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Diploma of
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Nutrition and Deficiency Diseases Course

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Contents

Feeding of poultry

Diverse as they appear to be, species of poultry have much in common in the kinds of feedstuffs and in the manner in which feeds are digested and nutrients are absorbed and metabolized. The major types of poultry are chickens or fowls (layers and broilers) and turkeys. Other poultry, of much less economic importance, include waterfowl (ducks and geese), ostrich, pigeons, and quail.

Poultry nutrition is more critical than that of other farm animals as their digestion is rapid, respiration and circulation are faster, their body temperature is higher 8 to 10° F than four- footed animals, more active, more sensitive to environmental influences, grow at more rapid rate, mature at an earlier age, and egg production is an all or none phenomenon. Metabolically poultry are a well developed "fast – living" animal.

NRC publishes bulletins giving nutrient requirements of birds on which the formulation of balanced diets depends. Genetic differences among bird strains affect requirements, where each strain has its own standards, as in broiler – type and egg – type strains of chicken. Requirements are presented on the basis of total concentrations in the diet or total consumed per day, and not given separately for each function or on a digestible basis.

Poultry diets are composed primarily of a mixture of several feedstuffs such as cereal grains, soybean meal, animal byproduct meals, fats, Ca-P - and Na supplements, and vitamin and mineral premixes. Diets also can include xanthophylls or other feed additives.

About 55 to 75% of the cost of production may be attributed to feed costs, with the production of egg towards the lower side of this range and the production of broilers and turkeys towards the upper side. Three fourths of this cost is being allotted to maintenance needs and the remainder for productive purposes. As a value for meat, the dressing percentage reaches 65 – 72% while it ranges between 45 and 55 in sheep and cattle.

The following is a functional knowledge of poultry anatomy and physiology before discussing the nutritional requirements.

I- Tissues

- Skin has low sensitivity to the degree that in the condition of cannibalism the weakling bird does not show any reaction to the others pecking at it. Pantothenic acid, biotin and niacin affect skin in deficiency.
- Feathers make about 20% of their growth in each of the 1st 3 weeks of age. High production birds molt rapidly after the end of the production season. Lysine, methionine & some trace minerals influence pigment formation in feathers.
- Medullary bone provides readily available Ca (25% of Ca used in egg shell).

II- Systems

- Uric acid N forms 80% of the daily urinary N, and formation of uric acid needs glycine. Bird uses $\frac{1}{10}$ only of the kidney size in normal conditions.
- Hearing is a well-developed sense. Birds do not have selective taste but prefer some colors. Eyes are on the forward side of the skull and the sidewise forward motion causes heavy feed waste in overly filled troughs. Smell is not highly developed.
- The intestine of chicken secretes enterokinase, which changes trypsinogen, secreted by the pancreas, to trypsin. Roasted or treated soya beans are an especially useful protein, but uncooked beans contain a trypsin inhibitor which effectively blocks the work of the pancreas in this particular respect.

Small intestine is a sensitive organ and its sensitive nature continues until the chick is 21 to 28 days of age, when the system becomes similar to that of the mature bird. A hen can utilize high- Ca uptake, 2 to 4%, without bringing about a trace element deficiency (Mn or Zn), whereas a chick of 2 to 21 days of age fails to absorb or utilize Mn or Zn when over 1.6% Ca is fed.

Bird can absorb all the food offered during only 3 hours. The intestine is 5 – 6 times the body length, the food passes through in about 3.5 hours and complete evacuation takes 16 – 20 hours. Food may remain in the crop for 20 hours. There is a tremendous outpouring of nitrogenous material by the duodenum. Expressed as crude protein this would amount to about ten times the amount of ingested protein. The bird is thereby able to utilize protein more efficiently, since the AAs are supplied in more optimal proportions, and enables it to maintain itself for short periods of time when one or more of the EAAs are deficient in the diet. This does not imply that EAAs can be omitted from the diet. This recycling phenomenon causes rapid AA depletion which is speeded up because each time the acids pass through liver, some are oxidized and deaminized. In scours reabsorption of endogenous protein may be severely impaired, leading to loss of flesh from the bird.

Wet mash passes faster than an equivalent weight of dry meal. Wet mashes are used to increase appetite. The gizzard function is to crush feeds and mix with water forming the chyme. The size and strength of the gizzard are related to the hardness of the food particles and the presence of crushed insoluble stones (grit). When an all-mash diet is supplied the need for insoluble grit is less absolute. Feeding very finely ground food causes abnormal softening, thickening of the lining, hemorrhages and erosion. Coarse food and grit prevent this problem.

- Reproductive system and egg production:
  a. At the time of hatching, the female chicks left ovary contains up to approximately 3600 to 4000 tiny ova.
  b. The oviduct is divided into five regions, each of which plays a specific role in the completion of the whole egg, funnel or infundibulum, magnum, isthmus, uterus, and vagina.
  c. About 8 – 10 days before the first egg is laid the yolks begin to increase in size rapidly, and the final size is reached in about 7 days.
  d. Prior to expulsion, the egg is turned 180° so that the large end is exposed firstly. During this turning hen makes sounds denoting egg laying.
  e. Magnum is the organ where albumen is secreted and uterus is the part in which the shell is secreted. The shell is formed from calcium carbonate. Blood carries the Ca and carbon atoms to the shell glands where it is united to from the carbonate. The shell contains many pores reaching 8000 in each egg. They aid in entrance of O_2 and coming out of CO_2 and fluids.
  f. There is an enormous range in size among the eggs of the different species ranging from 1400 g in ostrich to 0.5g in humming bird.
  g. An egg needs 25h in its sojourn along the oviduct, and it takes 30 min. for another egg to separate from the ovary.
  h. After peak, production starts to decline by 1 – 2% weekly till the end of the first production season.
  i. Yolk is rich in both fat soluble and water soluble vitamins.
  j. Errors in nutrition or management cause a cessation of egg production and when corrected it will take at least 7 – 8 days before production begins, as this length of time is required to produce the yolk.
  k. Avidin is a protein which possesses the power of combining with vitamin biotin, rendering it unavailable.
  l. In hot weather birds pant to get rid of the extra heat via respiratory system, by this process it loses a great amount of the CO_2 decreasing the level of carbonates in blood, leading to thin shelled eggs in summer season.

m. The source of shell Ca is from the diet and oyster shell kept behind the bird, but the bird may draw some Ca from medullary bone especially at night where there is no food consumption.

Nutrient requirements of poultry – in general

The nutrient requirements of poultry vary according to species, strains (type of production – broilers, layers, and breeders), breeds, age and activity. Requirements for growth of light breeds of pullets for replacement of egg production stocks are different from requirements of heavy breeds of chickens that are grown as broilers.

The requirements of poultry, particularly chicks and layer hens, are defined more precisely than those of other domestic animals. Recommendations in NRC do not provide any margin of safety (tables for requirements are at the end of the chapter). The nutritionist adds a margin of safety arriving at nutritive allowances to be used in ration formulation. Because of the small size of poultry and feeding in groups, the standards are usually stated in the amounts of the various nutrients required per kg of feed or in percentage, instead of allowance per head daily.

In NRC, the energy level of the diet was first established, under ideal environmental condition, for each species and age of poultry, and then the other nutrients were determined based upon the established level of energy. If a higher energy level, than the NRC requirement, is used in the diet, feed consumption will decrease; hence, the minimum level of the other nutrients should be increased in proportion to the energy content. Similarly, if a lower dietary energy level in used, then proportionally lower levels of other nutrients should be used in the diet. When free-choice feeding dietary protein levels that are low in relation to energy, fat deposition is markedly increased, with higher levels of protein, less fat is deposited. Increasing the protein level above that required for maximum growth rate reduces fat deposition still further. A deficiency of a nutrient can be, and often is, a limiting factor in egg production or growth. Broilers fed high energy diets show efficient feed utilization and improved growth rate.

Temperature as a factor affecting the nutritive requirements of poultry

1. The ambient temperature can have considerable impact on feed consumption of poultry, especially adult birds, because feed intake decreases when ambient temperature increases. As the temperature rises the food intake declines at an ever increasing rate, for example:
   - Leghorn hens consume approximately 1.5 g less feed per hen daily for each 1° C increase in ambient temperature over the range of 10 to 35°C. At temperature above 30°C, the decrease in feed consumption may be 2.5 to 4 g for each 1°C increase.
   - As the temperature changes from 20 to 30° C the rate of decline in food consumption was 1.5% per 1° C rise, whereas the fall may be 4 to 5% per 1°C with rise from 30 to 38 °C.
   - In respect of dietary calorie intake, this tend to fall by about 4 kcal/ bird/ day per degree centigrade °C rise in temperature, but the rate is slower at low temperatures and much faster at high temperatures. As it is clear from the following table at 20 °C high – producing birds may require about 320 kcal of ME daily, whereas at 30°C the figure may fall to 270 kcal.
2. If poultry house temperature is substantially below body temperature, food consumption increased and an important fraction of food will be devoted to maintaining the differential between her body temperature and that of the air which surrounds her.

If the house temperature rises the food required for body maintenance will fall, with the usual result that food intake will fall and the need for energy – producing feeds will decrease. While this may appear desirable, the specific nutrients required for egg production or growth must still be provided and, as feed consumption decreases, the quantities of essential nutrients, protein, vitamins, and minerals, must be increased accordingly by increasing their concentration in the diet. The margins of safety for vitamins and trace minerals in premixes will usually be sufficient to allow for changes in daily food intake but nevertheless the levels should carefully be checked.

High temperatures, those in excess of say 27°C, may seriously reduce appetite. In this case a ration, whilst perhaps not needing to be more dense in energy, would certainly need to be formulated with higher proportions of protein, vitamins, and minerals which would otherwise be certainly eaten at less than optimum rates. Another source mentioned that when temperature and humidity conditions deviate much from 16 – 21 °C and 40 – 60% relative humidity adjustments in nutrient levels should be made to compensate for changes in feed intake.

3. As ambient temperature approaches normal body temperature (41.7) the birds may at first utilize body reserves as a substitute for intake. Closer still to body temperature, food intake and production can be expected to collapse completely.
4. The optimum temperature for laying birds to allow most efficient food conversion and production would appear to be between 25° and 30°C whilst a minimum of 18 °C and a maximum of 32°C cover the range for good average production.
5. It is seldom practical to make frequent changes in the formulation to match it to the house temperature. One attempt at a practical solution is to prepare two standards of formulations, one for moderate temperatures and one for periods of high temperatures. In areas of high temperatures and particularly when high temperature accompanied by high humidity. The economic problem is to decide whether to spend money on air – conditioning equipments or whether it is better to produce the eggs in a more equable climate and transport them to the site where they are needed.

Table 1 Nutrient density as the ambient temperature rises

Temperature	**20°C**	**24°C**	**27°C**	**30°C**
Daily FI, g	110	105	100	95
ME/ day/ bird	320	300	287	270
ME/ Kg diet	2900	2860	2870	2840
CP%, 18g/ bird	16.5	17.14	18.0	18.95
Methionine	0.35	0.37	0.39	0.41
Methionine & Cystine	0.47	0.50	0.52	0.55
Lysine	0.75	0.79	0.83	0.87
C/P ratio	175.8	166.9	159.4	149.9

Clearly then, energy requirement is affected by environmental temperature and, as a result of the relationship, energy intake is likely to vary to a higher level than energy requirement (especially if the latter is related to a given end point of production).

If too little intake of energy occurs, too few nutrients may be provided for, say, yolk development. If too much energy is ingested, some may be recovered in increased egg size but most will be wasted (economically speaking) in heat production or in storage as fat in the body tissues.

Appetite as affected by the nature of the diet and density of nutrients

A- Nature of diet

a. Finely divided and dusty foods are not readily eaten and can lead to a marked drop in intake.

b. Energy concentration greatly affects feed intake, as do also the physical (bulk) density. Very fibrous foods are too fluffy and carry a low proportion of nutrients per unit volume rather than per unit weight. Too bulky a ration may be unable to maintain production and feeds, like bran, oats, and dried yeast are included in limited amounts. Both of these problems can be eased if the ration is presented in pellets. By the use of pellets, intake of food and also intake of energy (despite natural regulation) can be increased by 8 to 10%. This is why crumbs and pellets are very popular in feeding broiler chickens. In feeding pellets (especially in layers) concentration of some nutrients can be reduced.
c. Changes from one food mixture to another should be made gradually, for otherwise the chickens may decline to eat the new mixture for a few days. All animals are susceptible to health-related problems when radical changes are made in the composition of their feed. Therefore it is imperative that any great changes in feed composition be done gradually over a period of time.
d. Food intake may easily fall if stale food accumulates in the hoppers. Fresh food is most important at all times. Presence of unpalatable ingredients also affects feed intake.
e. Lack of appetite also may be due to a change over being made rather suddenly from one size of feeder to another. The change to the new food hoppers should be gradually.
f. Deficiency of some nutrients may affect food intake.

B- Density of nutrients

a. The levels of the various nutrients in a balanced food mixture are commonly related to the energy, the ingredient that can most readily be regulated in the diet.
b. As energy intake may tend towards a constant value (a tendency only as natural regulation is not sensitive enough to ensure this), then food intake falls as density rises, and increases as density is reduced.
c. In case of conditions which limit food intake in high productions, as body size, and high ambient temperature, increasing the nutrient density of the ration is the most obvious way by which productivity can be sustained. The advent of small-bodied, egg – laying hybrids focused attention on this particular aspect.
d. Accordingly the breeders publish guides to the food requirement of, and the methods of feeding for their strains and these should be followed carefully.
e. The cost of rations per unit of energy has to be worked out. In general it is safe to reduce the density so long as the bird can eat more each day to obtain the calculated intake of nutrients. The lower level to meet the requirements of hybrid layers appears to be about 2310 kcal/ kg while the higher the density the better will be the food conversion for egg produced. The decision depends on availability of ingredients and costs.

   The general rule is that high-density ingredients and rations are more expensive to purchase, but cheaper and more efficient to handle; low density are cheaper initially but are often expensive to utilize and may actually limit the level of production that the birds can show.

f. Except for appetite reduction due to high temperatures, the energy level of the ration is closely related to that of the other components. This relationship is known as the energy – protein balance or ratio (C/P) and is usually denoted by the number of energy units percent of CP in the mixture (energy required to metabolize the protein supplied to body tissues). In spite of the fact that energy is related to all nutrients, the relationship is denoted to by calorie-protein ratio as protein is the most expensive and needed in large amount.
   Example: A diet of 3200kcal/kg diet and 23% CP has a C/P ratio 3200 ÷ 23 =139.13

Components of poultry diets

I- Energy

Poultry together with non-ruminants are sometimes said to "eat for calories". Factors other than dietary energy and nutrient balance that affect feed intake include bulk density of the diet in addition to ambient temperature. Because of this, especial attention must be given to nutrient ratios, especially amino acids and minerals, and to the factors which may affect.

The ME values given in the NRC requirement tables are not intended as requirements. Rather, they are provided to give perspective to the other nutrient requirement levels.

The major **energy sources** of poultry feeds are the cereal grains & its byproducts and fats.

1- Cereals

Corn is the most important grain used by poultry, supplying more than half of the total which they consume. **Wheat** ranks second in importance and should not be ground finely. The **sorghums** rank third.

Broom corn should not be used at a rate more than 25 %. **Barley** is not used for young chicks, but can be used for growing chicks or adults at a rate not more than 25 %. It should be properly ground.

2- Byproducts

Fine **bran** is better than coarse bran and it should not exceed 5 % in broiler rations and 10 % in adults. In ducks and geese bran can be used at a rate of 35 % as they need more fiber and have a large food intake. **Rice polish** added to broiler and adult rations at a percentage not more than 10 %. For ducks, geese and turkey, it can be added at a rate of up to 35 %.

Corn, sorghums and wheat are high energy cereals, while barley, broom corn, bran, and rice polish are feeds rich in fiber content and of moderate energy value. **Molasses** can be used efficiently but excessive amounts cause wet droppings. It can be used at the rate of 1-2 % for chicks and 2-3 % for adults.

3- Fiber

The optimum level in poultry feeds for the fiber lies between 2-3 % and the normal maximum is 5 % in starter, grower, and layer rations. Rations containing 10-20 % fiber may, on occasions be suggested for special purposes e.g. holding rations for breeding stock to reduce the growth rate. Crude fiber is indigestible in poultry.

4- Fats

Animal & vegetable fats are usually added to the feed for meat-type poultry to increase overall energy concentration and improve productivity and feeding efficiency. It increases the intestinal retention time so complete digestion & absorption. The addition of fat improved the productive energy and is particularly valuable during high environmental temperatures. In addition to their high energy value, fats reduce the dustiness of feed mixtures, increase their palatability and improve the texture and appearance of the feed. Rancid fat may, when mixed with other food ingredients act upon the fat soluble vitamins to such an extent that their value is lost. Vitamin A, D and E may be depleted in this manner. All feed fats should be stabilized by an antioxidant to preserve unsaturated FAs. Fats are carrier for the fat-soluble vitamins and in addition the arachidonic and linoleic are essential nutrients.

Linoleic is the only essential fatty acid and its deficiency is not readily encountered, but symptoms are due to loss of membrane integrity. An increased need for water and decreased resistance to disease are characteristic deficiency symptoms. In male it can impair spermatogenesis and affect fertility. Insufficient deposition in the egg will adversely affect embryonic development. 1 % linoleic is sufficient in growing and adult birds. Higher levels may be needed to achieve and maintain satisfactory egg weight. A dietary need for α- linolenic acid (18:3, n-3) has yet to be demonstrated for fowl, especially for the development of specialized membranes in retina and nervous system.

Too much fat in the formulation of the diet gives problems with physical form of the ration and the way in which it can be handled. Fat can be added to broiler rations at the rate of 3-5 % and in sometimes it may reach 7 %. Hydrogenated fat with a very high melting point is not utilized well by poultry. High levels of fat are not recommended in poultry diets unless they suitably stabilized with antioxidants.

Effect of feeding rancid oils:

In recent years the inclusion in poultry diets of animal fats and vegetable oils is practically recommended. Many disorders in practical feeding have been attributed, on different occasions, to the oxidation of oils or fats in cereals, fish meals and meat meals. Feeding of rancid oils causes:

a) significantly reduced food intake and body weight gain. Congestion of comb and wattles.

b) diarrhea and general unthriftness.

c) impaired liver functions (alteration of many blood enzymes, Hb and bilirubin levels).

d) pancreatitis.

d) excessive internal hemorrhages, organs badly congested. Liver greatly congested and swollen with fatty change and distended gall bladder.

e) swollen kidney with peticheal hemorrhage, and hemorrhagic and catarrhal enteritis.

II- Protein

1- Level in diets

The protein requirements of poultry are commonly stated in terms of the percentages of total protein "not digestible protein" which are needed in rations for good results when the protein is of satisfactory quality (refer to the table). The calorie/ protein ratios calculated as kcal ME per kg/percent of CP should be followed in ration formulation.

Percentage requirements of protein and amino acids should be increased in warmer environments and decreased in cooler environments, in accordance with expected differences in feed intake; however, some precautions should be used in increasing the dietary protein concentration.

For the other species of poultry other than chicken refer to the tables at the end of the chapter. Protein has an immediate effect on egg weight and within the range 14-20 % rations that have been carefully balanced in respect to AAs give heavier eggs the higher the protein level (the choice of the level depends on the evaluation of the extra cost). 1% additional large eggs may be anticipated for every 1% increase up to a maximum of 20 % CP.

2- Quality of Protein

In poultry rations, it is important to have protein of good quality and to have a sufficient amount of protein. Rations, in which the protein comes entirely from grain and grain by-products, produce poor results, because of poor quality of protein, even if there are ample supplies of minerals and vitamins. Fish meal, meat scrap, tankage and other dairy by-products have a high value as protein supplements in poultry rations. Starting mashes for chicks should generally have at least 5-7 % animal protein supplements or only 4 % good quality fish meal. Now all plant protein diets are formulated with good results.

The application in feeding practice of standards for as many as ten or eleven amino acids is likely to be rather laborious. In practice it is usually found that the amino acid mixtures provided by the diet are out of proportion, and hence inefficiently utilized, because one or two amino acids are very markedly deficient. These are the **"limiting" amino acids**. For pigs the acid likely to be most deficient is lysine while for chicks it is commonly methionine although lysine and perhaps arginine and valine may also be deficient. Also cystine and tryptophan need particular attention. In practice it may be sufficient to ensure that diets for poultry contain adequate amounts of these acids most likely to be deficient, and in laying hens leucine and isoleucine should be also considered.

In the formation of uric acid in birds glycine is required as it contributes part of the uric molecule, and the bird is unable to synthesize arginine. In mammals a final step in urea cycle is a molecule of urea and a molecule of arginine.

Methionine is the first limiting amino acid for egg production, and glycine or serine is not essential for layers. In addition to the essential amino acids there must be sufficient total nitrogen for the chicken to synthesize the other amino acids needed.

Methionine and lysine are manufactured at an economical cost. This allows that the initial balance of the ration can be compounded on the basis of the balance of the less limiting amino acids so the calculated amounts of methionine and lysine can be added at later stage.

The usual assumption that amino acids are 80 to 90% available is not necessarily valid. For example, feathers or blood are either indigestible in native form or made indigestible by overheating in processing, respectively.

Generally protein of all cereal grains is low in lysine. Corn and sorghum are especially deficient (0.25 %). Peanut meal & CSM (1.6 %) do not supply sufficient lysine to correct the deficiency. SBOM (3 %), MM (2.6 %), FM (4.5 %), tankage (2.8 %), dried skimmilk (2.4 %) can remedy the deficiency. Meat scrap or tankage may be little deficient in tryptophan. Alfalfa meal also has a good content of tryptophan but high in fiber. Corn has more leucine than barley. Corn gluten meal is low in lysine but has considerable methionine than do for e.g. SBOM which has good content of lysine and tryptophan. Combination of these feeds corrects the deficiencies. Only few protein supplements supply more methionine. Fish meal, sesame oil meal and well-hulled sunflower-seed oil meal are good sources of methionine.

In addition to dietary energy concentration and ambient temperature; strain; productivity; protein level; AAs relationships, antagonism, relation to vitamins, and its availability, are factors affecting the amino acid requirements, and should be considered.

3- Protein or AA deficiency

A borderline deficiency is characterized by poor growth and feathering, reduced **egg size,** poor egg production (but hatchability is not affected), tendency toward greater deposition of carcass and liver fat, poor feed conversion into eggs or meat, and lack of melanin pigment in black- or reddish-colored feathers with low lysine. A severe protein deficiency is marked by-stopping of feed intake, stopping of egg production, loss of body weight, resorption of ova, a tongue deformity with leucine, isoleucine, and phenylalanine deficiency, stasis of the digestive tract, and death.

4- Protein supplements

Both animal and plant protein supplements are used. Most of that of animal origin contribute minerals and vitamins, but they are more variable in composition than the plant protein supplements. Among the animal sources are the meat meal, fish meal, milk by-products, blood meal, hydrolyzed poultry feathers, and poultry by-product meal.

Fish meals primarily herring, menhaden, and anchovetta are high in protein and extremely well balanced in EAA. However, since FM is high in fat, they tend to create a fishy flavor in meat and eggs when used in large amounts. This, together with the high cost of FM, restricts its use to one of a secondary source of protein supplementation.

The common plant protein supplements are the **oilseed meals** (SBM, CSM, PNM and limited amounts of LSM), corn gluten meal, alfalfa and other legume meals. SBM is the most widely used supplement in poultry rations. Corn gluten meal and alfalfa meal are used extensively for its protein and high content of carotenoids (deep yellow pigmentation to the skin).

Certain strains of rapeseed meal contain high levels of goitrogenic compounds to be toxic. Even SBM contains harmful substances as a trypsin inhibitor, but these are destroyed by proper heating. In CSM gossypol produces a mottling of egg yolks, or olive-green or dark-brown yolks, even in extremely small amounts. Cyclopropenoic fatty acids-another class of compounds found in CSM-impart a pink colour to egg whites. Because of that CSM is generally not used in laying rations, but it can be used effectively in growing and replacement rations. LSM can be used effectively in limited amounts, but it may depress growth and cause diarrhea if fed at high levels (it should not exceed 3-5 % of the ration).

III- Minerals

Feeds of animal origin are generally well supplied with minerals and those of vegetable origin usually have a low proportion. For example 10% fish meal in diet supply the full requirements for a number of minerals and excessive of other minerals e.g. salt.

To overcome the possibility of deficiency supplements are added. The constitution of the supplement will depend upon the quantity and availability of the minerals in the ingredients. It is important to ensure that diet has no excessive level of minerals which could be harmful. Also samples of inferior quality of meat and bone meal or fish meal can be a source of trouble. Presence of certain minerals may interfere with the absorption of other nutrients. Excess of sulfur decreases the yellow **pigments** in shanks and skin. An excessive amount of Ca supplements interferes with Mn (also excess P as in feeding large quantities of FM), Zn, I & Mg utilization and may reduce **egg production** and lower **hatchability** and with low vitamin D reduces the **egg weight.** Phytin may bind also Ca, Zn, Fe and Mn and render them unavailable. Excess Mg causes **laxation** and iodine has an effect on **egg production, semen production** and **fertility.** Excess Mg interferes with absorption of minerals especially Ca & P. If it is known that a diet contains a high level of Mg, levels of other elements should be increased.

Bone meal is capable **of adsorbing** Mn from the food in the gut. Some minerals have an effect of binding others thus counteracting the harmful effect which the latter may possess (chelating effect). Arsenic, copper, and potassium counteract excessive Se, Mo and Na respectively. Excess of iron or elemental sulfur decreases the absorption of D, (unless it is supplied in protected form).

In practice for every formulation the levels of Ca, P and salt should be calculated separately and specific inclusion is arranged. No supplement is needed to be included in rations for K, Mg, Co, F, Mo, and it is not wise to use Se supplements routinely as dietary additives. By contrast the trace minerals are best supplied as a trace mineral supplement. Thus making it unnecessary to consider each of them separately.

1- Calcium and phosphorus

Requirements of layers and breeders for Ca are high and it varies with egg production. Each egg contains 2 g of Ca (2/3 from ingested food and 1/3 from body stores). The convenient supplements for Ca are limestone flour, granular limestone or limestone grit or oyster shell available at choice.

A deficiency of Ca in poultry rations causes rickets in chicks and reduced egg production, hatchability, weak shells in many eggs, and egg size has been reported to be decreased. In laying hens the bones & sternum are rachitic and deformed. An excess of Ca interferes with the utilization of Mg, Mn and Zn.

All the phosphorus from animal origin is available. Organic P, in plants, is poorly utilized by growing birds, but is satisfactory for adult birds. Only about 30% of the P in plant products is available to the young chick, poult, or duckling. Wheat bran, rice bran, fish meal, S.B.O.M. and alfalfa meal have a good content especially the first two feeds. In deficiency of phosphorus the results are the same as that in Ca deficiency. Some mobilization of Ca and P from the bones during heavy egg production is a normal physiological process even as is the case for lactation.

For young poultry the Ca: P ratio should be about 1.2: 1, however 1: 1 to 1.5: 1 are well tolerated. For the laying bird, the ratio must be wider (4: 1 or more).

2- Salt

A deficiency of Na results in poor growth and decreased egg production. In Cl deficiency there is poor growth, mortality and hemoconcentration. Chicks also show nervous condition resembling tetany when stimulated with sharp noise. The amount of supplement added depends upon the food ingredients. In some cases no additional salt is needed (as in feeding large amount of FM). Generally

0.25-0.30 % corresponding to 0.1-0.15 % Na is included. 0.5 % is suggested as the upper desirable limit for the salinity of drinking water. This may be of particular importance in relation to ground water in an area intended for poultry development. Sodium level is sometimes reduced to minimal to control the moisture level of the feces.

A proper dietary balance of Na, K and Cl is necessary for growth, bone development, egg shell quality and AA utilization.

3- Potassium

A deficiency of K results in high mortality and retarded growth in chicks, and causes reduced egg production and egg shell thickness in laying hens. It is not deficient in normal rations, due to large amounts of plant products in poultry feeds.

4- Magnesium

Severe deficiency causes symptoms identical with nutritional encephalomalacia and chicks in a week stop growing and become lethargic. In mild deficiency chicks grow well but show convulsion then comatose state which may lead to death. In laying hens there is bone depletion, comatose state & death & decline in egg production and hatchability and shell thickness reduced. Mg requirements are affected by Ca and P levels in the diet.

No supplement is needed to be included in poultry rations as Mg is not normally deficient. Mg is not toxic (toxic level is more than 10 times the recommended one) but the inclusion of large amounts causes laxation.

5- Manganese

There is a special need for manganese by poultry. A deficiency of manganese in chicks or poults is the chief cause of perosis (also choline or biotin). Choline (0.13 %) in addition to Mn is necessary to prevent perosis and this role has no connection with its role in fat metabolism. A free-flowing Mn supplement should normally be included in all poultry feeds. Deficiency of Mn decreased egg production, lowered strength of egg shells (thin – shelled or without shells) and reduced hatchability. Many chicks that fail to hatch are deformed (parrot beaks, wiry down, short legs and wings). It also reduces the viability of the chicks after hatching (the same as iodine). Mn carbonate, oxide or sulfate (all are relatively stable) may be used. They contain Mn at a percentage of about 40-50, 60-62 & 31 -32 % respectively. Requirements for Mn are influenced by the breeds and the level of Ca & P in the diet.

6- Iodine

It is included at the rate of 0.5 ppm and if F.M. is included at 5-10 % no need for iodine supplement to be added. Inadequate production of thyroid hormones results in poor growth, egg production and egg size. In breeders "I" becomes low in the egg and so decreased hatchability and thyroid enlargement in embryos, and reduced the viability of the chicks after hatching. In areas deficient in iodine, goiter may occur (the gland may increase to many times their usual size), but egg production and health of the fowl are not generally affected. In such areas iodized salt must be used instead of common salt or include FM in the ration. The following products may, after stabilization, be used for providing supplementary iodine: Ca iodate 65 % I, K iodate 59% and K iodide 76.5 %.

7- Zinc

Zinc is widely distributed amongst poultry feeding-stuffs plus that from food and water receptacles, but zinc from feeds now is clear that it may not be available for the bird and therefore zinc content of feeds should be ignored. The addition of 50 ppm of suitable supplement is all what is necessary. Zinc oxide, carbonate, and sulphate can be used and they contain 80, 55-56, and 36 % zinc respectively.

Zinc is required primarily for the growth and development of the skeleton, the formation and maintenance of epithelial tissue and for egg production. In the young birds a deficiency quickly produces skeletal abnormalities causing leg weakness and ataxia. The leg bones are shortened and thickened and are sometimes crooked & the joints are enlarged (swollen hock syndrome) and rigid. The chicks adopted a goose-stepping walk, and poults develop a condition similar to that of perosis in chicks. A necrotic dermatitis appears, particularly on the legs and feet (as in biotin and pantothenic) and feather development is impaired and feathers appear frizzled and hyperkeratinization of the epidermis. In severely deficient embryos there are gross faults in the development of the skeleton and entire limbs may be absent, this may be due to the reduction in the activity of the alkaline phosphatase which is a zinc enzyme. Hatched chicks are weak, feather poorly and may die during the first week. The minimum requirement is 30-35 ppm. Hens fed a diet containing about 6 ppm zinc showed lowered egg production and laid eggs with very thin shells and very low hatchability percent.

SBM and sesame meal have some factors (probably phytate) which reduces the availability of Zn. Meat meal and fish meal are the rich sources. Zinc and Ca absorption are interrelated; hence, as the Ca level is increased, the Zn level should be increased also.

8- Copper

Its role in poultry metabolism has not been clearly defined. Most poultry food mixtures should contain a Cu supplement; especially if the diet has a high content of Zn (high intake of Zn depresses Cu & Fe absorption). It is essential for the highest levels of hatchability, for helping to build resistance to disease, and the development of blood pigments. It is also needed for proper utilization of iron.

In Cu deficiency birds show retarded growth, low egg production, reduced hatchability, bone abnormalities, depigmentation of feathers, and anemia. Dead embryos show anemia, retarded development, high incidence of hemorrhage, and mortality is due to defect in red cell formation.

Cu oxide, sulfate or hydroxide may be used. Compounds may be contaminated with arsenic which should not be allowed to exceed 40 ppm of the final mixture.

9- Iron

It is normal practice to supplement poultry foods with iron. The normal sources include carbonate, oxide and sulfate. They are all very insoluble (absorption as low as 5.5 - 10 %). Iron does not seem to be a cause of toxicity. Iron salts are used as a means of detoxifying gossypol from CSM. However iron salts do not prevent the pink discoloration of egg whites caused by cyclopropenoic acid in CSM.

10- Selenium

Signs of deficiency are exudative diathesis, poor growth, pancreatic fibrosis, muscular dystrophy and mortality ; requirement for supplementation is needed even in presence of vitamin E. Necrotic liver in rat, exudative diathesis in chick and enzootic muscular dystrophy (cattle and sheep) can be prevented by either substance, but Se is ineffective in preventing nutritional encephalomalacia (E deficiency) or muscle dystrophy in farm animals induced by feeding dietary fat high in unsaturated FAs. Fish meal and rapeseed meal are rich sources in Se. Se is very toxic and high levels (10 mg or more/kg diet) cause reduced growth, egg production and impaired hatchability. Hence care should be taken when adding it to poultry rations. The addition of Se in either Na selenite or selenate at the rate of 0.1 ppm to complete rations for growing chickens to 16 weeks of age, breeder hens; and at the rate of 0.2 ppm in complete rations for turkeys, was approved by FDA. NRC (1994) has recommended 0.1 ppm for growing chickens, 0.15 for broilers, 0.06 for layers, and 0.2 for turkeys.

IV- Vitamins

Vitamin requirements for the insurance of maximum egg production may be insufficient to provide for the normal growth of chicks before and after hatching. For most B vitamins quantities needed for maximum hatchability are appreciably greater than those for egg production alone. This is true for B2, pantothenic, biotin and folacin. For vitamin A & D this is not so. Rations giving to best production and hatchability provide egg of the highest nutritive value. For detailed information refer to the “undergraduate” course.

1- Vitamin A

A liberal supply of vitamin *A* or carotene is needed for normal growth, also for health. When chicks are fed a ration severely deficient in vitamin A, symptoms of the lack will begin to appear in about 3 weeks. Young chicks are more susceptible to vitamin A deficiency than adults as it takes a relatively long period for adult birds to deplete their body stores. Deficiency symptoms in chicks are characterized by retarded growth, staggered gait, xerophthalmia, and disruption of mucosal membranes.

Laying hens require a higher content of vitamin A in their feed in very hot weather than when it is cooler because they consume then less feed. The amount of vitamin A in eggs depends on the vitamin A value in the ration. In case of deficiency eye symptoms become more acute than in young chicks, also the deficiency results in "nutritional roup" in which there is a sticky or cheesy discharge from the eyes and the nostrils also a grouping of cheesy material between the muscles of the larynx. In adults, eye problems are prevalent along with decreased egg production and hatchability.

2- Vitamin D

Relatively short exposure to direct sunlight may provide enough vit. D for chicks. When poultry do not have ample exposure to direct sunlight, it is essential to include a vit. D supplement in the ration.

The first symptom of vitamin D deficiency in laying hens is the production of thin shell eggs, followed very shortly by decreased egg production. Hatchability is also greatly reduced. The breast bone becomes soft because of withdrawal of Ca & phosphorus. The bones of the legs and wings become fragile and easily broken,

3- Vitamin E

Vitamin E is advisable to be supplemented in all specialized poultry rations. Vitamin E in vegetable tissues is not so readily available as with E in oil concentrates. A prolonged vitamin E deficiency causes lowered hatchability and sterility of males. As with vitamins A & D, vitamin E is extremely susceptible to destruction from the oxidation of fats in the feed. To prevent this, antioxidants are commonly added to poultry feeds. Also, vitamin E is often added to feed in an esterified form to protect it from destruction. Reproduction is impaired in deficient adult birds. Degeneration of the testes is observed in deficient males – a condition that can lead to permanent sterility if not corrected in time. Layers do not show a dramatic drop in egg production, but hatchability is severely reduced. In vitamin E deficient chicks, three classical symptoms are observed, encephalomalaia, exudative diathesis, and nutritional muscular dystrophy. In turkey poults, a myopathy of the gizzard can be observed, enlargement of the hock joint.

4- Vitamin K

All specialized mixtures should be supplemented with K vitamin which passes along egg to young chick. The vitamin should be added to starter rations. Inclusion of 2.5 % high quality dried grass supplies all the vitamin required. Deficiency of the vitamin is not met with in adults as they are able to synthesize sufficient vitamin in their intestine. If laying hens are fed rations deficient in vitamin K, chicks hatched from their eggs may bleed seriously from minor wounds, such as wing banding. Treatment with sulphonamides increases the requirements for the vitamin, as well as parasitic infections such as coccidiosis.

