w/day	0.44 g/ kg b.w/day
Vitamin A	100 IU	-
Vitamin D	5 IU	-

ME requirement per day

For Maintenance = 132 kcal/kg$W^{0.75}$
Growth = 264 kcal/kg$W^{0.75}$
Adolescence = 200 kcal/kg$W^{0.75}$
Pregnancy = 188 kcal/kg$W^{0.75}$
Lactation = 470 kcal/kg$W^{0.75}$

NB: Standard balanced dog food should contain 20-22 percent crude protein, 4-5 percent fat, 5-6 percent crude fibre, 4-5 percent ash and 2.3-4 M cal ME or 2300-4000 kcal ME.

Calculate nutrient requirements for growing Beagle puppy and for adult dog

Attributes	Growing Beagle puppy	Adult dog
Body weight (kg)	3.00	10.00
Metabolic body size ($W^{0.75}$)	2.28	5.62
ME (k cal)	264 x 2.28 = 602	5.62 x 132 = 742
Fat (g)	2.7 x 3 = 8.10	1 x 10 = 10.00
Lenoleic acid (g)	1.6	2
Protein (g)	9.6 x 3 = 28.80	4.8 x 10 = 48

Calculate the nutrient requirements of 3 kg growing dog and formulate a balanced diet for growing dog (having 3 kg bodyweight)

Requirement of ME (Kcal) for 3 kg bodyweight or 2.28 metabolic body size ($W^{0.75}$)

ME requirement = 264 k cal/ kgW0.75 = 2.28 x 264

= 602 kcal

Fat requirement = 2.7 g/ kg body weight

= 2.7 x 3 = 8.10 g

Protein requirement = 9.6g/kg body weight

= 9.6 x 3 = 288 g

Formulate a balance diet from the following food stuffs

Feed ingredients	Protein (g/100g)	ME (kcal/100g)	Quantity / Parts (g)	Calculated Protein (g)	Calculated ME (kcal)
Milk	3.20	67.00	100.00	3.2	67.00
Egg	11.30	143.00	50.00	5.65	71.50
Green leafy vegetables (GLV)	4.25	50.00	50.00	2.13	25.00
Rice	6.80	345.00	75.00	5.1	259.00
Wheat	11.80	346.00	50.00	5.9	173.00
Pulses	22.5	350.00	25.00	5.63	88.00
Total			350 g	27.61	684.50

Balanced diet formulation for dogs

Feed ingredients	Protein (g/100g)	ME (kcal/100g)	Quantity / Parts (g)	Calculated Protein (g)	Calculated ME (kcal)
Rice	6.8	345.00	100	6.80	345.00
Meat	18.50	194.00	100	18.50	194.00
Milk	3.20	67.00	100	3.20	67.00
Total				28.50	606.00

Prepare a low cost balance diet formulation for a 10 kg actively growing dog

a) Nutrient requirement of 10 kg actively growing dog

DM requirement @ 50g/kg body weight = 50 x 10 = 500 g

ME requirement @ 274 kcal /kg $W^{0.75}$ = 274 x 5.62 = 1541kcal

Protein requirement @ 9.6g/kg body weight = 9.6 x 10 = 96 g

b) Balanced diet suggested

Rice / wheat	-	150 g
Ragi	-	150 g
Soybean meal	-	100 g
GNC (exp)	-	50 g
Water	-	1 litre, Cook well and cool, Add 1-2 hard boiled eggs, 1/4th tsp common salt, 2 tsp bone meal, and 1 tsp vitamin-mineral premix

All dietary ingredients mixed well and then fed to dog.

