Beni-Suef University
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POULTRY NUTRITION

Postgraduate - the main

Part IV

Feeds

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Contents

Feeds

Before describing feeds used in poultry rations, some technical terms oftenly used in nutrition science, should be identified or described.

Technical terms

I. Terms relating to nomenclature of feeds

Nutrient

Is any food constituent or group of food constituents of the same general chemical composition that may aid in the support of animal life, as proteins, carbohydrates, fats, minerals and vitamins, also air andwater.

Supplement

A feed or feed mixtures used to improve the nutritional value of basal feeds. Supplements are usually rich in protein, minerals, vitamins, or a combination of part or all of these; and they are usually combined with basal feeds to produce a complete feed.

Premix

A uniform mixture of one or more microingredients and a carrier, used in the introduction of microingredients into a larger mixture.

High-lysine corn (Opaque-2)

Corn that is much than normal corn in lysine and tryptophan; hence, it has a better balance of the amino acids for monogastric animals. Also high-lysine corn is higher in total protein, but lower in leucine than regular corn. It is called opaque-2 as the endosperm does not transmit light. The corn is lower yielding than normal corn.

Quality protein maize (QPM)

A corn that retains the high-protein quality of opaque-2 but with higher yields and a hard endosperm that is less susceptible to fungal and insect damage.

Floury-2 corn

Kernels with soft, fine textured starch.

Diet

Feed ingredient or mixture of ingredients, including water, which is consumed by animals.

Ration (s)

The amount of feed supplied to an animal for a period usually a 24-hour period.

Balanced ration

One which provides an animal the proper amounts and proportions of all the required nutrients.

Formula feed

A feed consisting of two or more ingredients mixed in specified proportions.

Medicated feed

Any feed, which contains drug ingredients, intended for the cure, mitigation, treatment, or prevention of disease of animals.

II. Terms relating to processing of feeds

Flakes

An ingredient rolled or cut into flat pieces with or without prior steam conditioning.

Pellets

Ground feed compacted by steaming and forcing the material through die openings. Some binders may be used to enhance the firmness of pellets.

Dry-rendered

Residues of animal tissues cooked in open steam-jacketed vessels until the water has evaporated. Fat is removed by draining and pressing the solid residue.

Wet rendered

Cooked with steam under pressure in closed tanks.

Expeller process

A process for the mechanical extraction of oil from seeds, involving the use of a screw press.

Hydraulic process

A process for the mechanical extraction of oil from seeds, involving the use of a hydraulic press.Sometimes referred to "old process".

Solvent extraction

Fat or oil removed from materials (such as oilseeds) by organic solvents. Also called "new process".

Extruded

A type of feed preparation in which the feed is forced through a die under pressure.

III. Terms used for expressing animal requirements and nutritional value of feeds

Calorie (always written with small letter c)

The amount of heat required to raise the temperature of one gram of water one degree centigrade.

Kilocalorie (Kcal or Cal with a capital c) = 1000 cal

Therm or Megacalorie (Mcal) = 1000,000 cal or 1000 Kcal

Joule

A proposed international unit (4.184 j = 1 calorie) for expressing mechanical, chemical, or electrical energy, as well as the concept of heat.

International unit (IU)

A standard unit of potency of a biologic agent (e.g., a vitamin, hormone, antibiotic, antitoxin) as defined by the International Conference for Unification of formulae. Potency is based on bioassay that produces a particular effect agreed on internationally. Also called USP as defined by the United States Pharmacopoeia.

Parts per billion (PPB)

It equals micrograms per kilogram or millmicroliters per liter.

Parts per million (PPM)

It equals milligrams per kilogram or microliters per liter.

Nutrient requirements

Refers to meeting the animals minimum needs of one of the several nutrients, without margins of safety.

Nutrient allowances

Nutrient recommendations that allow for variations in feed composition, possible losses during storage and processing; day-to-day and period-to-period differences in needs, age and size of animal; stage of gestation and lactation; the kind and degree of activity: the amount of stress; the system of management; the health, condition, and temperament of the animal; and the kind, quality and amount of feed-all of which exert a powerful influence in determining nutritive needs.

National Research Council (NRC)

A division of the National Academy of Sciences in USA established to promote the effective utilization of scientific and technical resources and publishes bulletins giving nutrient requirements and allowances of domestic animals.

IV. Terms describing the act of feeding and management

Ad libitum

Free choice access to feed.

Limited feeding

Feeding animals less than they would like to eat, sufficient for maintenance and growth, but not enough for their potential production of finishing.