5- Riboflavin

Riboflavin is the most important of the B-complex vitamins in feeding poultry. A deficiency of riboflavin causes poor growth of chicks and a characteristic paralysis of the legs and feet known as "Curled toe paralysis" or "Nutritional paralysis". In laying hens a deficiency of riboflavin results in low hatchability of eggs. More riboflavin is needed for good hatchability than is required for egg production and maintenance of health.

6- Thiamin

Thiamin is required by all poultry, but ample amounts are supplied by ordinary rations and deficiency is unlikely under normal conditions. Amprolium as a coccidiostat acts by interfering with the metabolic function of B_1 on the coccidia.

7-Niacin

Young chicks require more niacin /pound of feed than do older chicks or hens. This is apparently due to some synthesis of niacin by bacterial action in the digestive tract of old birds. Niacin of cereals is bound and unavailable to chicks so it is normal therefore to supply poultry diets with niacin especially if the supply of tryptophan becomes limited.

8- Vitamin B_{12}

Good quality fish meal, fish solubles and other foodstuffs, which are rich in animal protein are usually good sources of vitamin B_{12} and are the standard method of including this vitamin in the ration. If these products do not constitute 5 per cent of the ration, it is advisable to include supplementary vitamin B_{12} in the mixture. In all cases, turkey foods should generally include a vitamin B_{12} supplement. It is always more necessary in diets which are exceptionally rich in protein or fat. Deficiency of B_{12} may cause high mortality in very young chicks.

9- Biotin

Broilers and turkeys may require supplementary biotin in spite of its presence in most food ingredients. Deficiency of biotin causes fatty liver-kidney syndrome (FLKS) in commercial broilers and layers.

10- Others

Folic acid and **choline** may be needed to be supplemented to breeder's diets. All poultry food mixtures need supplementary **pantothenic acid**. It is found in a wide range of poultry food but it is in a bound form. Cereals are poor in pantothenic acid.

Vitamin C is synthesized by poultry; hence, it is not considered as a required dietary nutrient. There is some evidence, nevertheless, of a favorable response to vitamin C by birds under the stress of high temperature.

V- Water

Water makes 52-55% of the adult bird body and as much as 70% of the weight of the newborn chick. In tissues it forms 70-90% where the cell contents are lyophillic jells and the living elements are considered as water inhabitants. Water ranks far above every other substance as regards rate of turnover. It is the most essential nutrient as it has a variety of functions and for the magnitude of its requirement, although it is not so precise.

Properties and Functions

Water is the ideal dispersing medium because of:

1- It has solving and ionizing power which facilitates cell reactions.

2- Its high specific heat which enables it to absorb the heat of these reactions with a minimum rise in temperature (maximal muscular effort produces great heat).

3- Its latent heat of vaporization and the important role in regulating body temperature.

4- It is not an inert substance or only a solvent medium as it has other properties of large significance in physiology which are:

a- The high surface tension which aids in the development of plasma membrane and movements of molecules across it.

b- The tendency to form hydrates, thus acts as a substance for body reactions.

c- Has a high dielectric constant.

5- It actually takes part in reactions as the hydrolysis of proteins, fats, and carbohydrates which takes place in digestion and inside the body by many anabolic or catabolic changes, reactions requiring the chemical addition or release of water.

6- It is a structural element (frog's egg weighing few milligrams placed in sterile, filtered water gives a tadpole of several grams) and is vital as the body can lose practically all of its fat, over half of its protein and yet live, while the loss of one tenth of its water results in death.

7- It plays many special roles; as synovial fluid, it lubricates the joints; as cerebrospinal fluid, it acts as water cushion for the nervous system; in the ear, it transports sounds; and in the eye, it is concerned with sight.

- Nearly all the physical and chemical changes in the body take place in aqueous media.

Metabolic Water

Most of the water which is utilized by the body is ingested as such or as a component of the food. There is a further available source which is provided by the oxidation of hydrogen containing foods during metabolism. Oxidation produces water nearly in proportion to the caloric value of the food or food component from 10-15g of water per 100 Kcal (CP, 10; fat, 12; CHO, 14). So metabolism of glucose yields 60% of its weight water, protein 40%, while fat 107%.

The metabolic water is vital to the developing chick embryo. The standard 57 egg contains 39g water. The chick hatches from the egg would weigh about 40 and contain 32g of water. Yet measurement of the water loss during incubation shows this is equal to 10g, leaving a deficit of 3g to be made good by the production of metabolic water.

Body Temperature Homeostasis

Chickens are warm blooded with a body temperature of 40.6-41.0^{o}C. Comb and wattles play a great role in maintenance of body temperature. Body loses about 40% of heat via head. Atmospheric temperature more than 28^{o}C needs more than radiation but loss is via respiratory system. Birds have no sweat glands.

Heat loss may be sensible heat (measured by calorimeter) when environmental temperature is below 80^{o}F, or latent heat (heat required for evaporation of water in respiratory passage) as 1g water requires 577 calorie at 91^{o}F, with no change in temperature. Above 80^{o}F evaporation of water from respiratory tract is important and lungs and air sacs are the most important evaporative coolers.

Water Requirements and Factors Affecting

1- Poultry require an adequate supply of pure, clean water. If the supply of water is inadequate, birds become dehydrated, feed intake declines and physiological functions become impaired. Water is eliminated from the body by respiration and excretion and in reproductive products such as egg. Panting is a major mechanism for the regulation of body temperature in birds. Since respiration rate rises, and hence, evaporation of water from the respiratory tract increases, the requirement for water increases as the ambient temperature rises above the thermoneutral zone for poultry. Water intake may increase three to four-fold as temperature rises to levels that cause severe heat stress in chickens. If water supply is limited in hot environments, birds readily succumb to heat prostration because of loss of body fluids.

Survival under extremely hot conditions is influenced by the ability to consume large quantities of water or, more precisely, the ability to use water to remove heat from the respiratory surfaces of the body. The ability varies from strain to strain.

As summarized from NRC (1994) broilers consume 250ml in the first week of age increased by 250/week till 2000 ml at the 8th. This is under moderate temperature (20-25^{o}C). The water consumed varies considerably according to diet composition, rate of growth, and type of equipment used. Water consumption increases by about 7% for each 1ºC above 21ºC. Laying chicks started with 200 ml in the first week increased by 75 ml/week till about 1600 ml at 20 weeks of age. Laying hens consume from 150 to 300 liters per 1000 birds daily depending on temperature and other factors. For laying hens the type of watering system used influence water consumption. A dozen eggs contain 1 Ib water. Nonlayers consume between 2.1 and 2.6 g water per g food eaten, while layers may drink 3.6g.

The consumption for large white turkeys is 385 ml/bird/week increasing about 375 ml/week in males to 20 weeks & 275 ml/week in females.

2- Excessive dietary levels of minerals increase water requirements because water is needed to clear the body of the minerals provided in excess of the requirement. There is a direct relationship between salt intake and the amount of water drunk and excreted. This is true for all soluble minerals. Excess K and Mg also increase water intake and excretion.

3- The excretion of sulfates, phosphates, and nitrogenous products of protein metabolism contributes to increased water consumption and excretion in poultry fed excessive levels of dietary protein.

4- Diet high in indigestible OM or containing mucilage, accompanied by increased excretion of water as feces contain 75-85% water.

5- The minimal water expenditures of the body are related to the surface area. So chicks are more sensitive (as also young animals) to salt intoxication than mature animals as they have in total a small amount of water expended and a relatively large body surface.

6- In mammals the principal end product of protein catabolism is urea which is soluble in water and toxic to the tissues in concentrated solution, so much is required to dilute it to harmless concentration. Uric acid, the principal nitrogenous end product in birds, is excreted in a nearly solid form with a minimum loss of water. The breakdown of protein to uric acid provides more metabolic water than does its catabolism to urea. Thus other conditions being equal, birds have a lower water requirement than mammals and are much less sensitive to the temporary deprivation of it.

7- It is usually necessary to clean the water troughs at least two or three times a week. If these are neglected they quickly become slimy and the birds will avoid drinking.

Water Restriction

Water deprivation for 12 hours or more has adverse effects on growth of young poultry and egg production of laying hens, and water deprivation of 36 hours or more results in a marked increase in mortality of young and old poultry. Restriction to only 3 periods/day reduced growth and water content of the droppings increased. Accidental deprivation for few hours (as due to a leaking of water trough) caused disastrous results and ducklings deprived drank excessively when the trough was refilled, this proved fatal to many and others were seen to roll on their backs and paddle the air vigorously. Water restoration, after extended periods (36-40 hours) of water deprivation, may cause a "drunken syndrome or "water intoxication" leading to death in young turkeys.

So supply of fresh water should be available at all times, and in case of water fowl deep enough to immerse beak, nostrils and eyes. Some writers claim better hatchability when water fowl have access to water for swimming; others do not.

Intermittent provision of water is sometimes used to reduce the water content of the droppings and to control feed intake in laying hens. Because birds differ in their ability to conserve body water by increasing kidney resorption, there is a danger of causing dehydration of some birds by practicing water restriction of a flock. Generally birds drink twice as much water as the amount of feed consumed on a weight basis.

Water Quality

Water may carry many of the essential elements as well as toxic materials. Much of the water available for man and animals is contaminated with sediment, harmful amounts of mineral elements, parasites, and disease-producing microorganisms.

Some water supplies contain considerable concentrations of sulfur or sulfates, nitrates, and various trace minerals. They are usually readily absorbed from the intestine and may be either useful or harmful to the bird depending on concentration.

The National Research Council (1994) suggests the following guidelines for the suitability for poultry of water with different concentrations of total dissolved solids (TDS).

TDS (ppm)	Comments
Less than 1000	These waters should present no serious burden to any class of poultry.
1000 – 2999	These waters should be satisfactory for all classes of poultry. They may cause watery droppings (especially at the higher levels) but should not affect health or performance.
3000 – 4999	These are poor waters for poultry, often causing watery droppings, increased mortality, and decreased growth (especially in turkeys).
5000 – 6999	These are not acceptable waters for poultry and almost always cause some type of problem, especially at the upper limits where reduced growth and production or increased mortality probably will occur.
7000 – 10000	These waters are unfit for poultry but may be suitable for other livestock.
Over 10000	Should not be used for any livestock or poultry.

VI- Feed Additives

An additive is an ingredient or combination of ingredients of nonnutritive nature (other than the known nutrients) that is added to a basic feed, usually in small quantities for the purpose of fortifying it with stimulants, or medicines. Additives may be also identified as all products other than those commonly called feed stuffs, so it also includes vitamins, minerals, and amino acids.

They are added in small quantities so that it is not included in the main diet formula. Additives are added as a part of a special separate formula with vitamins (synthetic), minerals (only trace elements), and amino acids (Met & Lys commercially produced).

Additives may be added to affect the utilization of the feed (acceptability, stability, manufacturing and properties), the productive performance of the animal (growth, feed digestion and efficiency) and its health.

Additives have a nutritional effect but do not have a part to play in the metabolic processes. What they do is to make the processes more effective, in some way, either by counteracting some growth depressant, modifying hormonal balances, or improving the appeal or quality of the food mixtures.

In more recent years a trend has developed to restrict usage of additives for a variety of reasons. For example, it has been claimed but not proven that usage of some additives with animals result in the development of resistant strains of microorganisms that might be more pathogenic to humans or might be resistant to antimicrobial agents used in treating diseases in humans.

In some cases there can be a danger to public health. There may, with some additives, be a build-up of a specific mineral or compound, in the edible tissues of the bird, or in the egg. To guard against this possibility, a number of countries have regulations limiting or prohibiting the inclusion of additives in animal feeds.

More than 1000 drug products are approved by the FDA. Some of the drugs used can leave potentially harmful residues. For this reason, more than half of the products approved require drug withdrawal times, in order to protect consumers.

When additives are used the intensity of production increases, and the needs for production also increases. Thus the nutritive needs of the animal should be considered.

Methods of use

Additives are included in a food mixture in very small quantities and, in view of this, special consideration must be given to the manner in which they are mixed, in order to ensure that the additive is evenly distributed throughout the mixture.

The most satisfactory method of mixing is to incorporate the additives in a "pre-mix" or "carrier" before they are added to the main bulk of the ingredients in the mixers. The pre-mix might "bulk up" the additive in this way so that it may be added at the rate of, say, 3kg per tonne of ration.

If a withdrawal period is required the producer must have separate holding facilities for unmedicated and medicated feeds, or feed mixing facilities must be thoroughly cleaned after mixing medicated feed. The producer should also consider if the additive can be used in combination with other additives. Financial benefit, methods of mixing and storing, stability of the active ingredient, and comparison between competing brands should be put in mind.

The veterinarian responsible for the disease-prevention programme of the stock also requires to know the type and levels of additives used.

The possible effect of one additive upon others must always be considered. In some cases additives may be antagonistic whereas, in others, may be complementary. The combined value of two additives used at the same time may on occasion be greater than the sum of their individual values, and this phenomenon is known as a synergistic effect.

As they are added in small quantities they require very careful weighing, handling and mixing. Additives of special interest in the formulation of poultry foods include amino acids, antioxidants, antibiotics, drugs to prevent or control diseases, pigments, trace minerals and vitamins.

Inclusions must be detailed on a label along with the food container, or a delivery ticket in case of food delivered in bulk, and the manufacturer should give details of any preslaughter time during which the drug must be withdrawn from the diet. Preslaughter time is usually a period of 3-5 days.

I-Additives that Influence Feed Stability, Feed Manufacturing, Feed Intake and Selection, and Color and Quality of Animal Products

A- Additives that Influence Feed Stability

1- Antifungals

They are agents that destroy fungi and used to prevent fungal growth in stored feed ingredients and mixed feeds.

Feeds provide an excellent environment for the growth of fungi such as Asperigillus flavus, Fusarium, and Candida or Monilia albicans which are detrimental to health of poultry. Asperigillus flavus produces a potent toxin; aflatoxin. Candida albicans is the causative agent of "thrusth or moniliasis" or sour crop which is a fungal disease affecting the digestive tract of the bird especially the crop and sometimes mouth, throat, and oesophagus. The disease can be prevented through feeding balanced diets and use of antifungal materials to fooders and waterers (as mycostatin or copper sulfate). Aspergillosis or brooder pneumonia is a disease caused by asperigillus causing chicks to be unthrifty, emaciated and having pulmonary trouble resulting in rapid fatal pneumonia.

Moulding causes heating of feeds which results in destruction of vitamins and impairment of the availabilities of other nutrients. Some species of mold are definitely poisonous, others are harmless or beneficial, but it is safest to prevent the development of mold in feed for poultry.

Fungi can affect feed intake and subsequent production through contamination at one or more of four stages in the feeding chain: 1) in the field (preharvest), 2) during storage, 3) at mixing, and 4) in the bird itself. Fungal contamination can pose problems through production of toxins, alterations of the chemical composition of the feed, or alterations of the metabolic functioning of the bird.

There are four species of toxic molds known all over the world producing about 400 types of toxins (in addition to some other molds less toxic). About 1/3 of the toxins affect the animal health and production. The most common toxins in feeds are aflatoxins, zearalenone, fusarial toxins, ochratoxins, diacetoxyscripenal (DAS), deoxynivalenol (DON). Feeds may be affected by mycotoxins without the appearance of any physical signs pointing to mold growth as caking or musty odor.

Mould growth is prevented by adequate drying (moisture 12% or less), storage under dry conditions, and the use of mold inhibitors (antifungals). The use of mold inhibitors is strongly recommended when:

a-the moisture content of the grain exceeds 13-14% and are exposed to air during storage.

b-the relative humidity is above 80 to 85%.

c-the temperature is 55^{o}F or above.

d-the grain is damaged, broken, or insect infested.

Mold inhibitors should be added to high-moisture feeds that are exposed to air during storage. Propionic acid, acetic acid, and sodium propionate are used in high moisture feeds to inhibit mold growth. Many feed manufacturers add such antifungals as nystatin and copper sulfate to concentrate feeds to prevent further growth by molds.

Mycotoxins affect all the species, especially the youngs. Generally rummaints appear to tolerate higher levels of mycotoxins and longer periods of intake than simple stomached animals. Growing chickens are markedly susceptible to aflatoxins than ducklings, goslings, pheasants, or turkey poults. Fish are properly one of the most susceptible species of animals to aflatoxin poisoning.

Feeding poultry on diets containing mycotoxins causes great losses and high mortalities. Growth is retarded and there is decreased meat and egg production, and immunity is lowered resulting in bacterial and viral infections.

Care should be taken as feeds are imported and stored for a long period under high environmental temperature and relative humidity.

Residues of toxins in meat and eggs affect the human health. It has been shown that the toxins are carcinogenic.

Antifungal products

a- Antifungals preventing mold growth: the most common are the acids propionic, acetic, sorbic, formic, and lactic. Propionic acid or its salts, sodium or calcium propionate are particularly effective at a level of 1% of the grain or diet and it provides a protection for at least 90 days. They are used also to control the infestation by weevils, mites and molds. As a preservative it is used at the rate of 250-500 g per tonne of grain. A carrier is added to the organic acids, as Mg silicate, Al silicate or Fe silicate or any other compound having the power to liberate the carboxyl group which has the power of killing molds. They also adsorb the toxins. Examples of effective antifungals are also Na diacetate, gentian violet and Cu sulfate.

Ammonia treatment of grain inhibits mold growth in addition to the inactivation of the aflatoxin. Sodium metabisulfide and sulfur dioxide are useful preservatives for moist grains in small bins when the moisture content is less than 30% and the ambient temperatures are cool. Sulfurous acid is formed when sulfur dioxide contacts water and inhibits the growth of bacteria, yeasts, and molds, but there are some major problems in its use (poisonous, acidic, corrosive, palatability may be reduced, and thiamin in grains inactivated). Palatability reduction of the treated grains can be alleviated by the addition of sodium bicarbonate. Thiobendazol candles give rise to thiobendazol vapor having the power to reach molds in wall cracks. It is used in a closed space.

Mold inhibitors are routinely added to poultry diets to control the growth of molds and its secretion for toxins.

b- Antimycotoxins: some chemicals and mineral elements have the power of adsorbing toxins preventing its absorption. These chemicals have a large surface and small positive charge attracting the mycotoxins having the negative charges. Of the mineral elements used are Na, Ca and Al silicates. The toxicity of aflatoxin – contaminated feeds can be reduced when irradiated by U.V. light or exposed to anhydrous ammonia under pressure.

In the market there are also antimycotoxins which decompose the toxins by special enzymes. These antitoxins have a limited effect; they decompose some of the toxins but not all.

c- Antifungals working against the toxic effects: by increasing the vitamin levels in diets especially A, D, E and K, and also the level of lipids.

Active components

The active components of most of the antifungals on the market are:

• Organic acids and its salts:

Propionic, formic, sorbic, maleic, tartaric, lactic, citric, aminobenzoic, acetic & benzoic and its salts as ammonium, aluminum, calcium and sodium inhibit and kill microbes and molds in the intestinal tracts and the salts elongate the length of action. The organic acids are also good enteric disinfectants and inhibit and overcome pathogenic bacteria in intestine. Organic acids are also appetizing and increase digestibility.

• Silica and its salts

Silicone gel and silicates as Na, Ca, Mg and Al silicates – silicon dioxide all are inorganic adsorbents. They adsorb and bind mold toxins, especially by the electrostatic power of the silicates. Also the silicates absorb moisture and prevent caking. In one of the commercial products Al silicate is used as a carrier and reaches 60% of the components. The disadvantage of inorganic adsorbents is that they also adsorb nutrients as trace elements and drugs as ionophores and antibiotics, while in some products binding is affected through "Biomediation".

• Mono-, di-, tri-, and tetra carboxylic complexing agents

They are chelating agents inhibiting the action of toxins and chelate toxins transforming it to untoxic indigestible complexes.

• Na and Mg sulfates – Am Cl

Sulfates draw water from tissues, increase the secretion of bile and stimulate intestine to get rid of worms if any, while Am Cl is a diuretic.

• Vitamins and minerals – and AAs

Minerals and vitamins are added to improve immunity. Vitamin C aids in decreasing the body temperature in case of high environmental one and activates immunity, conception, reproduction and production. Vitamin C also can inhibit the effect of toxins and increase bird resistance to toxic effects. B2 is a diuretic and generally vitamins increase the appetite and by turn stimulate conception, reproduction and production. Essential AAs are tonics.

- **Sorbitol**

  Aids in bile formation, stimulates liver, and act as antitoxin.
  Reducing vitamins and organic acids
  Act as antioxidants

- **Yeasts, folic acid and enzymes**

  They are appetizers and aid in digestion.

- **Propenyl glycol**

  Aids the antifungal compounds in identifying the toxins and microbes and also can adsorb toxins and destroy microbes into the blood circulation.

- **Glycerin**

  Makes a good medium for the antifungal to act on toxins or molds

2- Antioxidants

All feeds are susceptible to spoilage, but those which are high in fat content are especially prone to autoxidation and subsequent rancidity. Rancidity takes place in two stages; an initial period when the changes occur very slowly, this is followed by a period when it develops rapidly. If an antioxidant is added when the fat is first produced the period of slow development can be prolonged but the final sharp rise is not affected. When the antioxidant is not added until the fat is ready for incorporation in the food some protection is afforded but this may be quite small.

In other words if the amount of antioxidant added is sufficient to double the keeping time of the fat when added at the time of production then, if it is added later, it will only double the length of the period of slow development of rancidity which has not elapsed. It follows from this that to obtain the maximal benefit they should be added during manufacture of the fat and, at the latest, before the fat is incorporated in the food.

Their importance can be illustrated by a simple calculation. If 5% is added this is equal to 50 kg/ton; 50 kg of fat occupies about 0.057 m3 and in a container would have about 0.093 m2 of surface exposed to the air. The incorporation of the fat in the mash would be equivalent to spreading out the fat in a layer at the most 0.25 mm, or more probably, 0.025 mm thick, thus increasing the surface exposed to the air by between 2400 and 24000 times. The more unsaturated the fat the more liable it is to develop rancidity and the more difficult it is to stabilize by the addition of antioxidants.

During the period of slow development of rancidity the free fatty acid content of the fat rises and this has sometimes been used as a measure of the freshness of the fat. However, unless the original FFA content of the fat is known it is unreliable and birds can utilize FFAs as efficiently as fats.

Unsaturated FAs may react with oxygen to produce undesirable products with offensive odors and toxic properties and destruction of nutrients, such as the fat-soluble vitamins, and several of the B complex ones. Also the breakdown products of rancidity may react with epsilon amino groups of lysine and thereby decrease the protein and energy values of the diet.

Antioxidants and its effect

Most animals will refuse to eat spoiled feed. But when feed is limited, they may consume it, with digestible disturbances resulting in many cases. It has been demonstrated that cows consuming oxidized oils produce milk with an off-flavor.

Antioxidants are preservatives that prevent the auto-oxidation of fat (rancidity) and which may be added to the food mixture itself, or the pre – mixes. They prevent the deterioration of stored feeds.

The ideal antioxidant would be harmless and should not form harmful by- products in the food; should be easily dispersed in the fat and the food; should be tasteless, odourless and colourless even after heating or long storage and should give a high degree of stability to the fat.

All vitamin/trace mineral mixtures, protein/trace mineral/vitamin mixtures, and fats, should contain an antioxidant as BHT, normally at a level of 0.02%. It increases the stability and storage life of certain nutrients which are prone to loss of value due to oxidation.

Besides protecting against peroxidation in feeds, synthetic antioxidants also prevent these reactions in animal tissues, thus having a sparing effect on vitamin E and Se requirements. On the contrary another source mentioned that vit.E can serve as an antioxidant both in the feed and in the cell of animal ingesting the feed. Such antioxidants as BHT (butylated hydroxytoluene) and EQ (6 – ethoxy – 1,2 – dihydro 2,2,4 trimethylquinoline) are unable to prevent peroxidation within the cell; consequently, they cannot reduce the dietary requirements for vit.E.

Studies show a marked effect of EQ in preserving the ME, digestible protein values, and the vit. content of fish meals, and in preventing deleterious effects of the polyunsaturated FAs on vits. in feeds.

In addition to preventing rancidity, synthetic antioxidants help to overcome toxic effects of peroxides. Cobel et al. (1988) fed levels of 50,100 and 175 meq/kg of diet of peroxide to broilers, with and without 62.5 and 125 ppm of ethoxyquine. Supplementary EQ prevented the deleterious effects of peroxides on growth performance.

In the diet of fattening poultry prior to slaughter, antioxidants have been used to improve the stability of the carcass fat and reducing its tendency to go rancid. The use of vit. E together with BHT and EQ has given encouraging results.

Antioxidant compounds

Examples of natural antioxidants are vit. E and vit. C. Synthetic antioxidants include ethoxyquin (santoquin – EQ), butylated hydroxytoluene (BHT), and butylated hydroxyanisole (BHA).

BHT and EQ have been shown to be effective in protecting fat compounds in food mixtures stored for a period of up to 27 weeks at temperature from 18-26°C. EQ at 0.125% of the feed mixture may be used to improve the stability of xanthophylls (which might lose their pigmenting value), and thus improve yolk pigmentation (even after storage for 3 weeks at 47°C).

It was reported in 1954 that no health hazard should arise if 0.01% propyl, octyl or dodecyl gallate or 0.02% BHA were added to edible oils or fats.

The final food mixture may, without naming them, contain a number of different antioxidants. They are routinely added to many livestock feeds to curb their oxidation.

B- Additives that Influence Feed Manufacturing

Pellet binders

In feeding birds of different ages – it is a common practice to use pellet sizes ranging from about 1/8 in. to 3/8 in. The length of the pellets must also be considered, so that pellets are not too long for the bird consuming it. Crumbling allows the feed manufacturer to employ a larger die size thus increasing pellet mill volume and thereby reducing cost even though an added process is involved. Each pellet is a complete diet.

Pelleting advantages are:

a- increases the density of feed,

b- increases the feed intake,

c- improves growth and feed efficiency,

d- reduces feed wastage,

e- eliminates sorting of ingredients by the animals,

f- reduces dust,

g- increases ease of feed handling,

h- they give firmer, stronger pellets with a reduced tendency to crumble,

i- has less feed storage and feeder space are required,

j- improves the palatability for a number of feedstuffs and salmonella organism may be destroyed by heat, and

k- it is readily adaptable to automatic equipment.

The major disadvantages are:

a- added cost (10% or more),

b- it may hide a multitude of sins in terms of the quality of the ingredients,

c- presence of fines (small feed particles),

d- tendency of pellets to crumble and break apart and clog the feeders, if it is soft,

e- poor quality pellets may lead to waste of feed,

f- nutrients may be destroyed by heat,

g- incidence of cannibalism may be increased,

h- camouflaging of feed ingredients may occur, and

i- water and feed consumption are increased without an increase in egg production.

Binders

Pellet binders are products that enhance the firmness of pellets. Several binders are used, among them:

a- Sodium bentonite (clay):

Although bentonites have no nutritive value, several reports indicate that at the level of common usage (2 – 2.5% of the ration) they may even improve the growth and/or feed utilization of animals. They are probably the most widely used binders. They are clay minerals (montmorillonite or hydrated aluminum silicate) with ion-exchange and surface – active properties.

Bentonites are usually added at 1-3% of the diet and most effective in the presence of steam. It is nutritionally inert. Because of its ion – exchange properties, it may influence metabolism of N in ruminants by complexing with ammonium ion. It absorbs ammonia from solution when the ammonia concentration is high and releases it when the ammonia concentration is reduced, which may improve the utilization of urea by ruminants. Bentonite also absorbs mycotoxins and facilitates their excretion.

Sodium bentonite has been found to absorb the drug amprolium to a degree which affects chemical analysis. However, this may not necessarily reduce the biological efficiency of the coccidiostat.

b- Wood pulp industry:

Liquid or solid byproducts of the wood industry are consisting mainly of hemicelluloses, or combinations of hemicelluloses and lignin. Hemicellulose preparations at levels up to 2.5% may serve as good energy sources, but lignin has practically no nutritive value.

Hemicellulose extracts and lignin sulfonate, byproducts of the wood-processing industry, are used as pellet binders. Hemicellulose extracts of wood may have "unidentified growth factor" activity attributed to the biological activity of phenolic compounds.

Sodium bentonite and lignosulphonate are used as die lubricants in pelleting.

c- Molasses:

Molasses used at the rate of 2.5% of the mixture is effective as pellet binder. Molasses or fat are sometimes added as an aid in pelleting, as well as concentrated source of energy.

Products are available which combine the binding and sweetening properties of condensed molasses soluble together with a hardening agent.

C- Additives that Influence Feed Intake and Selection

Feed flavors

A number of commercial feed flavors are available. Feed flavors are used to increase the acceptance of diets of low palatability, increase the intake of palatable diets, and increase the intake of diets during periods of stress such as weaning. Virtually all animals except carnivores have a "sweet tooth" and prefer diets with added sweeteners. However, addition of a sweetener to the diet does not usually alter feed intake or animal preference. In pigs it was suggested that passage of the flavor through the milk will imprint youngs with a preference for that particular flavor.

The addition of flavoring agents or spices to poultry food mixtures has not yet been shown to be necessary. Such products do not contribute to the value of the food in any way. Chickens possess a sense of taste but this differs from that of man. Efforts to find flavoring agents that will increase food consumption have been made, but so far have proved unsuccessful.

In general, it appears that feed flavors do not improve performance of animals. Stimulating an animal to consume more of a diet than normal, even if possible, would probably not be advantageous. Feed intake is regulated according to metabolic need; excessive feed intake exceeds protein synthesis capabilities, so the extra nutrients are deposited as fat. Thus the most probable useful role of feed flavors would be to stimulate adequate or normal intake of unpalatable but otherwise nutritious diets.

In poultry molasses is useful in improving the palatability of rations and also helps to reduce dustiness. The main problem in the use of molasses is that of handling it.

D- Additives that Influence Colour of Products

Xanthophylls

They are red and yellow carotenoid pigments that are important in poultry nutrition because they are deposited in egg yolk and body fat, producing the yellow pigmentation of eggs and the skin and shanks of broilers.

Consumer can be rather vain in their conception of what a quality product should look like. This is especially true, in the marketing of poultry products. Many marketing concerns have brain washed consumers into believing that broilers having a deep yellow color are of top quality. Consequently the poultryman will often get a premium price for its cosmetically esthetic product.

A similar situation exists relative to eggs in which deep yellow yolks are considered to be highly desirable. The demand from the shell – egg market in respect of yolk colour varies. However, from the liquid – and dried egg market the demand is for deeply coloured egg yolks which in turn will impart the right degree of color to the cakes and other products made by caterers.

A rapid oxidation loss of xanthophylls from ingredients takes place, particularly during hot weather, but the presence in the mixture of a suitable antioxidant can be of considerable help in slowing down the rate of loss. The analysis of food ingredients to determine their total xanthophylls content includes both the pigmenting and the non-pigmenting xanthophylls, and the content of the latter may range from 15 to 25%.

Sources:

Sources include green plants as alfalfa, yellow corn, and a variety of yellow or red plant materials. The richest source is marigold petal meal, which is produced commercially for poultry feeding. It contains 6000 to 10000 mg xanthophyll/kg ; alfalfa (dehydrated) 200 mg, corn 20 mg/kg.

The major xanthophylls in alfalfa is lutein, which is yellow, while in corn & corn gluten meal the major pigment is zeaxanthin, which imparts an orange – red colour.

Fresh and dried green food are the main sources of xanthophylls and in addition, carry quantities of the carotenoid precursors of vit. A. In view of this it is often considered that dark – yolked eggs are also rich in vit. A, and pale – yolked are low, but this may not be the case. Vitamin A itself is almost colourless.

Content of active pigmenting xanthophylls (i.e. pigmenting for egg yolks) (total amount of xanthophylls has been reduced by 20%)

	mg/kg
Grass meals	750
Maize – yellow (US)	12-15
Maize – plate (Argentine)	25-28
Maize gluten meal, 60%	150

A number of synthetic carotenoids (e.g., canthaxanthin) have been developed and marketed for poultry. The use of even 1-3% alfalfa meal is considered undesirable by the industry because it reduces feed convertion efficiency (high – energy diets). Synthetic xanthophylls are increasingly used in poultry diets. Xanthophyll pigments are also important in fish nutrition.

Also arsanilic acid, sodium arsanilate, and roxarsone are drugs that can be used to promote pigmentation in poultry.

Benefits:

Xanthophylls have no known nutritional value other than pigmentation, although some suggested that they may stimulate the immune system.

The use of xanthophylls will be most likely when mixtures low in maize or green food (grass or Lucerne) have to be used. Colouring in naturally yellow – skinned birds is dependent upon the level of deposit in the fat, skin, shank and beak of pigments known as xanthophylls. The majority of strains of broiler chickens are yellow – skinned. When the preference is for white – skinned birds yellow maize and its byproducts and fresh or dried green foods are not included in their diet during the last four weeks prior to slaughter. In order to enhance the yellow pigmentation, xanthophylls are routinely incorporated into broiler feeds.

Level of addition

Specially prepared sources of pigments are available for inclusion in the diet. When they are included to supplement the naturally occurring xanthophylls, to provide a level of 10-15 mg/kg of pigmenting xanthophylls in the total diet of layers, the yolk color will normally be acceptable. In broilers level needed may reach 22 mg/kg but only needed for the last weeks prior to the birds being marketed.

E- Additives that influence the quality of animal products

Chlortetracycline and oxytetracycline are incorporated in mink diets to promote pelt size, while oxytetracycline is said to improve the texture and quality of eggshells.

Saponins: Steroid saponins in yucca desert plant have been given the trade name sarsaponin and are sold commercially as agents to improve animal performance. Saponins also complex with cholesterol and have been shown to have blood – cholesterol – lowering properties. They showed no effect in lowering the cholesterol content of meat and eggs. Some found that it reduces the transfer of dietary cholesterol to egg yolk but fails to lower egg cholesterol content. Apparently, synthesis of cholesterol within the bird obviates any dietary effect.

II- Additives that Modify Animal Growth and Feed Efficiency

A- Growth promotants

1- Antibiotics

Antibiotics are natural metabolites of fungi that inhibit the growth of bacteria. They may be used for improving rate of growth and food efficiency as well as for the prevention and treatment of disease. This definition may give a clue to the reasons why the use of antibiotics in poultry food mixtures may sometimes lead to better results. Some antibiotics appear to be selective in their action in that they affect specific organisms without apparently influencing others. In such cases, they might destroy harmful pathogenic bacteria without harming useful bacteria involved in the processes of digestion. This may help the bird to make better use of its food.

There is some evidence to suggest that the effect of antibiotics may be due to the presence in established poultry units of a low level of infection by certain disease micro-organisms which the antibiotics overcome. This same effect is usually conspicuously absent if antibiotic-enriched diets are fed to birds in a new poultry house in which no such low-level infection could have built up.

Antibiotics are usually classified as either narrow spectrum antibiotics, which include procaine benzyl penicillin, and those with a broad spectrum of activity, including the tetracyclines, (aureomycin and terramycin), bacitracin, oleandomycin and virginiamycin. The names "broad" – and "narrow" – spectrum antibiotics distinguish between those that are effective against a wide range of bacteria and those which operate against only a few species.

Favorable effects on animal performance were noted, with improvement of growth and feed efficiency and a reduction in health problems such as postweaning diarrhea.

Subtherapeutic levels of antibiotics increase an animals ability to withstand stress and in control of postweaning diarrhea. The response is usually less when animals are housed in a new building; as microbial loads in the environment build up, the response to antibiotics increases. Broad spectrum antibiotics, active against both gram - positive and gram – negative organisms, such as chlortetracycline, are usually more effective than narrower spectrum agents such as penicillin and bacitracin.

These findings led to the adoption of the practice of feeding subtherapeutic levels of antibiotics to animals, particularly swine and poultry, as growth promotants. Subtherapeutic doses are lower than therapeutic levels used for treatment of disease, prophylactic doses are used for disease prevention. Thus antibiotics used as growth promotants are fed at lower levels than when they are used for the treatment or prevention of disease.

High prophylactic levels of inclusion would be at the rate of 50 to 100 g per tonne for 7 to 10 days, followed by 25 to 30 g per tonne for a further 10 days, or until the antibiotic is no longer required.

High-level antibiotics should be used only on the advice of the veterinary surgeon but inclusion in the ration is a convenient way of ensuring that all birds in a flock are treated evenly.

The mechanism of action of antibiotics in their growth – promotion effects is not conclusively known but definitely appears to be due to actions on the gut microflora. Some of the most plausible theories identified are as follows:

1) Microbes responsible for mild but unrecognized infections are suppressed.