Diet formulation

Food stuffs	**Protein (g/100g)**	**ME (kcal/100g)**	**Quantity / Parts (g)**	**Calculated Protein (g)**	**Calculated ME (kcal)**
Rice	6.8	345	150	10.20	517.50
Ragi	7.3	328	150	10.95	492.00
SBM	41.7	270	100	41.70	270.00
GNC	40.9	260	50	20.50	130.00
Egg (2 Nos)	11.3	143	100	11.30	143.00
Common salt	-	-	¼ tsp	-	-
Bone meal	-	-	2 tsp	-	-
Vitamin-mineral premix	-	-	1 tsp	-	-
Total	-	-		94.60	1553.00

General guidelines, feeding frequency, nutrient profile and feeding of pet cats

- Cat should be fed individually and food selected should promote health,
- The food should result in the formation of well formed stools and normal defection frequency,
- The food should contain optimum nutrients,
- Rapid change in the diet should be avoided,
- New diet should be introduced gradually by mixing it with the old diet in 25% increment each day,
- Cats are carnivores in nature,
- Feed should be rich in protein of animal or fish origin,
- Either raw or cooked meat can be fed. Sometimes there may be digestive trouble,
- Also provide vegetables, green grass etc to avoid digestive trouble,
- Green grass helps to expel fur balls from the stomach,
- Grass will be having vitamins and minerals especially trace minerals and so grass feeding is advantageous,
- Cat should be given plenty of drinking water,

Energy requirement for cat

- The dietary requirement for cat is more than other omnivorous species.
- Domestic cat required high protein along with its need for taurine, arachidonic acid and vitamin A in the diet impose requirement for the inclusion of animal tissues in the diet.

Feeding frequency

2-3 months: 4 meals/day

3-5 months: 3 meals/day

6-8 months: 2 meals/day

For Adult: 2 meals/day

After each feeding, the stomach of kitten should be rubbed with coarse warm towel. Feeding pot should be very thick otherwise it will be spoiled by the cat stepping on it.

Energy needs of pet cat

Age and level of activity	Calculation of energy need	Kcal per day
Adult cat		
Inactive	60 kcal x body weight (kg)	240
Moderately active	70 kcal x body weight (kg)	280
Highly active	80 kcal x body weight (kg)	320
Kitten		
3 months (1 kg)	250 kcal x body weight (kg)	250
5 month (2.5kg)	130 kcal x body weight (kg)	325

Nutrient profiles of Cat food

Nutrients	Units DM Basis	Growth and Reproduction Minimum	Adult Maintenance Minimum	Maximum
Crude Protein	%	30.0	26.0	
Arginine	%	1.25	1.04	
Histidine	%	0.31	0.31	
Lsoleucine	%	0.52	0.52	
Leucine	%	1.25	1.25	
Lysine	%	1.20	0.83	
Methionine-cystine	%	1.10	1.10	
Methionine	%	0.62	0.62	1.5
Phenylalanine-tyrosine	%	0.88	0.88	
Phenylalanine	%	0.42	0.42	
Threonine	%	0.73	0.73	
Tryptohan	%	0.25	0.16	
Valine	%	0.62	0.62	
Crude Fat	%	9.0	9.0	
Linoleic acid	%	0.5	0.5	
Arachidonic acid	%	0.02	0.02	
Minerals				
Calcium	%	1.0	0.6	
Phosphorus	%	0.8	0.5	
Potassium	%	0.6	0.6	
Sodium	%	0.2	0.2	
Chloride	%	0.3	0.3	
Magnesium	%	0.08	0.04	
Iron	mg/kg	80	80	
Copper (extruded)	mg/kg	15	5	
Copper (canned)	mg/kg	5	5	
Manganese	mg/kg	7.5	7.5	
Zinc	mg/kg	75	75	2000
Iodine	mg.kg	0.35	0.35	
Selenium	mg/kg	0.1	0.1	
Vitamins and Others				
Vitamin A	IU/kg	9000	5000	750000
Vitamin D	IU/kg	750	500	10000
Vitamin E	IU/kg	30	30	
Vitamin K	mg.kg	0.1	.01	
Thiamine	mg/kg	5.0	5.0	
Riboflavin	mg/kg	4.0	4.0	
Pantothenic acid	mg/kg	5.0	5.0	
Niacin	mg/kg	60	60	
Pyridoxine	mg/kg	4.0	4.0	
Folic acid	mg/kg	0.8	0.8	
Biotin	mg/kg	0.07	0.07	
Vitamin B 12	mg/kg	0.02	0.02	
Choline	mg/kg	2400	2400	
Taurine (extruded)	%	0.10	0.10	
Taurine (canned)	%	0.20	0.20	