Phase feeding

Refers to changes in the animals diet to adjust for age and stage of production, season of the year and climatic changes, to account for differences in weight and nutrient requirements, and for economic or availability reasons.

Cannibalism

The habit of one animal pecking after eating on another animal, as in fowl and pigs. Also it is the eating of young, such as sow may do after farrowing or a doe rabbit may do if disturbed soon after kindling.

Efficiency of feed conversion

This is expressed as units of feed per unit of product-meat, milk, or eggs.

V. Terms relating to digestibility of feeds

Digestion coefficient (DC)

It is the percentage of each nutrient digested in a feeding stuff.

$$\text{DC of nutrient or DM} = \frac{\text{Digested nutrient or DM}}{\text{Intake}} \times 100$$

It is found that feeds, which contain little fiber such as corn and wheat, are highly digestible, while oats & bran are somewhat less digestible. The roughage has considerably lower digestion coefficient.

Digestible nutrients (DN)

This term covers that portion of each nutrient which may be digested and taken into the animal body. To find the amount of the digestible nutrients in any feeding stuff, the percentage of each nutrient is multiplied by the digestion coefficient for that nutrient.

VI. Terms used in describing the energy value of feeds

Gross energy (GE)

It is the amount of heat given off by the feed measured in calories when burned in pure oxygen gas under pressure in a calorimeter. It measures the value of any feeding stuff as a fuel for animal.

Digestible energy (DE)

It is the amount of energy given off by the total digestible nutrients in the feed. It can be determined by burning samples of the feed and of the feces in a bomb calorimeter. It aids in the calculation of TDN but the method is not in general use (the energy value of 1.0 Ib TDN is about 1,814 Calories).

Available or metabolizable energy (ME)

It is the amount of energy left after deducting from the gross energy of the feed these three total losses to the animal:

1) energy lost in feces
2) energy lost in urine
3) energy lost in combustible gases as methane (in ruminants 8% of GE at maintenance level and 6-7% at higher levels, in non-ruminants is negligible).

Metabolizable energy values are useful measures of the value of poultry feeds. In case of other farm animals, metabolizable energy values do not furnish a much better index to the relative values of feeds high in fiber and those low in fiber than do total digestible nutrient values.

VII. Terms describing the protein content and its value in feeds

Biological value (BV)

It is the proportion of the digested and absorbed protein that is not excreted in the urine.

$$BV = 100 \times \frac{\text{N intake} - [(\text{feces N} - \text{metabolic N}) + (\text{urine N} - \text{endogenous N})]}{\text{N intake} - (\text{feces N} - \text{metabolic N})}$$

This term is not one that can be set down in tables of food description because food protein does not have fixed biological value as it depends on the level of protein intake.

Protein equivalent

A term indicates the total nitrogenous contribution of a substance in comparison with the nitrogen content of protein (usually plant protein). For example the non-protein nitrogen (NPN) compound urea contains approximately 45% nitrogen and has a protein equivalent of 281% (6.25 x 45%).

Chemical analysis

Analysis of feeds is for both the prevention and diagnosis of nutritional problems. In order to combine various feeds into rations that will meet the requirements of livestock, it is necessary to have definite knowledge concerning their chemical analysis. A chemical analysis gives a solid foundation on which to start the evaluation of feeds. Thus, feed composition tables serve as a basis for ration formulation and food purchazing and merchandising.

Commercially prepared feeds are required to be labeled with a list of ingredients and a guaranteed analysis (percent minimum CP and EE- the higher cost items, maximum CF and ash- the lower cost items). Some also include maximum salt, minimum TDN, and/or minimum Ca and P. In addition to the mostly applied proximate analysis, new and sophisticated techniques are now being used in feed industry which can detect certain compounds in the range of parts per billion (mcg/kg of tissue or feed), and many analytical procedures have been improved through automation, thereby reducing cost per sample. New procedures are now being used to monitor contaminants, such as pesticides, and chemical pollutants, in feed.

a- Proximate analysis (Weende system)

It is a method has been developed by two scientists for more than 100 years ago. It is the most generally used in spite information may be of uncertain nutritional significance, if not misleading. Feeds are broken down into 6 components: (1) moisture, (2) ash, (3) crude protein, (4) ether extract, (5) crude fiber, and (6) nitrogen-free extract.