2) Microbial production of growth-depressing toxins is reduced.

3) Antibiotics reduce microbial destruction of essential nutrients in the gut or, conversely, improve the synthesis of vitamins or other growth factors.

4) There is enhanced efficiency of nutrient absorption because the intestinal wall is thinner.

Improved nutrient absorption from the thinner intestinal wall reduces the maintenance energy and protein requirements. The intestinal mucosa is the most rapidly regenerating tissue in the body. Enterocytes have a very rapid turnover, and this turnover rate is increased by exposure to bacterial toxins and metabolites, thus substantially increasing endogenous losses of protein and energy. Antibiotics reduce the turnover rate of intestinal mucosal cells. Antibiotics reduce formation of ammonia and amines in the gut; these compounds are irritants that increase the turnover rate of epithelial tissues. Another possibility in explaining the mode of action of antibiotics is that they may reduce the intensity of the immune response.

Although antibiotics have been used as feed additives since 1950, their effectiveness has not diminished with time. The magnitude of the growth response is about the same now as when their use first began. This suggests that the development of microbial resistance to antibiotics, which is well documented, does not alter their growth – promoting activity.

Some of the most commonly used growth-promoting antibiotics are bacitracin, bambermycins, chlortetracycline, erythromycin, lincomycin, neomycin, oxytetracycline, oleandomycin, penicillin, streptomycin, tylosin, flavomycin, and virginiamycin.

Both narrow – and broad – spectrum antibiotics appear to be equally satisfactory for young birds, but those of broad – spectrum are generally used for adults. Antibiotics may be included in either the food or the drinking water, but their use at the "nutritional" level is generally confined to inclusion in the food mixture.

Continued use of antibiotics as growth promotants is of economic benefit to consumers and to antibiotic manufacturers.

Claims made for the use of antibiotics in poultry food mixtures include the maintenance of food intake under conditions of stress which, in turn, helps to reduce the loss from culls. More obviously, growth rate is thought to be improved by 5 to 7%. The use of antibiotics to overcome subclinical disease should only be resorted to when management and all other relevant details have been carefully checked; antibiotics are no cure for bad management.

There is some evidence that tetracyclines may be more effective in food mixtures that are low in Ca compared with the standard recommendation. The antibiotic is said to be potentiated by the use of low – Ca diets. It must be stressed that any departure from the recommended requirements should only be made following veterinary advice. It is not desirable to lower the Ca levels, or the levels of any other nutrients, below those recommended for a period of more than one to two days, otherwise less satisfactory results may occur.

One method of using antibiotics which attempts to minimize the problem has been to remove all the food from the birds and then to provide a low – Ca diet, together with the antibiotics, for a period during which the birds can consume up to 20% of their normal intake of food for the day. Once the potentiated food has been consumed then normal feeding is resumed.

Antibiotics feed additive use and human health

The extensive use of subtherapeutic levels of antibiotics as feed additives has sparked controversy as to possible adverse effects of this practice on human health. The major concern is that widespread use of antibiotics may lead to the development of antibiotic – resistant strains of bacteria, which could make treatment of human diseases more difficult. The worse – case scenario is that bacteria resistant to all antibiotics could develop and create life – threatening infections in humans. It was believed that there is indirect evidence implicating subtherapeutic use of antimicrobials in producing resistance in infectious bacteria that causes a potential human health hazard.

One of the ways in which antibiotic resistance could be transferred from microbes in livestock to bacteria infecting humans is via contamination of carcasses in animal and poultry processing plant with E. coli, salmonella, and other enteric bacteria. Improvements in processing techniques could reduce or eliminate this potential hazard.

2- Chemotherapeutic agents

A variety of compounds that have growth – promoting activity are not antibiotics. They include the following:

• **Nitrofurans :** are synthetic compounds with antimicrobial activity. Chemically they are based on a nitrofuran ring (a five – membered ring with an NO_2 – group attached). Furazolidone is an example of a commonly used nitrofuran. Nitrofurans inhibit bacterial reproduction. Their primary use as feed additives is in controlling enteric diseases. Furazolidone has growth – promoting activity in poultry and swine.

• **Sulfonamides:** are derivatives of sulfanilic acid (a benzene ring with – NH_2 and – SO_3H groups attached). They have broad – spectrum bacteriostatic effects (bacteriostats inhibit bacterial reproduction). They are also effective against protozoa that cause coccidiosis, and some viruses. Sulfaquinoxaline has been extensively used in poultry as a coccidiostat. Sulfanomides are competitive inhibitors of vitamin K and may induce a deficiency of the vitamin if low – vitamin – K diets are used.

• **Carbadox:** is a synthetic antibacterial compound that is similar in action to antibiotics. It is extensively used in swine diets for its growth – promotant effects.

• **Copper sulfate:** has been extensively studied as a feed additive. The dietary requirement for copper for normal health and production is approximately 10 to 20 ppm in most species. At much higher levels (125-250 ppm), copper sulfate is a growth promoter for swine and poultry and is now used extensively for this purpose. This particularly true in Great Britain, where use of antibiotics as feed additives has been curtailed. Copper sulfate is an effective substitute for antibiotic, and probably has a similar mode of action. Copper sulfate produces a 5 to 10 percent improvement in growth and a 4 to 8 percent improvement in feed conversion. There is often a favorable effect in reduction of enteric disease.

Although copper is an effective growth promotant, there are several concerns regarding its use. Copper accumulates in the liver when feed additive levels of the element are fed. There is concern as to whether these high copper levels in the liver represent a potential human health hazard. However, the livers of pigs fed 250 ppm copper are of similar copper content as normal beef liver (200-600 ppm), so the hazard is likely slight. Since copper is primarily effective during the immediate postweaning period, it is probably desirable not to use it in finisher diets, which would ensure normal liver copper levels at slaughter. The other major concern with use of copper as a feed additive is the possible environmental effects. Swine and poultry manure are often used to fertilize crop or pastureland, and there is the possibility that crops and pastures could take up excessive levels of copper. Sheep are particularly sensitive to copper toxicity. In addition, broiler litter or dried poultry waste (DPW) is often used as a feed stuff for ruminants; manure from birds fed copper sulfate may cause copper toxicity in ruminants.

Two outbreaks of copper toxicosis in cows fed chicken litter were described. One involved a dairy herd fed chicken litter containing 620 ppm copper, with a copper concentration in the complete diet of approximately 300 ppm. Two cows died of copper-induced hemolytic crisis. In the other incident, 15 steers fed a diet containing high copper (700-800 ppm) broiler litter died with hemolytic crisis. It is apparent that high-copper poultry litter is a hazardous feed.

3- Saponins

They are used as agents to improve animal performance. Some found an improvement in gains of steers fed urea-containing diets supplemented with sarsaponin saponin and suggested a role of sarsaponins in ammonia metabolism in the rumen. These authors also noted a slight improvement of feed efficiency in finishing pigs fed sarsaponin. Others investigated the effect of 120 ppm dietary sarsaponin on nitrogen metabolism in rats, and they concluded that it has little effect, if any. Nitrogen digestibility, nitrogen balance, growth, and feed efficiency were unaffected by dietary sarsaponin.

B- Digestion modifiers

1. **Enzymes,** animals produce adequate quantities of digestive enzymes for digestion of the proteins, carbohydrates, and lipids that they are capable of digesting. The main potential of enzyme addition to feed appears to be for digestion of substances that the animal is intrinsically incapable of digesting. For nonruminants, addition of **cellulase** to feeds would provide a means of digesting cellulose. There are commercial sources of cellulolytic enzymes available, but responses have not been encouraging.
2. Enzymes occur naturally in feedstuffs and special supplementation of the food mixture is not usually necessary. However, a wide range of enzymes exists and each one has a particular part to play, so it is not surprising that mixtures of enzymes have been included in poultry diets in an attempt to ensure complete digestion of the ration.
3. The primary use of enzymes as feed additives has been the provision of sources of **β-glucanase** to swine and poultry to increase the digestion of β-glucan. Glucans are an important source of carbohydrate in barley and oats. β-glucans are composed of glucose molecules linked together by chemical bonds that are different from those found in starch. Animals cannot digest β-glucans. The glucans are viscous, hydroscopic, gummy materials. The viscosity reduces intestinal flow rate and thus feed intake. The viscous glucans also inhibit the formation of lipid micelles and reduce fat absorption. In poultry, the hydroscopic nature of glucans makes the excreta wet and sticky, causing management problems. The manure in poultry houses is normally quite dry and can build up beneath the cages in well-shaped cones, or build up in a deep-litter floor pen system. When barley is fed, the droppings may become "soupy", increasing environmental humidity and ammonia and causing problems in manure removal. With young chicks, the glucans in barley may cause a pasty vent condition, in which the sticky excreta dries on the vent, blocking the gut. This material must be removed or the affected bird will die. This problem makes it impractical to use barley in diets for young chicks. The effect of β-glucans can be largely overcome by incorporating a source of β-glucanase in the feed. Various bacterial and fungal enzyme sources are useful for this purpose. Soaking barley in water activates β-glucanases in the seed, reducing the glucan content.
4. Sources of glucanase, isolated from fermentation products, are available commercially. The addition of the enzyme to barley – containing poultry diets results in significant improvement in growth rate and feed conversion and reduces or eliminates sticky droppings.
5. Water – soluble pentosans are the major antinutritive factor in rye. Enzyme treatment with fungal enzymes reduces the viscosity of rye in the gut and improves its utilization by poultry. The endosperm cell walls of wheat and rye contain pentosans. Feeding a source of **pentosanase** to broiler chickens improved growth and reduced the severity of wet litter and sticky droppings.
6. The supplements used contain a very large number of enzymes and the one specifically responsible for the improvement in results has not been identified. Response to enzyme supplementation is by no means uniform and is possibly determined by the climatic conditions at the time of harvest of the cereals used. It has been suggested that harvesting during wet climatic conditions may activate the naturally occurring enzymes in the barley and, therefore, the addition of enzyme supplements becomes unnecessary.
7. Also **phytase** enzyme is used to liberate phosphorus from phytates present in vegetable feeds. It was found that addition of 1 kg of phytase enzyme to feed can provide phosphorus as that found

in 6 to 7 kg of calcium phosphate. Commercial products are available in 5 or 25 kg bags, valid for 1 year, and added at the rate of 600 – 1000 g/tonne according to the activity of the product.

8. **Ion-exchange compounds**, the principal ion-exchange compounds used in feeding are **zeolites**, which are clay minerals consisting of hydrated alumino- silicates of various cations. They can gain and lose water reversibly and exchange their constituent cations. Besides natural zeolites, there are also synthetic zeolites. One of the major natural zeolites used in feeds is **clinoptilolite**. The last is recognized as having the ability to exchange ammonium ions. This property is used to remove ammonia from poultry houses. Some aluminosilicates are effective absorbants of aflatoxin, and they have been used in poultry to alleviate the effects of toxic levels of dietary aflatoxin.
9. **Ionophores**, they are a class of antibiotics that are extensively used as feed additives for cattle. Their name is derived from their mode of action in interacting with metal ions and serving as a carrier by which these ions can be transported across membranes. The main ionophores used are produced by various strains of streptomyces fungi and include monensin, lasalocid, salinomycin, lysocellin, and narasin. These compounds are also used as **coccidiostats** in poultry. Monensin is called monensin when used in poultry feeding and rumensin when used as a cattle-feed additive.
10. **Acidifiers** (organic acids), a significant increase in growth rate of broiler chicks was observed with dietary levels of 0.5 and 1.0 percent **fumaric acid**. Some suggested that part of the beneficial results of citric and fumaric acids in pigs in the starter period may be attributed to their effects on energy metabolism, since both **citric** and fumaric acids are intermediates in the tricarboxylic acid cycle of cellular energy metabolism. Propionic acid or its salts are used to control the infestation by weevils, mites and moulds of food ingredients during storage particularly grains of high moisture content. The preservative is used at the rate of 250 to 500 g per tonne of grain.

III- Additives that Modify Animal Health

Drugs

A variety of drugs may be added to the feed for the treatment and/or prevention of disease or internal parasites. Some of the drugs used in feeds include worming agents (e.g. phenothiazine, piperizine) and coccidiostats (e.g. monensin, amproluim, sulfaquinoxalene). A discussion of these in detail is inappropriate here. From time to time, new vermifuges, or wormers, are approved and old ones are banned or dropped.

IV- Mineral and Vitamin Supplements

Mineral Supplements

- The common calcium supplements are ground limestone, crushed oyster shells or oyster shell flour, bone meal, calcite, chalk and marble.
- Most of the phosphorus in plant products is in organic form and not well utilized by young chicks or turkey poults. Hence, for poultry, emphasis is placed upon inorganic phosphorus sources in feed formulation (bone meal, dicalcium phosphate & monocalcium phosphate).
- Salt is added to most poultry rations at 0.2 to 0.5% level. Too much salt will result in increased water consumption and wet droppings.
- The other macroelements are supplied by the different feed ingredients while most of the trace elements are supplied by premixes.

Vitamin Supplements

Today, special vitamin supplements, which in many cases are chemically pure sources are used and in very minute amounts. In modern poultry feed formulation and production, premixes often represent the commonsense approach to provide both vitamin and mineral needs for poultry.

According to the Ministerial Decree no. 554 of June 1984, Egypt-the mineral/vitamin premix should supply vitamins per Kg of poultry diets by: A, 10000 iu; D, 1000 iu; E, 10 mg; K, 1 mg; B_1, 1 mg; B_2, 4 mg; B_6, 1.5 mg; B_5, 20 mg; folic, 1 mg; pantothenic, 10 mg; choline, 500 mg; biotin, 50 µg; B_{12}, 10 µg – and minerals, in mg, by: Zn, 45; Mn, 40; Fe, 30; Cu, 3; I, 0.3; Se, 0.1.

Nutrient Requirements of different species

Chickens

Broilers

Starting and growing market broilers

Broilers are young, rapidly growing birds raised for meat. The term can apply to all species but commonly taken to refer to young chickens. Broilers are young chickens that are grown to 5 to 7 weeks of age, at which time they are marketed for human consumption. A distinguishing characteristic of modern broiler chickens is their rapid growth, deposition of a large proportion of breast and leg muscles, and their relative inactivity as compared to chickens of lighter breeds that are used for egg production.

The rate of growth decreases with age, resulting in progressively lower nutrient requirements as the broiler approaches market age, so the growth period is divided into intervals. The following are data for growth and feed intake:

- Male chicken starts to have a weight of 152g at one week of age and reaches a weight of 3550 at 9 weeks of age. The respective figures for the female are 144 and 2840. They consume 135 and 131g diet in the first week and 1600 and 1250 in the 9^{th} one in male and female with a cumulative feed consumption of 8000 & 6700g in nine weeks, NRC (1994). When chicks are raised mixed the weight at the first week is 140 and at the ninth 3070 consuming a diet of 7300 (1993- cited from Allam, 1994). Body weights of commercial types may increase 50 – to 55 – fold by 6 weeks after hatching.
- The nutrient requirements of broilers are presented in NRC (1994) for three intervals and 42 nutrients. The phases are 0- to 3-, 3 – to 6 -, and 6- to 8 week. The finisher diet for the last phase has a higher energy to protein ratio to increase the deposition of the subcutaneous fat. Less research has been done on growing and finishing broilers especially on some of the trace elements and vitamins and extrapolations from the starter period are reflected in the requirements table on assumption that the quantitative relationship among AAs; minerals; and vitamins are constant throughout the growth of the broiler. The energy density in the three diets is 3200, while the CP % is 23, 20 & 18 in the starter, grower and finisher respectively.
- Requirements are guidelines and must be adjusted to the wide variety of strains of broiler chickens. Thus a special strain catalogue with special requirement levels is usually distributed by the different chick producers.
- As to appetite in broilers, it is even more critical than in layers. Growth rate may be regarded as a function of food consumption since the live weight of a broiler increases in proportion to the amount of food consumed over and above that needed for maintenance. For this reason a certain quantity of food will not lead to the same increase in body weight at any age for, as the weight increases, so does the amount of food required for maintenance. Loss of appetite in broilers may be due to coccidiosis or non-specific infections which should be checked.

Feeding programs other than that of NRC

In raising broilers usually two or three different diets, or even one, are used: a “starter”, a “grower”, and a “finisher”. The feeding period is divided into different phases according to the breed and catalogue recommendations. The grower – finisher or finisher rations need to be fed for different intervals depending on desired market size.

Table 2 Broiler feeding programs

Program	Diet	Age period	CP%	ME/Kg
I (NRC)	Starter	0 to 3 wk	23	3200
	Grower	3 - 6 wk	20	3200
	Finisher	Last 2 wk	18	3200
II •	Starter	0 to 2 wk before marketing		
	Finisher	Last 2 wk		
III	Starter	0 to 7 wk only		
IV ☉	Grower	0 to 9 wk	20	3200

• In this program the change from high protein – starter to a low protein – finisher stresses the bird. Change should be gradual by mixing the two mashes for 2 – 4 d.

☉ Compensatory growth at the end of the period is expected.

From 50 days of age till marketing a diet of 16% CP and 3050 ME can be fed (Ministerial decree, 1996). Remove from the diet any animal protein source, antibiotics, coccidiostats, and add 1/2 the needed amount of mineral and vitamin premixes, for cost.

In respect to programs, most are using at least 3 stages (starter, grower, and finisher) to reduce costs and make more efficient use of the nutrients. In the 3 – stage program the starter feed can be used for 3 – 4 weeks, the grower for about 2-3 weeks and the finisher for the remainder of the feeding period. The birds should be left on the higher nutrient feed formulation until the target weight per age is reached.

NRC 3-stage system was found to be optimal for most of the breeds if the producer has no breed recommendations.

Broiler breeder pullets and hens

Unlike the laying strains, broiler breeders (the parents of meat-type chicks) do not appear to exert such a rigid regulation of their energy intake and excessive deposition of fat within the adipose tissue results if these birds are allowed food ad libitum. This is associated with depressed egg production, and decreased fertility but the direct causes of these effects have not been established. It may be that reduced egg output results from an increase of internal laying; since yolk material is rapidly removed from the body cavity. This situation can only lead to an exacerbation of the obesity. However, if internal laying is the cause, the effects are probably related to mechanical than physiological factors.

Broiler breeders become excessively fat and heavy, causing leg problems and low egg production, if full – fed on high energy feed. Broiler breeder diets are formulated to provide about 120% of the requirements, for egg-type breeders, for all nutrients (other than energy) and their consumption limited to 80% of what ad libitum intake would be. Meat-type hens may need a diet with 19.5% CP.

Replacement chicks are usually fed a diet lower in energy than broiler chicks (2900). Also, feed and daily light periods may be restricted, so as to permit the pullets to reach larger body size before they start to lay. They are fed starter feeds to 5 weeks, growing ration to 11, then developer feed until lay. Feed accounts for 60% of the cost of raising replacement pullets.

A bird of the heavier breeds eats 43.2 to 52.3 kg/ year (compared to about 36.4 kg in light breeds producing about 20 dozen eggs), hence they are not as efficient egg producers.

Managemental and productivity assumptions

1. Broiler may reach a market weight over 2 kg at less than 7 weeks of age and score a feed conversion index of 2.0 or less compared with 8.0 in beef cattle. Feed represents 60 – 75% of the total cost and mortality is under 1%.
2. Economical growth does not always mean the fastest possible rate of gain or the best possible feed conversion.
3. To bring out the full potential of any type of broiler chicks you must follow the recommendations outlined in its guide in addition to the scientific known ones.
4. Broilers are most susceptible to heat stress the first of severe heat wave. They normally build up a degree of tolerance after a gradual exposure to high temperatures. Relatively high phosphorus levels in the feed together with low Ca should improve tolerance to heat stress.
5. Feed wastage should be decreased, and in well-equipped houses "meal time" feeding should be started 3 weeks of age by allowing broiler to "clean up" feed between meals. Caution must be used in programmed feeding since feed efficiency may be significantly decreased if broilers are without feed for more than 2 hours between feed cycles. Adequate feeder space is vital for successful programmed feeding.
6. Salt or Na levels appear to significantly influence feathering rate and cannibalism especially with certain coccidiostats. In general keep the Na level as high as possible without causing a wet litter problem.
7. Methionine is the first limiting AA in corn-soy diets and DL & or MHA are used as supplements.
8. Fresh food should be delivered to the farm in not more than 2 week-periods, and before arrival of chicks by 2 to 5 days.

Layers

Layers are chickens raised for egg production; most are of the Leghorn breed. They have a slower growth rate and thus lower nutritional requirements than broilers during the early growth stages. Those used as broilers or broiler breeders (meat-type) have rapid growth rates and a large body size.

Because of the high nutrient content of eggs, and the high level of production of the modern layers, the nutritional requirements of birds in full production are very high, particularly for protein, energy and Ca. A 1800g hen at the start of lay contains in her body 20g Ca and 725g DM. The production of 280 eggs will involve the voiding of 560g Ca and 2030g protein (280 X 7.25g CP), so 28 times the Ca content of the body and 2.8 times the initial DM

Egg composition

In egg production a good flock of layers produce an average of 250 eggs/ year/ hen (average weight 57g/ egg). The yolk forms 31%, albumen 59% and shell 10% of the egg weight. The following is the chemical composition of eggs in the main poultry species.

Table 3   Composition % of eggs (excluding shell) of domesticated species*

Species	Average weight (g)	Water%	Protein%	Fat%	Ash%	Calorific value Kcal / 100g
Fowl	52					
Edible egg		73.7	12.9	10.9	0.9	148
Albumen		87.1	11.4	0.1	0.6	51
Yolk		49.1	16.2	33.0	1.1	362

Duck **Edible egg** **Albumen** **Yolk**	67	70.1 86.9 45.3	13.5 11.2 17.3	14.5 0.06 35.7	1.0 0.8 1.2	185 45 377
Goose **Edible egg** **Albumen** **Yolk**	177	70.0 86.5 43.7	13.9 11.5 17.7	13.7 0.03 36.1	1.1 0.8 1.4	183 47 395
Turkey **Edible egg** **Albumen** **Yolk**	72	73.7 86.6 48.3	13.3 11.5 16.8	11.4 0.03 33.0	0.9 0.8 1.2	155 46 366

Fowl egg including the shell contains 66% water; 12.1% protein; 10.5% lipids; 0.9% CHO; 10.5% ash; and 90 Kcal.
* Source: W. Bolton and R. Blair (1974).

Egg strains

There are 2 strains, one with white feathers producing egg with white shell, and a strain with brown feathers and producing brown shelled-eggs.

The characteristics of a good egg-laying strain

- Growing period is from hatch to 140 d of age reaching a weight of about 1400g for white strains and about 1700 for brown ones. The bird consumes 8 kg diets for the white & 9 kg for the brown. Mortality rate is 3% for the white and 2% for the brown.
- Sexual maturity starts at 140 d (first egg) and full maturity reaches at 22 week (brown is late by 10 – 15 d).
- 50% production is reached at 155 – 157 d in white and 160 – 162 d in brown.
- Production is starting at 22 wk at low rate then increased rapidly to reach a peak at 30 – 35 wk then declines gradually to end.

Table 4 Production characteristics

	White strains	**Brown strains**
Hen-housed egg (H.H.)	270 (75%)	265 (74%)
Average-hen egg (A.H.)	280 (77%)	273 (75%)
Egg weight	60 g	63.5 g
Egg mass (kg)	17 kg	17 kg
Shell thickness (mm)	0.32 mm	0.38 mm
Diet consumed/ d	120g (H. H.) 125 g (A. H.)	130g (H. H.) 135g (A. H.)
Diet/ egg	163g	177g
Diet/ kg egg	2.55 kg	2.65 kg
Diet/ hen in production (12 mo.)	44 kg (H H.)	47 kg
Mortality rate in production	8% (0.5 – 0.7 monthly 1% in usual)	6% ideal
Hen wt. at 500 days	1.8 kg	2.3 – 2.5 kg
Rate of egg production		

22 weeks	30%	
23	60	
24	75	
25 – 30	85 – 93	
30 – 80	93 – 68	
(the decrease is about 1% every 2 weeks)		

Rearing in cage system

It is a most profitable system and as it is too costy, rearing in cages starts at the age of 18 weeks. This should be in closed houses because of the high stocking density (20 – 30 bird/ m^2) and ventilation should be 6 – 7 m^3/ kg/ h. Rearing in cages can be in open houses and the cages should be two levels at maximum, windows 30% at least and 10 – 12 bird per m^2 and 4 bird for the brown and 5 for the white/ cage (cage area 40 × 45 cm or 50 × 45).

Increasing of stocking density decreases egg production by 2 – 3% and decrease egg size by 0.5 – 1.0 g and shell decreases in thickness.

Decreasing of stocking density causes the bird to increase in weight at the end of the production period. On litter, brown strains need 1m^2 for 5 birds and 6 in white.

Managemetal suggestions

Growing period: from hatch to sexual maturity at 22 wk.

Brooding: first 3 weeks.

As chicks: from 3 – 7 weeks.

As replacement pullets: from 7 – 21 weeks.

Production period: from 22 wk to 12 – 13 months.

Peak: age of 32 weeks (85 – 90%) and continued for 4 – 5 weeks.

Feeding costs 50 – 70% of the total cost, though in exceptional cases it can run as low as 45% or as high as 75%. In the final analysis, the objective of feeding is to produce a dozen eggs at the lowest possible feed cost. Feed consumption per bird varies primarily with egg production and body size, and also by health and environmental temperature.

Normally, a mature Leghorn, or other light weight bird eats about 80 lb feed per year and produces about 20 dozen eggs (4 lb food/ dozen). A bird of heavier breed eats 95 to 115 lb / year, hence they are not as efficient egg producers.

Nutrition and egg formation

The turnover of material during reproduction in domestic avian species is enormous. A reasonable production of a commercial laying strain of hen is approximately 280 eggs during the first season. Since each egg weights 60g, the total material voided is in the order of 15 kg- a mass of about 10 – times her body weight. No other domestic species has such a reproductive capacity. As a consequence of this, a greater proportion of the nutrient intake is directly related to reproductive effort, and any variation in dietary intake could be expected to have profound effects on egg production.

When the nutritional environment is not suited to optimal egg production, the hen responds in several ways. It could reduce **the size** and/ or **number of eggs** produced, while maintaining the ideal composition, or could modify the composition while maintaining the output, alternatively.

Starvation

Not surprisingly the complete removal of some specific item (e.g. Ca and Na) from the diet rapidly leads to a complete cessation of egg production. With complete starvation the ovary rapidly becomes atretic and regresses, however in the case of Ca deficiency this is not so, and both the ovary and oviduct remain almost normal. The response of the ovary is undoubtedly mediated through the pituitary gonadotropins.

Energy

Commercial layer strains appear able to adjust their voluntary food intake to meet their daily energy requirements. Consequently when very high energy diets are fed, voluntary food intake could be reduced as to lead to a deficiency in intake of a specific nutrient in the diet. The calorie/ nutrient ratios should be kept as required.

Ultimately, high energy diets will lead to an unbalanced nutrient supply and the general overproduction of lipid material that the liver utilizes to produce yolk lipoproteins. The increased yolk weight relative to the other components of the egg could be a reflection of this, particularly since the composition of the yolk remains unaltered.

Energy deficiencies lead to a reduced egg size and ultimately a reduction in egg numbers but, again, this may simply be a reflection of general dietary deficiencies rather than a specific deficiency of energy per se. The laying strains appear to exert a rigid regulation of their energy intake.

Proteins

It is not surprising that there is a lack of any effect of dietary protein on the composition of egg protein, since the embryo requires certain amino acids for development. Hence an egg deficient or unbalanced in amino acids would be detrimental to embryonic development. Since all the egg proteins are synthesized specifically an unbalanced content is unlikely, although the total amount available may vary and may cause a reduction in egg size. This effect makes it difficult to assess the direct effects of protein and AA intake on hatchability although, surprisingly, in view of the AAs that are apparently essential for embryo development, dietary deficiencies of Try, Lys, or Met did not appear to affect the hatchability of eggs produced.

Lipids

Nearly all the lipid in the egg is present in the yolk. Synthesis of yolk lipoproteins occurs in the liver. The experimental evidence available suggests that the lipid content of the egg is not sensitive to the dietary lipid intake even high-fat diets do not affect total egg lipid, although proportions of egg yolk fatty acids can often be related to the fatty acid composition of the dietary triglycerides. However, lipogenesis decreases as dietary fat levels increase in most animals and, if this is also true in the bird, as dietary fat content increases the liver may use proportionally more dietary fat for synthesis of yolk material. Under these circumstances dietary unsaturated FAs appear more suitable precursors than saturated FAs.

Despite these last general conclusions there is no doubt that certain FAs are essential in diets for laying hens if they are to produce viable offspring. These acids, e.g. linoleic and arachidonic acids, are derived predominantly from vegetable oils and are stored in the body for sometime so that dietary deficiencies are not always immediately apparent.

Nevertheless, the amount of linoleic (and arachidonic) acid found in the yolk is ultimately related to the intake in the diet, and dietary deficiencies of linoleic are associated with a marked reduction in egg production, egg size and the proportion of DM and lipid content of the yolk. This is accompanied by a reduction in fertility and an increase in embryo mortality. In severe deficiency of either linoleic or arachidonic acid, the acid could not be detected in the yolk and hatchability was reduced at zero.

In one experiment, the weight of eggs from pullets was not affected by increases in dietary levels of Met, linoleic, or protein, above the requirements. Another study showed that increasing the linoleic from 0.6% to 4.3% increased egg weight during the first 14 weeks of production; however, average daily egg yield was not affected. The unsaturated fatty acid linoleic acid has been shown to be one of the factors leading to higher egg weight. The acid is found in vegetable oils and maize is one of the highest natural contents among the common ration ingredients. The effect of the acid is on size and not on egg number.

In contrast to the major yolk lipoproteins, there are minor lipid components of yolk which do appear to be directly related to the quantities present in the diet. For example, high dietary levels of cholesterol bring about high levels in blood plasma and in the yolk, but not all plasma cholesterol is derived from the diet and the type of dietary fat may influence cholesterol production in the bird. Thus a high dietary level of safflower oil results in a high output of cholesterol by the liver. It seems likely that substances such as cholesterol accumulate in the oocyte incidentally with other components because the specific mechanisms for the uptake of the major components are not selective.

Vitamins

There are many constituents which also appear to enter the yolk incidentally along with the main yolk components, although the mechanisms for the transfer of all constituents may not be identical.

Experimentally there is a relationship between dietary intake of B_2 and the production of a viable offspring by a breeding hen. Chick development during the 1st week of life was determined mainly by the B_2 the egg obtained during development, and this depended on the parental vitamin B_2 intake.

The concentration of vitamins A, E and K, pantothenic, nicotinic acid, pyridoxine, folic acid and biotin in the egg have also been shown to be dependent upon their concentration in the diet. This suggests that the bird has no specific mechanism for ensuring that adequate quantities of vitamins are present in the egg, which is surprising in view of the essential nature of the vitamins in normal development of the embryo, hatching and survival of hatched chicks.

Inorganic ions

Their effect on egg production is complicated by the fact that most ions have widespread effects on physiological processes in the body and particularly on these associated with heart, muscle and nerve.

Consequently there are efficient mechanisms of regulation to maintain the ionic balance in blood plasma constant within very narrow limits. It is extremely difficult to determine whether a particular response within the reproductive system to a specific ion deficiency is a secondary consequence of an effect elsewhere or whether it represents a primary effect. Concentrations of ions within the yolk or albumen tend to reflect their concentrations in the diet. Consequently the first effects of changes in the mineral composition of diet appear in the composition of the egg and only if the deficiency is severe enough will it eventually causes a fall in egg numbers. The exceptions are Ca and Na; both appear to have a primary effect on egg output rather than on egg composition, although composition may be affected also.

The requirement for dietary Ca varies with the level of vitamin D_3 and that of a high Ca level with low level of D_3 may result in significant decrease in egg weight.

In a similar way to the vitamins, it appears that most of the ions in the egg (except those in the shell) are present in concentrations proportional to dietary intake. This is not unexpected since most ions (e.g. Na and K) enter passively into the egg in the large quantities of water present. Furthermore most of the divalent ions (Ca, Mg, Zn, etc.) of the yolk are transported bound to the lipoproteins.

Conclusions

1. Variations in the diet can be expected to have profound effects, both direct and indirect, on the production of shelled eggs because a large proportion of the nutrient intake of domestic birds is directly related to reproduction.
2. However, it is not always easy to separate the primary and secondary effects of a specific nutrient deficiency.
3. Moreover, in terms of conversion of food material into eggs, variations may occur in the numbers of eggs produced as well as in egg size and composition.

4. It is not generally possible to explain the effects of a specific nutrient limitation in terms of specific physiological mechanisms, although some general conclusions can be drawn.
   - Where synthesizing mechanisms exist (e.g. lipoproteins of yolk and albumen proteins), and where specific uptake mechanisms operate (e.g. mechanisms in the oocyst for the uptake of certain yolk components), then the bird can apparently maintain the relative composition of the egg irrespective of reasonably wide fluctuations in diet amount and composition.
   - In contrast some minor components of the egg (in particular the vitamins and minerals) appear to enter passively as a result of the uptake mechanisms for the major components and for these minor components egg composition tends to depend more directly on the diet.
5. In marked deficiency egg production decreased or stopped completely. In less severe deficiency eggs may be smaller or differ somewhat in composition. It is now generally accepted that the composition of egg is, to a certain extent, dependent on the diet of the chicken. Any change in nutrition which affects the composition would be expected to show first in albumen, followed gradually in the next week in the yolk e.g. a change from a breeders mash to a layers mash is followed by a reduction in the B_2 content. The concentration decreases first in the albumen then in the yolk and is accompanied by impairment in hatchability.

Factors affecting egg shell

- ***Calcium – phosphorus – Magnesium – the main***

Shell texture can be controlled by the nutrition of the bird. In the absence of sufficient Ca, or if the ratio of Ca to P grossly exceeds the optimum, or if vitamin D and/ or manganese is deficient, shell strength and thickness are reduced. The quality of egg shells is intimately linked with the presence in the diet of adequate levels of vitamin D_3 and certain minerals including Ca, Mg, P, Mn and possibly Zn. There is a relationship between the level of vitamin D_3 and the minerals Ca and P and a deficiency or imbalance of one or other of these nutrients may result in a decrease in shell thickness and misshapen eggs followed by reduced egg production. The production of thin -shelled eggs is one of the first symptoms of vitamin D_3 deficiency.

Excess dietary P may decrease eggshell strength. 250 mg nonphytate P should be adequate for normal production and health. Poultry encountering heat stress may require additional P, as the chickens were more tolerant of high ambient temperatures than were those fed normal levels.

The amount of P in NRC (1994) has been decreased from amounts recommended in earlier editions. This fact may assume more importance in the future if manure application rates to land are determined on the basis of P content.

Thin and brittle-shelled eggs have been associated with a deficiency of Mn. An excess of dietary Mg above 0.2% may result in *a* loss of shell thickness.

The administration of certain sulphonamide drugs (sulphanilamide, soluseptazine, neoprontosil and sulphapridine) was followed by a reduction in the intensity of egg shell colour and by the production of thin-shelled eggs. On the other hand, sulphathiazole, sulphaguanidine, sulphadiazine and sulphamethazine had no noticeable effect.

- ***Level of nutrients other than Ca may also affect egg shell strength.***

A wide Na–to – Cl ratio can increase blood pH and bicarbonate concentrations. These increases may be the mechanism by which eggshell strength is improved at thermoneutral zone temperatures with some diets when NaCl is replaced by $NaHCO_3$ in the water or feed.

- ***Other non-nutritional causes of thin-shelled eggs are:***

a. the most important seems to be the genetic constitution of the hen. The shell thickness is a highly heritable character. The amount of oyster shell consumed had no effect on the amount of Ca secreted or on the percentage of Ca in the shell. Genes regulate the efficiency of absorption, mobilization and secretion.

b. amount of Ca secreted per egg remains constant unless there is a pause in production of at least two weeks.
c. the egg size increases during lay, therefore the thickness decreases during lay and in addition radius of curvature of the egg increases.
d. the feeding of seed grains that have been treated with certain insecticides and fungicides has been shown to be responsible for the production of malformed eggs.
e. the use of rancid cod liver oil in the diet has been reported to be responsible for the appearance of eggs with rough shells, showing an absence of natural glossiness.
f. the first egg in a clutch normally has a stronger shell.
g. when the bird is scared, the shell gland may undergo violent peristalsis, leading to the expulsion of partially shelled egg.
h. egg-shell quality also falls towards the end of the laying period. This appears to be due to a failure in Ca metabolism and is not remedied by increasing the Ca content of the ration.
i. a sudden increase in the environmental temperature or subnormal body temperatures of several hours duration, can cause a reduction in shell thickness.