Diet chart, formulation and preparation and feeding schedule of pet birds

Feeding of caged birds:

- Based on the feeding behaviour cage birds can be differentiated into various categories.
- Munias, Parakeets and Budgerigar are seed eaters or hard bills.
- Mynah is insect eater or soft bill.
- Koels, Pegions and doves fall into two classes seed eater and fruit eaters.
- Generally insect eater requires more care in feeding where as seed eaters are easily fed.
- In addition to seeds like cowpea, peanut, Bengal gram; grains like rice, maize, millet and wheat; vegetables, greens and mashes; minerals and vitamins should also be provided.
- Soaked seeds are better than un soaked seeds.
- Cuttle fish bone and shell grit should also be available to seed eating birds. Grit enables a seed eater to digest its food properly.
- Although birds lack teeth they still require a grinding surface to break up its hard seed and make it accessible to digestive enzymes.
- Shell grit is broken down in the digestive tract and provides additional source of minerals to the birds.

Feeding of hand reared birds:

- Hand-reared birds are in great demand because they are usually tamer and more easily handled.
- Birds that are hand-reared need to be provided a brooder or heating pad so that the birds can be kept warm.
- A spoon bent up on the sides makes an ideal tool for hand-feeding young birds.
- Hand-feeding is very time consuming; newly hatched birds need to be fed every 3 or 4 hours.
- Feeding is required from early morning to late evening.
- Foods commonly used are dry baby cereals, fruits, and canned baby food.
- These foods are mixed with water in a blender and then heated; the food must be warm and fairly runny.
- Supplements such as calcium and vitamins can be added.
- As the birds get older, they can be gradually weaned from the liquid diet to seeds.

Diet for baby cockatoos and baby parrots

- ½ cup baby food cereal
- 1/8 teaspoon salt
- ½ teaspoon fine cuttle fish bone meal
- 1 teaspoon corn syrup or honey
- 2 fresh egg yolks
- Milk or water
- 4 drops vitamins supplement
- Mix the dry ingredients; add the syrup and eg yolk and then the milk or water to make a soup like mixture.
- Boil over low heat 3-5 minutes, stirring gently.
- Cool until finger warm. Stir in the vitamin supplement. Feed the mixture with a spoon.
- The baby birds should be fed three to six times daily.

Diet for small weight pigeon and doves

White millet	1 part
Canary seed	1 part
Wheat	1 part
Milo	1 part
Yellow millet	1 part
Oat groats	1 part
Mineralized grit and shell grit	

For Large breed pet bird

Wheat	2 part
Milo	2 part
Pigeon peas	1 part
Whole corn	1 part
White millet	1 part
Mineralized grit and shell grit	

Diet formulation for pet birds (Parrot)

Ingredients	**Quantity**
White millet	1 part
Canary seed	2 part
Red or yellow millet	1 part
Oats groats	1 part
Wheat	1 part
Mineralized grit and shell grit, cuttlebone when available	

Feeding and nutrient requirement of Wild ruminants

Spotted Deer (Cheetal):

Spotted deer feed on wide range of plants. They are primarily a grazer and grazing forms the bulk of their feed. They are categorized as generally feeder, consuming grasses, forbs and leaves of woody plants. Their grazing behaviour is also influenced by season and food availability.

Nutrient requirement is calculated on the basis of nutrient requirement of goats.