Moisture

Principle:

The moisture of the sample is lost by volatilization caused by heat (in hot air oven). The amount of material left is the dry matter. High temperature-drying can cause volatile compounds (as VFAs and some sugars that decompose above 70°C) to be lost (in some feeds or excreted feed residues) or sample characteristics to be altered. Several other methods are used and suited for these kinds of materials.

A rapid moisture testing equipment in which the drier consists of a heating element, an infra-red lamp, fitted to a balance equipped with a scale showing the moisture in percentage, may be used. A constant weight is attained in about 5 minutes. It is called the moisture balance. Although the determination is not extremely accurate, it does permit a good indication of the DM content.

Oven determination procedure

1. Weigh about 5 g of fresh sample in a moisture can.

2. Allow to dry overnight in an air oven at 105°C and for greater than 18 hours or in a vacuum oven at 50°C for 18 hours. The vacuum oven can also be used at 100°Cfor 5 hours.
3. Cool in a desiccator and reweigh.
4. Calculations,

   (can + sample) - can weight = sample weight

   (can + sample) - (can + dry sample) = moisture weight

Comments

- The greatest difference in nutritive value between many feeds, as fed, is traceable to differing moisture content, e.g. corn with 10% moisture has 80% TDN on as fed-basis and 90% on dry- basis, while sugar beets with 87% moisture has 10% TDN on as fed-basis, and 77% on dry- basis. Dry matter, therefore, becomes a common denominator for the comparison of foods.
- Cereal grains usually contain 9% water or more. Milling or other byproducts (as corn gluten feed, linseed meal and cottonseed meal) contain less than grains as they are heated or dried in the manufacturing process. Hay contains 15% or less while fresh green forages have 70-80%. Roots are especially watery (more than 90% water).
- Foods carrying more than 14% moisture can not be stored in bulk, and likely to mold, and spontaneous combustion may also take place.
- Corn grains, for e.g. are graded into 6 grades on the basis of its moisture content.
- Shrinkage of at least 5% in moisture in newly harvested grains is likely to occur after several months of storage. In ensiling, newly cut forages may be needed to be wilted and more mature forages may require the addition of water.

Ash

Principle

The sample is ignited at temperature in excess of 600°C to burn off all organic materials. The inorganic materials which do not volatilize at that temperature are called ash.

Procedure

1- Weigh 1.5 to 2.0 g of sample into a porcelain dish.
2- Put into furnace for two hours at 600°C.
3- Allow furnace to cool below 200°C.
4- Place crucibles in desiccator with stopper top, cool and weigh.

Calculations

(crucible + sample) - crucible weight = sample weight

(crucible + ash) - crucible weight = ash weight

$$100 \times \frac{\text{ash weight}}{\text{sample weight}} = \text{ash \%}$$

Comments

- Crude ash may enable the calculation of Ca& P in bone meal and fish meal, since the composition of the ash in these products is relatively constant.
- For plant materials, it has little direct use except for the calculation of carbohydrate by difference.
- Many feeds are high in silica (of no nutritional value).
- Ash determination is very crude as it does not indicate what minerals are present, does not include volatile minerals (I &Cl), weights the minerals as oxides or carbonates, does not indicate availability, and ignores minerals in such small quantities.
- Ash analysis is used quite often in forages to estimate the amount of dust and dirt harvested with the feed, and to monitor the amount of "filler", which are sometimes added.

Crude protein (kjeldahl method)

Principle

The material is digested with conc. H_2SO_4 (95-98%) to decompose it and convert nitrogen to ammonium sulfate. The solution is cooled, conc. alkali (50% w/w NaOH kjeldahl nitrogen grade) is added to make the solution alkaline, and the volatile ammonia is distilled into a weak acid (boric acid 4% or H_2SO_4 N/10). Following the distillation, the ammonia which is trapped as ammonium borate (or sulfate), is quantitated by titrating with a strong standard acid (N/14 HCl) or with standard alkali (NaOH N/10) if it is trapped in H_2So_4 N/10. The digestion is speeded by adding potassium sulfate, to increase the boiling point, and by adding a catalyst, copper sulfate.

The amount of protein is calculated by multiplying the % of N by 6.25 since most of the proteins contain 16% N (1/0.16) = 6.25).

Procedure

Digestion

1- Weigh 1.00 g dried, ground sample into an 800 ml kjeldahl flask.

2- Add 8.0 g copper catalyst mixture (96% anhydrous Na_2 or K_2 sulfate, 3.5% $CuSO_4$ and 0.5% selenium dioxide) and two glass boiling beads.

3- Turn on the exhaust fan to the digestion rack.