   A frequent cause of poor-quality egg shells during periods of very hot weather is the failure to increase the nutrient density of layers food in respect of the nutrients other than energy. In hot environment a supplement of 50 mg ascorbic acid per kg diet tended to improve shell quality. A temperature of 80° F and 75-80% R.H. for 10 hours during daylight and 65-70°F and 50-60% R.H. the rest of the day equals the quality in cold environment of 55° F and 50-60% R.H. A constant 85-80%RH causes heat stress.

j. A diseased oviduct or more general infectious conditions (fowl pest or infectious bronchitis and Newcastle) may be indicated by the thin-shelled eggs even at low level.
k. In regions of lower humidity eggs tend to be less porous than in regions of high humidity and hence keep better in storage.

Requirements for layers

- ***Starting and growing pullets***

Energy intake may be the limiting factor for growth of egg-strain birds reared under most environmental conditions. Assuming no AA deficiency, and an intake of 1 kg of protein (140 d), growth seems most responsive to E intake. A total intake of 21 Mcal ME to 20 wk seems ideal for white-egg laying pullets (21000 ÷ 2900= 7.24 kg diet).

However, manipulation of E intake is not always easy, since the pullet appears to have a fairly precise innate ability to regulate its energy intake regardless of dietary energy level. Manipulation is therefore, best considered in relation to feeding management, and in particular, methods of stimulating feed intake. For example, feed intake may be increased through use of pelleted feed, increased frequency of feeding, feeding at cooler times of the day, and, where possible, use of longer periods of light. Pullet growth is initially most sensitive to dietary protein and AAs, whereas E intake becomes more critical as the bird approaches maturity.

As to protein requirements, flock replacement chicks are fed a 18% CP all-mash starter diet for the first 6 weeks, followed by a 15 to 16% protein grower feed to 12 wks, and a 15% protein developer feed until sexual maturity (age at first egg - laying, approximately 18 to 20 weeks).

The Na requirement of the Leghorn pullet is approximately 0.15% of the diet regardless of age, although somewhat lower level can be used after 10 weeks of age if excessive water intake is problematic.

- ***Prelay period (10-17 days before first egg)***

1-Daily nutrient requirements of pullets 10 to 17 d before first egg are generally considered to be greater than during the preceding 4 to 6 wk periods, although there is little evidence to show that pullets cannot meet these requirements through increased voluntary feed intake.

No change in growth (Leghorn) in response to elevated levels of dietary energy or protein. Energy intake is the most critical for this age, and can perhaps be manipulated best through stimulation of feed intake rather than by simply increasing the energy level of the feed.

NRC (1994) recommends the same energy density at 18 weeks to first egg (sexual maturity), but 17% CP compared to 15% in 12 – 18 weeks of age period.

2- Importance of Ca requirement at this time lies in its relation to the metabolism of medullary bone prior to maturity. Since modern egg - strain pullets exhibit a rapid increase in egg production and prolonged first multiegg clutch, it is obvious that a change in the requirements related to calcification must be accommodated before or at time of first egg.

3- A diet containing 3.5 % Ca from as early as 14 wk of age or as late as 19 wks has no adverse effect on skeletal integrity, apparent renal function, or subsequent reproductive performance.

4- Ca levels of 0.9 to 1.5% at 19 wk of age were detrimental to early shell quality. NRC recommends 2% Ca in the prelaying period.

- ***Hens in egg production***

Progress continues in the quest to use less feed in producing eggs, through decreasing the feed that is required for body maintenance of laying hens.

Energy

Body maintenance needs

Management practices, as well as nutritional regimes can affect requirement. In warmer houses, layers need less energy from their feed as they expend less energy in maintaining body temperature. Hens eat less feed with increasing temperatures and decrease feed consumption drastically at temperatures above 30° C.

Energy needs for production

An increase or decrease of 1% energy concentration causes an increase or decrease in energy intake of only 0.5% or less. Depressing the energy concentration to less than 2.3 Mcal ME depresses the energy intake and reduces the egg production. Concentrations greater than the recommended 2.9 Mcal increase in body weight gain rather than the number of egg laid (egg weight may be greater).

Genetic selection can also affect the amount of feed required for maintenance. With chickens bred for higher rates of egg production, there is a decrease in maintenance requirement relative to eggs produced (at a rate of 100 % egg production, maintenance requirements must be fulfilled for the 12 d needed to produce a dozen, and at a rate of 75 %, 16 days-12÷ 16 = 0.75).

Body size also affects and basal metabolism equals 78.3 kcal per day x (kg body weight)$^{0.723}$ and utilizes ME with a combined efficiency of 80%. The bird is in a postabsorptive state, in a thermoneutral environment, and as nearly at rest as possible. Maintenance requirement in the thermoneutral range of temperatures is approximately 90/ kg$^{0.75}$ or 100 kcal per day per kg body weight. Strains may differ because of metabolic or behavior characteristics. About 3 – 5 kcal should be considered for every 1 g gain (1 – 2g/ d when fed to appetite).

Equations have been developed to predict the energy required by chickens during egg production.

ME per hen daily= $W^{0.75}$ (I73- 1.95 T) + 5.5 Δ W + 2.07 EE (NRC, 1981- cited from NRC, 1994)

W= body wt in kg, T= ambient temperature (°C), Δ W= change in body weight (g/d) and EE = daily egg mass (g).

The estimated energy requirement can be used to estimate daily feed intake by relating the hen's energy needs to the dietary energy concentration.

Protein needs

A hen producing at a high rate needs 17 or 18 g protein daily (19% in high – energy fed in a hot climate or as low as 15% in moderate – energy diet fed in a cool climate). NRC (1994) has recommended 15% CP, with a consumption of 100g diet per day, and ambient temperature of 22°C.

Minerals and vitamins

Mineral needs in production for chicken are similar to mineral requirements of other poultry. The onset of egg production creates a need for more Ca to make the eggshell.

As to the time of switching pullets from a low-Ca growing diet to a high-Ca laying diet, feeding a diet with 3.25 % starting at 50 days of age increased the incidence of urolithiasis in later life. Changing at 14 wk of age or later, however, caused no detrimental effects on performance through 60 wk. Although high-Ca levels are detrimental when fed early in a pullet's life, feeding high-Ca levels several weeks before the onset of egg production seems to do no harm.

Layers are often "phase – fed" with an adjustment after approximately 40 weeks of age to increase the Ca level to maintain eggshell quality. The high Ca need is met by producing adequate Ca in the diet and often by providing crushed oyster shell ad libitum as well. For maximum egg yield, the choline requirement was about 1050 mg per hen daily.

Brown-egg-laying layers

Requirements and estimates are listed as 10% greater than those of the white-egg-laying layers (in feed intake and nutrient densities). This is as they have heavier body weights and generally produce more egg mass per hen daily.

Egg-type breeders

The major nutrient requirements are the same for producing an egg for human consumption, as for producing an egg for hatching: however dietary levels of trace minerals and vitamins that result in maximum egg yield per day may be too low for the developing embryo. Vitamins and trace mineral levels in the egg can be increased by increasing the dietary levels.

Higher B_2, pantothenic acid, and vitamin B_{12} levels are especially critical for maximum hatchability, although several other nutrients may also become limiting.

Feed intake in layers

Modern statements of food requirements are made in relation to an assumed daily food intake for; it has long been the practice to feed productive birds to choice, allowing them to regulate their total intake themselves. Some types of laying chickens eat very economical, but others especially heavy strains show less control and may overeat to the point that production may suffer.

Nutritional factors can affect the amount of feed to produce eggs. For example hens are able to make good adjustment of food intake to provide nearly identical daily energy intakes with up to 6% added dietary fat, another suggests the hen is not very accurate when offered a range of dietary energy conditions. Regardless of the accuracy, hens eat less of a high – energy, nutritionally balanced feed than a low – energy feed to produce a dozen eggs.

Offering food ad libitum to brown and white pullets, it was found that intake shows variation of 10 – 12% at the times the bird approaching peak rates (intake is of critical importance). Also intake increases regularly with time, that of others only quite late in lay and some scarcely at all. It is clear that "standard" ration is unlikely to be equally suitable for all strains all the time.

Nutritionists have been permitted, or sometimes forced to formulate diets differently than they did several years ago. Generally it is assumed that daily requirements for nutrients, other than energy, are not changed by the level of feed consumption, and so differences in daily feed consumption can cause the need for dramatic differences in dietary nutrient concentration. In NRC table nutrient requirements are expressed for three levels of daily feed consumption (80, 100 & 120g).

As to the appetite poultry, as an example for animals, may have the capacity to eat more each day in order to match intake to requirement. Then it could be useful to specify ingredients not per unit weight of food but per unit of energy. Small departures in appetite regulation may also be buffered by storing energy in the body as fat and then remobilizing stored energy in times of deficit.

In general terms it would be fair to say that appetite is regulated (by mechanisms not completely understood but monitored by the hypothalamus in the brain) to achieve just such a balance. Appetite varies with health, size, and level of production. A layer eats about 110g $\pm$ 15 – 20g in temperate zones without serious consequences and having 300 – 330 Kcal/ day.

Live weight is an important factor in egg production as more food is required for maintenance (from 64% at 60% production to 54% of food intake at 90% production – in a hen of body weight 1800 g). The 1800 g bird needs 70 g food for maintenance while a 2500 bird needs 87, so additional 15 g food (on average) for a difference in weight of 700 g which represents an additional annual consumption of 5.48 kg. Ration formulation should be altered at stages to correspond to changes in weight and productivity.

Diets for laying hens, however, can be most accurately formulated on the basis of feed intake data obtained frequently (every 1 to 2 wk) for individual flock.

The physiological mechanisms in laying birds are not sensitive enough that voluntary appetite regulation could be a basis for formulating rations. All the strains tend to increase their energy intake as the nutrient density of the diet is increased (even though they may have reduced food intake). Some do so to a greater extent than others. White Leghorn increases energy intake by 2 – 3% for each 10% increase in nutrient density. Larger strains increased by 4 – 5%. This is well appreciated by restricting the daily food intake of broiler breeding stock.

Daily food intake measurement in a poultry house (bags or feed in bulk ÷ number of birds ÷ number of days) is not likely to be good enough if there are variations in productivity or if some of feeding equipments permit substantial wastage. Waste can reach 20 – 30% of that on offer. Infestation with rats and mice should have a regular policy for the extermination of these pests.

The nutrient density of a ration designed for laying birds with an intake of 110 g/ bird daily will need to be increased when daily intake falls to 100 g, unless the margins of safety are designed to cover this eventuality. Alternatively the same rations fed to birds whose daily intake was 130 g would be overgenerous in nutrients and wastefully expensive.

As a rule increase about 5.5g food for every 0.25 kg increase in weight and 0 production starting at 45 g at 1.0 kg body weight, and about 6 g for each 10% production. This gives the approximate quantities of feed required per day by adult chicken in relation to body weight and egg production. This is based on the following equation.

$$F = 0.523\, W^{0.653} \pm 1.126\, \Delta W + 1.135\, E$$

Where F = feed consumption (g) W = average body weight (g)

Δ W = average daily change (g), assumed 0 average.

E = grams of egg produced.

Assume 21.1° C, for each 1°C increase in temperature, feed consumption is expected to decrease 1.2%.

The nutrient requirement values in tables and the performance characteristics are based on the assumption that the birds will be allowed to consume feed in ad libitum manner.

Ad libitum consumption is important especially when Leghorn birds reared in hot climates, because of their inherently low appetites. Managers should routinely consider restricted feeding only for brown-egg-laying strains, and even then only in temperate climates and with high-energy diets.

Restricted feeding

Restricted feeding of Leghorn-type pullets is seldom practiced during the growing period because restriction of lighting effectively controls feed consumption and sexual development. Feeding programs for Leghorn pullets and hens may be modified after maximum rate of egg production has been attained.

Occasionally, laying hens will consume excess feed during the latter phases of egg production with resultant obesity. Feed efficiency is reduced and the incidence of fatty liver syndrome is increased under these conditions.

Most egg type hens are given ad libitum access to feed; however, feeding program may be modified after the maximum rate of egg mass output has been attained. Laying hens eat more feed than is needed to support egg production. As a result, it may be more profitable to limit their feed intake. Limiting feed intake to 90 to 95% of full feed consumption seems desirable when over consumption of energy is a problem. Doing so will also reduce the likelihood of health problems that can also result when hens are overly fat. Data on feed consumption in individual flocks, together with information on body weight, ambient temperature, and rate of egg production may be used to determine the degree of feed restriction deemed appropriate.

Feed may be restricted during the developer period to delay onset of sexual maturity. This is desirable to reduce the number of small eggs produced when the birds begin laying.

Some strains of birds are known to eat substantially more than they should and may be deliberately restricted. The program recommended by the breeder for such birds should be followed; this may involve specially designed formulation for restricted feeding.

Phase feeding

A relatively new concept and term “phase feeding” refers to changes in the laying hens diets (a) to adjust to age and stage of production (b) to adjust for season of the year and climate changes (c) to account for differences in body weight (d) to adjust one or more nutrients as other nutrients are changed for economic or availability reasons.

Research has shown that

- A hen laying at a rate of 60% has different requirements than one laying at 80%.
- Hens have different requirements in summer and winter.
- A 24 – week old layer has different needs than one 51 weeks old.

So the aim of phase feeding is to reduce the waste of nutrients and reduce the cost of producing a dozen eggs.

A phase feeding programs generally call for:

I. High-protein feed (17 – 18%) from the onset of egg production through the peak production period, then 16% CP for the next 5 or 6 months. Lower level of protein (usually 15%) for the rest of laying period.

This plan takes age into consideration, but for greatest benefits other factors will also need to be considered. Phase feeding can help production reach higher peak and sustain it longer (very much like “challenge” feeding in dairy cows).

A phase feeding program adjusts daily nutrient intake according to expected requirements for maintenance and egg production. Generally daily intakes of protein, AA, and P are reduced with each succeeding phase. Daily Ca intake usually is increased with each phase. Thus the dietary concentrations of these nutrients are changed accordingly.

Experimental results have failed to prove that a hen requires more nutrients per day at one stage than at another. Relatively low levels of feed intake during early egg production, however, necessitate the use of high nutrient concentrations in diets during this phase of production.

II. In phase feeding, NRC (1994) mentioned that, phase 1 is designated as the time from the onset of egg production until past the time of the maximum egg mass output. Phase 2 is the period between 36 and approximately 52 wk, a period of high but declining egg production and increasing egg weight. Phase 3 is from 52 wk to the end of the rate of egg production cycle, in some instances to 80 weeks. During phase 3 the rate of egg production continues to decline while egg weight increases only slightly. On the other hand the amount of nutrient needed each day is assumed in NRC table to remain the same throughout a hen's time of production, and the diet is fixed at 15% CP and 2900 ME.

III. Three diets may be also formulated in the laying period, one (A) from the onset of production to after peak lay and down to 77 – 78% production. The second (B) should be used when production falls in the range of 77 down to 67%, and formula (C) diet should be fed to birds under 67% rate of lay. The CP% is 18.5, 17 and 15.5 respectively.

IV. Tow diets may be fed; the first is from 22-40 weeks and the second after 40 weeks. An adjustment is done after approximately 40 weeks of age to increase the Ca level to maintain egg shell quality.

Turkeys

Turkeys are raised for meat. Strains have been selected for rapid growth and efficient meat production. Most birds are white, whereas in the past the bronze-colored breeds predominated. Turkey meat has changed from being a seasonal dish (thanksgiving and Christmas) to having year-round consumption.

Young turkey poults have a higher protein requirement than chickens. Starter diets (0-4 weeks) should contain 28% CP. The protein content can be reduced by approximately 2% during each 4 – week period, up to a market age of approximately 20 weeks (NRC 1994).

Turkeys are affected by a number of disorders that have a nutritional component. These include:

1. leg weakness: is associated with deficiencies of nutrients involved in bone formation, including Ca, P, D_3, choline, biotin, folic acid, Mn and Zn.
2. enlargement of the hock joint: may occur with deficiencies of niacin, biotin, vitamin E, or zinc.
3. footpad dermatitis: is typical of biotin deficiency. Diets causing sticky droppings, such as with barley or poorly processed SBM may cause droppings to adhere to the feet and cause dermatitis.
4. pendulous crop: caused by yeast proliferation in the crop, may occur with diets high in fermentable CHO. The distention of the crop associated with gas production from the fermentation may interfere with passage of ingesta from the crop to the proventriculus, causing the pendulous crop condition. The disorder can be treated with a fungal inhibiting antibiotic.
5. ascities, or fluid accumulation in body cavities: has been observed with high salt intakes. Se deficiency also causes an edematous condition, exudative diathesis.
6. gizzard myopathy: or degeneration of the gizzard caused by Se deficiency in turkeys.
7. aortic rupture: occasionally occurs in market turkeys. Although aortic aneurysm can be induced experimentally with Cu deficiency and by feeding lathyrogenic substances (lathyrogens are toxic AAs in seeds of lathyrus species), the causes of the problem under field conditions have not been identified. It was suggested that gizzerosine, the gizzard erosion factor, may play a role in aortic aneurysm and rupture.

The following are further pointers pertinent to feeding turkeys:

1. Prevent poult "starve out": upon arrival, poults should be encouraged to consume feed and water as soon as possible. The use of colored feed, or the placing of brightly colored marbles in the feed and waterers, may help. It may be necessary to dip the beaks of some of them in feed and water to start them eating and drinking.
2. Turkeys grow faster than chickens; hence, they have relatively higher feed and protein requirements.
3. Younger turkeys use feed efficiently.
4. There is a tendency among turkey breeders to provide a high-fiber holding ration, for use beginning at 16 weeks of age. This type of ration retards sexual maturing and may result in some desirable effects upon later reproductive performance. The holding ration limits energy intake, but should not limit protein, vitamins, and minerals. Where a holding ration is used, the birds should be switched to the breeder 2 weeks prior to egg production.
5. Good range provides green feed and tends to reduce feed costs. However, it may make for higher losses from blackhead and other diseases, and predators.
6. As they approach maturity, turkeys fed for market purposes should be fed rations that are quite different from those that are fed to turkey breeders.
7. Turkeys are classified according to feather color or bird weight. There are the white, bronze, grey, brown or copper. Most birds are of the heavy weight bronze and the Holland white medium weight strains. Producers prefer the white strains especially if the birds are marketed slaughtered. The presence of black down on carcass decreases its marketing value. In immature birds more down could not be removed and waiting till the bird matures represents an economical loss and high feed conversion index.

Raising for meat production

According to body weight turkeys are divided into three classes, light, medium and heavy. This classification is related to the age of marketing for meat and feed conversion rate. The light breeds can be marketed at 9 and 12 weeks with an average of body weight of 2.6 and 4.2; and FC of 2.1 and 2.4 respectively. Males surpass females by about 25% while in mature birds the cocks average 10 kg and hens about 5.5. In medium – weight breeds the birds can be marketed at 12, 14 for males and females and 16 weeks for males. The respective weights are 4.5, 5.5 & 7.5 and FC 2.2, 2.5 & 2.6. The mature birds weigh 15 for cocks and 8 for hens. The heavy breeds marketed at 12, 16 & 20 for both sexes and 24 for cocks with a weight of 4.8, 7.2, 9.3 and 13.6 and FC of 2.3, 2.7, 3.1 & 3.5. The cocks may reach at maturity 20-22 kg and hens 8-10.

The heavy breeds for marketing birds of more than 10 kg are the most economical as it has a low FC even at an age of 20 – 24 weeks. On the other hand the FC rises greatly after the age of 12 – 16 weeks in light and medium breeds. In heavy breeds cocks can be fattened till the age of 24 weeks to reach a weight of about 13 kg, and hens fattened till the age of 18 – 20 weeks to reach a weight of 7 kg.

In meat production the fattening period is divided into 3 phases in which diets starter, grower, and finisher are fed. The following is the composition of the three diets:

	Starter	**Grower**	**Finisher**
ME	2800	2900	3100
CP%	26 – 28	18 – 22	15 – 18
Ca	1.4	1.2	1.0
Av.P	0.6	0.5	0.4
Salt	0.5	0.5	0.5
Met	0.56	0.48	0.48
Lys	1.8	1.4	1.0
	Breeds		
Starter diet	**Light**	**Medium**	**Heavy**
Age	0 – 4	0 – 4	0 – 4
CP%	28	26	26

Grower diet

Age	4 – 8	4 – 12	4 – 9
			9 – 16
CP%	22	20	20 & 18

Finisher diet

Age	8 – 12	♀ 12 – 14	♀ 16 – 20
		♂ 12 – 16	♂ 16 – 24
CP%	18	16	15

According to the Ministerial decree (1498 on 1996) 5- phase and 3- phase programs were suggested for meat production.

5- phase program				
Starter 1	Starter 2	Grower 1	Grower 2	Finisher

Age (wk)	0 - 2	2 - 4	4 - 8	8 - 10	10 to marketing
CP %	29	26.5	23	19	17
ME	2900	3000	3200	3250	3275
3- phase program					
	Starter	Grower	Finisher		
Age (wk)	0 - 4	4 - 10	10 to marketing		
CP %	29	23.5	19.5		
ME	2900	3050	3150		

It appears that the Ministerial programs are suitable for the light breeds.

Daily food intake in heavy breeds

Week	FI, g	Week	FI, g	Week	FI, g
1	15 (10)	8	140 (100)	20	280
2	25 (20)	9	160 (120)	22	300
3	40 (30)			24	320
4	60 (40)	10	180 (140)	26	340
		12	200 (160)	28	360
5	80 (55)	14	220 (180)	The food intake is about 1.5 times that consumed by light or medium to 18 weeks.	
6	100 (70)	16	240 (200)		
7	120 (85)	18	260 (220)		

The figures in parentheses are for light and medium breeds. Females are not usually marketed after 20 weeks of age.

Breeding:

In a program for raising breeding hens the period can be divided into three phases:

1. Incubation period from 4 – 6 weeks.
2. Growing period from 6 weeks till the start of production at 32 weeks. In this period there is a special program of feeding and lighting. The programs limits growth rate and retards sexual maturity.
3. Production period starts at about 32 weeks and extends for 20 – 24 weeks according to the breed when production stops and molting starts. Some prefer to keep the flock for another season, while the others get rid of the flock at the age 12 – 13 month.

The feeding program includes

Starter diet	0 – 6 weeks	26% CP (with boiled eggs)
Pullet diet	6 – 28 weeks	(6 – 12 wk 18 – 20% CP, 12 – 28 wk 16% CP)
Breeder diet	from 28 weeks till the end of production period.	

With the pullet diet there is limited feed intake and lighting (12-28 wk) to retard sexual maturity till full body maturity. Barley is offered 20 – 30 g/ bird before turning off the light by about 2 hours. Grit should be sprinkled on the feeders, 2 – 3g/ bird, once weekly 3 – 5mm along the growing period.

The breeder diet 17 – 18% CP for heavy breeds and 18 – 19 for light ones, offered at the age 29 weeks making the period from 29 to 32 as transitory (gradually increasing feed intake and lighting).

NRC feeding program

NRC (1994) suggested another feeding program in which a starter diet is fed from 0 – 4 weeks (28% CP) then five grower diets are used in which CP decreases from 26 to 14 (2% during each 4- week period) while ME increases from 2900 to 3300. The growing period extends to 24 in males and 20 weeks in females. A holding ration of 2800 ME and 12% CP is fed till the start of laying where 2900 ME and 14 CP% - diet is fed. Males are fed a diet of 12% CP and 2900 ME. NRC program is the best to be used with the consideration of age of marketing.

Waterfowls and game birds

The white Pekin duck breed is the principal meat producer. In China and Southeast Asian countries, ducks are raised extensively for meat and eggs. Egg – producing breeds, such as the Indian Runner, can achieve egg – production rates equal to or greater than those of chickens.

Geese are raised to produce meat, feathers, down, and in France, liver pate. Fatty livers are produced by force feeding the birds with a high – energy diet.

Ducks and geese can be fed diets similar to those for chickens.

Leg weakness is a major problem in waterfowl because of their rapid growth rate; adequate choline and niacin are necessary to prevent this disorder.

Geese are grazing birds and can be fed on range. The amount of concentrate for geese can be limited to 1 to 2 pounds of feed per bird per week. If full fed on grain, they will reduce their forage intake. For several weeks prior to marketing, they should have free access to concentrate feed to develop adequate finish. Although goslings have a very rapid growth rate, a large amount of the gain is skin, fat, and feathers. They are less efficient than chickens in the accretion of lean tissue. Their ability to utilize forage may be of value in some countries where feed grains are expensive. Although geese are herbivorous and accept high-fiber diets, the digestibility of fiber is low in this species. The ability to utilize fibrous feeds results from a fast passage time that allows a high-feed intake, plus efficient manner in which the gizzard breaks down plant cell walls, which allows digestion of the cell contents. Growth on fibrous diets was improved when the diets were pelleted. Geese are sensitive to bitter substances in the diet-they prefer grasses and weeds to alfalfa (contain bitter substances such as saponins). Refer to the nutrient requirements table at the end of the chapter for ducks, geese and game birds.

The pointers pertinent to feeding ducks

1. Ducks should be fed pellets rather than mash. Pellets will make for a saving of 15 to 20% in the feed required to produce a market duck.
2. Ducks are nearly good foragers as geese.
3. Ducks should be ready for market between 7.5 and 8 weeks of age.
4. The holding rations are designed to maintain breeding ducks from about 8 weeks of age until the breeding season commences, without their getting too fat. Also the food is limited to about 1/2 pound per bird per day.
5. The breeding diet should be substituted for the holding diet about 4 weeks before eggs are desired for hatching purpose.
6. There are three breeds, one for meat production, the other for egg production and the third is for hoppy.

Meat production

Usually the Pekin ducks are used as it has a rapid rate of growth, also a mix between Muscovy or Sudani with Pekin to produce the "duck mule". The last has many problems in conception as the males are larger in size than females, so low hatchability.

Feeding for meat production

The feeding for meat production is for a period of 8 weeks, consuming 8 kg diets, at 1: 3 FC, and reaching about 2.6 kg body weight. Don't extend the period more than 8 wks as the ducks are inclined to store fat and the FC rises to 1: 5 or 1: 6. Also after 8 weeks ducks start molting which continues to the age of 13 weeks, which affects growth rate and feed consumption.

In the feeding period chick weight increases 50 times. The program of feeding includes a starter and a grower diet, and no finisher is given lest the increase in fat precipitation. For energy and CP and other nutrients refer to NRC (1994). According to the Ministerial decree, chicks are fed a starter diet (22, 2900) and a finisher one (17, 3000), in the 2- phase program, and starter (22, 2900) grower (18, 2900) & finisher (16, 3000) in the 3- phase one.

Breeding

The growing period extends till the age of 22 – 24 wk in which limited feeding and lighting followed till the start of egg production (otherwise inverted uterus a condition could not be rectified as long as it appears).

In incubation period	Feed ad libitum, 20% CP
From 2 – 7 weeks	Pullet feed 16% CP, ad libitum
From 7 to 21 weeks	Feed 70% of normal consumption (about 170g), CP 13%

The program of limited feeding ends at the starter of the 22nd week and breeding diet offered (17% CP). Egg production starts at 25 week of age and continues for 9 – 10 months (150 eggs), production can be continued for 12 months (180 – 200 eggs). No more than one season as ducks are inclined to be too fat at the end of the production season and start of molting, so the production in the subsequent seasons will be low except in egg breeds as in Indian Runner. The last can be kept for 4 seasons.

Laying bird consumes about 250g feed containing 16 – 18% CP (NRC- 15%) and containing not less than 6% animal proteins of which 4% fish meal (for high hatchability).

The pointers pertinent to feeding geese

1. They can live almost entirely on good pasture.
2. Weeder geese are used with great success to control and eradicate troublesome grass and certain weeds in a great variety of crops and plantings, including cotton, onions, garlic, corn … etc. At the end of the weeding season the geese are generally brought from the field and placed in pens for fattening for 3 or 4 weeks, until they weigh 10 – 12 pounds or more. Markets are highest during the 4 to 6 weeks prior to Thanksgiving and Christmas.
3. Rations should be in pellet form. Crumbles cause too much feed wastage and should not be used.
4. Geese should be ready for market at about 15 weeks of age. Geese could be marketed at 10 weeks as Green geese (fed rations to satiety), 14weeks (fed limited amounts of a commercial diet), or 18 weeks (if fed a starter diet, then grazing and grains).

Notes on feeding geese

Geese usually tend to precipitate a large amount of fat as body fat reaches 31% of the carcass, while it is 5.6% in chickens, 11.7% in turkeys and 17.2% in ducks. The geese liver is of large size and fat could be precipitated in it, liver pate (pate de foie gras). Liver is sold at a high price to the degree that it covers the cost of geese raising and meat production is considered a subsidiary product. Feathers also are a valuable product.

Greenages should be used to decrease the cost of feeding. Light breeds are fed for 8 – 10 weeks for meat production where a concentrated diet is offered. This method is called the early or rapid fattening. The fact that geese are grazers could be used and the birds are left in range till near maturity where it is moved to fattening and given a finisher. This is the "late fattening".

- **Fattening, early**

Period 9 – 10 weeks	End weight 4 – 6 kg
Feed consumed	15 – 16 kg
Starter 20% CP	for 4 weeks.
Rest of period	15% CP.

- **Fattening, late**

Incubation 3 weeks then left in range till near age of maturity without any additional diets.

30 days before slaughter treat as follows:

- The bird is gradually moved to the concentrated feed and the 30 days are divided into 3 periods:
  a. The first 10 days : Graduation in feeding but less than satiety level.
  b. The second 10 days : Full-feeding.
  c. The third 10 days : A diet high in energy and low in protein.
  Bird should be slaughtered only when the sternum completely disappears.

- **Fattening by forced feeding to produce liver pate:**
  Forced feeding is performed either by hand or mechanically before slaughter by one month. The goose is forced fed 800 – 1000g corn divided on 2 – 4 times per day. In the forced feeding goose gains 3 – 5 kg and liver increases in weight by 500 – 800g with the increase in fat% in liver to 60%.

Feeding in egg production

In egg production feed a diet of 2900 kcal ME/kg diet and 15 % CP as CP recommended by NRC (1994).

Egg production

- Produce egg efficiently for successive 10 years.
- Can reach to the age of 20 years and still laying.
- 40 – 50 egg/ season.
- 20 – 30 egg/ season in some light breeds.

Laying most of it is in winter (January to April) in one group or two groups. The best rate of laying is in 2 – 6 years of age and decrease till the age of 10 – 12 years. The first season is less in hatchability by 20% than the second season. Males can be used for mating starting at 1 year of age till 6 – 8 years.

Ostriches

Ostriches and other ratite birds (emu, kiwi, cassowary, and rhea) are large flightless birds that have been separated from the main lines of avian evolution for 80 to 90 million years, since the

Middle Cretaceous period. Their occurrence in Africa, South America, and Australia stems from having common ancestors that lived when these continents were joined. These birds have enlarged ceca and microbial fermentation and utilize fibrous vegetation to a considerable extent. There is evidence of nitrogen recycling from the cloaca to the cecum, increasing the efficiency of protein utilization. The metabolic rate is lower than for other avian species, thus contributing to their ability to survive on low – quality diets.

In Ostrich young chicks can be started on turkey or game bird starter ration containing at least 26% CP. They should have continuous access to the starter diet for the first 3 weeks, after which they can be fed all the starter diet they will consume in two 30 – minute feeding periods per day. At this time they should have free access to alfalfa pellets. This feeding program will help to prevent excessive weight gain which causes leg weakness problems. At 8 weeks of age the ostrich chicks can be fed a game bird or turkey grower ration for two feeding periods daily, with continuous access to alfalfa pellets. If good-quality pasture is available, they can be ranged on pasture with the supplemental ration provided twice daily. Forages should be young and succulent. Adult birds can be kept on pasture, with daily supplements of a turkey breeder diet during the breeding season. Birds in dry lots can be fed alfalfa pellets or good quality hay.

Exotic birds

A variety of exotic birds such as canaries, finches, parrots, and cockatiels are raised by bird fanciers. With the widespread destruction of the native tropical rain forest habitat of many of these birds, an interest in raising and propagating them in ovaries is developing. Some feed companies produce special feed formulae for this purpose. Knowledge of the nutritional requirements and digestive abilities of the birds is necessary for optimal formulation of cage-bird diets. This is especially true when reproduction is desired as nutrient requirements are much higher than for an adult kept under maintenance conditions, as many pet birds are. Relatively little research has been conducted in this area.

The majority of cage birds are psittacines and passerines. Psittacines are members of the parrot family.

Feeds and ration ingredients

Before attempting to balance a ration the following should be considered:

1. **Availability and cost of the different feed ingredients:** The cost should be based on delivery after processing. The ingredients should be available for at least 3 month – rations. Formulation should be changed considering any changes in availability of feeds, prices, change of bird weight and productivity. The cost per unit of production is the ultimate determination of what constitutes the best ration.
2. **Feed composition tables or average analysis,** should be considered only as guides. Whenever possible, especially with large operations, it is best to analyze for the more common constituents-protein, fat, fiber, nitrogen free extract, moisture, and often Ca, P, and carotene. Such ingredients as oil meals and prepared supplements, which must meet specific standards, need not be analyzed so often, except as quality-control measures.
3. **Vitamin and mineral supplements:** Today vitamin supplements (which are in many cases chemically pure sources that need to be used in very minute compounds) are used in feed formulation instead of using a wide variety of crude feedstuffs. In modern poultry feed formulation and production, premixes are used to provide both vitamin and mineral needs for poultry.

Vitamin concentrate must supplement each kilogram of poultry diets by: vitamin A, 10,000 IU; vitamin D, 1000 1U; E, 10 mg; K, 1mg; B_1, 1mg; B_2, 4mg; B_6, l.5 mg; B_5, 20mg; folic, 1mg; pantothenic, 10 mg; choline, 500mg; biotin, 50ug; B_{12},10ug. And the trace mineral concentrate in mg by: Zn 45, Mn 40, Fe 30, Cu 3, I 0.3, Se 0.1. These are the recommendations of the Ministerial Decree No, 554 of June 1984, Egypt.

It is preferred not to add the premix of the trace minerals to vitamin mixtures as in case of unfavorable storage conditions, minerals may affect the activity of the vitamins.

It is well known that the nutritive content of the egg in respect of many of the important trace minerals and vitamins depends upon the level of these nutrients in the diet of the laying hen (e.g. iodine can rapidly be increased by the addition of suitable iodine supplements to the diet, and B_2 in diet is reflected in B_2 in the egg). Sufficient quantities of B_2 impart to the albumen a very slight yellowish-green tinge. Vitamin K and iron salts (and alfalfa) have been implicated from time to time to be the cause of blood spots in eggs.

4. Broiler or layer concentrates

Nowadays these concentrates are used to supply good quality protein (as it contains mostly animal proteins) & minerals, especially the trace elements, and vitamins. In addition the concentrates contain coccidiostats, antioxidants, growth promotants and other additives.

Poultry rations

The poultry man has the following alternatives for purchasing and preparing rations:

1. Commercially prepared complete feed.
2. Commercially prepared protein supplement, reinforced with vitamins and minerals, which may be blended with local grains.
3. Commercially prepared vitamin-mineral premix which may be mixed with oil meals and grains.
4. Purchase of individual ingredients, including vitamins and minerals.
   Most choose option 3 or 4.

Special nutritional disorders in poultry

(Refer to deficiency diseases in minerals and vitamins)

I- Leg Disorders

Leg abnormalities are a problem in poultry, especially in birds kept on wire. Perosis or slipped tendon is caused by deficiencies of choline and manganese. Perosis is due to an abnormality of the joint in the long bones of the leg causing the tendon to slip and pull the leg sideways. Cage layer fatigue is a type of osteoporosis that involves excessive mobilization of calcium from the leg bones, which causes the birds to have difficulty in standing. Insufficient dietary calcium is a causative factor.

Another leg disorder seen in broilers is tibial dyschondroplasia (TD) in which there is abnormal formation of cartilage in the long bones. The cartilage forms a thickened layer below the epiphyseal plate. Dietary electrolyte balance and dietary alterations that affect acid-base or cation-anion balance have a role in TD. High dietary chloride levels provoke an increased incidence. Dietary zeolite has been shown to reduce the incidence and severity of TD, apparently by facilitating calcium utilization. High levels of vitamin A were reported to increase leg disorders, but this result was not confirmed. It was found that a diet low in calcium and high in phosphorus and chloride produced a high incidence of TD in broilers. Supplementation of high phosphorus diets with calcium reduces the incidence of TD. Some of the diseases are going to be discussed in detail.