Dry matter intake (DMI):

Sorghum based diet: DMI was 50 g/ $KgW^{0.75}$

Combination of Oats, Berseem concentrate: DMI was 71 g/ $KgW^{0.75}$

Combination of leguminous and cereal fodder was found to be a better source of roughages for spotted deer in comparison to either of the forages fed alone.

On an average, DMI ranged from 2.28 to 2.41% in spotted deer fed mixed ration comprising oat, berseem and concentrates. The DM digestibility varied from 63 to 78% depending upon type of fodder and diets.

Diet composition

Dietary components	**Quantity**
Berseem or Any other legume fodder	3 kg
Oat or any other cereal fodder	3 kg
*Balanced concentrate mixture	0.5 kg

Composition of *balanced concentrate mixture (CP= 16%, GE= 3940 kcal)

Feed ingredients	Parts
Crushed maize	47%
Wheat bran	30%
Soybean meal	20%
Mineral mixture	2%
Common salt	1%

The above diet would provide 154 kcal ME/$kgW^{0.75}$, 16.4% CP, 68% TDN, 1.2% Ca, 0.53% P, 213 mg/kg Fe, 33 mg/kg Zn and 11.7 mg/kg Cu.

Blackbuck (Antelope):

The blackbuck is an endangered species of antelopes. They are primarily grazers, but do occasionally browse. They prefer open grasslands and wastelands and avoid thick covers. Although they feed mostly on grasses, browse pods and leaves of various trees and can form a significant portion of their diet. They also regularly feed on crops such as peanut, wheat, barley, millet and black gram.

DMI fed oat or berseem diet was 2.2 and 3.5% of their body weight fed different type of forages, either fed alone or in combination with leguminous fodders.. Total DMI ranged from 58.7 to 60.1 g/$kgW^{0.75}$.

The minimum CP requirement for maintenance of blackbuck was 10.5%. A diet of oat fodder supplemented with 150 g balanced concentrate mixture was able to provide 130 kcal ME/ $kgW^{0.75}$ and maintain their body weight.

Diet composition

Dietary components	**Quantity**
Oat fodder	2 kg
Berseem fodder	1.5 kg
Balanced concentrate mixture	150 g

The above diet should provide 12% CP, 65% TDN, 1% Ca, 0.4% P, 230 mg/kg Fe and 10 mg/kg Cu.

Table Nutrient requirement of wild ruminants (Spotted deer and blackbuck) as per NRC (2007) and ICAR (2013)

Species	**Body weight (kg)**	**Dry matter intake (g/d)**	**TDN requirement (g/d)**	**Protein requirement (g/d)**
Spotted deer	60	1380	831	165
	65	1495	882	180
	70	1610	936	195
	75	1725	983	207
	80	1840	1031	220
	85	1955	1059	235
Blackbuck	20	460	310	45
	25	575	366	60
	30	690	420	70
	35	805	471	80

Feeding and nutrient requirement of wild non-ruminant herbivores

Indian rhinoceros (*Rhinoceros unicornis*) is categorized as an endangered species and it is also protected. They are simple stomach with ability for hind gut (caecum and colon) fermentation and derived most of their energy through fermentation of fibrous feeds. They are categorized as mixed feeders. Their natural diet consists mainly of grasses, but they can also eat branches of shrubs and trees. They occasionally consume leaves of floating and submerged aquatic plants.

A typical diet for adult female rhinoceros (1,600 kg, body weight) should consist of:

Balanced concentrate mixture - 2 kg

Green fodder - 100 kg

A typical diet for adult male rhinoceros (2,200 kg, body weight) should consist of:

Balanced concentrate mixture - 3 kg

Green fodder - 130 kg to fulfil their nutrient requirements.