4- Add from 20 to 40 ml conc. H_2SO_4 from the dispensing buret, washing down any sample adhering to the neck of the flask.

5- Digest for 30 minutes, after the digest clears (about l-11/2 hours). Turn the flask frequently during digestion using an asbestos glove.

6- Allow the exhaust fan to run after digestion until the flasks are cool.

7- Slowly add about 300 ml of deionized water and swirl to mix. Allow to cool before distilling.

Distillation

1- Add 50-80 ml of 4% boric acid to an Erlenmeyer flask and place on the lower shelf of the distillation apparatus. Insert the condenser tube into the flask.

2- Turn on the condenser water.

3- Slowly add 80 ml of 45% NaOH from the dispensing buret to the digest to run down the neck of the flask. **DO NOT SHAKE OR SWIRL.** Note intense heat is generated and the contents are caustic, they may boil and

4- Add a few pieces of zinc to the flask to prevent bumping.

5- Place the flask on the distillation heater inserting the rubber stopper into the mouth. Quickly swirl the flask vigorously and place on heater. Immediately raise the Erlenmeyer flask up to the upper shelf so the condenser tube is submerged beneath the boric acid.

6- Turn the heater switch to HI.

7- Allow the flask to distill until about 250 ml of distillate has been collected in the Erlenmeyer flask.

8- Transfer the flask to the lower shelf and rinse the condenser tip with deionized water.

9- Remove the Erlenmeyer and place a plastic beaker of deionized water under the condenser tip, switch off the heater, and as the kjeldahl flask cools, the water in the beaker will be siphoned up through the condenser into the kjeldahl flask and cleans out the condenser.

Note: If the flask starts bumping, place a wire gauze under the flask. If the bumping is too violent, discontinue distillation and 200 ml of distillate should be sufficient.

Titration

Titrate the boric contained the liberated ammonia (with methyl red indicator) against N/14 HC1 or N/10 H_2SO_4. Use magnetic stirring bar into the boric flask and read the buret to the nearest 0.1 ml and record.

Calculations

1 ml HCl N/14 = 0.1 mg N

1 ml H_2SO_4 N/10 = 1.4 mg N

$$\therefore \frac{\text{mls of HCl} \times 1\ \text{mg N}}{1000\ \text{mg sample}} \times 100 \times 6.25 = \text{CP\%}$$

Or

$$\frac{\text{mls of H2So4} \times 1.4\ \text{mg N}}{1000\ \text{mg sample}} \times 100 \times 6.25 = \text{CP\%}$$

Example:

- mls of NaOH N/10 exhausted from the buret to reach and end point = 30
- mls of H_2SO_4 which bind the ammonia = 50 - 30 = 20
- Amount of N in mg = 20 x 1.4 = 28
- Percentage of CP = $\frac{28\ \text{mgN}}{1000\ \text{mg sample}} \times 100 \times 6.25 = 17.5$

In the official methods of analysis of AOAC there is a table showing the already calculated protein percentages for mls of acid recorded, for ease and rapidity.

Comments

1- The method is time-consuming and involves the use of hazardous chemicals.

2- Now different recent apparatuses are available in which the analyst can digest 20 samples at the same time, and distillate each in 5 minutes.

3- Nitrate nitrogen is not converted to ammonium salt so the N in this form is not included in the analysis.

4- The usually accepted classification of feedstuffs is essentially one based on protein content.

5- Not all proteins contain 16% N, and hence this estimation leads to inaccuracies of varying degrees. The nitrogen content of various feeds ranges from 13% to 18% and urea from 46% to 48%. A large part of fecal nitrogen is of metabolic origin to which the factor 6.25 may not apply.

6- Thus while N×6.25 may be a rough estimation of total protein and little or no estimate of its quality, it still is reasonably satisfactory index to compound rations. Quality of protein is of minor importance in herbivorous animals, and with other farm stock the amino acids can be well assured by the inclusion of small quantities of feeds of animal or marine origin.

Ether extract (Soxhlet method)

Principle

Ether is continuously volatilized, then condensed and allowed to pass through the sample, extracting ether soluble materials. The extract is collected in a flask. When the process is completed, the ether is distilled and collected in another container and the remaining crude fat is dried and weighed. More simpler is the weighing of the extracted sample where the weight lost is the amount of fat.

Procedure

1- Enclose about 5 g of a dried feed sample in a pre-weighed filter paper (be careful to see that both ends are completely closed to prevent loss of the material- use a stapler to fix).

Reweigh the enclosed sample and record.