1- Perosis: Deficiencies of Manganese and Choline

If young chicks are fed a diet deficient in manganese, symptoms of perosis will develop within 2 to 10 weeks, depending on the severity of the deficiency, the breed and strain of chicken, the composition of the diet, and the age at which the deficient diet is first fed. If the deficient diet is fed from the first feeding-that is, when the chicks are 1 or 2 days old, the symptoms generally develop between the ages of 3 and 6 weeks, but if it is not fed until the chicks are 10 weeks old, the usual symptoms may not appear.

The first readily noticeable symptom is a tendency on the part of some of the chicks to rest for long periods in a squatting position. If the tibiotarsal joints, or hocks, of these chicks are carefully examined, a slight puffiness may be observed. Within a few days the joints become slightly enlarged, and frequently the skin covering them has a bluish-green cast. Apparently, this is a critical stage, because in some cases, especially among the more resistant breeds or strains, the chicks frequently recover to such an extent that no readily noticeable permanent deformity results.

As the joints become further enlarged, they tend to become flattened, and the metatarsi, or shank bones, and tibiae exhibit a slight bending and also undergo a rotational twisting. As the condition continues to develop, the bones become more and more bent until gross deformity results. Frequently the articular, or joint, cartilage at the lower end of the tibia slips from its normal position, and this in turn causes the main tendons to slip from their condyles. Sometimes the curvature of a tibia is so great at its lower end that the tendons slip even though the articular cartilage has not been displaced. These changes may take place in either one or both legs; when they take place in both legs, the chicken is forced to walk on its hocks.

Histological and chemical findings in perosis:

If the bones of perotic chicks are compared with those of normal chicks of about the same age and weight, it is found that they tend to be thicker and shorter. In rickets, as in perosis, the leg bones may become thickened and shortened, but the shafts are poorly calcified and tough, whereas in perosis they are well calcified and relatively brittle. In osteoporosis the shafts are of normal length and much thinner than in rickets or perosis and are somewhat more springy than in perosis. In all three conditions the upper end of the tibia becomes enlarged but it has a bulbous shape in rickets, a conical shape in perosis and an approximately normal shape in osteoporosis.

The damage in the joints is caused by changes in the cartilage. The epiphyseal cartilage is deficient in mucopolysaccharides; the synthesis of which is decreased in dietary manganese deficiency.

Other effects of a deficiency of manganese:

If adult chickens are fed a diet deficient in manganese, no observable changes in their leg joints and bones occur, but the shells of their eggs tend to become thinner and less resistant to breakage. If the deficiency is sufficiently great, egg production is decreased, and the eggs that are produced have a very low hatchability. The lowered hatchability results from an increase in the embryonic mortality that occurs after the tenth day of incubation. The embryonic mortality reaches its peak on the twentieth and twenty-first days of incubation. The embryos that die after the tenth day are chondystrophic; they have short, thickened legs, short wings, parrot-like beaks, a globular contour of the head, protruding abdomen, and, in the most severe cases, retarded development of the down.

If the deficiency of manganese in the diet of laying hens is marked but not extreme, a few of the eggs may hatch. The resulting chicks may have very short leg bones, and in some cases the bones may be deformed as in chicks that develop perosis after hatching.

Deficiency of choline:

A deficiency of choline will cause perosis in chickens, even though the diet contains ample manganese. The principal functions attributed to choline are (1) the formation of phospholipids which contain choline, (2) the formation of acetyl choline, and (3) the supplying of active methyl groups.

The chief symptoms of choline deficiency in the chick are reduced growth and the development of perosis. If the deficiency is sufficiently severe, feed conversion is impaired. There is a tendency for the fat content of the liver to increase on low choline diets, but the extreme fatty liver condition seen in other species does not occur in the chick due to choline deficiency per se. There is also a tendency for the hematocrit (packed blood cell volume) to increase on low choline diets.

The perosis resulting from choline deficiency is essentially the same, in gross appearance, as that caused by manganese deficiency. Nevertheless, there are histological differences between the two. In choline deficiency there are fat deposits in the epiphyseal cartilage layer but not in manganese deficiency. Calcification is normal in the perotic chick, bone ash and phosphatase values are within the normal ranges.

Other causes of perosis:

In addition to manganese and choline, at least three other factors are necessary for the prevention of perosis, these other factors are biotin, folacin, and niacin; it is probable, however, that compratively little niacin is needed if the feed supplies sufficient tryptophan.

It should be noted that when chicks are reared on hardware cloth (e.g., in battery brooders), about 0.5 to 1.0 per cent of the chicks may develop a condition of the hock joints that resembles perosis, even though the diet contains adquate quantities of all known-to-be essential nutrients. The development of this condition is believed to be the result of injuries to the hock joint or the result of severe strain on that joint.

It has been reported that perosis may be produced by the feeding of high levels (0.5 per cent) of thiouracil.

2- Cage Layer Fatigue

Egg production normally causes osteoporosis owing to the withdrawal of calcium from the skeleton for shell formation. This depletion is accentuated by high egg production and the restriction of movement in battery cages; it will become pathological if the hen is unable to reduce egg production when the skeleton has become grossly depleted. Cage layer fatigue is believed to be caused in this way rather than by a dietary deficiency. However, an increase in the calcium or phosphorus content may be beneficial when the flock is known to be susceptible. Genetic factors also appear to influence susceptibility.

Hens in good bodily condition and high egg production suddenly fall on their sides and show signs of paralysis, especially in the legs which are extended. Death usually follows quickly but some may recover if hand-fed. Others die without showing any specific abnormality. The bones are extremely thin and brittle, the ribs and sternums are deformed and fractures occur in several parts of the skeleton, degeneration of the spinal cord, thereby producing paralysis. The egg shells on the other hand show no abnormality. There are no visceral lesions apart from venous congestion in the peracute cases. Refer to “deficiency symptoms of macroelements”.

3- Rickets

Since rickets is almost always diet-associated, the majority of birds in affected flocks are normally involved and the commonest age at which this problem is encountered is between two and three weeks. First signs include reluctance to rise and an unsteady gait. Early diagnosis and dietary correction can prevent chcks to growth rate and the development of skeletal deformities which include anteroposterior bowing of the proximal tibia and, sometimes, enlargement of the tubercula and capitula of the ribs.

Diagnosis of rickets depends upon the demonstration of soft, rubbery bones and beak and can be confirmed by cutting undecalcified histological sections of the ends of long bones and staining by Von Kossa's method to show a failure of calcification of hypertrophic cartilage. It should be noted that the growth plates are not necessarily widened in all cases of rickets and growth plate and metaphyseal architecture often appear normal.

Rickets may be caused by deficiencies of calcium, phosphorus or vitamin D_3 or by calcium-phosphorus imbalance. Less commonly, the condition may arise because vitamin D_3 is not absorbed or not converted to its active metabolites in liver and kidney. Mycotoxicosis can lead to such an event. In the field rickets is usually caused by vitamin D_3 deficiency or by lack of available phosphorus. Calcium deficiency is rare and would be associated with marked stunting of affected birds which would be of far more significance to the stockman than rickets. It is important to realize that attempts to treat phosphorus deficiency rickets with a vitamin D_3 preparation administered in the drinking-water may well exacerbate the condition by enhancing calcium absorption and increasing calcium-phosphorus imbalance. It is therefore better to change the feed immediately rickets is diagnosed and not to indulge in water treatment. Suspect feed should be sent for analysis of calcium, phosphorus and vitamin A levels. It should be noted that normal levels of total phosphorus do not preclude the possibility of a deficiency of available phosphorus. Unfortunately, there is no simple way to measure vitamin D_3 levels in finished feeds and it is therefore normal to check vitamin A levels because these two vitamins are usually added to feeds together. When feed is marginally deficient or imbalanced, rachitic flocks may often recover spontaneously without treatment or change of diet since, as they age, the specific growth rates of the birds decline, with a consequent reduction in requirements for antirachitic factors in the diet. It is interesting to speculate on the extent of undiagnosed subclinical rickets in broiler flocks and whether this could be a contributing factor, along with tibial dyschondroplasia, to the high incidence of anteroposterior bowing of tibiae commonly encountered in broiler flocks of slaughter age.

II- Anemia

Deficiency of iron or copper can cause anemia. Iron is needed for the formation of hemoglobin. It is also a constituent of cytochrome and other respiratory enzymes.

If there is insufficient iron in the diet, anemia results because hemoglobin cannot be formed. Copper is essential for normal utilization of the iron. In either case (deficiency of iron or copper), there is a reduction in the hemoglobin content of the blood and in the size of the red blood cells.

Other causes anemia: We have already noted that deficiencies of certain water-soluble vitamins can cause anemia. Among these are deficiencies of folacin (folic acid), pyridoxine, and vitamin B_{12}. The type of anemia-as determined by cell counts, hemoglobin, and hematocrit-sometimes helps to identify the cause. Any substantial loss of blood will also cause anemia. This, in turn, can be due to heavy infestation with internal or external parasites, or to hemorrhage due to impaired blood clotting.

III- Fat Disorders

1. **Excessively fat broilers** are a problem in the United states poultry industry. Selection of birds for very rapid growth rate and the use of high-energy diets are implicated. Maintaining a proper balance of protein to ME helps prevent excessive fat deposition.
2. **Fatty liver syndrome:** (also known as fatty liver and kidney syndrome) it affects layers, with the deposition of large amounts of fat in the liver. The cause is not completely understood, but lipotropic agents (substances that reduce fat deposition in the liver or hasten its removal) such as choline, vitamin B_{12}, and methionine show evidence of protective activity.
3. **Oily bird syndrome** is sometimes a problem with broilers, observable only after the birds have been processed, and involves a greasy appearance of the fat and skin. Nutritional factors such as the protein-to-calorie ratio may have a role in the syndrome.
4. Another nutrition-related problem with broilers is **sudden death syndrome (SDS)** or flip-over disease. This appears to involve a heart failure (heart attack). Birds that develop SDS have altered fatty acid content of tissues, with decreased arachidonic acid levels. This could result in reduced prostaglandin synthesis, leading to imparired heart function. Biotin deficiency has also been implicated in SDS. Biotin is a cofactor for enzymes involved in fatty acid metabolism. Feeding high-energy diets increases incidence of SDS.
5. **Fatty Liver Haemorrhagic Syndrome (FLHS).** This disease occurs sporadically in laying hens, particularly in caged flocks of the heavier breeds during hot weather. Under these conditions they may not reduce their food intake sufficiently to compensate for the raised environmental temperature and lack of exercise. Consequently their carbohydrate intake is excessive and hepatic lipogenesis is increased. Heat stress may also be involved and dietary factors such as the cereal used as the source of the carbohydrate may affect the amount of fat synthesized.

Signs

Usually the first indication of the presence of the disease is sporadic low mortality. Sometimes egg production falls suddenly by 10-50%. The hens may be up to 25% over-weight. Some may have pale combs and appear to be unduly nervous. They are hyperlipaemic but the individual variation is so great that this abnormality can only be detected by examining large groups of hens in affected and normal flocks simultaneously.

Lesions

Death is due massive haemorrhage from the liver which is grossly enlarged, putty-coloured and very friable. Large amounts of fat are present in the adipose tissues in the abdominal cavity and around the viscera. This is usually yellow and almost liquid at room temperature. The mortality does not give a true indication of the incidence of the disease since a large proportion of the flock is affected subclinically. In livers of these birds there are long-standing haematomas, necrotic areas and frequently evidence of more recent minor haemorrhages.

The enlargement and abnormal colour of the liver is due to the presence of excessive amounts of fat. In birds the liver is mainly responsible for lipogenesis and the adipose tissue functions simply as a storage depot whereas in mammals the adipose tissue makes a major contribution to fat synthesis. The metabolic activity of the liver of the fowl is therefore extremely high especially during egg production when the amount of fat synthesized per year is almost equal to its body weight.

Histologically the hepatocytes can be seen to be grossly distended with fat globules which disorganize their internal structure and eventually rupture their membranes. The reticulin bands surrounding the cells disintegrate and degenerate. In some areas there is a breakdown of vascular integrity and evidence of secondary inflammation, necrosis and regeneration. Recent experimental work supports the theory that the haemorrhage results from the steatosis but the pathogenesis of the syndrome is still not completely understood.

Control

A reduction in the amount of food provided or an increase in its fibre content is recommended, especially in hot weather. Supplementation with vitamin E or selenium and yeast may be beneficial. Lipotropic agents such as choline and inositol usually have little effect.

Extra – Comments

Many chicken diseases affect the appearance, composition, and functioning of the liver. Before nutritional aspects are considered it is necessary to rule out abnormalities caused by other agents. Among these is the enlarged liver often seen in the leukosis complex due to massive lymphoid infiltration. Examination of the liver is a useful diagnostic aid.

The "fatty liver disease" is chiefly a problem in cage layer operations. Many factors contribute to the condition. Laying hens have a higher liver fat than non-laying hens. It has been observed that the average per cent of fat in the livers of laying hens was 40.3, on a dry-weight basis, while there was only 27.6 per cent of fat in the livers of non-laying hens. The feeding of higher energy diets increased the size and the percentage of fat in the livers.

Low protein diets, or diets with an amino acid imbalance, tend to cause fatty livers. Methionine may have a special role in the prevention of fatty infiltration of the liver. Choline, especially in combination with low protein diets, may be a factor in preventing fatty livers. However, experience does not indicate that choline deficiency per se causes fatty livers in chickens.

Poisoning with elemental phosphorus or carbon tetrachloride causes fatty degeneration of the liver. When fatty liver is caused by such agents the stored fat is relatively saturated and has a low iodine number. Removal of the pancreas also causes fatty livers.

Unusually low muscular activity seems to increase the incidence of fatty livers. This is believed to be the chief reason why the incidence is higher in caged layers than in layers kept on the floor.

One of the problems is to distinguish between a high, but normal, fat level in the liver and an abnormal condition in which liver function is impaired. One of the many functions of the liver is the systematic handling of fat. In contrast to mammals where the lymph system carries much of the fat, in the chicken the portal vein transports most of the fat to the liver. Estrogens are important in increasing the fat content of the liver to meet the demands for heavy egg production. The liver is also involved in the metabolism of fat, protein, and carbohydrates and in detoxification reactions as well as the formation of plasma proteins and phospholipids. A serious situation occurs when degeneration of the liver reaches the point where its ability to function is impaired, either due to fatty degeneration or to the development of nodular cirrhosis. Sometimes the liver becomes so soft that blood vessels break and hemorrhage occurs.

The cause of "fatty liver disease" is still unknown. A number of nutritional factors may be involved. The liptropic factors, such as choline, methionine, inositol, etc., have little effect on the incidence of severity of the condition. An excess of thiamine, pyridoxine, or biotin tends to increase the per cent of fat in the liver; but these are not believed to be causative factors in the syndrome seen in commercial laying flocks.

One recommendation is that 1,000 grams choline, 12 milligrams vitamin B_{12}, and 10,000 I.U. vitamin E be added per ton of feed. This treatment has seemed beneficial in some cases, and useless in others. Antibacterial agents (such as antibiotics and nitrofurans) have helped in some cases, and have not been helpful in other cases.

6- Fatty liver and kidney syndrome (FLKS)

This is a metabolic disorder with a complex aetiology involving a deficiency of biotin, other dietary factors and stress. It affects broiler and layer type chickens, usually at the age of 10-30 days, and tends to be associated with wheat-based diets with low protein and fat contents. Out- breaks are precipitated by an interruption in the food supply, handling, excessive noise, high or low temperatures and lighting failure. In another source it is mentioned that the disease is also known as “Fatty liver syndrome”.

Signs

The onset of the disease is sudden. Well grown chickens become lethargic and aphagic and may show signs of paralysis. Severely affected cases are frequently found lying on their sterna with their necks extended or on their sides with their heads bent over backwards. Such cases usually die within a few hours. The mortality is generally below 5% but sometimes reaches 30%. Typical signs of biotin deficiency (poor feather development, exudative dermatitis, “parrot” beak and skeletal abnormalities) are usually absent.

Lesions

Pale and enlarged liver and kidneys are characteristic of the disease. Sometimes there are small petechial hemorrhages on the margins of the liver. Adipose tissue is often pink due to congestion of small blood vessels. The heart is frequently pale and flabby and there may be excessive amounts of pericardial fluid. A blackish-brown fluid containing blood is often present in the crop and other parts of the digestive tract.

The pallor of the liver and kidneys is due to the presence of exessive amounts of fat (two to five times normal). This is mostly triglyceride with a high palmitoleic acid content. In the liver it accumulates in the intercellular spaces as well as in the hepatocytes but is not usually accompanied by disorganization of the cell contents or by degenerative or inflammatory changes. Large amounts of fats are deposited in the epithelial cells of the proximal convoluted tubules causing swelling of the tubules and compression of renal structures. There are degenerative lesions in the tubules and these, together with the very conspicuous amounts of fat, are diagnostic. Fatty infiltration is widespread but less marked in other tissues, including cardiac and skeletal muscle and the central nervous system.

Biochemical changes

Very little glycogen is present in the liver. Its biotin content is also very low (<0.35 ug/g) and there is a large reduction in the activity of pyruvate carboxylase. This enzyme contains four biotin molecules and four Mn atoms per molecule and controls the rate of gluconeogenesis from pyruvate.

Factors affecting the development of FLKS

The availability of biotin is low in certain dietary ingredients, particularly cereals (except maize) and meat and fish meals, and diets that induce FLKS are usually deficient in biotin to some extent even though analysis may indicate that the levels are adequate. Low reserves of biotin in the parent hens may be involved in some outbreaks or there may be antagonistic factors.

This situation may be aggravated by a low protein intake, which will limit the supply of amino acids for gluconeogenesis, and by a low intake of fat which may be expected to increase the competition for biotin from acetyl CoA carboxylase by permitting lipogenesis to proceed at a faster rate. If the food intake is reduced the meagre reserves of glycogen will be rapidly depleted and severe hypoglycaemia will result.

Death is probably due to severe hypoglycaemia (<150mg/100 ml plasma)and a lactate acidosis that follows a rise in pyruvate levels.

Several biochemical changes as well as a low fat intake seem to be responsible for the presence of excessive amounts of fat in the tissues. There is evidence that lipogenesis from pyruvate is increased by the large pool of this substance resulting from the reduction of gluconeogenesis. Furthermore the transport of lipids from the liver is impeded by inhibition of lipoprotein lipase and the mobilization of lipids from adipose tissue is increased in response to hypoglycaemia and stress. However, these disturbances do not appear to play an important part in the pathogenesis of FLKS.

Control

The disease can be almost completely prevented by adding biotin to the diet either as the pure chemical (up to 150 ug/kg) or as a rich sources such as molasses or yeast. An increase **in the fat and** protein content is also beneficial.

IV-Other Diseases Sometimes Related to Nutrition

Resistance to infectious disease:

As a general rule, a healthy animal is more resistant to infection. Beyond this generalization, it is difficult to cite specific examples. It has been shown, however, that high dietary levels of vitamin A reduce the mortality due to coccidiosis and enable the surviving chicks to make a faster recovery. High dietary vitamin K is also beneficial when the chicks have coccidiosis-probably by minimizing hemorrhage.

Very high levels of all vitamins were helpful in resistance to infection in studies by C. H. Hill and his associates at the North Carolina Experiment Station. On a theoretical basis, high protein diets should help to promote resistance. However, in some instances, high protein diets have made chickens more susceptible to infection.

Enteritis:

Inflammation of the intestine chiefly of the small intestine is frequently observed in chickens that are raised without access to the soil and green growing plants. On autopsy, the intestine is often found to be filled with bits of shavings, straw, or other material that had been used as litter; sometimes large quantities of grit are also found. Attempts to demonstrate that the enteritis is caused by a micro- organism or other causative agent have failed.

Paralysis:

As has been pointed out in preceding pages, a deficiency of vitamin E in the diet of the young growing chicken produces lesions in the brain; of pantothenic acid in the spinal cord; of riboflavin, in the main peripheral nerve trunks; of vitamin A, in the central and peripheral nervous systems. Moreover, a deficiency of thiamine produces a toxicosis. or poisoning, of the nervous system. Accordingly, a deficiency of one or more of these vitamins may produce paralysis or a similar condition.

Paralysis, presumably of nutritional origin, has been observed, however, when adequate quantities of all five of the vitamins just mentioned were supplied. In some instances the supplemental feeding of alfalfa, and in other instances the feeding of large quantities of dried brain, cartilage, wheat middlings, yellow corn, or wheat, prevented the development of the paralysis.

Dermatosis:

From time to time a dermatosis similar to that produced by a deficiency of pantothenic acid or a deficiency of biotin is observed in growing chicks that are receiving supposedly adequate diets. This condition often disappears if a complete change of diet is made, but is not cured by adding rich sources of pantothenic acid to the original diet.

Aortic rupture:

Occasionally, chickens may die from massive hemorrhage caused by rupture of the aorta. This condition is more frequent in turkeys than in chickens. Part of the problem stems from the very high blood pressure of the avian species. Anything which weakens the walls of the blood vessels poses a potential threat. It has been demonstrated that feeding beta amino propionitrile will cause aortic rupture.

Recent work has shown that a deficiency of copper will cause a weakening of the walls of the blood vessels. The condition can be caused by a toxic level of molybdenum in the diet. Copper has an antagonistic action against molybdenum, and may provide some protection against excessive molybdenum.

Feather Picking and Cannibalism

Cannibalism is a term used by some poultrymen in referring to the habit sometimes developed by chickens, other poultry, and game birds of picking one another's feathers, toes, beaks, heads, combs, backs, vents, and other parts of the body. Most poultry men, however, restrict the use of this term to cases in which blood is drawn. Inasmuch as there are many instances in which only the feathers are picked, or pulled, it is desirable to distinguish between feather picking and cannibalism.

Often the only result of feather picking is that some of the chickens lose many of their feathers, but cannibalism nearly always leads to heavy losses through death. In flocks of pullets just starting to lay, cannibalism generally follows a case of prolapses of the oviduct; in such cases a number of chickens may become disemboweled, and rather heavy losses may result. Cannibalism among chicks often appears first in the form of toe picking, back picking or wing picking; once established, it spreads rapidly through the flock.

Although there is evidence that feather picking and cannibalism are the result, in part, of unsatisfactory diets, there often are other contributing causes, such as overcrowding and overheating-especially in the case of chicks in battery brooders. The exact nature of the nutritional deficiency or deficiencies involved is not known but it has been found that feather picking and cannibalism are less likely to occur if the diet contains about 20 per cent of barley or oats or about 30 per cent of bran and middlings.

It has been reported by several poultry nutrition workers that feather picking and cannibalism may be controlled, by using ruby colored lights in place of ordinary lights in battery brooders and brooder houses. It also has been reported that if oats are fed as the sole grain in diets for growing and laying pullets, cannibalism is significantly reduced. It has been suggested that the effective part of the oats is the hulls. In any case there is evidence that feather picking and cannibalism are likely to appear if diets of very low fiber content are fed.

A fairly effective method of stopping feather picking and cannibalism is to increase the salt content of the diet for one or two days. If an all-mash diet is being fed, add 2 per cent of salt- but if both mash and grain are being fed, add 4 per cent of salt to the mash. Usually the feather picking or cannibalism stops within a few hours, but in some cases two days may be required. **It is not desirable to feed high salt diets for more than two days.**

An alternate form of the salt treatment is to place the extra salt in the drinking water. A suitable quantity is about one heaping table-spoonful per gallon of water. The salty water should not be kept before the chickens more than one-half day at a time; it is suggested that they be given the salty water in the morning and plain water in the afternoon often, a single half day is enough. If this form of the salt treatment is not effective after the third half day, there is no point in continuing it.

It should be noted that the salt treatment is suggested only as a curative treatment and not as a preventive measure. If the salt treatment is not effective after one to two days, it may be necessary to trim or sear back to the quick the upper mandible of the beaks of all the birds. The trimming may be done with a sharp knife, the searing with a hot soldering iron or an electric "de-beaker." When carefully done the trimming of the upper mandible is painless. Ordinarily, only about 3/16 of an inch of the tip of the beak is removed; the proper amount can be judged readily by the appearance of the beak substance.

Egg Eating

Egg eating is a vice that quickly develops when the chickens do not get enough calcium. The development of the vice appears to be greatly stimulated if there is overcrowding. Also, it has been observed that egg eating is likely to develop when the diet does not contain enough vitamin D.

Gizzard Erosion

Gizzard erosion is a disorder that has been observed in poultry for many years. It is characterized by erosion or necrosis of the gizzard lining, often with ulceration into the muscular gizzard wall. The entire lining of the gizzard may have a dry, scaly, brownish color rather than the normal greenish yellow color. The upper part of the small intestine may be ulcerated as well. The condition is related to dietary ingredients, particularly fish meal or grains contaminated with mycotoxins.

The gizzard erosion factor in fish meal has been identified by Japanese scientists as a dipeptidelike compound composed of histamine and lysine. This compound, called gizzerosine, is formed by a Maillard (browning) reaction when fish meal is heated. Gizzerosine induces an abnormally high secretion of hydrochloric acid in the proventriculus, apparently acting as an analog of histamine, which is the physiological regulator of gastric acid secretion. It is approximately ten times as potent as histamine in stimulating gastric acid secretion. Gizzerosine is metabolized much more slowly than histamine and has a higher affinity than histamine for gastric histamine receptors. A maximum concentration of 0.4 ppm gizzerosine in practical poultry diets is suggested. Higher levels cause retarded growth and mortality.

Mycotoxins also cause gizzard erosion. Some mycotoxins cause damage to the liver and bile duct, decreasing the normal secretion of bile. Bile is periodically regurgitated into the gizzard, neutralizing gastric acid. Absence of normal bile levels thus results in hyperacidity of the gizzard and mucosal damage. In addition, fish oils not adequately protected with antioxidants may cause gizzard erosion, probably due to peroxidation of membrane tissue.

Vitamin E protects against this damage. The synthetic antioxidant ethyoxyquin is also very effective in protecting against peroxide damage.

Ascites Disorders

Ascites is fluid accumulation in body cavities. Significant occurrence of abdominal ascites is noted in broilers in many countries. In most cases, ascites is associated with liver, heart, or lung damage. Fast-growing broilers are most susceptible; the mortality rate in affected flocks can be reduced by restricting feed to reduce growth rate. The problem may be that the extremely rapid rate of muscle growth in modern broilers outgrows the cardiovascular support systems. Another cause of ascites is high altitude, which intensify the condition because of the lower oxygen content of the air. Mycotoxins and other hepatotoxic agents increase susceptibility. Excess sodium in the feed or water also may cause ascites, as do poor-quality dietary fats containing oxidized fatty acids.

Heat Stress

Heat stress is a major problem in poultry production in the southern United States and in tropical countries. Dietary management may aid in minimizing the detrimental effects. Heat stress has various physiological effects; for example, increased respiration rate decreases the blood CO_2 level, which increases blood pH. The consequences of decreased blood CO_2 and elevated pH are not fully known. Increased weight gain in heat-stressed broilers given carbonated water or water supplemented with NH_4Cl and HCL has been noted. On the other hand, it was observed that addition of o.48 percent KCL to drinking water increased the growth rate of heat stressed broilers by 20 percent though the blood had an alkaline pH and blood CO_2 was depressed, indicating that factors other than blood CO_2 and pH arc involved.

Egg Production Disorders

With layers, maintenance of good egg shell quality can be a problem. The major concerns are with shell thickness and shell structure. It is desirable that egg shells not break during handling of eggs and that the shell resists penetration by microorganisms. Shells should be attractive in appearance that is not misshapen, bumpy, or blotchy. The shell is virtually 100 percent calcium carbonate. Thus adequate dietary levels of calcium arc essential for good shell

Quality; adequate vitamin D is necessary for calcium absorption and shell formation. Dietary zeolites improve egg shell quality presumably facilitating calcium utilization, whereas excesses of phosphorus and deficiencies of manganese can cause thin eggshells.

Besides calcium, a source of carbonate ion is needed to form the carbonate in the shell. The blood bicarbonate is the source of carbonate used in shell formation. Blood acid-base and electrolyte balance influence availability of carbonate ion. In hot weather, the respiration rate of birds increases markedly. This can so increase carbon dioxide loss that blood bicarbonate levels are too low to support proper egg shell formation. Providing a dietary source such as sodium bicarbonate, may be useful under these conditions. There is some evidence that feeding ascorbic acid may also improve egg shell quality under stress conditions.

Egg size is another important economic consideration for the poultry producer. Energy intake is a major nutritional determinant of egg size. Some feedstuffs, such as canola meal, may cause a reduction in egg size, probably due to a reduction in feed intake.

Egg size is affected by the lipid content and composition of the diet. Corn and corn oil in the diet stimulate production of maximum egg size, due to their content of linoleic acid. It was concluded that linoleic acid is necessary for the synthesis of lipoproteins in the liver that can be transported to the ovary for uptake by the developing ova. Egg size cannot be maximized if the amount of linoleic acid present is not adequate to support maximal lipoprotein synthesis.

Other Nutritional Problems

Urolithiasis in poultry is a syndrome characterized by mineralization of the kidney (kidney stones), resulting in acute uricemia (elevated blood uric acid), visceral gout. and mortality. The condition may be induced by excessive dietary calcium. Urinary acidification by feeding ammonium chloride may aid in reducing renal urolith formation. Dietary methionine hydroxy analog has also been shown to reduce calcium-induced kidney damage.

Mycotoxins can cause important losses in poultry production. Some of the important mycotoxins such as aflatoxin, zearalenone, trichothecenes, citrinin, and ochratoxin have been mentioned earlier. Moldy feed ingredients may impair performance even when mycotoxins are not detectable. Aflatoxins affect the immune system, increasing susceptibility to disease. Mycotoxins have a role in field hemorrhagic syndromes in which small hemorrhages may blemish the carcass. Aflatoxins can cause pale bird syndrome by impairing pigment absorption.

Formulation of poultry diets

The larger commercial feed companies, and the larger poultry producers who do their own mixing and formulations, generally rely on the services of a nutritionist and the use of a computer in formulating their own rations. Even though they are more time-consuming, and fewer factors can be considered simultaneously, a good job can be done in formulating rations by the hand method.

Today, the most up – to – date standards are those of NRC (1994). The experimental data are not available for all the concerned nutrients, eventually many entries are tentative or interpolated, and there are many blank spaces remain among minerals and vitamins. It must be recognized that requirements and allowances must be changed from time to time, as a result of new experimental findings.

Statements of NRC are not always directly applicable to poultry not kept in temperate zones, but modifications can be made especially when more information's becoming available from countries with extreme climates (the same with animals). The requirements have not been increased by a "margin of safety". The The margins of safety are due to the variable feed composition, inadequate mixing, improper processing, and unfavorable storage conditions which may reduce effective concentration of nutrients below those calculated to be present. In case of foods have to be transported long distances in hot climates, higher margins still of safety may be required to guard against almost total loss of vitamin value at normal levels of inclusion. The addition for a margin of safety to the stated requirements arrives at what is called nutritive "allowances" which is used in ration formulation. A chick needs 1500 IU vitamin A and 200 IU vitamin D as NRC recommends while premix 10,000 A and 1000 D.

Moreover, feeding standards tell nothing about the palatability, physical nature, or possible digestive disturbances of a ration. Neither do they give consideration to individual differences, management differences, and the effects of such stresses as weather, disease, parasitism, and surgery in animals or debeaking & caponizing in poultry. Thus, there are many variables that alter the nutrient needs and utilization of animals and birds-variables that are difficult to include quantitatively in feeding standards, even when feed quality is well known.

The requirements stated in NRC are the minimum so in formulating diets, it is wise to increase the level of nutrients by about 10%. As an example a diet with 20% CP can be formulated to contain 22% in case of low cost protein sources. In case of high cost protein feeds, the minimum needs are followed at the C/P ratio stated. The NRC tables of chickens and other poultry expressed the requirements in 7 main items; ME, CP, fat, macrominerals, microminerals, fat-soluble vitamins, and water soluble ones. In total the required nutrients are 42 in number, 15 for CP and AAs, 1 for fat, 12 for minerals and 13 for vitamins, in addition to energy (ME).

In tabulating the list of requirements there is no need to include the nutrients covered by the diet ingredients or premixes. Eventually in diet formulation the more critical needs ME, CP, Met + Cys, Met, Lys, Ca, av.P are considered with the inclusion of 0.5% salt (NaCl) and vitamin-mineral premix, in addition to additives needed to be added. In the following table the nutrients needed to be satisfied when formulating poultry rations are listed, the figures of NRC could be approximated and rounded to be grouped in rules of thumb easy to keep in mind.

Diet formulation is a topic that should be mastered to some degree by anyone concerned with feeding livestock or poultry. Some of commercial animals and the vast majority of poultry are produced in large units, and controlled environment, wherein the maximum science and technology should be applied and density of nutrients in ration is increased to compensate for the lowered feed consumption. Therefore different types of rations may be needed.

Table 5 Nutrient requirements of the different species of poultry (NRC, 1994)*

Weeks	Kcal ME/ Kg Diet	Protein and AAs					Ca	Av. P	Na		C/P ratio approximated
		CP	Lys	Met & Cys	Met						
Chickens											
Broiler											
1d – 3	3200	23	1.1	0.9	0.5		1.0	0.45	0.20		140
3 – 6	"	20	1.0	0.72	0.38		0.9	0.35	0.15		160
6 – 8	"	18	0.85	0.60	0.32		0.8	0.30	0.12		180
White egg – laying strains (immature)											
1d – 6	2900	18	0.85	0.62	0.30		0.9	0.4	0.15		160
6 – 12	"	16	0.60	0.52	0.25		0.8	0.35	"		180
12 – 18	"	15	0.45	0.42	0.20		"	0.30	"		195
18–1st egg (5% production)	"	17	0.52	0.47	0.22		2.0	0.32	"		170
Layers	"	15	0.69	0.58	0.30		3.25	0.25	"		195
Turkeys											
Growing											
1d – 4	2800	28	1.6	1.05	0.55		1.2	0.60	0.17		100
4 – 8	2900	26	1.5	0.95	0.45		1.0	0.50	0.15		110
8 – 12♂ **8 – 11♀**	3000	22	1.3	0.80	0.40		0.85	0.42	0.12		140
12 – 16 **11 – 14**	3100	19	1.0	0.65	0.35		0.75	0.38	"		160
16 – 20 **14 – 17**	3200	16.5	0.8	0.55	0.25		0.65	0.32	"		195
20 – 24 **17 – 20**	3300	14	0.65	0.45	0.25		0.55	0.28	"		240
Breeding											
Holding	2900	12	0.5	0.4	0.2		0.50	0.25	"		240

Laying	"	14	0.6	"	"		2.25	0.35	"		210
Geese											
1d – 4	2900	20	1.0	0.60	-		0.65	0.30	-		145
After 4	3000	15	0.85	0.50	-		0.60	"	-		200
Breeding	2900	15	0.60	0.50	-		2.25	"	-		195
Ducks											
1d – 2	2900	22	0.90	0.70	0.40		0.65	0.40	0.15		130
2 – 7	3000	16	0.65	0.55	0.30		0.60	0.30	"		190
Breeding	2900	15	0.60	0.50	0.27		2.75	-	"		195
Japanese Quail											
Starting & growing	2900	24	1.3	0.75	0.50		0.8	0.30	0.15		121
Breeding	2900	20	1.0	0.70	0.45		2.5	0.35	"		145
Bob white Quail											
0 – 6	2800	26	-	1.0	-		0.65	0.45	0.15		108
After 6	2800	20	-	0.75	-		0.65	0.30	"		140
Breeding	2800	24	-	0.90	-		2.4	0.70	"		117
Ring – Necked Pheasants											
0 – 4	2800	28	1.5	1.0	-		1	0.55	-		100
4 – 8	"	24	1.4	0.93	-		0.85	0.50	-		120
9 – 17	2700	18	0.8	0.6	-		0.53	0.45	-		150
Breeding	2800	15	0.68	0.6	-		2.5	0.40	-		190

* Expressed as percentages or units per kilogram of diet.