Feeding schedule of adult elephant in captivity/ zoo:

For male elephant (Body weight; 4000 kg)

Concentrate mixture (Moisture 10%) - 6 kg

Green fodder (Moisture 75%) - 225 kg

For female elephant (Body weight; 3500 kg)

Concentrate mixture (Moisture 10%) - 5 kg

Green fodder (Moisture 75%) - 165.5 kg

Or

Green fodder/sugarcane - 200 kg

Tree leaves - 60 kg

Dry fodder - 15 kg

Banana - 24 Nos

and a boiled mixture of various ingredients

Molasses - 1 kg

Pulse - 1 kg

Rice - 2 kg

Bajra - 1 kg

Haldi - 100 g

Salt - 250 g

Mustard oil - 250 ml

However, the food items such as

Banana tree leaves - 150 kg/day

Maize plants - 25 kg/day

Banana - 10 kg/day

Banana tree leaves - 30 kg/day

Vegetables - 15 kg/day

Gram - 5 kg/day

Sugar cane - 5 kg/day are also recommended for a captive/zoo elephant. In South India, coconut is given in the diet of a pregnant mother.

Feeds and feeding schedules of non-human primates

Very few experiments have been conducted to standardize the feeding schedule of non-human primates in the zoo/ captivity. For rhesus monkey two meals or 8 h feeding per day gives moderate growth. Feed intake increases if feed is available to the animal for a longer time.

Energy and protein allowances for non-human primates

Species and stage	Energy (DE Kcal/kg, BW)	Protein [a]% calories	g/kg body weight
Baboon: Infant	<290	12.0	5.0
Adult	53-72	12	2.0
Chimpanzee: Infant	120-100	12	5.0
Adult	50-60	12	2.0
Rhesus: Infant	270-190	12 (6.6)	8.0 (4.0)
Adult	75-120	12 (6.6)	3.0

[a] High quality protein; [b] Values in parenthesis are minimal requirements

Diet schedule/ feed formulation of langur in zoo/ captivity

Bread	-	100 g/d
Ground nut	-	20 g/d
Mango	-	125 g/d
Banana	-	750 g/d
Gram	-	50 g/d
Vegetables	-	500 g/d
Pineapple	-	250 g/d and one egg/ day.

Diet formulation for non-human primates based on dietary crude fibre

Ingredients	Percent dietary crude fibre		
	2.4	**7.0**	**9.8**
Wheat flour	50.00	39.00	28.00
Wheat middling	6.30	4.75	3.50
Wheat bran	4.20	3.50	3.00
Alfa alfa meal (17% protein)	2.25	6.25	10.00
Oat hulls	1.00	10.00	19.00
Soybean meal (48% CP)	7.50	7.50	7.50
Skim milk powder	2.75	2.70	2.70
Fish meal (60% protein)	4.00	4.50	5.00
Brewer's yeast (dried)	2.50	2.50	2.50
Sugar	3.00	3.00	3.00
Corn starch	8.40	8.60	8.40
Soybean oil	3.70	3.60	3.50
Calcium carbonate	1.70	1.50	1.30
Monosodium phosphate	0.40	0.50	0.50
Salt	0.30	0.30	0.30
Mineral mixture	1.00	1.00	1.00
Vitamin premix	1.00	1.00	1.00

Non-human primates feed on a variety of foods in their natural states. The wild diets consist of leaves, fruits, insects and small animals. Commercial diets given to captive primates are easy to prepare, relatively economical and have satisfactory results on growth and development. Commercial chows prepared from natural food ingredients have also successfully been used for captive nonhuman primates.

Composition of chow:

Chow contains soybean meal, corn, skimmed milk, fish flour, cereal products, animal fat and vegetable oil. The ingredients are mixed, pressure cooked, blended and shaped into chow and fortified with proteins, minerals and vitamins.

A young rhesus monkey requires energy @150-200 kcal/kg, whereas an adult monkey is needed about 100 kcal/kg, while Pregnant and lactating females are required 175 kcal/kg and 150 kcal/kg respectively.