2- Transfer to the extraction flask of the Soxhlet apparatus.

3- Put in a pre-weighed Erlenmeyer flask an amount of ether $1^{1}/_{2}$ times the volume of the extraction flask & install the apparatus.

4- Turn on the condenser water.

5- Turn on the heater first to HI till boiling then at the LI, and continue extraction for 16 hours or as instructed.

6- Remove the, Erlenmeyer flask and distill ether for reuse, dry in air, then in hot-air oven at 105°C, put in desiccator to cool and calculate the weight of the extracted material. Also the ether extract can be estimated by recording the loss in weight of the moisture-free sample following extraction.

Calculation

$$\frac{\text{Wt. of ether extract}}{\text{Wt. of sample (dried)}} \times 100 = \text{\% ether extract}$$

Comments

1- The ether extract consists of glycerides of FAs, FFAs, cholesterol, lecithin, chlorophyll, alkali substances, volatile oils, and resins. The last four are not classified as nutrients.

2- The food value of ether extract is not constant, it may differ in sterol content which has no energy value & it may contain vitamin A which is of particular importance, for e.g.

3- It has been taken, in practice, to yield 9 Kcal of ME/g.

4- When feces are extracted with ether, soaps that may have been formed in the intestinal tract from FFAs and calcium will not be removed. This gives erroneously high values for the digestibility of the ration fat, particularly in diets containing relatively high calcium content.

5- Except for the linolenic acid, EE is considered as a non-specific source of energy. But fat calories have a high efficiency and there is a reduced heat loss on the higher fat diets (have lower specific dynamic action).

6- Metabolic fecal fat is of bacterial origin and perhaps synthesized form dietary carbohydrates rather than dietary fat. It affects the apparent digestibility of EE to the extent that low fat diets often give negative digestibility. Also in feeds as roughages the neutral fat component of ether- extractives may be relatively small, and most of the other components are non-digestible.

7- Oats and corn are the highest in fat among the cereal grains (oats, and corn grade no. 1, 4.6%). Certain seeds, such as, cottonseeds, flaxseeds and soybeans serve as important sources of oil and the oil meals that remain, which contain much less fat, are important stock feeds.

Crude fiber

Principle

Boiling a fat-free dry sample in dilute acid and alkali to dissolve all the soluble compounds leaving behind the fiber-ash residue which can be filtered down and ignited to extract the amount of fiber left.

Procedure

1- Boil 5g of dried sample free from fatty materials, with 200 ml of 1.25% sulfuric acid in a flask for 30 minutes. Maintain a constant volume by the addition of distilled water if needed or join an assembly which aids in condensing any evaporated water.

2- Rotate the flask every few minutes in order to mix the contents and remove particles from the sides.

3- Allow to stand for one minute and then pour immediately under gentle suction in a prepared Buchner's funnel. The filtration of the bulk of the 200 ml is completed within ten minutes.

4- Wash the insoluble matter with boiling distilled water until the washing is free from acid, then wash with 1.25% sodium hydroxide.

5- Transfer to a bottle containing 200 ml of sodium hydroxide, boil for 30 minutes, using the aforementioned precautions,

6- Repeat the same steps for filtration and washing, and transfer the residue to a weighed crucible, to dry at 105°C to a constant weight.

7- Ignite in a muffle furnace, subtract the weight of the ash from the dried weight before ignition to obtain the weight of crude fiber.

Comments

Crude fiber refers to the residue of a feed that is insoluble after successive boiling with dilute alkali and dilute acid in accordance with the procedures by the Weende Experiment Station. It is made of (1) all of the original cellulose, (2) variable proportions of hemicellulose, and (3) a small, though again highly variable proportions of the lignin.

The reason for the relatively high digestibility of crude fiber by ruminant animals lies in the fact that the largest component (perhaps 95%) of crude fiber is cellulose, and we know that the microorganisms of the rumen are able to break down cellulose for their own needed energy, and that in the process they produce acetic acid (and some butyric and propionic), which is absorbed from the rumen and supplies the energy to the host. Corn grain contains only 2% fiber, wheat less than 3%, while oats because of the woody hulls, have 11%. Hay and straws are especially high in fiber (24 and 37% respectively).

Nitrogen-free extract

Nitrogen-free extract is a mixture of all of the starches and sugars of the sample, plus some hemicellulose, and unfortunately much of the lignin which has a very low feeding value. It is the difference between the original weight of the sample and the sum of weights of its water, ether extract, crude protein, crude fiber, and ash, as determined by their appropriate analyses. Thus its numerical value will be affected by the chemical errors in the analyses of all five of the separate fractions, as well as by the lack of precision of the crude fiber procedure.