Note:

- For values not listed in quails and pheasants see requirements for turkeys.
- ME = metabolizable energy, CP = crude protein, Lys = lysine, Met = methionine, Cys = cystine, Av. P = available phosphorus, C/P ratio= calorie/ protein ratio, d = day.
- The vitamins and rest of mineral elements are supplied by feed ingredients and added premix. As Na is needed at a percentage of 0.12 – 0.20 and as NaCl contains 39% Na so 0.31 to 0.51% salt is needed and it can be considered as an "allover" percentage 0.5% in all diets. If an animal protein source is used its salt content should be considered. The 17 AAs mentioned in NRC tables are satisfied by different diet ingredients, except Met and Lys which are available in the market at a commercial price. The percentage of the commercial AAs added differs according to the content of diet feeds.
- Linoleic acid is supplied by corn, the main source of diet energy.
- No K or Mg are needed to be supplemented.
- The need of the bird for ME is expressed by Kcal / kg diet and the need of the protein by the amount in 100 units diet (in percentage). Energy is used as the basis to which the rest of nutrients are related. If for example a diet is formulated to contain 80% of the optimal ME density, the rest of the nutrients should be decreased in its concentration to the same percentage. If the density of ME is increased to 120% the concentration of the nutrients is also increased. As protein is one of the main nutrients and highly expensive so the C/P ratio stated should be strictly followed in calculating CP%.
- The bird decreases its feed intake when energy density increased, but as the regulation is not precise, so the optimal ME density in NRC tables should be followed (or in the breed catalogue).
- C/P ratio = Amount of energy (ME) in Kcal in 1 kg diet ÷ CP percentage.
  Example = 3200 ÷ 20 = 160

- ME is in Kcal/ kg diet, other nutrients are in percentage except Mg and trace elements in mg/ kg and also the water-soluble vitamins. Fat-soluble vitamins are in international units per kg.

Requirement rules of thumb

1. In immature bird the phases are 3 in number in chickens (each of 3 weeks in broilers and 6 weeks in layers) 6 in turkeys (4 weeks each in male and 3 in female) and 2 in geese and ducks (4 weeks and after 4 weeks in geese, and 2 weeks and 5 in ducks).
2. The ME in immature phases is 3200 in broiler chickens and 2900 in layers; 2800 to 3300 in turkeys (with 100 Kcal increase per each phase); and 2900 and 3000 in geese and ducks. So the ME ranges from 2800 to 3300 in all diets.
3. The ME density is 2900 in prelaying and laying phases in chickens, holding and breeding in turkeys, and breeding in geese and ducks.
4. The starter phase is 3 weeks in broiler chickens, 6 in layers, 4 in turkeys and geese and 2 in ducks. The CP% is 23, 18, 28, 20 and 22 respectively. The CP decreases on the average by 2 units in each phase in broilers, 1.5 in layers, 2.5 in turkeys, 5 in geese and 6 in ducks.
5. In holding ration in turkeys the CP% is 12, while in laying and breeding rations in all species it is 15%. In chickens the prelayer diet contains 17% CP.
6. Ca is 1 – 1.25% in all phases and all species except the following:

Species	Immature	Holding	Laying
Chickens	**Prelaying 2.0**	**-**	**3.25**
Turkeys	**12 or 11 to 24 or 20 wk 0.75**	**0.5**	**2.25**
Geese	**0.75**	**-**	**"**
Ducks	**"**	**-**	**2.75**
Quail	**0.65 – 0.8**	**-**	**2.5**

7. P % is 0.3 to 0.45 in all species and all phases except in turkeys where the requirement started with 0.6 in the first phase and decreases gradually to 0.25 in holding and increases again to 0.35 in laying.
8. Turkeys can be fattened and marketed at 10 weeks for light breeds, 14 for medium, and 21 in males and 16 in females in heavy breeds. In light breeds phases are 4, 3 & 3 weeks, in medium 4, 6 & 4 and in heavy 4, 4, 6 & 7 (♂) and 4, 4, 6 & 2 (♀). The protein in light breeds is 28, 22, 18 – medium 26, 20, 16 – and heavy 26, 20, 18 & 15.
9. Chickens start laying at 21 weeks; turkeys 32; ducks 24; and geese at 96 and can continue laying for as long as 10 years.
10. In ration formulation the diet needs considered are 8 in number; ME, CP, Lys, Met + Cys, Met, Ca, av. P, and Na. Addition of vitamin and mineral premix should be always kept in mind.

Poultry requirements rules

	No. of phases	**Phase in weeks**	**Total in weeks**	**ME Kcal/ kg**	**CP%**
Growing birds					
Fowls					
• **Broilers**	3	3	8 – 9	3200	23 minus 2.5/ 3 wk
• **Layers**	"	6	18	2900	18 minus 1.5/ 6 wk

Turkeys					
• **Males**	6	4	24	2800 to 3300 (+ 100/ phase)	28 minus 2.25/ 4 wk
• **Females**	"	4 & 3	20	"	"
Geese	2	4 & > 4	9 – 10	2900 & 3000	20 & 15
Ducks	"	2 & 5	7	" "	22 & 16
Breeding and laying					
Fowls					
Prelaying	1	3	3	2900	17
Laying	"	52	52	"	15
Turkeys					
Holding	"	8	8	"	12
Breeding	"	24	24	"	15
Geese	"	Up to 10 years		"	"
Ducks	"	48 weeks		"	"

Semiextensive tables for nutrient content of feeds

The nutrient content of the commonly used feeds in formulating poultry diets is displayed in the following table. But to ease the calculation procedures, semiextensive tables for the nutrient content of different amounts of feeds and supplements are designed to be ready for use.

Table 6 Feed composition (figures are approximated and rounded)*

ingredient	**ME Kcal/kg**	**CP %**	**Met + Cys %**	**Met %**	**Lys %**	**Ca %**	**Av. P %**	**Total P %**
Corn	3330	9	0.36	0.18	0.26	-	0.08	0.28
SBM	2330	44	1.28	0.62	2.69	-	0.27	0.65
FM	3000	72	3.6	2.16	5.50	2.33	1.70	
Bran	1300	14	0.50	0.21	0.55	-	0.20	1.15
Fat	8500	-	-	-	-	-	-	
Di Ca-P	-	-	-	-	-	22	18	
Mono Ca-P	-	-	-	-	-	16	20	
LS	-	-	-	-	-	35	-	
Rice polish	3060	12.2	0.32	0.22	0.57	-	0.14	1.31
Sorghums	3288	8.8	0.33	0.16	0.21	-	-	0.3

* The figures are approximated to ease calculations, and corn, SBM and bran are considered to contain no Ca.

Corn

Corn	**CP**	**Met + Cys**	**Met**	**Lys**
35	**3.15**	**0.126**	**0.063**	**0.091**
40	**3.60**	**0.144**	**0.072**	**0.104**
45	**4.05**	**0.162**	**0.081**	**0.117**

50	**4.50**	**0.180**	**0.090**	**0.130**
55	**4.95**	**0.198**	**0.099**	**0.143**
60	**5.40**	**0.216**	**0.108**	**0.156**
65	**5.85**	**0.234**	**0.117**	**0.169**
70	**6.30**	**0.252**	**0.126**	**0.182**
75	**6.75**	**0.270**	**0.135**	**0.195**
80	**7.2**	**0.288**	**0.144**	**0.208**

One unit corn contains 0.09 CP, 0.0036 Met + Cys, 0.0018 Met & 0.0026 Lys.

Soybean meal

Soybean meal	CP	Met + Cys	Met	Lys
20	**8.8**	**0.256**	**0.124**	**0.538**
25	**11.0**	**0.320**	**0.155**	**0.673**
30	**13.2**	**0.384**	**0.186**	**0.807**
35	**15.4**	**0.448**	**0.217**	**0.942**
40	**17.6**	**0.512**	**0.248**	**1.076**
45	**19.8**	**0.576**	**0.279**	**1.210**
50	**22.0**	**0.640**	**0.310**	**1.345**
55	**24.2**	**0.704**	**0.341**	**1.479**
60	**26.4**	**0.768**	**0.372**	**1.614**

One unit SBM contains 0.44 CP, 0.0128 Met + Cys, 0.0062 Met & 0.0269 Lys.

Bran

Bran	CP	Met + Cys	Met	Lys
2	**0.28**	**0.010**	**0.0042**	**0.11**
4	**0.56**	**0.020**	**0.0084**	**0.22**
6	**0.84**	**0.030**	**0.0126**	**0.33**
8	**1.12**	**0.040**	**0.0168**	**0.44**
10	**1.40**	**0.050**	**0.0210**	**0.55**
12	**1.68**	**0.060**	**0.0252**	**0.66**
14	**1.96**	**0.070**	**0.0294**	**0.77**
16	**2.24**	**0.080**	**0.0336**	**0.88**
18	**2.52**	**0.090**	**0.0378**	**0.99**
20	**2.80**	**0.100**	**0.0420**	**1.10**

One unit bran contains 0.14 CP, 0.005 Met + Cys, 0.0021 Met & 0.0055 Lys.

Dicalcium phosphate

Av. P	Salt	Ca
0.20	1.11	**0.244**
0.22	1.22	**0.268**
0.24	1.33	**0.293**
0.26	1.44	**0.317**
0.28	1.56	**0.343**
0.30	1.67	**0.367**

Av. P	Salt	Ca
0.46	2.56	**0.563**
0.48	2.67	**0.587**
0.50	2.78	**0.612**
0.52	2.89	**0.636**
0.54	3.00	**0.660**
0.56	3.11	**0.684**

0.32	1.78	**0.392**	**0.58**	3.22	**0.708**
0.34	1.89	**0.416**	**0.60**	3.33	**0.733**
0.36	2.00	**0.440**	**0.62**	3.44	**0.757**
0.38	2.11	**0.464**	**0.64**	3.56	**0.783**
040	2.22	**0.488**	**0.66**	3.67	**0.807**
0.42	2.33	**0.513**	**0.68**	3.78	**0.832**
0.44	2.44	**0.537**	**0.70**	3.89	**0.856**

One unit salt contains 0.18 av.P and 0.22 Ca.

Salt (NaCl)

Na	Salt	Na	Salt
0.10	**0.256**	**0.18**	**0.462**
0.11	**0.282**	**0.19**	**0.487**
0.12	**0.308**	**0.20**	**0.513**
0.13	**0.333**	**0.21**	**0.538**
0.14	**0.359**	**0.22**	**0.564**
0.15	**0.385**	**0.23**	**0.590**
0.16	**0.410**	**0.24**	**0.615**
0.17	**0.436**	**0.25**	**0.641**

One unit salt contains 0.39Na.

Limestone (LS)

Ca	LS	Ca	LS	Ca	LS
0.1	**0.29**	**1.6**	**4.57**	**3.1**	**8.86**
0.2	**0.57**	**1.7**	**4.86**	**3.2**	**9.14**
0.3	**0.86**	**1.8**	**5.14**	**3.3**	**9.43**
0.4	**1.14**	**1.9**	**5.43**	**3.4**	**9.71**
0.5	**1.43**	**2.0**	**5.71**	**3.5**	**10.00**
0.6	**1.71**	**2.1**	**6.00**	**3.6**	**10.29**
0.7	**2.00**	**2.2**	**6.29**	**3.7**	**10.57**
0.8	**2.29**	**2.3**	**6.57**	**3.8**	**10.86**
0.9	**2.57**	**2.4**	**6.86**	**3.9**	**11.14**
1.0	**2.86**	**2.5**	**7.14**	**4.0**	**11.43**
1.1	**3.14**	**2.6**	**7.43**	**4.1**	**11.71**
1.2	**3.43**	**2.7**	**7.71**	**4.2**	**12.00**
1.3	**3.71**	**2.8**	**8.00**	**4.3**	**12.29**
1.4	**4.00**	**2.9**	**8.29**	**4.4**	**12.57**
1.5	**4.29**	**3.0**	**8.57**	**4.5**	**12.86**

The process of ration formulation by hand

The process leads to empirical, rather than a "least cost" formula being prepared. The task may be simplified by using a protein-vitamin –and- trace mineral concentrate, thus reducing task of formulation to the best combination of cereals and perhaps of one vegetable protein rich ingredient.

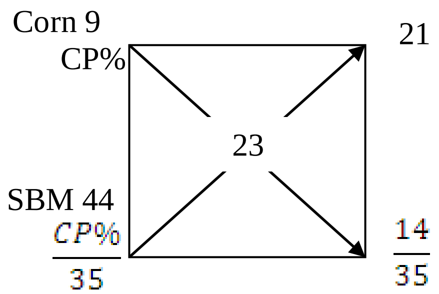
There are two main methods (mathematical or algebraic and Pearson's square) of balancing diets for one or two nutrients using two or more ingredients, in addition, in some times, to using ingredients at fixed levels. If we want to add more nutrients, we will require more than three squares and will be tedious to formulate by hand.

I- Pearson's square method

Some individuals prefer to formulate simple diet using the square method. The amounts of the ingredients are the unknowns. As mentioned there are two main methods, algebraic and Pearson's square to solve formulation problems. In the square method, diet is balanced for one nutrient, or in double square method for two nutrients using two or more ingredients respectively.

How to use the square?

Place the desired percentage of protein in the centre of the square. Place the percentage of protein in each of the two main feeds corn and SBM at the left hand corners of the square (refer to the composition table). Subtract diagonally the smaller percentage from the larger one and place the answer in the right-hand corners of the square. The figures on the right hand corners are called parts. The parts can be totaled and the individual parts are changed to percentage (individual parts ÷ total parts × 100). The following is an example.



Percentage of corn 21 ÷ 35 × 100 = 60

Percentage of SBM 14 ÷ 35 × 100 = 40

An example for ration formulation

Suppose we need to formulate a starter chicken broiler diet having a characteristic of 23% CP, 1.1% lysine, 0.9% Met + Cys, 0.5% Met, 1% Ca, 0.45% P and 0.2% Na. The ingredients nominated to be used are corn, SBM, wheat bran, fat – and for supplements dicalcium phosphate, limestone, salt, vitamin – mineral premix, Met and Lys amino acids. In spite of being logical to start with the square and CP, some problems should be first solved. The problems are:

1. Neutralizing the diluting effect of the supplements on ME and CP.
2. The amount of ME and CP in the corn/ SBM mixture.
3. Correcting the C/P ratio if no fat is added or increasing or decreasing the ME and CP using fat and wheat bran.

The first step is to calculate the needed supplements.

- Supplements

Na: 0.2 ÷ 0.39 = 0.51 salt (NaCl)

P: 0.45 ÷ 0.18 = 2.5 dicalcium phosphate

(The small amounts of av. P in feeds are not considered)

Ca in dicalcium phosphate = 2.5 × 0.22 = 0.55

The balance of calcium needed = 1.0 – 0.55 = 0.45

Amount of LS for Ca needed = 0.45 ÷ 0.35 = 1.29

Total supplements = 0.51 + 2.5 + 1.29 = 4.30

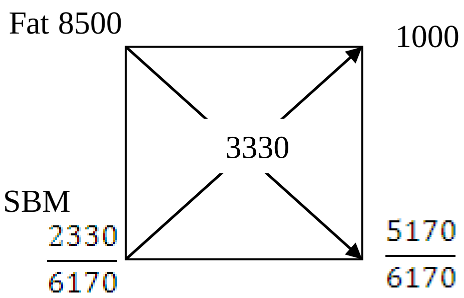
Corrected CP = 23 ÷ (100 - 4.30) × 100 = 24.033

Corrected ME = 3200 ÷ (100 – 4.30) × 100 = 3343.78

The correction can also be performed by multiplying both of the figures on the left hand corners by the balance of 100 (100 – 4.30 = 95.70).

- The square is then used to make a mixture of corn and SBM satisfying the CP (24.033) then the ME of the mixture is calculated and corrected by substituting a mixture of fat and SBM in place of corn. Generally the mixtures for correction are one of two as follows:

a- Increasing the protein content of the mixture using a mixture of fat and SBM mixed at the ME of corn, when the diet is first balanced for the corrected ME.



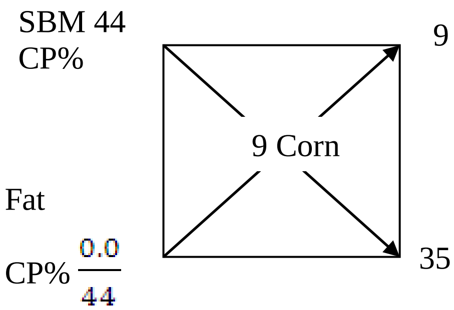
Fat % = 1000 ÷ 6170 × 100 = 16.21 **I**

SBM% = 570 ÷ 6170 × 100 = 83.79

CP of the mixture = 36.87

Every addition of one unit of the mixture in place of corn will increase CP by 0.2787 or roundly 0.28.

b- Increasing the ME content using a mixture of fat and SBM mixed at the CP% of corn, when the diet is first balanced for the corrected CP.



SBM % = 9 ÷ 44 × 100 = 20.45 **II**

Fat% = 35 ÷ 44 × 100 = 79.55

ME of the mixture = 7238.24/ Kg

Every addition of one unit of the mixture in place of corn increases ME by 39.08 or roundly 39.

The mixture satisfying the CP (24.033% or 24.0) is:

Corn 9 — 20 or 57.14% (In 100 units) × 0.957 = 54.68 corn (In 95.7 units)

24

SBM $\frac{44}{35}$ — 15 or 42.86 % × 0.957 = 41.02 SBM

- The ME content of the mixture 1820.84 for corn plus 955.77 for SBM with a total of 2776.61, so the ME is needed to be increased by SBM/ fat mixture (I) in place of corn.

  3200 – 2776.61 ÷ 39 = 10.86 (2.22 SBM and 8.64 fat).

  ∴ The diet is composed of the following main ingredients

  Corn 54.68 – 10.86 = 43.82

  SBM 41.02 + 2.22 = 43.24

  Fat 8.64

  95.70

- The content for Met + Cys = (43.82× 0.36 ÷ 100) + (43.24 × 1.28 ÷ 100) = 0.158 + 0.556 = 0.714 and containing (43.68 × 0.18 ÷ 100) + (43.24 × 0.62 ÷ 100) = 0.347 methionine.

  On the basis of Met + Cys calculation it is needed to be supplemented by 0.186 Met (the need is 0.9) and on the basis of Met calculation needs only (0.5 – 0.347) 0.153 so the supplement will be the higher figure 0.188.

- The content for lysine = (43.68 × 0.26 ÷ 100) + (43.24 × 2.69 ÷ 100) = 0.114 + 1.166 = 1.28

So there is no need for lysine addition as the need is only 1.1%.

∴ Salt is 0.51%, dicalcium phosphate 2.5%, LS 1.29% and per ton Met 1.86, Lys 0.0, and premix for vitamins and minerals.

II- Double square method

In many situations we need to have exact amounts of two major nutrients, such as CP and energy. We can accomplish this by going through three squares as shown below.

Suppose we need to formulate a starter diet with 23% CP and 3200 ME. Supplements are calculated as before and CP is corrected to 24% and ME to 3344.

Mixture I

Corn 9 — 20

24

SBM 44 — 15

Corn 57.14%
SBM 42.86%
ME 1903 + 997 = 2900

Mixture II

SBM 44		24
	24	
Fat 0.0		20

SBM 54.55
Fat 45.45
ME 1271+ 3863 = 5134

Mixture III

Mix I 2900		1790
Mix II	3344	
<u>5134</u>		<u>444</u>
2234		2234

Mix I	80.13	Corn 45.79	
		SBM 34.34	45.18
Mix II	19.87	SBM 10.84	
		Fat 9.04	

∴ The end mixture is composed of 45.79 corn, 45.18 SBM and 9.03 fat, each is multiplied by o.957 to be 43.82 for corn and 43.24 for SBM, and 8.64 for fat (the same result).

III- Trial – and – error/ square method

In the trial – and – error method the feeds are interchanged until the right combination is found. This is a time – consuming process. In a new method the square method is tried several times, on trial – and – error basis, till the proper combination of corn and SBM having the correct C/P ratio, or nearby, is achieved.

Corn 9	24		25		26	
SBM 44		15		16		17

SBM %	42.9	45.7	48.6
ME of mix	2901	2873	2844
C/P ratio	120.9	114.9	109.4

9	21		22		23	
44		12		13		14

SBM %	34.3	37.1	40
ME of mix	2987	2959	2930
C/P ratio	142.2	134.5	127.4

The C/P ratio 141.8 approximates that of NRC, so the diet will be composed of:

Corn (100 – 34.43) × 0.957 = 62.75 ⎤ 20.15 CP

SBM 34.43 × 0.957 = 32.95 ⎦ 2857.3 ME

Salt is 0.51, dicalcium phosphate 2.50, LS 1.29, and per ton 2.52 Met, 0.51 Lys, and vitamin/ mineral premix.

This gives diets having nearly the same C/P ratio, but not having the optimal level of CP and ME and so free of fat.

How Methionine is calculated?

- Met + Cys in corn = 0.36 × 0.6275 = 0.2259
  SBM= 1.28 × 0.3295 = <u>0.4218</u>
  0.6477

  ∴ Needs = 0.9 – 0.6477 = 0.2523
- Met in corn = 0.18 × 0.6275 = 0.113
  SBM= 0.62 × 0.3295 = <u>0.204</u>
  0.317

  ∴ Met needed is 0.5 – 0.317 = 0.183
- ∴ Met is added according to the higher figure 2.52 per ton and not 1.83

The proportions can be also corrected using another method:

In another way the ingredients with the supplements are totaled and corrected as follows:

Corn	65.57 ÷ 104.3 × 100 =	62.87
SBM	34.43 ÷ 104.3 × 100 =	33.01
DiCa P	2.5 ÷ 104.3 × 100 =	2.4
LS	1.29 ÷ 104.3 × 100 =	1.24
Salt	0.51 ÷ 104.3 × 100 =	<u>0.49</u>
Total		100.01

The 0.01 in the total is due to approximation of figures to only two decimals.

Introduction of fish meal in the diet formulation

In introducing FM, a certain percentage is designed to be added and after correcting the ME and CP for the amount the FM shares by, the amount of FM is added to the supplements and the balance of ME and CP is only considered. Or FM added by means of substitution as follows:

0.41 FM + 0.59 corn = 0.80 SBM + 0.16 fat + 0.04 di Ca P

∴ for every 1 FM add 1.45 corn, and remove 1.95 SBM, 0.40 fat and 0.1 di Ca P, on percent – basis. For one unit FM percent added remove 0.003 LS, and replace it by corn, and from each ton 0.12 kg Met and 0.06 Lys.

IV- Trial and error method

Feeds are interchanged by trial - and - error until the right combination is found. This is a time - consuming process. A Knowledge about the approximate amounts of the different ingredients is the basis for starting formulation.

V- Simultaneous equations method or algebraic solution

a- To formulate rations involving two sources or unknowns (X+Y) and one nutrient (for e.g. protein % where X = amount of corn in the mixture and Y = amount of SBM).

Equations will be X + Y = 100 parts (dummy equation) and X x its CP% (0.09) + Y x its CP % (0.44) = CP % (20) of mixture needed (original equation).

To solve this problem, it is necessary to multiply the dummy equation by a unit that will allow one of the unknowns in the second equation to factor out. Thus if we multiply by 0.09 we have 0.09 X + 0.09 Y = 9. The problem is then solved as shown:

Unknown or original equation $0.09\,X + 0.44\,Y = 20$
Subtract from it $0.09\,X + 0.09\,Y = 9$
and the answer is $0.35\,Y = 11$
So one can compute $Y = 11 \div 0.35 = 31.43$
and thus $X = 100 - 31.43 = 68.57$
The answer, obviously, is the same as with Pearson's square.

b - To formulate rations involving two sources (X & Y) and two nutrients (a & b)

$(a_1)\,X + (a_2)\,Y$ = Amount of the nutrient needed (a) in a certain amount of mixture.
$(b_1)\,X + (b2)\,Y$ = Amount of the nutrient (b) in the same amount of the mixture.

The Simultaneous equations can be solved by multiplying the free factor of one by the other or divide the elements of each equation by its first factor, in order to cancel one of the two unknowns (X& Y) in the two equations together ,

In this algebra method we can arrive at a solution for two nutrients with only two feeds (sometimes), but the answer will be in weight units rather than percent.

VI- The 2 × 2 matrix method

$a_1\,X + b_1\,Y = C_1$

$a_2\,X + b_2\,Y = C_2$

$$X = \frac{\begin{matrix} C_1 & b_1 \\ C_2 & b_2 \end{matrix}}{\begin{matrix} a_1 & b_1 \\ a_2 & b_2 \end{matrix}} \quad \text{or} \quad \frac{(C_1\ b_2\ -\ C_2\ b_1)}{(a_1\ b_2\ -\ a_2\ b_1)}$$

$$Y = \frac{\begin{matrix} a_1 & C_1 \\ a_2 & C_2 \end{matrix}}{\begin{matrix} a_1 & b_1 \\ a_2 & b_2 \end{matrix}} \quad \text{or} \quad \frac{(a_1\ C_2\ -\ a_2\ C_1)}{(a_1\ b_2\ -\ a_2\ b_1)}$$

It is a matter of solving the same simultaneous equations in a different way.

VII- Calorie/ Protein ratio suggested method

In our opinion the "simultaneous equations" method is not suitable for formulating poultry diets as it gives the corn and SBM in weight units and it should be transformed to percentage changing the amounts of the given ME & CP calculated. Another method is suggested (unpublished) in which the proportions of corn and SBM are calculated for different calorie/ protein ratios basing on ME and CP and using an unpublished suggested equation.

Calorie / protein ratio equation

C/P ratio = Amount of ME in 1 Kg feed or diet expressed in Kcal ÷ CP expressed in percentage

If mixture is composed of corn and SBM, 60 and 40% respectively, the C/P ratio will be $\frac{(3330\times0.6)+(2330\times0.4)}{(9\times0.6)+(44\times0.4)}$ = (1998 + 932) ÷ (5.4 + 17.6) = 2930 ÷ 23 = 127.39

The C/P ratio for corn is 3330 ÷ 9 = 370, and so replacing one unit of SBM in a mix of 100% corn and the C/P ratio will be equal:

(3330 – $\frac{1000}{100}$ (ME difference between corn and SBM) ÷ (9 + $\frac{35}{100}$ (CP difference between corn and SBM) = 355.08

Considering corn proportion is "X" and its energy is "A" and CP is "B", while SBM proportion is "Y", energy is "a" and CP is "b".

So C/P ratio = (A – $\frac{A-a}{100}$ Y) ÷ (B + $\frac{b-B}{100}$ Y) =

(3330 – 10 Y) ÷ (9 + 0.35 Y)

So (355.08 × 9) + (355.08 × 0.35 Y) = 3330 – 10 Y

3195.72 + 124.278 Y = 3330 – 10 Y

∴ 134.28 = 134.278 Y

∴ Y= 1 and X = 100 – 1 = 99

Using these equations the proportions of corn and SBM could be determined for all the C/P ratios of poultry diets as follows:

Table 7 Corn/ SBM mixtures of certain calorie – protein ratios

C/P ratio	Ingredient Corn	proportion SBM	CP%	Met + Cys%	Met%	Lys%
100	46	54	27.90	0.867	0.418	1.562
110	51.75	48.25	25.89	0.816	0.394	1.423
120	56.73	43.27	24.14	0.771	0.373	1.303
130	61.08	38.92	22.62	0.732	0.354	1.198
140	64.92	35.08	21.28	0.698	0.338	1.106
150	68.32	31.68	20.09	0.667	0.323	1.023
160	71.36	28.64	19.02	0.640	0.310	0.950
170	74.10	25.90	18.06	0.615	0.298	0.884
180	76.58	23.42	17.20	0.593	0.288	0.824
190	78.82	21.18	16.41	0.573	0.278	0.770

200	80.88	19.12	15.69	0.555	0.270	0.720
210	82.75	17.25	15.04	0.538	0.261	0.675
220	84.48	15.52	14.43	0.522	0.254	0.633
230	86.08	13.92	13.87	0.508	0.247	0.595
240	87.55	12.45	13.36	0.495	0.241	0.559
250	88.92	11.08	12.88	0.483	0.235	0.526
260	90.20	9.80	12.43	0.471	0.230	0.495
270	91.39	8.61	12.01	0.461	0.225	0.467
280	92.50	7.50	11.63	0.451	0.220	0.440

The corn and SBM can be corrected and fat added to satisfy a certain amount of CP and ME, using the mixtures previously mentioned. The amounts of the different ingredients are corrected considering the total of the supplements added; in the previous example the amounts are multiplied by 0.957.

The ingredient proportion and CP and AA content in the different C/P mixtures can be expressed in the form of thumb rules to be easy to be kept in mind, as in the following table.

Table 8 Thumb ruling for corn-SBM mixtures and its content of CP & AAs

C/P ratio	Differ-ence	Corn	SBM	CP	Met+Cys	Met	Lys
100		46	54	28	0.87	0.42	1.5
							0
							10
							10
							25/10

Example

We need a mixture of 3343.78 ME and 24.033 CP% and having a C/P ratio of 139.13

The difference from 100 C/P = 39.13

∴ Corn proportion = $46 + (\frac{39.13}{10} \times 5) = 65.565$

SBM proportion= $54 - (\frac{39.13}{10} \times 5) = 34.435$

or considered to be the balance of 100 = 100 – 65.565 = 34.435

CP % = $28 - (\frac{39.13}{10} \times 1.75) = 21.152$

Met & Cys % = $0.87 - (\frac{39.13}{10} \times 0.04) = 0.713$

Met and Lys are calculated the same.

The ME and CP are increased using SBM/fat mixture, and after consideration of the amounts of supplements.

The process of ration formulation using the computer:

1. It is the electronic feed formulation and sophisticated but nothing magical or mysterious.
2. Computers can alleviate many human errors in calculations, but data come out are no better than those which go into it.
3. The people back of the computer-the producer-and the nutritionist who prepare the data and who evaluate and apply the results, become more important than ever.
4. The computer knows nothing about-palatability, disease prevention, limitations imposed on certain feeds and others.
5. Is of most use where a wide selection of feed ingredients is available and / or prices shift rather rapidly.

6. The information needed is exactly the same as in the hand method, requirements, content of feeds, costs, limitations.
7. Computer gives the least - cost rations and its efficiency depends upon how the information's fed are so precise.
8. Computer gives formulation in a matter of minutes.
9. The rations formulated should be reviewed at frequent intervals for availability of feeds, prices or chemical composition. Also restrictions should be validated.

The following are, in general, the steps which should be taken in an orderly fashion in order to formulate economical ration, for poultry without using computer:

1. Find and list the nutrient requirements and/ or allowances for the particular poultry going to be fed.
2. Choose the most nutritious and cheap protein concentrate available.
3. Calculate the amount of nutrients (ME, CP, Ca, av. P, salt, methionine and lysine) satisfied by the added percentage of the protein concentrate or fish meal if it is going to be added.
4. Deduct the nutrients in the concentrate, or fish meal, from that required to extract the amounts needed to be satisfied by any other feeds available.
5. Meet the needs for Ca & P by using limestone, bone meal or any other supplement. Meet the needs for the common salt.
6. correct the ME and CP for the FM, concentrate, or supplements added.
7. Using for example yellow corn and soybean oil meal to meet the requirements for ME and CP, an algebraic method should be used to calculate the percentage mixed of each of the two feeds. The CP or ME should be corrected using SBM and fat mixtures. The percentages of the ingredients are corrected to make a total of 100%.
8. Calculate the amount of methionine and lysine the corn / SBM mixture will contain and the balance is supplemented using methionine and lysine amino acids, available in Kg in the market (in units per ton). Add vitamin/ mineral premix and additives if needed.
9. Check the calculations and the end formula, using the formulation sheet, before mixing.
10. Without the addition of fat, energy density will be lower than the optimal and so the amount of Ca, P, salt and AAs can be corrected to keep the calorie or energy/ nutrient ratios.

The following are worksheets for feeds and formulation, and also examples of chicken and turkey diets.

Available feeds worksheet

Bird and species

Production kind

Farm and size

Ration or mixture number

Other details

Compounder

Date

Ingredients	DM%	Energy	CP%	Met+Cys	Met	Lys		Ca%	P%	Cost
Energy feeds										
1										
2										
3										
4										
Protein feeds										
1										
2										
3										
4										
Supplements										
1										
2										
3										
Additives										
1										
2										
Medicines										
1										
2										

<u>Ration formulation worksheet</u>

Bird:

Species: Breed: Sex: Age: condition:

Production kind: Intensity of production:

Production period: Expected rate of production:

Farm: Size of farm:

Ration or concentrate mixture kind: Form:

Ration or mixture number:

Other details: As a need for adding additive or medicines for example – environmental temperature

Compounder:

Date:

No.	Ingredient	Amount Kg	Proximate analysis in amounts			Energy	Macromineral			AAs		
			CP	EE	Others		Ca	P (av.)	Na	Met+ Cys	Met	Lys
1												
2												
3												
4												
5												
6												
7												
8												
9												
10 Total												
11 Percentage*												
12 Specifications•												
13Nutrient balance⊙												
14 Remarks												

* The amounts formulated may be in tons.

• Ration requirements

⊙ To be sure that needs are satisfied.

Chicken Feed formulas

(Supplements approximated)

Phase	Corn %	SBM %	Fat %	Bran %	LS %	DiCaP %	Salt %	Met per ton	Lys per ton	Premix Per ton
Broilers										
0 – 3	42.62	43.58	9.30	-	1.5	2.5	0.5	1.90	-	+
	62.0	33.5	-	-	"	"	"	2.33	0.5	+
3 – 6	55.05	34.21	6.74	-	1.5	2.0	0.5	0.80	-	+
	68.5	27.5	-	-	"	"	"	1.0	1.0	+
6 – 8	62.36	28.09	5.97	-	1.33	1.75	0.5	0.4	-	+
	73.84	22.58	-	-	"	"	"	0.5	0.75	+
Layers										
0 – 6					No need for fat					
	67.25	26.27	-	2.4	1.33	2.25	"	-	-	+
6 – 12					No need for fat					
	70.33	19.16	-	6.76	1.25	2.0	"	-	-	+
12 – 18					No need for fat					
	74.21	16.21		5.60	1.33	1.75	"	-	-	
18-1st	66.5	25.27	1.22	-	4.75	1.75	0.5	-	-	
	68.91	24.09	-	-	"	"	"	-	-	
Layer	65.64	20.75	3.11	-	8.50	1.5	0.5	0.78	-	+
	71.48	18.02	-	-	"	"	"	0.5	-	

- The diets were formulated according to the analysis of the ingredients shown in table 6.
- Supplements, except AAs, can be reduced in the diets containing no fat.

Turkey feed formulas

(Supplements approximated)

Phase	Corn	SBM	Fat	Bran	LS	Di	Salt	Met	Lys	Pre.
0 – 4	33.71	56.76	4.20	-	1.5	3.33	0.5	2.0	-	+
	43.55	51.12	-	-	"	"	"	2.25	1.0	+
4 – 8	41.09	50.72	3.69	-	1.25	2.75	"	1.5	0.3	+
	49.42	46.08	-	-	"	"	"	1.75	1.33	+
8 – 12	50.79	39.62	5.51	-	1.25	2.33	"	1.1	1.0	+
	62.27	33.65	-	-	"	"	"	1.33	2.5	+
12-16	63.3	30.25	2.70	-	1.0	2.25	"	0.5	0.2	+
	68.68	27.57	-	-	"	"	"	0.5	1.0	+
16-20	68.76	23.52	4.57	-	0.9	1.75	"	0.2	-	+
	77.35	19.50	-	-	"	"	"	0.10	1.0	+
20-24	75.40	16.36	5.49	-	0.75	1.50	"	0.10	0.14	+
	85.14	12.11	-	-	"	"	"	0.25	1.25	+
Holding	74.78	6.85	-	15.62	"	"	"	-	-	+
Laying	74.74	16.59	0.84	-	5.33	2.0	"	-	-	+
	76.27	15.90	-	-	"	"	"	-	-	+

- The diets were formulated according to the analysis of the ingredients shown in table 3.
- Supplements, except AAs, can be reduced in the diets containing no fat.
- These are basal diets will be subjected to pelleting and addition of additives as probiotic, prebiotic, or synbiotic and enzymes. The improvement may reach to more than 25% in the bird growth and feed intake.

Feeding of Rabbits

INTRODUCTION

Rabbits are raised for a variety of purposes, including for meat, fur, wool, and as laboratory animals. Large numbers of rabbits are raised for exhibition and showing and many simply as pets. Production of rabbit feed is a minor but significant component of the manufactured feed industry. Domestic rabbits are raised commercially for meat particularly in European countries such as France, Italy, and Spain. To lesser extent, they are also raised for fur and angora wool (as a luxury fiber in apparel items such as sweaters). They are also used as teaching tools and as animal research models. Rabbit production may have considerable potential in developing countries as means of converting forages and agricultural by-products to meat.

Commercial rabbit producers are much concerned with diet cost, whereas raisers of exhibition rabbits are less concerned with cost than with the effects of the diet on animal health and show quality of the animals.

A number of generalizations can be made about rabbit feeds. They should be pelleted because nonpelleted feeds are not well accepted by rabbits and give low growth rates and high feed wastage. Perhaps more than with other livestock the feed has a major impact on the health of the animals. Rabbits are quite susceptible to enteric diseases (enteritis, diarrhea) that have a major dietary component. They are very sensitive to palatability factors and often refuse to consume a batch of feed even though it has the same ingredient specifications as the previous batch that they readily consumed. Per unit of feed produced, feed mills probably have more complaints about rabbit feed than about any other feed.