Nutrient requirements of nonhuman primates in captivity/zoo

Protein	:	15-25%
Energy	:	Young (150-200 kcal/kg), Adult (100 kcal/kg), Pregnant & Lactating (175 kcal/kg)
Dietary fat	:	3-5% (They are found to be well adjusted to total 10% dietary fat).
Calcium	:	0.6-0.8 percent
Phosphorus	:	0.3-0.4 percent
Water	:	Wild nonhuman primates mostly fulfill their water requirements through natural dietary ingredients. However, water should be offered for zoo/ captive specimens. Food is offered in the morning and afternoon.

Food /diet formulation/ diet chart/dietary schedule in zoo/ captivity

Fruits	:	1 kg
Milk	:	1 Litre
Bread slice	:	6 Nos.
Boiled egg	:	One
Garlic and Onion	:	100 g
Tea	:	2 cups

Water should be available regularly.

Dietary chart/ feeding schedule for gibbon in zoo/ captivity

Apple	-	2 nos.
Orange	-	2 nos.
Banana	-	2 nos.
Bread slice	-	2 nos.
Hard-boiled egg	-	2 nos.
Cabbage	-	Good amount
Meat (horse meat)	-	Small amount
Monkey pellets	-	one handful
Fine bone meal	-	one tea spoonful
Cod-liver oil	-	one tea spoonful

They are fed twice daily i.e. morning and evening

Diet schedule/ feed formulation of langur in zoo/ captivity

Bread	-	100 g/d
Ground nut	-	20 g/d
Mango	-	125 g/d
Banana	-	750 g/d
Egg	-	1 no/d
Gram	-	50 g/d
Vegetables	-	500 g/d
Pineapple		250 g/d

Feeds and feeding schedule of wild carnivores in captivity

Exotic felids are highly adapted to a carnivorous diet. They are intermittent feeders in the wild state. Felids require high amounts of protein and fat in the diet. They need about 3 g protein per kg body weight per day as maintenance ration. Adult felids require a minimum of 21-22% protein in their diet on DM bases. However, kittens are required a minimum of 33% protein for growth purpose. Many essential amino acids are required in felids as they do not synthesize in sufficient quantities by conversion of other amino acids. They require relatively high levels of dietary methionine. This is especially important when diet lacks vitamin E. Deficiencies of fats of animal origins may result in poor coat condition and reproductive failures.

Felids do utilize soluble carbohydrates obtained from other sources. However, these animals derive most of their blood glucose from amino acid metabolism. They poorly utilized cellulose and un-boiled starch. Sucrose is well tolerated by these animals. Felid lacks intestinal enzyme lactase resulting in less utilization of lactose. A diet may contain 3-4% crude fibre.

An adult small felid in zoo/captivity needs food about 4-8% of its body weight daily, whereas young and growing animals may require more. The diet is provided once a day for captive animals. Young, however, should be given twice a day.

Felids require vitamins A, D and E. They are unable to synthesize vitamin A from the plant derived precursor, beta-carotene. Therefore, animal tissue is the important source of vitamin A for felids. It occurs mostly in the viscera of prey, particularly the liver. Muscle meat contains very low calcium. So felids should be given 100 mg of calcium per kg body weight per day.

Feeding of Lion in captivity/ zoo:

The diet of lion in zoos/ captivity include meat of slaughtered animals goats, sheep, horse, buffalo and other vital organs of slaughtered animals like liver and kidneys. A lions may be offered 8-12 kg meat/lion/ day. In addition to meat items some amount milk 500 ml, chicken 0.75-1 kg once a week, 1-2 eggs, supplemented with vitamin-mineral mixture @10 g/lion/day should be supplemented in their captive diet.

Feeding of Tiger in captivity/ zoo:

They can be offered meat along with vital organs especially liver and kidneys of slaughtered animals. Adult tigers may be offered 8-10 kg meat/tiger/day. The captive diet should include other food items like milk 250-500 ml, 1-2 kg hen once a week, 1-2 eggs in off day and vitamin-mineral mixture @10 g/tiger/day. The tiger may also supply bones with muscles for the purpose of exercising jaw muscles in captivity. Enough supply of fresh clean drinking water should be ensured. Frozen meat should be thawed before feeding.