Cereal grains are high in N-free extract which may reach to 70% and nearly all is starch. May and other roughages are much lower (about 40%) in N-free extract and considerable of it consists of hemicelluloses and the soluble portion of the cellulose and lignin.

General comments on "Weende" method of analysis and development of the new method "Van Soest"

Weende method separates carbohydrates into those well digested (NFE) and those less well digested (CF). The method aids to separate the feeds into roughages and concentrates, but has the following disadvantages:

1- Since the NFE is determined by difference, it accumulates all the errors in the other assays.

2- CF is not a precise descriptive terms as in some cases its digestibility is higher than the NFE in the same feed.

3- CF undergoes a very considerable breakdown in the digestive tract of the herbivores particularly ruminants, and it does not remain entirely unattached in omnivore.

4- NFE includes pentosans and other complex polysaccharides which are by no means completely digestible.

5- Lignin which is slightly digested by any species is partially removed by the alkali of the method.

Due to these problems Van Soest separated feedstuffs into these components a) mostly available b) incompletely available and c) mostly unavailable. Boiling the sample with a neutral detergent solubilizes the cell contents and pectin leaving behind the cell wall fraction, cellulose, hemicellulose and lignin (neutral detergent fiber, NDF). Subsequent boiling with an acid detergent hydrolyzes the hemicellulose leaving behind cellulose and lignin (ADF). Oxidation of lignin with potassium permanganate leaves cellulose and ash, which upon ignition, gives the value for cellulose.

b- Bomb Calorimetry

When compounds are burned completely in the presence of oxygen the resulting heat is referred to as gross energy (GE) or the heat of combustion. It is used to determine the GE of feeds, waste products from feed (feces & urine), and tissues.

Principle

An electric wire is attached to the material being tested, so that it can be ignited by remote control: 2,000 grams of water are poured around the bomb, 25 to 30 atmospheres of oxygen are added to the bomb; the material is ignited: the heat given off from the burned material warms the water; and a thermometer registers the change in temperature of the water.

A correction factor is determined through the use of a standard-benzoic acid. This factor is referred to as the hydrothermal equivalent (HE) of the calorimeter. This is in addition to two additional correction factors, the oxidation of the fuse wire and the acid production from the combustion. The determination of GE is not as difficult or time-consuming as the chemical analysis used in arriving at TDN values.

c- Chromatography

It is first used to separate colored substances, hence the origin of the term chromatography today, many of the compounds that are separated and identified are colorless. It separates compounds through the use of two phases-a stationary or fixed phase and a mobile phase. The difference between the various chromatographic techniques lies in the variation of the materials used in these phases.

d- Colorimetry and Spectrophotometry

They arc chemical analyses whereupon light is passed through solutions to yield information about the concentration of certain compounds. A particular wavelength of the light is passed through the samples, and the amount of light absorbed by the sample gives an indication of the concentration of the compound being tested. Colorimetry is useful for measuring using wavelengths in the visible region of the light spectrum whereas Spectrophotometry utilizes wavelengths in the ultraviolet, visible, and infrared regions of the spectrum.

Colorimetric procedure is for e.g. used for vitamin A determination and atomic absorption spectrophotometer is one of the most widely used instruments for mineral analysis, having the ability to detect many minerals at concentrations less than 1 part per billion (1 mcg/ kg). The principle differs from that of regular spectrophotometers. It is that certain compounds (for example, minerals) are volatilized; they emit light of a characteristic wavelength. The machine is calibrated to detect this light.

e- Biological analysis

It is oftenly used in the analysis of micronutrients in feeds. There are two types (1) microbiological assays (2) the use of nutrient-deficient animals.

Biological assays tend to be laborious and time-consuming, in addition large numbers of samples are needed to produce statistically reliable results. Animals should be approximately of the same age, sex, and weight and time is required to induce the deficient conditions. The parameters used are different and include growth, concentration of the nutrient in tissues (blood, liver, bone. etc.), histopathology of some tissues, and others.

Classification of feedstuffs

A feedstuff is any product of natural or artificial origin that has nutritional value in the diet when properly prepared. Feeds can be grouped according to their protein and energy content and by other special nutritional attributes that make them useful.