The importance of rabbit feeding during a time of food scarcity must be stressed, for the rabbit converts waste products into meat for human food more efficiently than other animals.

The correct nutrition of the domestic rabbit is perhaps the most important aspect of rabbit keeping. The rabbit can be fed on a very wide range of feeding-stuffs. The variety means that the feeding program will be adapted to circumstances of the breeder. Rabbit can be kept on household and garden residues.

Commercial operations must produce at least 6 litters per doe annually to make a profit. To attain that, young rabbits are weaned at 3-4 weeks (30-40days on maximum) of age and raised separately from their mother until they reach market weight, generally at 8-12 weeks of age. Rabbits raised as a breeding stock from 1 to 5 months. Intensive breeding programs require that doe be rebred anywhere from 14 to 30 days after kindle, whereby 8 litters per does are produced annually. Since one doe can produce from 4-6 litters, she has the ability to produce from 130 to 250 pounds of live meat through her reproductive ability. In large operations one buck is kept for 10-15 does (better 5-10) and produces more than 500 offspring annually. From this, it may be concluded that one buck and 4 does producing 4 litters each can produce more meat annually than an average beef cow-and produce it on less feed.

Economic Importance of Rabbits

Rabbits compare very favourable in feed conversion with the more traditional animals (rabbit 3:1, broilers 2.2-2:1, while steer 9:1). Protein efficiency in rabbits is 6:1, compared to 1.9:1 in broilers and 10.6:1 in steers.

Since rabbit possesses an enlarged cecum, similar to that of the horse, it can digest and absorb most roughages and forages, to a limited degree (so less competition with humans for feedstuffs). The meat of the domestic rabbit is white and contains little fat. The low fat content reflects the low energy value of typical rabbit feeds. Close to 80% of the carcass is edible thus making it an efficient meat-producing animal (dressing % is about 55%).

When rabbits are raised for meat production it reaches to a weight of more than 2 kg at 8 weeks or to more than 2.5 kg at 10 weeks. Bucks can be used for breeding at the age of 6 months (better at 8-10 months) and a buck can fertilize 2-3 does in half an hour (bucks better to be used 3 times weekly).

The productive life for bucks or does is 2-3 years. And a doe is ready for fertilization at 5 months and it is better to be at 6-7 months.

Nutritive Needs

Rabbits are nonruminant herbivores. The digestive anatomy and physiology closely resemble the horse and in many ways the requirements are similar. Several differences, such as the habit of coprophagy (the ingestion of fecal material) and decreased fibre utilization in rabbits, alter the requirements somewhat. Nevertheless, the types of feeds used for rabbits and horses are very similar.

Coprophagy plays an important role in the modification of their nutritive requirement (as early as 3 weeks of age). This act aids in the absorption of some of the essential amino acids and certain vitamins (K and B complex). By recycling the digesta, certain feeds are digested and absorbed those were not utilized the first time. Also some fibre digestion takes place in the cecum.

General Aspects of Rabbit Husbandry

There are many breeds of domestic rabbits. The New Zealand White and the Californian are the major breeds for commercial meat production. The Rex rabbit, which has no guard hairs and a soft, luxurious pelt, is the major fur breed. The angora produces wool, which is sheared or plucked and used as a luxury fiber. For showing and exhibition purposes, there are many breeds available, ranging from dwarfs (e.g., Netherland Dwarf, Dutch, Polish) to giants (Flemish Giant, Champagne d'Argent). Mature body weights range from under 2 Ib for dwarfs to over 20 Ib for giant breeds.

Rabbits have a rapid growth rate and reach sexual maturity in about 4 months from birth. Because they are induced ovulators, the females (does) do not have an estrus cycle, but can be bred at virtually any time. Ovulation occurs about 12 h postmating. The gestation period is 31 days. The does will rebreed within 24h of parturition (kindling). Although this immediate remating after kindling is the normal reproductive behavior of the wild rabbit, it is not recommended for domestic rabbits. Normal rebreeding schedules are 7, 14, or 21 days postkindling. Depending upon rebreeding schedule, weaning age is 28 to 42 days, although it is possible to wean at 3 weeks.

Rabbits are normally raised in wire cages, with a wire-screen cage bottom. This prevents the accumulation of droppings in the cage, reducing diseases such as coccidiosis. Major disease problems are respiratory disease (snuffles) and digestive disorders (enteritis). Adequate ventilation is important in minimizing respiratory disease. Enteritis, as will be discussed, is mainly diet related.

Rabbits are very finicky or fastidious eaters. They require a good quality pellet and will reject a feed with dust or fines, often scratching it out of the feeder. They are also very sensitive to as yet poorly understood palatability factors.

Thus a major problem for feed manufacturers is complaints that their feed is unpalatable to rabbits. The second major concern is that rabbits are very sensitive to digestive disturbances, characterized by inflammation of the intestinal and cecal lining (enteritis) and severe diarrhea.

High mortality may occur in an enteritis outbreak. In many cases, the enteritis outbreak is associated with a new batch of feed, suggesting, particularly to the rabbit raiser, that the feed is the direct cause of the problem.

Digestive Tract Physiology of the Rabbit

Livestock can be classified into three groups according to their digestive tracts:

(1) simple nonruminants; (2) ruminants, and (3) nonruminant herbivores.

Nonruminant herbivores have digestive tract modifications to facilitate microbial fermentation, with many of the same functions performed as in the rumen. Intermediate between simple nonruminants and ruminants in their digestive physiology and nutritional requirements, nonruminant herbivores share similarities with each.

They are (a) foregut fermentors (there is one avian species, the hoatzin), (b) colon fermentors as Equids and (C) cecal fermentors like the rabbit having a digestive strategy that emphasizes fermentation of the nonfiber constituents of forages.

The rabbit is a small nonruminant herbivore with an enlarged hindgut. The cecum is the major site of microbial growth and fermentation. Small herbivores like the rabbit have evolved a unique digestive strategy that allows them to utilize a forage-based diet. In simple terms, this digestive strategy involves the selective separation of fiber particles from the non-fiber components (e.g., starch) for fermentation in the cecum. The selective separation and excretion of fiber is accomplished by muscular activity of the proximal colon. Fiber particles are less dense than other components of forage, so they tend to segregate out in solution. The separated fiber particles are moved rapidly by peristaltic action to the colon, forming the fecal pellets (hard feces). Reverse peristalsis moves the nonfiber components (starch granules, proteins, and fluids) from the proximal colon to the cecum, where they undergo microbial fermentation. About once every 24h, the colon is completely emptied of hard feces, and the soft feces or cecotropes are excreted. In this process, the cecum contracts to move the cecal contents into the proximal colon. Mucus is secreted from goblet cells in the lining of the proximal colon, forming mucus-covered cecotropes or soft feces, which resemble peeled grapes in appearance. These are moved through the colon by peristaltic action and are consumed directly from the anus by the animal. Consumption of the cecotropes (cecotrophy) is an essential part of the normal digestive processes of rabbits. The cecotropes continue fermentation in the stomach, protected by the mucus coating from being broken down by the stomach acid, and then are digested in the small intestine. They provide the animal with energy (from volatile fatty acid production), B-complex vitamins, and microbial protein. Experimental prevention of cecotrophy results in markedly reduced digestibility of all nutrient fractions. Thus the digestive strategy of the rabbit is to consume a forage-based diet, separate out and rapidly excrete most of the fiber, and ferment nonfiber components in the cecum. The nutritional effectiveness of cecal fermentation is enhanced by the animal’s consumption of the cecal contents by cecotrophy. The above discussion explains why the digestibility of fiber in the rabbit is very low, even though its natural diet is high in fiber.

Relative Size

The digestive system of the rabbit is well adapted for the utilization of forages and feeds of plant origin. The digestive system occupies a large portion of the body cavity. In the New Zealand White adult rabbit (4-4.5kg) the digestive tube can be as long as 5m. the development of the digestive system is almost completed at 9 weeks of age. The cecum and the colon start to develop around 3-5 weeks of age, when feed ingestion, other than milk, starts to be significant, and the microflora population becomes important in those organs.

The size of the different parts of the digestive system varies with age, breed, physiological status, and type of feed given to the rabbit, close to 80 percent of the digesta is contained in the stomach and the cecum. These two compartments are the ones with the largest capacity.

Values for different parts of the rabbit digestive system[a]

Digestive System Part	Weight,g	Length,cm	Capacity,g	DM,%	pH
Stomach	20		90-100	17	1.5-2.0
Small intestine	60	330	20-40	7	7.2
Cecal appendix	10	13	1		
Cecum	25	40	100-120	20	6.0
Colon	30		10-30		
Proximal colon		50		20-25	6.5
Distal colon		90		20-40	

[a] Values from 12-week-old New Zealand rabbits fed a pelleted complete diet.

Digestibility of Feeding-Stuffs

There are many factors affecting the digestibility probably the most important is the fibre content. Young animals can digest this matter to a very limited extent. Generally if the fibre content is more than 20% the ration is liable to cause digestive disturbance.

Retention in the Stomach

The amount of time that the feed stays in the digestive system affects the amount of time enzymes and microorganisms can act over the ingested material, therefore affecting both nutrient absorption and utilization. The average retention time of ingested material in the digestive tract is 17-18 h, being less for large particles (14-16h) and longer for finer particles (20-21h). The longest retention time occurs in the stomach and in the cecum. Retention time in the small intestine is relatively low. The rabbit's stomach is almost always full. Gastric secretion is continuous and very acid (pH 1-2), the result of HCl secretion. Gastric digestion is characterized by a significant production of lactic acid that is absorbed directly by the gastric mucosa or in the small intestine.

Cecotrophy (pseudo-rumination):

The contents of the caecum is normally a thick fluid and at certain periods contractions of the caecum force some of this material through the colon and rectum thus forming the peculiar type of pellet eaten by the rabbit during coprophagy. The final residue of the twice digested food passes through the colon wherein much of the moisture is removed and the normal faecal pellets formed, these latter passing through the rectum and being excreted.

As mentioned above the normal healthy rabbit forms two kinds of faecal pellets. One type is that normally seen on the floor of the hutch, the other type is never normally seen as it is taken directly from the anus by the rabbit and swallowed.

At least, half and probably more, of the material excreted by the rabbit is reingested as coprophagous pellets.

Several reasons for the peculiar physiological habit have been advanced. On a dry matter basis, the coprophagous pellets contain 3.5 times as much crude protein as do the normal pellets but only a third of the fibre. In addition it contains a considerable amounts of vitamins B-complex. There is little doubt therefore that part at least of the explanation of this process lies in the increased efficiency of digestion and the production of some at least of the animal's vitamin requirements. The habit can be observed at many times of the day.

The reingestion of the soft feces by the rabbit is called cecotrophy. The production of two type's of-feces and the ingestion of only one type of these distinguishes cecotrophy from coprophagy. This process is one of the important characteristics of the digestive physiology of the rabbit which allows the animal maximal utilization and absorption of total ingested nutrients. The soft feces are higher in water, electrolytes, and nitrogen (N) content, and lower in fiber. A significant proportion of the total N content of cecotrophs (60-80 percent) is from cecal microbial cells. Total N from cecotrophs represents an important source of protein for the animal and could amount to up to 20 percent of the total N intake of the rabbit. Cecotrophs contribute approximately 20 percent of the protein and 10 percent of the energy for maintenance, vitamins, and minerals. Producers should take advantage of this characteristic in order to feed rabbits with nontraditional ingredients.

The cecotrophs are removed directly from the anus and are swallowed whole. Cecotrophy usually occurs once or twice per 24-hour period, generally at night, since the common name "night feces" for the cecotrophs. When they reach the stomach they do not mix immediately with the rest of the stomach contents but lie in a mass in the fundic region for 6-8 h. From there on the cecotrophs follow a digestion pattern as does any other ingested feed.

Nutrient Requirements of Rabbits

The nutrient requirements of rabbits are influenced by their digestive tract physiology. The requirement figures are provisional; in many cases they are not well supported by data. Rabbit nutrition research has been quite limited as compared to that with most other domestic species. The National Research Council (NRC) publication Nutrient Requirements of Domestic Rabbits (NRC, 1977) is outdated and does not reflect current knowledge of rabbit nutrition. The NRC does not plan to publish an updated version. Whereas the estimates cover all nutrients, on a practical basis only a few of these need to be considered in diet formulation. Usually, the nutrients that should be used in diet formulation are crude protein, S-amino acids (methionine + cystine), lysine, digestible energy, crude fiber, Ca, P, and vitamins A, D, and E. As is discussed in the section on dietary factors and enteritis, the most important feed-related problems in rabbit nutrition are generally not nutritional deficiencies or toxicities, but feed-induced problems such as enteritis. Feed palatability is also a major concern. With the exception of vitamin A deficiency and toxicity, which are discussed in the section on vitamins, rabbit raisers generally encounter few problems relating to the other nutrients. Dietary indigestible fiber, reflected in crude fiber or acid detergent fiber (ADF) levels, is also an important consideration because of its roles in preventing enteritis and fur chewing.

Maintenance Requirements

In addition to the basal metabolic energy required, if the animal is to move about, digest food, more energy will be required. It is common practice to double the basal metabolic rate to arrive at a figure for the amount of energy which the rabbit requires to maintain itself. The animal eats from 3 to 4% of its weight as a total daily food.

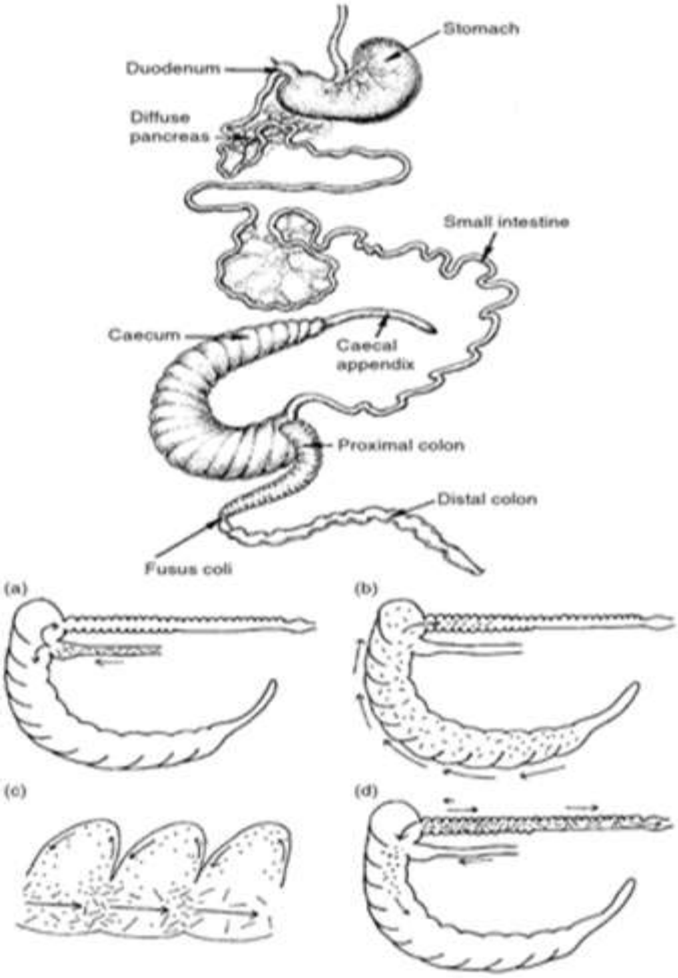


Figure 1 Schematic view of parts of the rabbit digestive tract (top) and the mechanism of the selective excretion of fiber and retention of small particles and solubles for fermentation in the cecum of the rabbit. (a) Intestinal contents "'enter the hindgut at the ileocecal-colonic junction and uniformly disperse in the cecum and colon. Dashes represent large fiber particles, and dots represent non-fiber particles; b) Contraction of the cecum moves material into the proximal colon. (c) Peristaltic: action moves large fiber particles (dashes) down the colon for excretion as hard feces. Contractions of the haustrae of the colon move small particles (dots) and fluids (backwards into the cecum. (d) Small particles and fluids are thus separated from fiber (Cheeke, 1987).

Requirements for growth

The growth of rabbit is extremely rapid and consequently its nutritive requirements are relatively high during the early period of life. Well fed animal will develop much more quickly than the poorly fed and maturity in body growth is closely related to maturity in sexual development. Also fertility and good bodily condition are closely related. Excessive fatness and very poor condition both lead to sterility. Improved nutrition is the essential cause of the highest percentage of fertile matings in the green season.

Requirements for pregnancy

For the production of healthy well developed young and a satisfactory milk supply in the doe, her nutrition must be on a rising plane throughout pregnancy. It is particularly during the last half of pregnancy that the main requirements come (1.33 maintenance at the start of pregnancy rising to double the maintenance at the end). We need more protein and more minerals (protein 16-18% and minerals 5-6%). The size of the mother has the greatest influence which affects the birth size and the litter size.

Requirements for lactation

A satisfactory doe will produce approximately half an ounce of milk per pound body weight each day. The milk contains 13-15% protein, 10-12% fat, and 23% minerals. The gross energy is about 1000 kcalories/Ib compared with 350kcalories per Ib of cow's milk and 750 kcal for milk of bitch. The efficiency with which food energy is turned into milk varies but is in the region of 45%. The needs for lactation are approximately on the same level at the end of pregnancy (double maintenance). The total needs of the doe, allowing also a small proportion for her young when they first start eating food, may rise as high as four times maintenance at the end of the fourth week of suckling.

As the quality of the milk protein is very good so if possible animal protein should be incorporated in the first feeds of the young.

Mineral requirements for lactation are the same as in pregnancy.

Requirements for dry does and stud bucks

To remain vigorous and in good health the buck requires more than the normal maintenance ration. Approximately 10-15% above maintenance both of the TDNs and DCP is satisfactory.

A good quality leafy, fine-stemmed legume hay plus trace mineral salt can maintain dry does and bucks not in service, if the feed is available free-choice. If carbonaceous hay is to be offered free-choice or the hay is not of good quality, supplementation is recommended.

Feed and Water Intake (feeding behavior)

Quantifying feed and water intake is important in order to ascertain the economics of the rabbit enterprise. It would also help in the early detection of health problems whose first sign could be a lack of appetite or an excess of drinking.

Knowledge of feed intake helps the manager to decide whether or not there is an excess of feed waste. Feed and water intake values are helpful in diet formulation and disease control, so that concentration of nutrient or medicine can be formulated according to requirements, age, or body weight.

During the first 3 weeks of life, the rabbit consumes only maternal milk. When milk production is not enough, then the rabbit starts to consume solid food and water. The animal then changes from one or two feedings a day to several feedings in 24 h.

During a 24-h period, adult and growing rabbits (4 weeks or older), will consume feed in several meals of small amounts (feed and water), utilizing usually 2 -4 h/d for feeding. Feed and water consumption in g/meal is lower during the day (time with light) than during the night (dark hours). In lactating does, feed consumption occurs mostly during the night. This behavior must be taken into consideration for feeding practices.

The average feed and water consumption varies according to age and physiological status of the animal. In general, rabbits will consume water in quantities close to twice their dry feed intake. Adult animals (4 kg body weight) will consume on the average 200-300 ml of water/d, while lactating females can drink 3-4 liters/d. The water requirements of rabbits is higher in youngs than in old ones and thus shortage of it in early life has much more serious effect and even a restricted amount of water may seriously retard growth. Thus for medium sized breeds on maintenance ration the requirements would be between 3/4 and 1 pint per day. The requirement for young animals probably is in the region of double of that of adults. Lactating females increase their feed intake proportionally to milk production and number of suckling rabbits. A doe with a litter of seven can drink up to 1 gallon of water per day.

Water and feed consumption vary according to environmental temperature and humidity. There is a direct relationship between dry feed intake and water intake. As temperature rises, water consumption increases, but at high temperatures (30°C and over) feed and water consumption decline, affecting the performance of growing and lactating animals. Feeds that are high in protein and fibre increase the need for water because the increased need to excrete end products produced in the digestion and metabolism.

Water should be supplied ad libitum. Rabbits have a high requirement for water in relation to their body weight. Water is necessary for maintenance, production, and lactation. Because dry matter intake is related to water intake, any restriction in water causes a decline in dry matter consumption. However, if feed is restricted, water intake may increase. Water should be clean, fresh, and free from biological and chemical contaminants.

Nutrients

Protein

All production parameters require high levels of good-quality protein. Unlike ruminants rabbits have been shown to require certain AAs in the diet. The EAA profile is very similar to that of the chick and the pig. The adult rabbit (probably) obtains 10-20 percent of its total protein intake from cecotrophy as good-quality bacterial protein. Gidenne reported that in 6-week-old young New Zealand rabbits, independent of the type of diet, cecotrophy accounted for 29 percent of the total protein intake. Part of the amino acids produced in the cecum by microorganisms are absorbed directly by the cecum wall, and after cecotrophy, the rest are absorbed by the small intestine. The contribution of microbial protein to young rabbits (4-8 weeks old) is very small, and steps should be taken to supply good-quality protein to growing animals. Rabbits require a-good-quality protein intake in terms of quantity and quality. The essential amino acids are the same as in other species. Glycine can be synthesized in adequate amounts in the adult rabbit. However, in the fast-growing rabbit the rate of synthesis of glycine is not adequate, therefore, glycine should be supplemented in diets for these animals. Protein quality is related to-feed intake and thus to performance.

Essential amino acid minimum requirements for rabbits

Amino Acid	Growth	Gestation	Lactation
Arginine, %	1.00	0.80	1.11
Glycine, %	0.40	0.40	0.40
Histidine, %	0.45	0.42	0.45

Isoleucine, %	0.70	0.70	0.71
Leucine, %	1.05	1.05	1.25
Lysine, %	0.70	0.70	0.85
Methionine + cystine, %	0.60	0.60	0.95
Phenylalanine + tyrosine, %	1.20	1.20	1.20
Threonine, %	0.55	0.60	0.64
Tryptophan, %	0.15	0.15	0.15
Valine, %	0.70	0.75	0.82

Total crude protein requirement for maintenance in adult rabbits is 13 percent of the ration. Digestible protein requirements for growing rabbits can be computed using the following formulas:

Minimum DP = $\frac{DE}{250}$ Maximum DP = $\frac{DE}{230}$

Digestible protein requirements for lactating does can be obtained by the following formulas;

Minimum DP = $\frac{DE}{200}$ Maximum DP = $\frac{DE}{180}$

Where DP = percent digestible protein in the diet and where DE = digestible energy, kcal/kg in the diet.

The protein requirements for lactating does are higher than those for growing rabbits due to the protein demands during lactation. There is a high secretion of protein and energy in the milk during lactation. This secretion is directly proportional to milk production. The producer should take into account that protein levels below 18 percent without the proper levels of energy have a negative effect on milk production and, therefore, on the rate of gain of the suckling rabbits.

Protein nutrition is of special concern in fur- and hair-producing rabbits. Because the final product (pelt and hair) is high in N- containing compounds and S-containing amino acids, the level in dietary protein should be high, with a minimum of 17 percent crude protein and a minimum of 0.6 percent of S-containing amino acids (methionine, cystine). It should be noted that, in the usual rabbit feeds, the first limiting amino acids are the S-containing ones, followed by lysine.

Rabbits require dietary sources of **essential amino acids**. However, consumption of the cecotropes does provide a source of microbial protein. On diets of low protein quality, the microbial protein in the cecotropes can significantly improve the absorbed amino acid balance. Whereas swine and poultry fed diets containing low-quality proteins will have markedly reduced growth, in rabbits the effect of low dietary protein quality is much less because of the amino acids derived from the microbial protein.

Compared to swine and poultry, rabbits have a much better ability to digest and utilize the protein in forages such as alfalfa meal. The ability to digest forage proteins efficiently is a consequence of the selective retention of nonfiber components in the cecum. Cecal fermentation with subsequent cecotrophy is a digestive strategy that extracts protein from forages with high efficiency. Experimentally preventing cecotrophy markedly reduces the digestibility of forage proteins in rabbits. It should be noted that keeping rabbits in wire mesh-floored cages does not affect cecotrophy. The cecotropes are consumed directly from the anus; once they are excreted, the animals do not eat them. The quantity of cecotropes consumed reflects dietary protein status. On high-protein diets, cecotropes are not consumed, but on low-protein diets, they are avidly consumed. Thus cecotrophy seems to be physiologically regulated by metabolic need for amino acids.

The dietary protein requirements are 16% for maximum growth and 18% for lactation. Cecal fermentation and cecotrophy allow rabbits to utilize some NPN, such as urea or biuret, but in most cases, the dietary ingredients (alfalfa meal, wheat milling byproducts) provide adequate total nitrogen for cecal fermentation. In another source NPN is of little value in rabbit rations. It is degraded and absorbed in the small intestine and subsequently eliminated as waste products before it ever reaches the cecum where it might be transformed into bacterial protein. Dietary protein quality is particularly important for rapidly growing weanling rabbits, which may not have well-developed cecal fermentation.

Excess dietary protein is not desirable because of the effects on air quality. Rabbits are normally raised in confined buildings with a fairly high stocking density. Compared to swine and poultry, they have high water requirements and excrete large quantities of urine, promoting high humidity. High humidity in conjunction with high atmospheric ammonia is very undesirable in a rabbit building. The ammonia dissolves in the water vapor, and when breathed by the animals, damages the cilia and mucous membranes in the nasal passages. This disruption allows the bacterium *Pasteurella multocida to* invade, causing respiratory disease (snuffles). The ammonia arises from excess dietary protein. The nitrogen from excess protein and amino acids is excreted in the urine as urea, which is converted to ammonia by bacterial action in the manure. Additionally, the excretion of large amounts of urea in the urine increases water excretion, further intensifying air quality problems.

Ammonia levels in rabbit buildings are controlled by not feeding excess protein and by providing good ventilation. A feed additive based on extracts of the yucca plant (*Yucca schidigera*) is also effective, because it binds ammonia in the excreta and reduces its volatilization into the environment.

The NRC (1977) recommended 2500 kcal DE/kg for growth, gestation and lactation; and 16, 15 & 17% CP respectively, while 12% for maintenance (feeding is ad libitum). Others recommend 18, 16-18, 16-18 & 14% respectively.

Energy

Digestible energy levels in typical rabbit diets are quite low, being in the range of 2400 to 2800 kcal/kg diet. Higher energy levels impair animal performance and result in reduced energy intake. Higher energy diets tend to promote microbial overgrowth in the cecum and lead to enteric disease (diarrhea). Thus rabbit diets usually contain alfalfa meal or other fibrous feedstuffs as the main ingredient. Rabbits do not digest fiber efficiently. Their digestive strategy is to eliminate fiber rapidly and retain the nonfiber components in the cecum for fermentation, followed by cecotrophy. This apparent anomalous situation is related to dietary fiber. As dietary energy levels are raised, the fiber level decreases. Indigestible fiber plays an important role in rabbit nutrition by stimulating intestinal and hind gut motility. With low-fiber diets, hypomotility (constipation) occurs, reducing feed intake. Further, this leads to disturbance in cecal microbe populations, often causing enteritis. Thus, high-energy diets are unsuitable for rabbit production. Rabbits evolved as small herbivores with a digestive tract physiology allowing them to meet their high energy requirements (small animals have a high metabolic rate) on low-energy forages, by having an enlarged gut (hence high feed intake) and a means of separating and rapidly excreting fiber. Attempts to feed rabbits on high-energy, low-fiber diets, such as those fed to poultry, are doomed to failure. The result will be poor animal performance and a high incidence of enteritis.

Volatile fatty acids (VFA) produced in cecal fermentation make a significant contribution to the energy requirements of rabbits (estimates range from 12 to 40% of maintenance energy requirements provided by VFA). In contast to ruminants, propionic acid is a minor VFA in rabbits; acetate and butyrate are the major VFA. This reflects a unique microbial population of the hindgut, dominated by *Bacteroides spp*. of bacteria.

Dietary fiber is important in rabbit nutrition. Indigestible fiber has a scabrous, physical effect on the gut mucosa, maintaining normal gut motility. Low-fiber diets result in hypomotility and digestive disturbances, and increased enteritis incidence. For optimal growth and gut function, 10 to 15% dietary crude fiber is recommended. On low-fiber diets, fur chewing may occur, apparently as an attempt by the animal to increase its fiber intake. Fur chewing involves animals pulling fur from their cagemates and consuming it. It reduces the value of the pelt and may result in the formation of hairballs in the stomach. These cause mortality by forming a gut blockage.

The highest energy requirements **are for lactation**. Lactating does in peak lactation (10-21 days postparturition) are usually in negative energy balance and mobilize body tissue to support their high lactational output. The use of high-energy lactation diets during peak lactation may have a place in intensive commercial rabbit production. However, this would need to be done very carefully. The energy status of breeding females is quite critical. If energy intake is inadequate, body condition declines and subsequent reproductive performance is impaired. A positive energy balance at the time of mating is necessary for good conception rates. However, if does are excessively fat, reproductive performance is also reduced. Small litter size and a high rate of mortality of kits at birth may occur. The high neonatal mortality is due to increased fetal size and accumulation of fat deposits in the abdominal cavity of the doe, causing constriction (dystocia) of the fetuses during birth.

The energy requirements for **maintaining dry does** or young bucks not in service are low with the result that good-quality hay should be sufficient.

About 3% (2.5-5%) **fat** is recommended in rabbit diets. Vegetable oils provide unsaturated fatty acids which provide a glossiness or sheen to the hair coat. This is particularly important for show rabbits. Dosing orally with a teaspoon of vegetable oil every few days can accomplish the same thing. Dietary fat is well utilized by rabbits and improves diet palatability. Added fat also increases energy level without causing carbohydrate overload of the hind gut. Higher fat levels might be feasible, but caution should be exercised to prevent digestive disturbances as scours.

Most of the required energy in the rabbit is supplied by carbohydrates, to a lesser extent by lipids, and in some cases by excess protein. Rabbits, like most other animals, adjust their feed intake to maintain a relatively constant energy intake. Therefore, when formulating a diet, nutrients should be supplied in relation to energy.

Energy requirements vary according to factors such as animal age and size (younger and smaller animals require more energy), physiological status (growing animals require more energy than inactive adults; lactating does require more energy than nonlactating animals), environmental temperature and humidity (animals in cold and humid environments require more energy in order to maintain body temperature and level of production), diet fiber concentration, and type of enterprise.

For the growing period the average daily digestible energy (DE) requirement for maintenance and production can be estimated by the following formula:

$$DE = 4MW\ (20\text{-}WW) + 55WW + 3.6DG - 50$$

For lactating animals, the average daily DE requirement can be estimated by the following formula:

$$DE = 290 + 65DW + 35G$$

Where: DE = daily digestible energy, kcal/d
MW = estimated market weight, kg
WW = weaning weight, kg
DG = expected average daily gain, g
DW = doe weight, kg
G = number of suckling rabbits

Example

For a rabbit that is going to be marketed at 2 kg, with a weaning weight of 0.6 kg, and an expected daily gain of 30 g, the estimated DE requirement per day for the growing period would be

$$4 \times 2(20 - 0.6) + 55(0.6) + 3.6(30) - 50 = 246.2 \text{ kcal/d}$$

If the feed utilized contains 2500 kcal DE/kg, then feed consumption/animal/d (waste not included) will be

$$\frac{246.2 \times 100}{2500} = 98.48 \text{ g of feed}$$

For primiparous lactating females, the energy requirement should include an increase in energy to fulfill the requirements for growth of the female. That can be quantified as an extra 6.5 kcal/d/kg body weight.

As lactation progresses, the lactating female increases her feed intake to a maximum in order to satisfy her energy needs. If the ration does not contain a high level of energy/kg, then the female will use part of her body reserves in order to maintain milk production. This will cause the female to lose condition, affecting future breeding performance and efficiency. Furthermore, if the feed is of a low caloric density, the young rabbits will not be able to maintain a high growth rate when they start to consume dry feed. This has been shown to also affect growth rate and feed efficiency in the postweaning period.

With the estimated energy requirement and the estimated level of intake per day, it is possible to calculate the energy concentration in the diet. Diets with a minimum concentration of 2500 kcal DE/kg will satisfy the requirements of growing rabbits, and 2500-3000 kcal DE/kg will be sufficient for lactating does with more than seven pups. Rations with 2200 kcal/kg are adequate for inactive adults.

With an increase in fiber content in the diet there is a reduction in the utilization of energy and organic matter. This relationship seems to be linear. However, some minimum level of fiber must be present in the diet (12-14 percent crude fiber for growing rabbits) in order to maintain proper digestion and gut motility and to prevent some metabolic disorders such as diarrhea. For each 1 percent increase in cellulose content in the diet there is a decrease of 0.7 units in organic matter digestibility. French researchers have estimated that by replacing the diet's starch with cellulose there is a reduction of the DE in a proportion of 60 kcal DE/kg diet for every percent point increase of cellulose.

Digestibility is the combined effect of rate of passage and the digestibility coefficient of the feed itself. An increase in crude fiber will increase feed intake and decrease feed efficiency. In general, an increase in retention time increases the digestibility of the diet, but in the rabbit it also increases the incidence of digestive disorders. It has been suggested that a low retention time is a normal characteristic in the rabbit. Gidenne reported that increasing lignin concentration in rabbit diets decreases protein digestibility and to a lesser extent energy and cellulose.

Part or all of the fiber should be given in the form of large particles (2-4 mm) in order to decrease the incidence of digestive disorders, reduce weight loss, and promote gut function and hard feces formation. Part of the fiber could be ground below the 2 mm size to permit longer cecal retention and increase digestibility. Research is needed in this area to determine the minimum proportion of long fiber needed by growing and by lactating animals.

Minerals

Rabbits require Ca, P, Mg, K, Na, Cl, Mn, Zn, Cu, Fe, I, Co, and Se. Other minerals such as chromium and fluoride, which are essential for other mammals, have not been reported as having an important role in rabbit nutrition. Mineral requirements are higher during lactation because they are either secreted in milk or are required for milk secretion. Available information on rabbit mineral nutrition and requirements is scarce and contradictory. Data presented here refer to mineral levels based on a 2500-kcal/kg feed mix.

Ca and P requirements are highest for the lactating females because of the higher amounts of these minerals that are secreted in the milk. The recommended ratio of Ca to P is 2:1, however, rabbits can tolerate up to a 12:1 ratio. Although rabbits can tolerate high amounts of Ca in the diet, this can bring on a Zn or a Mg deficiency in growing animals and a P deficiency in lactating does. Some of the feed Ca comes from buffers added to the diets. Buffers can be added to rabbit diets in order to lower the pH of the cecal contents, which in turn increases feed intake. Ca deficiencies are rare in commercial rabbit production because most of the ingredients utilized in rabbit diets are high in this mineral. Ca can be supplemented in the diet as inorganic Ca with calcium carbonate ($CaC0_3$) or dicalcium phosphate (HP_4Ca_2).

The major mineral elements of concern in rabbit diet formulation are Ca and P. The other minerals are usually provided in adequate amounts by the ingredients used plus the addition of trace-mineralized salt.

Most rabbit diets contain adequate Ca provided by alfalfa meal. Ca is absorbed very efficiently in rabbits and the excess is excreted in the urine rather than the fecal rout typical of most species. Often the urine contains white sediment composed of calcium carbonate and has a cloudy appearance due to its high content. Prolonged intake of excess Ca may lead to kidney damage and urinary calculi. This is particularly a problem with pet rabbits, which have a long lifetime compared to commercial animals, and unless lactating have low Ca requirements for maintenance. Therefore pet rabbits may develop chronic kidney and urinary tract blockages because of prolonged excretion of excess Ca. The feeding of a low Ca diet (e.g., a diet low in alfalfa meal) can help prevent the condition. Administration of a urine-acidifying agent, such as ammonium chloride, can be beneficial by promoting acidic urine. Calcium carbonate is soluble under acidic conditions. Diets with high (40 to 60 percent) levels of alfalfa meal usually contain excess calcium, which is excreted in the urine.

Rabbit diet ingredients usually contain adequate P. Grain milling byproducts such as wheat bran and wheat middlings are commonly used in rabbit diets and are high in P. Plant protein supplements such as soybean meal are also good sources. The bioavailability of organic P (phytates) in rabbits is high, because of the microbial activity in the hind gut.

The best sources of P are ingredients of animal origin, but these ingredients are not popular in rabbit diets. Most of the P ingested is of plant origin and is present in phytate form which is poorly utilized by the animals. There seems to be a microbial process in the cecum that frees the P, making it available through cecotrophy. However, it does not cover the animal's requirements, making it necessary to supplement with P. The best supplements are in the form of Ca salts; of these the best is monocalcium phosphate.

Mg is required for proper-growth, gestation, and lactation. Mg requirements increase during gestation and lactation due to fetus uptake and milk synthesis. Deficiencies of this element cause retarded growth, fur chewing, poor fur condition, and whitening of the ears. Excess of Mg can cause diarrhea.