Feeding of Leopard in captivity/ zoo:

Dietary choice is similar to the ingredients provided to the lion in the zoo/captivity. Normally a leopard diet may include 2-4 kg meat, milk 250 ml/leopard/day, hen 0.5-1 kg, 1-2 eggs and 150-250 g liver once a week.

Feeding of Cheetah in captivity/ zoo:

The zoo/ captive diet consists of fresh meat of common slaughtered animals and liver, kidney and bones of slaughtered animals along with processed canned food.

Feeding of fox, Wolf and Jackal in captivity/ zoo:

They do well on a well balanced mixture diet consists of minced raw meat, commercial dog food, rats, chicken heads, fruits, boiled vegetables, powdered bone meal and cod liver oil supplemented with milk and mineral vitamin premixes.

Feeding schedule of Fox, wolf and Jaikal

Fox	-	0.5-1 kg meat
Wolf	-	1.5-4 kg meat
Jackal	-	1-2 kg meat

Feeds and feeding schedule of wild reptiles in captivity

Reptiles comprise a diverse array of species that cover a broad spectrum of dietary requirements. Usually reptiles are fed no more than 20% of their body weight at a time. The diet should contain 11 to 12% protein for reptiles which feed on mostly plant materials and about 18-20% protein for carnivorous reptile. Most of the reptiles feed on carnivorous diets which include fish, rats, mice, small birds, small rabbits, guinea pigs and amphibians.

The reptiles may be sub-classified on the bases of feeding habits given below. It is important to note that all these species maintain some degree of insectivory or carnivory throughout their life cycle.

Classification	Species Examples	Typical wild diet
Insectivorous	Small Skinks, Juvenile Bearded Dragons, Geckos	Insects, small invertebrates
Omnivorous	Adult Bearded Dragon, Blue tongue and Shingle back Skink	Insects, snails, invertebrates, plant materials, flowers and fruits
Omnivorous	Short-necked Turtles	Fish, Crustaceans, invertebrates, algae, carrion
Carnivorous	Long-necked Turtles	Fish, crustaceans, invertebrates, carrion
Carnivorous	Large goannas, snakes	Small mammals, birds, frogs and other reptiles

Crocodiles should be offered intact preys such as whole fish or mice. The viscera along with strips of meat may also be given. Diet should be provided in water. Young are fed *ad libitum* on chopped meat, mice and fish with vitamin and mineral supplements every second day. The gharial in the zoos/captivity should be fed more often. It is reported that they feed better when the dietary ingredients are tossed to them just lateral to the mouths. Normally feeds are provided two times a week. An adult crocodiles may consume 30 kg meat in each feeding.

A baby snake should be fed every other day. The small size adult snakes should be fed once every 7 days. A more active snake may need more frequent meals. In many cases, breeding females may also require more frequent meals. The larger snakes like python should be fed once every 10-14 days. For easier and simplest digestion of food and for better absorption and utilization of nutrients, it is generally preferred to feed smaller prey more frequently than that of large size prey items less frequently. Never feed snakes together in the same vivarium. Assisted feeding may be necessary at times. Smaller snakes can be fed pinkies with gentle pressure, patience and lubrication. The snake always swallows its prey intact. Poisonous snakes kill or paralyze their preys by envenomization before swallowing. Snakes often eat dead food or even strips of meat. Larger snakes may be tube fed with canine or feline invalid diets. Long crop needles or a variety of sizes of stomach tubes are used. As in other categories of reptiles, insect prey should first be fed a calcium-fortified diet. For feeding of snakes in the zoos/ captivity, rodents can be purchased from commercial suppliers and thawed prior to feeding.