I. Concentrated food or concentrates

A broad classification of feedstuffs which are high in either energy or protein or both and low in crude fiber (under 18%). They are often broken down into (a) carbonaceous feeds, and (b) nitrogenous feeds.

a- Carbonaceous concentrates or energy feeds generally contain less than 20% protein, (but also contribute a significant amount of protein) such as the cereal grains (as maize and wheat) & some of their products, and molasses or fats & oils.

b- The protein or nitrogenous concentrates are the products with more than 20% protein and may be of animal origin as milk, fish meal, meat meal, blood meal, or of plant origin as oilseed meals (cottonseed cake, soybean oil meal etc.), grain legumes and milling byproducts.

II. Dry roughages, coarse feeds, or dry forages

They are feeds in the dry state that are bulky and low in weight per unit of volume; they contain more than 18% low digestible crude fiber and relatively low in energy. In this class are included the hays, straws from cereals and leguminous crops. A considerable part of the gross energy is used in the work of digestion leaving a small percentage of net energy.

III. Green fodders

They include grasses, berseem, darawah or silage. They are characterized by the high moisture content & fairly high fiber content, although the fibers are more digestible than that of dry roughage. They form the source of the yellow pigment carotene, and the dry matter includes, in most, a large amount of protein and highly digestible nutrients.

IV. Feed additives

Are ingredients, which are added to basic feed mixtures, usually in small quantities for the purpose of fortifying it with certain nutrients, stimulants and/or medicines, or any other purpose.

Carotenoid pigments are needed in feeds in order to satisfy consumer preference for yellow to orange color of skin and eggs in chickens, waterfowl, and other species. Natural sources of pigments are used in the United States. These include corn, corn gluten meal, and marigold petal meal among others. Synthetic carotenoids are added to feeds in other countries depending on local regulations concerning feed formulation.

Nonnutrient additives to poultry diets usually include antioxidants to help stabilize the vitamins and unsaturated fatty acids that are included in the diet. Antibiotics are often included, especially in diets of young poultry that are grown for meat. They tend to promote growth, possibly by suppressing the growth of undesirable intestinal microflora. Some antibiotics have specific antimicrobial functions. Anticoccidials, for example, control various species of Eimeria. These are organisms that infect the intestinal tract when birds are grown in floor pen environments where the Eimeria can be continuously reintroduced to the bird by consumption of droppings.

Poultry feeds

Poultry feeds typically comprise high-energy feed grains such as corn or wheat and often medium- energy ingredients such as wheat middlings, barley, and oats in combination with high protein ingredients such as soybean oil meal, meat and bone meal, poultry byproduct meal, fish meal, or other protein-rich foodstuffs. Diets usually include supplements of fat or oil as well as sources of minerals and vitamins.

Plant feedstuffs may vary in composition depending on environmental factors during crop production and harvesting or the nature and extent of processing. Heat treatment is required to inactive trypsin inhibitor activity and other toxic substances in beans. Unheated soybean meal, for example, can suppress the growth or egg production of poultry. Overheating may also suppress performance because of chemical damage to amino acids in the feedstuff. Lysine is particularly susceptible to destruction because of the reactivity of the amino group with reducing sugars and certain amino acids. Nutritionists must be aware of the nutrients content and quality of ingredients when formulating feeds for poultry. Nutritional and toxicological problems can arise if ingredients are not prescreened for nutritional quality and presence of harmful constituents such as mycotoxins prior to their incorporation into poultry feeds. However, at the present time the major ingredients utilized in poultry rations center on extensive use of corn for energy and soybean meal for protein, although many other feedstuffs may be used in smaller amounts. In general the variety of ingredients used in a given ration tends to be greater than for most other animal species.

General Considerations

In selecting feedstuffs for use in poultry rations, a number of factors should be considered. Ration palatability is important and while it may be inherent in the feedstuff; such as presence of tannins in some milos or sorghums, it may also be affected by such factors as moisture content, variety of ingredients, and contaminants such as molds. Birds may be attracted to feeds by light reflections from granite grit or differences in color, factors which are sometimes considered in feeding newly hatched poults (young turkeys). Physical condition of the feed, such as fineness of particle size or its hygroscopic properties, can also influence feed consumption.

In addition to factors that have been mentioned, physiological effects on both the bird and the product it produces must be considered. For example, care must be taken to avoid excessive use of feedstuffs which contain growth inhibitors or other undesirable substances that are often found in common plant protein sources. Similarly, both yellow corn and alfalfa contain xanthophyll pigments which may be undesirable when present in excess as far as yolk color is concerned, but which are desirable for broiler skin pigmentation.