Zn is required in rabbits to maintain a normal pregnancy, for proper fetus growth, and for proper pre- and postweaning growth. Zn also plays a role in the quality of hair and fur. A level of 50-70 ppm in the diet seems to be appropriate. However, these levels should be increased if the diet contains more than 2 percent Ca. Pregnant does fed diets low in Zn pull little or no hair for nest building.

Under normal conditions **K** will not be a limiting mineral in rabbit diets. High-energy diets will be lower in K due to the high grain concentration. Some of the K is excreted via the milk. K levels in the diet should be increased to their maximum under high-temperature conditions, especially for lactating does. If K is increased, total Na should also be increased. An imbalance of K and Na may cause renal problems. High levels of K (greater than 2 percent) can cause low fertility rates and low embryonic survival.

Mineral minimum requirements for rabbits[a]

Mineral	Growth	Breeding	Lactation
Calcium, %	0.9-1.0	0.9-1.0	1.0-1.2
Phosphorus, %	0.6-0.7	0.6-0.7	0.8-1.0
Potassium, %	1.3	0.75	1.3
Sodium, %	0.4	0.25	0.4
Chloride, %	0.4	0.2-0.25	0.4
Manganese, ppm	8.5	8.5	8.5
Magnesium, ppm	400-500	400-500	400-500
Cobalt, ppm	1	1	1
Copper, ppm	5	5	5
Zinc, ppm	50-70	50-70	50-70
Iodine, ppm	0.2	0.2	0.2

[a] Assumes a 2500 kcal DE/kg diet.

Diets should contain 0.25 to 0.5% **trace-mineralized salts**. This will prevent deficiencies of trace elements under practical conditions. Because of the high relative feed intake of rabbits and the high alfalfa meal levels typically used in rabbit diets, trace element deficiencies are virtually unknown in rabbit production. Trace element deficiencies can be produced for experimental purposes only by using purified diets.

Addition of chelated salts of Cu, Co, Fe, Zn, Mn, and I to rabbit diets have been reported to increase rate of growth, dressing percentage, and feed efficiency.

Copper sulfate is often used as a nonnutritive feed additive as an aid in preventing enteritis. As with swine and poultry, levels of 125 to 250 ppm copper sulfate in the diet have an antibiotic-like effect. Although it is not recommended that copper sulfate be fed routinely as a feed additive, its addition to the feed can be very effective in stopping an enteritis outbreak. Routine use may diminish its effectiveness when enteritis does occur and may also cause environmental pollution with high copper levels in the excreta.

When diets are supplemented with crystalline synthetic amino acids, the levels of Cl and Na in the diet should be adjusted both in quantity and in ratio. This is due to the fact that most of the synthetic amino acids are of the hydrochloride form, thus adding extra Cl to the diet.

Vitamins

In general, meeting the vitamin needs of rabbits is quite simple. The B complex vitamins and vitamin K are synthesized by microbial action in the cecum and obtained by the animal via cecotrophy. In adult rabbit, B-complex vitamins are synthesized in the cecum.

Recommended vitamin supplementation for growing and adult rabbits

Compound	Premix Units/kg
Vitamin A, 1U	**3,530,000**
Vitami D_3, 1U	**353,000**
Vitamin E, 1U	**15,985**
Vitamin B_{12}, mg	**5**
Riboflavin, mg	**1325**
Niacin, mg	**19,845**
d-Pantothenic acid, mg	**4765**
Choline chloride, mg	**242,510**
Menadione SBC, mg	**620**
Thiamine mononitrate, mg	**480**
Pyridoxine HCI, mg	**1060**
Biotin, mg	**40**
Folic acid, mg	**80**
β-Carotene	**4410**

However, not all B-complex vitamins are synthesized in the needed amount for fast-growing rabbits, therefore they should be supplied in growing rabbit diets to obtain a high-performance in the commercial meat operation

Under typical dietary conditions, only vitamins A, D, and E need be considered in feed manufacturing. The requirement for vitamin D is probably very low, because Ca and P are readily absorbed in rabbits. The regulation of calcium absorption by l,25-$(OH)_2$,-vitamin D_3, which is an important role of vitamin D in other species, does not seem to be important in rabbits, because Ca is absorbed far in excess of metabolic need and excreted in the urine. Although vitamin D deficiency is unlikely, toxicities sometimes occur as a result of feed mixing error. Signs of vitamin D toxicity include progressive emaciation and weakness, loss of appetite, diarrhea, and paralysis. The soft tissues, including liver, kidney, artery walls, and muscle, become extensively calcified.

Vitamin A is sometimes a problem in rabbit nutrition. Signs of vitamin A deficiency and toxicity are similar, with major effects on reproduction. Low conception rates, fetal resorption, low survival of newborn kits, and hydrocephalus (fluid on the brain, causing a swollen head) in fetuses occur with toxic levels. Vitamin A toxicity is usually associated with the addition of synthetic vitamin A to diets high in good quality alfalfa. Alfalfa is an excellent source of β-carotene, and relatively small amounts of supplementary vitamin A added to high-alfalfa diets may be enough to create toxicity. Except for rare genetic instances of hydrocephalus, the occurrence of this condition is a strong indication of a vitamin A problem, either toxicity or deficiency. Diet and liver vitamin A analysis is needed to ascertain which situation is involved when hydrocephalus outbreaks in newborn kits occur.

Vitamin A-deficient rabbits exhibit poor growth, leg deformities, and increased susceptibility to disease, because of the role of vitamin A in maintenance of epithelial tissues and mucous membranes. A high incidence of enteritis occurs in vitamin A-deficient rabbits.

The vitamin A requirements of rabbits have not been adequately determined. A level of 10,000 lU/kg of diet is adequate. Levels in excess of 40,000 IU/kg diet may adversely affect reproduction. The toxic level of supplemental vitamin A depends upon the dietary β-carotene content, which in turn depends on the amount and quality of alfalfa meal.

Both deficiency and toxicity of vitamin A cause reproductive problems, including resorbed fetuses, abortion, hydrocephalus, and small, weak kits at birth. Deficient and toxic dietary vitamin A levels have not been well defined but are in the region of 5,000 and 70,000 IU/kg diet, respectively. Little information is available on **vitamin E** requirements.

The absence of a vitamin or its inadequate amount in the diet will result in poor performance and, if severe, in specific deficiency symptoms. Vitamins should be present for normal absorption and utilization of the other required nutrients. Frye recommended a vitamin premix be used as a supplementation for growing rabbits. This premix should be used at a minimum rate of 2.5 kg/1000 kg of complete feed. **Vitamin C** (ascorbic acid) supplementation is recommended for diets of rabbits under stress.

Some of the factors that can affect the amount of a given vitamin in a diet are: improper formulation, low-quality supplemental vitamin product, amount of time the feed is stored, and environmental conditions such as temperature and humidity. Vitamins will be degraded under conditions of high temperature and humidity. It is recommended that feed should be utilized within a maximum of 3-4 months after blending in order to have the proper nutritive value. If feed is contaminated by mold, insects, or rodents, the shelf life may be much less than 3-4 months.

Factors that can influence the vitamin requirement level in rabbits are: general health of the animals (parasites and diseases damage the lining of the digestive tract and increase the requirements), environmental stress, medication (especially with antibiotics, which decrease the rate of B-complex synthesis), rate of growth (animals that grow faster require more quantities of vitamins per day), quality of the product being used as a source for the vitamin (bioavailability), and system of production: intensive versus extensive (animals under intensive systems of production have a higher requirement).

Dietary levels below the requirement for vitamins A, D, E, and K will produce deficiency symptoms similar to those in other species. **Excess** vitamin A and D are known to cause health problems in rabbits. Supplementation of fat soluble vitamins in the diet may be necessary but should be done with care.

Mineral and vitamin more nutritional considerations

Sodium chloride (salt)

Added at the rate of 0.5-1% (in deficiency of I iodized salt is used). Rabbits enjoy salt, and if a salt spool is available; they will satisfy their requirements. The disadvantage of salt spools, especially in all-wire hutches, is that the salt is corrosive to the metal.

Phosphorus (P)

Rabbits raised on low-P soil- alfalfa showed

1- retarded growth

2- more matings per conception.

3- lower breaking strength of bone.

Magnesium

Rabbits suffering from the lack of dietary magnesium exhibit poor growth, fur-chewing habits, and hyperirritability.

Potassium

A form of muscular dystrophy which resembles a deficiency of vitamin E occurs in rabbits suffering from K deficiency. Generally a diet consisting of 50% roughage is adequate in fulfilling the K requirement of rabbits.

Cobalt

Since the microorganisms of the cecum have the ability to synthesize vitamin B_{12}, all the precursors-including Co-must be supplied. No quantitative requirement for Co has been established.

Iodine

The needs have not been determined, however it is recommended that iodized salt be used routinely. Rations could contain at least 0.22 mg of iodine/kg.

Iron and Copper

Deficiency causes anemia and requirements are similar to those of the horse.

Manganese

Deficiencies of manganese in rabbits cause bone deformities such as crooked legs, brittleness, decreased weight, decreased ash content and smaller size have been observed in deficient rabbits.

Zinc

Symptoms in deficiency include lowered feed consumption, weight loss, graying of hair, alopecia, dermatitis, lowered hematocrit, and reproductive problems.

Vitamins

The amount of information, as with minerals, is very limited. As in the other chapters a chart summarizing symptoms of deficiencies and notes should be reviewed.

Fat-soluble vitamins

Vitamin A & E are probably the only two vitamins for which there is a serious need for dietary supplementation.

Vitamin A

Requirement for gestation is double that for growth and generally the deficiency affect the reproductive performance of the female before other symptoms can be recognized. Premature degeneration of ova, reduced numbers of fertile ova, abortion, or resorption of fetuses in the latter part of gestation occur in the adult female suffering from A deficiency. Offspring from a deficient female may be hydrocephalic at birth. 50 ug/kg body weights prevent the symptoms of deficiency.

Vitamin D

Exposure to sunlight supplies the needs for vitamin D. Deficiency (rabbits reared in confinement) causes rickets.

Vitamin E

The NRC suggests a need for a level of 40 mg/kg diet. Unlike other animals Se does not exert a vitamin E-sparing effect. Symptoms of deficiency are muscular dystrophy, with paralysis in hind legs reproductive failure, and fatty livers.

Unlike the situation in some other animals, vit.E deficiency does not affect the fertility of the rabbit but produce muscular dystrophy. The feeding of excessive amount of cod liver oil, by destroying the vitamin E content of the rations may thus produce this trouble. Vit.E itself is present in fresh green foods, in cereal grains and particularly in the cereal germ.

Vitamin K

Bacterial synthesis and coprophagy should supply the needs. However research has indicated that K is required for reporduction, (0.22 mg/kg diet for pregnant does). If drugs are being used that could reduce the microflora of the gut, supplemental K may be indicated.

Water-soluble vitamins

The requirements for pantothenic, B_2, biotin, folic & B_{12} are met through bacterial synthesis in the cecum. Research has indicated that some supplementation of niacin, pyridoxine, and choline will aid in production. Cobalt must be supplied for B_{12} synthesis.

In spite of being that the bacterial population of the caecum manufacture these vitamins, there have, however, been reports of poor growth & reproductive failure due to lack of these vitamins.

FEEDSTUFFS FOR RABBITS

The major ingredients used in rabbit diets are feed grains, milling by-products, protein supplements, forages, fats, synthetic amino acids, and mineral and vitamin supplements. Selection of ingredients should be done on the basis of availability, freshness, nutrient content, price, and palatability.

Feed Grains

Feed grains are used as source of energy. Barley, wheat, oats, corn, and sorghum, can be included in rabbit diets. Grain milling by-products can be utilized in rabbit diets as a source of fiber and a limited source of protein. The contribution of feed grains to diet protein is limited.

Additives

In some cases, it may be desirable to use additives in rabbit diets. The most common additives are antibiotics, coccidiostats, and antioxidants. These additives, when included in any diet, should be in accordance with FDA regulations.

Coccidiosis is the most prevalent parasitic disease in rabbits. Four species of this protozoa live in the intestine of the rabbit, while an additional species infiltrates the liver. The intestinal species cause diarrhea, loss of appetite, weight loss, and sometimes death. The liver species-the most pathogenic form of coccidiosis in rabbit- enters via the intestine and travels up the bile ducts to the liver. While this form may not be lethal, infected livers must be condemned. One treatment calls for the addition of 0.025% sulfaquinoxaline in the ration for 30 days. The drug should not be used on a continuous basis as the coccidia organism can develop tolerances to it over extended periods of exposure. Rabbits should not be treated for coccidiosis within 10 days of slaughter if they are to be used for food. Since most rabbit producers feed on one feed or at the most two, the addition of anticoccidial drugs to the feed becomes impractical. The best method to administer these drugs is through the drinking water. Withdrawing these drugs can then be facilitated by merely changing the water.

Molasses may be added to rabbit diets to increase the energy content of the diet, to increase palatability, or to reduce dustiness of the mix. Caution should be taken when using molasses because high levels (greater than 6 percent) may produce diarrhea. Buffers and pellet binders are also added to the diets. Of the pellet binders, Ca and Na lignosulphonates have been reported to produce high incidences of colon ulcerations and high mortality, while Mg lignosulphonates appear to have no such effects.

Protein Supplements

Most of the protein supplements used in rabbit diets are of plant origin. However, when offered, animal protein supplements (fish meal, meat meal) will be consumed by rabbits, but to a lesser extent than those from plant sources. Animal and fish products are seldom included in rabbit diets because of their high costs. Plant protein sources are usually cheaper than those of animal origin. The most common protein supplements are soybean meal, cottonseed meal, peanut meal, rapeseed meal (canola meal), sesame seed meal, sunflower meal, and safflower meal. Caution should be taken when feeding cottonseed meal and rapeseed meal. Cottonseed meal can contain high levels of gossypol, making the ration unpalatable and toxic. Problems may also be encountered with rapeseed meal if the levels of erucic acid are high. Rapeseed meal has been reported to cause problems in fertility and reproduction in does. Peanut meal should be used with caution because this feedstuff may sometimes contain aflatoxins.

In some parts of the world, beans have been used as a protein source. Some raw beans (including raw soybeans) as well as soybean meal have been reported to affect animal performance due to high contents of antitrypsin factors and other growth depressant compounds. Proper heat treatment of beans and soybean meal inactivates these compounds.

Forages

Forages are used in rabbit diets as a source of fiber and bulk. Forages can be directly incorporated into a completely pelleted feed or be used as a complement to pellets. It is more convenient from the point of view of handling and knowledge of animal intake to include forages in the pellets. However, in some situations, direct use could be more convenient, as is the case in backyard and other small operations. When given apart from the pellets, it is better to offer forages in the form of hay. Care should be taken to avoid moldy forages, because these can cause digestive disorders in rabbits

Of all forages, alfalfa is the most widely used and preferred by the animals. This legume provides not only a good source of fiber, but good levels of protein and Ca. However, caution should be taken when using very young alfalfa. Alfalfa from very early cuts is high in protein (greater than 20 percent) and xanthophylls, but when used in growing rabbit diets it may cause diarrhea.

Certain carbonaceous hays can be used effectively in rabbit rations, to reduce feed costs. Generally they are less palatable and contain less protein. They can be used in maintenance rations, but not more than 10% in rations for production.

Fats

Fats can be added to rabbit diets as a concentrated source of energy and a source of essential fatty acids. Rabbit diets will contain, on the average, 3 percent fats that come from the different feedstuffs used for typical diets. Added fats increase the diet energy density, but sometimes they also increase the price of feed. An economic analysis comparing price to performance will be required to ascertain whether increasing feed price per unit will increase profitability. It has been reported that adding fats increases the feed to gain ratio in growing rabbits, and that this increase was noted with fat additions up to 6 percent. However, high levels of fat present a problem for pelleting. Pelleting will be done properly if the added fat does not exceed 3 percent. Fat could be sprayed on the pellets.

Other-Nonconventional Feedstuffs

Other materials have been used as feedstuffs for rabbits as a partial substitute for the conventional grains and forages or as a primary source, as is the case of some tropical plants. Pomaces, the residue of industrial processing of some fruits (apples, grapes, tomatoes, pears), have been utilized without detrimental effects in diets of growing and adult rabbits. These pomaces have variable levels of fiber and soluble carbohydrates and are low in protein.

In tropical areas cassava root meal, coconut meal, tropical kudzu, palm oil, whole corn plant meal, amaranthus, carrot leaves, bananas, sweet potatoes, sugar cane, and NaOH-treated straw have been used as feedstuff for rabbits. However, the water content of roots and tubers tends to be extremely high (about 90%) and the protein level is quite low (1 to 4%). They are highly palatable and are good sources of vitamins and minerals. A deficiency in some of the nutrients may result when feeding roots and tubers, because rabbits preferentially eat this type of feed first, subsequently neglecting the higher quality feeds. For this reason, the daily allowance of roots and tubers in a maintenance ration should be limited to 1.5% of the body weight. Rabbits in production should not be fed any roots or tubers.

Trifolium alexandrium is utilized in rabbit diets and has a good level of protein.

Diet Formulation

One important factor to consider in rabbit diet formulation is the quality of the ingredients, because these will have a direct impact on rabbit health and performance. Quality includes shelf life and nutrient profile.

Feed manufacturers provide a feed label tag. where information regarding composition and feed analysis is displayed. Rabbit producers should read these labels carefully, but the label guarantee does not imply consistent nutrition or performance in some cases because required information is not sufficient to make an evaluation. Performance of a mix is obtained by comparing those feeds on actual feeding tests. The best policy is to buy feed produced by a reputable feed company.

Producers formulating their own feeds should follow the nutritional recommendations and select the feed ingredients as described earlier in this chapter. Formulating a diet for rabbits may be approached as follows: (A) identify the target animal (gestating, lactating, growing, breeding) for which the diet is intended; (B) select the appropriate nutrient requirements (see Tables); (C) select appropriate feed ingredients in order to formulate a diet that is nutritionally balanced, palatable, and safe; (D) formulate the ration based on nutrition, efficiency, and cost.

Feed manufacturers have three types of pellets available in the market: all-grain pellets, all-hay pellets, and complete pellets (grain and forage together). The type of pellet required will depend on the type of feeding management adopted in the rabbitry. An all-grain pellet requires a supplementation of hay; use of a hay pellet requires a supplementation of grain; a complete pellet does not require supplementation of any kind.

Mixing of rabbit diets should have the end result of satisfying all of the minimum daily requirements for energy, protein, minerals, and vitamins within the limits of the animal's normal feed intake. Supplementation, therefore, should not be necessary. If the mix is adequate, extra supplementation will cause a nutritional imbalance which leads to subopfimal performance. Examples of some sample diets for rabbits are presented in Table.

A feed mix of uniform quality is the ideal target for rabbit feeding. Formulas may vary according to local feed price changes. If a change is economically necessary, keep in mind that significant variations during a short period of time in ingredient or nutritional composition will alter the cecal environment. This change will alter the cecal bacterial composition and its byproducts and will change the rabbit's ability to utilize nutrients. To obtain a uniform mix, the ingredients of the ration should be ground and then pelleted. Pellets should be 3-4 mm in diameter and no longer than 8 mm. Pelleting prevents selection by the animal, should reduce waste, and increases total dry matter intake.

Sample diets for rabbits

Ingredient	Maintenance	Growth for weaned rabbits		Lactation	
Alfalfa hay, %	52.4	40.0	45.0	36.4	34.9
Barley, %	18.1	15.9	34.0	—	—
Corn, %	—	—	2.7	32.5	41.1
Oats, %	9.6	15.8	—	—	—
Soybean meal, %	—	10.4	—	16.3	—
Sunflower meal, %	3.5	—	11.1	—	17.8
Wheat bran, %	13.0	12.5	2.1	10.2	1.7
Cane molasses, %	1.5	3.0	3.0	1.6	1.5
Dicalcium Phosphate, %	1.1	1.6	1.3	2.2	2.2
Salt (NaCI), %	0.5	0.5	0.5	0.5	0.5
Supplement,* %	0.3	0.3	0.3	0.3	0.3

**** The supplement must contain the sources to balance microminerals, vitamins, and amino acids.***

Feed Storage

Feed should be stored in containers (bins or silos) that can be emptied and cleaned on a regular basis to maintain the quality of the diet. Nutrient stability in complete mixed rabbit diets is inversely related to environmental temperature and humidity. Knapka reported that although the quality of rabbit diets may decrease during the shelf life period, there is no research documentation of problems as a direct result of this loss in quality. The same author recommended to feed rabbit diets as soon as possible after manufacture and not to use diets when there is doubt regarding their quality. In general, it is recommended that feed should be used as soon as possible after mixing, and to have the objective of not keeping feed more than 4-6 weeks in storage.

Feeding Schedule

In any type of rabbit operation, time of feeding should be constant, since rabbits can be influenced by changes in routine. Any changes in routine should be done in a stepwise fashion. Time of feeding will depend on the type of exploitation. If the operation is an extensive one, in which feed is available to animals at all times, the filling of feeders should be done at the same time every day, making sure the animals will not run out of feed between refillings. Operators should verify feed consumption, as reflected by the time between refills, because any changes in consumption will indicate problems, like diseases, or waste, and these should be corrected quickly. If the animals are fed several times daily, the routine should be maintained.

Caution should be taken to feed late in the day, because rabbits are more active during the night and feed consumption is highest during that period. The producer must make sure that feeders are at the appropriate level before leaving in the evening. Feeders should be checked in the morning to verify consumption. This practice will alert the producer to possible problems which usually begin with reduced feed intake. A number of different types of feeder are available.

Breeding Animals

Feeding young breeding animals properly is very important because it affects the lifetime reproductive capacity of the animals. Proper feeding and nutrition during their growing period will result in a higher production for a long time. Growing breeding rabbits must have adequate nutrition in order to fulfill all of their growing needs, but not above these levels, or they may become overweight. Overweight breeding animals must be avoided because it causes poor reproductive performance, may cause metabolic problems (young doe syndrome), and also wastes feed.

Overweight may also cause breeding failures during the periods of high temperature (summer months). Temperatures in the rabbitry should be maintained at 21-24° C. During periods of high temperature, rabbits' physical activity decreases, thus reducing energy use. The excess energy could result in extra body weight.

Growing breeding animals should be fed a diet in an amount that keeps the animals in good physical condition and promotes normal growth, but that prevents them from becoming fat. These animals should be observed closely and their feed should be adjusted accordingly. Restriction of feed can be done by physically reducing the amount of diet offered or by offering forage (hay).

When feeding growing breeding stock, care should be taken to ensure enough floor and feeder space. When animals are kept in a group (up to 12-13 weeks of age), floor space should be a minimum of 0.07 m/animal. The feeder space should be such that all animals can eat at the same time. This practice will ensure proper intake and growth by all animals and will reduce the risk of diseases.

Adult males and nonpregnant and nonlactating adult females should be restricted in their feed intake when not reproductively active, to avoid body overconditioning. During the breeding activity period the amount of feed offered to bucks and does should be increased moderately. When rabbits are restricted in their feed, the producers should monitor on a regular basis the condition of the animals to adjust accordingly the amount being offered. The ideal situation is to maintain the body weight of the animals without overweight or weight loss.

Pregnant Does

Pregnant does should also be restricted in their feed intake during the gestation period to control their body weight. Feeding pregnant does ad libitum will result in reduction of litter size, problems at kindling, and waste of feed.

In pregnant females, feed and water consumption increase to a maximum around the tenth day of gestation. From the tenth day on, consumption is kept constant and then decreases at the end of the gestation period. A day or two before kindling, some does consume almost no feed and water. An adult New Zealand White doe will consume on the average 105-115 g/day of feed (2500 kcal/kg) in the first 10 days, and then level at 150-160 g/day until kindling.

Lactating Does and Litters

Lactating females have a high nutrient demand due to their milk production level. Milk production is associated with litter size and nutrient intake. Proper feed intake will ensure proper nutrient intake, which will be reflected in the milk output, and hence, in the initial rate of growth of the rabbits. Overall feed digestibility diminishes with the advance of lactation in lactating does, thus the importance of providing feed with the proper nutrient density to these animals. Preweaning rate of growth is directly associated with postweaning rate of growth and feed efficiency. Improper feeding of lactating does not only affects milk production and litter performance but also will have a negative effect on future reproduction performance and productive longevity of the doe.

Lactating does must be fed a good-quality feed. This will ensure the availability of nutrients required for milk production. After the second week of lactation some of the young rabbits will start to come out of the nest and will also start to consume some of the doe's feed, so it is important to have feed available at all times for the doe and her litter. A good manager will check several times a day the level of feed in feeders for lactating does and her litters. The most economical gains of growing rabbits are made during the time they are with the doe.

After kindling, feed and water consumption increase as milk production increases. Feeding the lactating does ad libitum right after kindling may cause a carbohydrate overload or increase the possibility of mastitis. The amount offered to does the day of kindling should be around half the normal amount. From the second day on, feed offered to lactating does should be increased gradually to ad libitum, usually in a week's time. Feed consumption may reach 500 g/d (2500 kcal/kg) in New Zealand does. The amount of feed and water consumption depends on the milk production level of the doe. Feed intake will increase in order to fulfill the nutrient demand of lactation, however the doe may not be able to eat enough feed to meet those requirements because of the physical gut fill limitation of the animal. Some producers recommend a special lactating diet which has a higher caloric density. Animals eating a high caloric-density diet consume less volume of feed to obtain the required amount of nutrients.

The feed offered to lactating does could be the same as that offered to fast-growing animals. Having only one diet has the advantages of reducing feeding and storage for different diets, and because the young animals consume their mother's feed they will continue to use the same feed after weaning without going through a period of adaptation.

Feeders utilized for lactating does with a litter should have a capacity for at least 2-3 days' feed supply. Feeders should be checked regularly for contamination, ease of flow, and level of feed. The physical location of the feeder should be low enough for the small animals to have easy access to the feed, but high enough to prevent the litter climbing and laying on the feed.

Creep feeding is practiced in some rabbit enterprises. This system consists of offering a special type of feed, usually higher in energy and protein than the doe diet. This diet will allow the young animals to grow faster, allowing an earlier weaning. The creep feed is offered in special feeders from which the young can eat but the doe cannot. The adoption of this practice depends on the economics of it.

Does that are producing a high amount of milk at weaning time should be restricted to a minimum in the amount of concentrate offered. These animals should be offered a good-quality hay. When the does dries off, then feeding of concentrate could be resumed, in a progressive manner. This practice is intended to reduce mastitis problems in heavy milkers.

Growing Rabbits (Weaning to Slaughter)

In meat rabbit production, the growing animals and the lactating females are the ones with the highest nutrient demand. These animals should have feed of good quality and fresh water available at all times.

For intensive meat rabbit operations, feeding is done almost exclusively with pelleted complete mixes, and there is no need for additional supplementation of either grains or forages. In less intensive operations it may be necessary to feed animals forage in order to limit energy intake. In these cases, forages should not be ground. It is recommended that they be fed as hay and cut to at least 7-10 cm for best results.

Growing rabbits of 5-10 weeks of age will have an average daily dry feed consumption of 80-95 g/kg body weight (2500 kcal/kg). For practical feeding, allowances should be made for feed waste in order to buy and store appropriate amounts of feeds for the rabbit operation. Daily water consumption will be 135-150 ml/kg body weight.

Feeding management for meat rabbits should be done based on specific targets. These targets include the expected feed conversion and average daily gain. Feed conversion should be calculated in terms of total feed utilized and total gain obtained. Feed conversion varies widely among rabbit breeds and managements. An average feed conversion for meat-producing rabbits should be 3:1, that is, 3 kg of feed for each kg of live weight gain. Feed conversion decreases with increase in age, especially after 10 weeks of age. For a good economic return it is important to produce rabbits that reach slaughter weight in the shortest time. Total feed utilized includes both feed consumed and feed wasted, the latter being one of the targets for reduction in the operation because waste has a negative impact on feed efficiency. A good feed efficiency and average-daily gain can be obtained through good animal genetic selection, proper nutrition and health, good feeding practices, and constant management improvement.

Feeding orfan litters:

Transferred to a recently kindled doe, but if not possible, a procedure like the following may be used.

1- For the first tow weeks of life, feed cows or goat’s milk heated to body temperature using an eyedropper or a doll’s nursing bottle. The eyes of the young rabbits will open at about day 10.

2- After the initial nursing period, solid food, such as fresh grass and rolled oats, can be offered in addition to milk. This will stimulate the development of the gut.

3- When the young are about 17 days of age, they can be taught to drink from a pan and offered small quantities of a good growing ration.

4- Gradually the quantity of solid feed can be increased.

Hair- and Fur-Producing Rabbits For hair and pelt rabbit production, it should be noted that production is done with adult animals, and thus feeding should be of good quality but restricted. In this type of operation postweaning rate of gain is not as important as for the meat rabbit enterprise. Protein levels, and in particular, S-containing amino acids, are critical for proper performance because the final product (pelt and hair) consist mainly of protein material, primarily keratin. The minimum recommended level of total protein is 17 percent, with a minimum of 0.65-0.70 percent of total S containing amino acids in the diet.

In order to restrict pellet consumption and at the same time maintain a high protein level in the diet, good-quality alfalfa hay and oats can be used together with the pelleted ration.

It is recommended to fast the animals at least once a week. This practice will ensure the emptying of the stomach, reducing in a significant way accumulation of ingested hair. Ingested hair has the tendency to aggregate in "balls" that obstruct the pylorus of the rabbit, causing the animal's death.

From the aforementioned discussion for feeding the raising can be divided into several stage periods:

1- The suckling period to the feeding time (30-40 days on maximum).

2- Rabbits raised as a breeding stock from 1to 5 months.

3- Rabbits raised for meat production to the age of 10 weeks.

4- Nonpregnant does. 5- Pregnant does. 6- Lactating does. 7- Adult bucks.

Composition of Diets and Feeding Practices

The North American rabbit industry has not developed sufficiently to justify the use of different diets such as starter, grower, finisher, and lactation diets. Generally, only one feed is used, with allowance for different nutrient requirements made by adjusting the amount of feed offered. Growing and lactating animals are usually full-fed ad libitum, whereas bucks and nonlactating does are usually limit-fed restricted amounts of feed. If the rabbit industry becomes more intensive, use of more than one type of production diet will probably become more common.

Lactating does have higher requirements for protein, energy, Ca, and P than do fryers and are more tolerant of fermentable carbohydrate (grain). For maximum reproductive efficiency, at least 18% crude protein is needed, whereas 16% protein is adequate for fryers. With does in intensive breeding systems (rebreeding within 7 days postpartum) the animals are simultaneously pregnant and lactating and should be fed ad libitum. When does are not lactating, feed should be restricted if necessary to prevent obesity. Excessive body condition has adverse effects on reproduction.

Although breed differences in nutritional requirements have not been well studied, there is some evidence that dwarf breeds are not as tolerant of high-fiber diets as the larger breeds. This is presumably a reflection of the effect of body size on hind gut capacity and rate of passage.

Generally diets for rabbit are based upon low-energy, high-fiber ingredients. Inclusion of grains increases the incidence of enteritis losses and often reduces animal performance. The digestive tract of rabbits has a poor adaptation to the use of high-energy diets.

Examples of suitable diets

Ingredient	Grower diets for weaned rabbits			Lactation diets		Satisfactory diets for rabbits		
	Diet A	Diet B	Diet C	Diet A	Diet B	Diet A	Diet B	Diet C
Alfalfa meal	54	40	40	40	30	54	40	40
Ground barley	-	20	25	20	23	-	20	25
Ground oats	-	27.5	-	-	26.5	-	27.5	-
Wheat mill run	36.5	-	23.5	20	-	36.5	-	23.5
SBM	6	9	-	14	16	6	9	-
Molasses	3	3	3	3	3	3	3	3
Fat	-	-	-	1.5	-	-	-	-
Cottonseed meal	-	-	8	-	-	-	-	8
Dicalcium phosphate	-	-	-	0.75	1	-	-	-
Salt (trace, mineralzied)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5

- If good quality, bright green alfalfa meal is used, a vitamin supplement is unnecessary. If the alfalfa quality is questionable, it is advisable to add a vitamin premix (a swine or poultry vitamin premix is satisfactory).
- Refer to other examples under the title "diet formulation"

Health Problems

Health of the animals is related to proper feeding and nutrition practices. Proper feeding and nutrition will give the animals the basis for building resistance and maintaining their immunological system in good working condition.

Health problems associated with feeding could be the result of nutrient imbalances, improper feed or fiber particle size, or inappropriate feeding schedules. A significant imbalance between protein and fiber can increase the risk of enteritis. It is recommended that the protein level be kept between 16 and 18 percent and the fiber at a level of 12-15 percent. Other nutrient balances to keep in mind are Ca:P and K and Na. Fiber particle size could be a problem if it is too finely ground. This will increase feed retention time in the digestive tract and in turn could modify the cecum microflora. Modification of the microflora will bring as a result a change in the volatile fatty acid rate of production and induce a series of reactions that produce amines and ammonia, changing the cecal pH and favoring increases in coliform bacteria. Feeding in irregular patterns (lack of a systematic schedule), could favor enteritis. Irregular patterns of work will cause stress to the animals. Stress may cause diarrhea, especially in growing rabbits, producing a Na and K imbalance. To avoid these problems, all routine work in the rabbitry (feeding, breeding, cleaning) should be done at the same time every day if possible.

For certain health-related problems, such as cecum stasis or lung edema, the cause could be associated with pellet size, feed grinding, or particle size. A routine inspection of particle size will help prevent some of the associated digestive problems in rabbits.

When feeding forages to rabbits it is recommended to use a good-quality hay rather than green feed. Green-forage may cause noninfectious diarrhea, thus affecting animal performance and economic returns.

Enteritis

One of the major problems in commercial rabbit production is enteritis. Most cases of enteritis are enterotoxemia, meaning that such cases are caused by bacterial toxins elaborated in the gut. The major organisms involved are Clostridium spiroforme and toxigenic strains of E. coli. Enterotoxemia is of particular importance in weanling rabbits. At weaning, the gut of the young rabbit is susceptible to microbial invasion because the stomach pH (approximately 5) has not dropped to the very acid (pH 1.5 to 2) bacteriocidal level typical of the adult rabbit. If the diet is high in energy (from starch or other readily fermentable carbohydrate), carbohydrate overload of the hindgut may occur, with a proliferation of microbes in the cecum. The high quantity of VFA causes a temporary drop in cecal pH, killing many of the normal microbes and allowing proliferation of pathogens such as C. spiroforme and E. coli, which produce lethal toxins.

Postweaning enteritis can be minimized by feeding a low energy, high fiber diet. The crude fiber content should be 13 to 15 percent, and the diet should contain less than 20 percent cereal grain. Grain milling by-products, such as wheat middlings, are an excellent substitute for grain in rabbit diets. The use of high- fiber, low-starch diets reduces the likelihood of carbohydrate overload of the hindgut, and the fiber helps maintain normal gut motility. **Hypomotility**, or lack of normal gut contractions, with low-fiber diets is a contributing factor to enteric problems. Adequate dietary fiber also helps to prevent cecal impaction **(mucoid enteritis)**. In this condition, the cecum becomes impacted with fine particulate matter. The goblet cells of the colon mucosa secrete increased quantities of mucus, resulting in large amounts of mucus being excreted with the feces.

Other Nutritional Problems

Fur chewing is a common problem in rabbits; animals pull and consume their own hair or that of other animals in the cage. Besides ruining the pelt of market animals, fur chewing leads to hairballs in the stomach. Animals with hairballs stop eating and eventually die of inanition. Fur chewing seems to occur mainly when the diet is inadequate in indigestible fiber. Increasing the crude fiber content of the diet, or providing a source of fiber such as hay or straw to the animals, generally eliminates the problem. Oral administration of a source of proteolytic enzymes, such as bromelain, papain, or raw pineapple juice, results in digestion of the mucus holding the hairball together and allows it to pass through the pyloric sphincter.

Reproduction in rabbits is influenced by nutrition. Inadequate energy intake may result in resorption of the fetuses, or small, weak litters at birth. Excessively fat does will similarly have small, weak litters and poor milking ability. One of the major causes of poor reproduction during the winter is inadequate energy intake of does, often a result of limit-feeding the same amount of feed as provided in the summer. In cold-climate areas, feed intake must be increased during the winter to meet the animals' higher energy requirements. Another common source of reproductive problems is vitamin A malnutrition. As mentioned above, deficient (less than 5,000 lU/kg of diet) or toxic (more than 70,000 lU/kg) levels of vitamin A can result in fetal resorption, abortion, fetal hydrocephalus and small, weak, nonviable litters. Maintenance of adequate vitamin A status is complicated by variability in quality of alfalfa meal, which is usually the main ingredient of rabbit diets.

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