Nutrient availability is also a factor. Availability may be affected by differences among feed ingredients, fiber content, presence of fat, amino acid balance, and other factors. The cost of the ingredients involved is a critical factor.

Feeds

A wide variety of feedstuffs can be, and is, used in poultry rations. Broadly speaking these may be classed as energy feedstuffs, protein supplements, mineral supplements, vitamin supplements, and non-nutritive additives.

Energy Feedstuffs

The major energy sources of poultry feeds are the cereal grains and their byproducts and fats.

Grains

Corn is the most important grain used by poultry, supplying on minimum about one-third of the total feed which they consume.

Oats, barley, and the sorghum grains are also used extensively in poultry rations. Oats are lower in energy than corn and are generally too expensive for broiler and layer rations. But oats can be used very effectively in feeds for replacement birds. Barely is less palatable than corn and is lower in vitamin A and energy. However, various processing methods, such as enzyme-water soaking treatments, have shown some promise for increasing the feeding value of barley. The sorghum grains can be readily substituted in the place of corn as energy feed.

Wheat may replace corn when available and the price is right. It is slightly lower in energy than corn, but higher in protein. Because wheat is gelatinous and has a tendency to "paste" on the beaks, it should be coarsely ground and pelleted when fed at high levels.

Surplus rice along with broken and low grade rice can be effectively used in poultry rations. Milled rice is quite comparable to corn in feeding value, except that it is lacking in vitamin A activity and pigmenting qualities.

Cereal Milling By Product Feeds

Numerous byproducts result from the milling and processing of grain. Many contain large amounts of protein as well as energy. Examples are corn bran, corn germ meal, corn gluten meal or feed, and rice polishing.

Fats

Animal and vegetable fats are not used extensively in poultry feed. They serve many functions and also help to homogenize and stabilize certain feed additives, especially those of a very fine particle size. However, the use of fats in poultry feeds requires good mixing equipment. Also, it is necessary that the fat be properly stabilized in order to prevent rancidity. Chickens are capable of tolerating high levels of fats, but costs usually permit only a maximum of 4 to 5% fat added to the ration.

Molasses

Molasses can be used effectively as an energy feed in poultry rations provided the level of usage is closely monitored. Excessive amounts cause wet droppings. Although molasses occasionally constitutes as much as 10% of poultry rations, levels are generally restricted to 2 to 5% (as it has a laxative effect).

In addition to its use as an energy feed, molasses is also used to reduce the dustiness of a ration, and as a binder for pelleting.

Cane and beet molasses are by-products of the manufacture of sugar from sugarcane and sugar beets, respectively. Citrus molasses is produced from the juice of citrus waste. Wood molasses is a by-product of the manufacture of paper, fiberboard and pure cellulose from wood; it is an extract from the more soluble carbohydrates and minerals of the wood material. Starch molasses is a by-product of the manufacture of dextrose from starch derived from corn or grain sorghums in which the starch is hydrolyzed by use of enzymes and/or acid. Cane or blackstrap is, by far, the most extensively used type of molasses. The different types of molasses are available in both liquid and dehydrated forms.

Protein Supplements

The usefulness of a protein feedstuff for poultry depends upon its ability to furnish the essential amino acids required by the bird, the digestibility of the protein, and the presence or absence of toxic substances. As a general rule, several different sources of protein produce better results than single protein sources. Both vegetable and animal protein supplements are used for poultry. Most of the protein supplements of animal origin contribute minerals and vitamins which significantly affect their value in poultry rations, but they are generally more variable in composition than the vegetable protein supplements.

Plant Proteins

Even though they are not especially high in protein by comparison with other feedstuffs, the vegetative portions of many plants supply an extremely large portion of the protein in the total ration of poultry, simply because these proteins of feeds are consumed in large quantities. Needed protein not provided in these feeds is commonly obtained from one or more of the oilseed by-products. The protein content and feeding value of the oilseed meals vary according to the seed from which they are produced, the geographic area in which they are grown, the amount of hull and/or seed coat included, and the method of oil extraction used.

Additional plant proteins are obtained as byproducts from grain milling, brewing and distilling, and starch production. Most of these industries use the starch in grains and seeds, then dispose of the residue, which contains a large portion of the protein of the original plant seed.

Oilseed Meals

Several rich oil bearing seeds are produced for vegetable oils for human food (oleomargarine, shortening, and salad oil), and for paints and other industrial purposes. In processing these seeds, protein-rich products of great value as poultry feeds are obtained. Among such high protein feeds are soybean meal, coconut meal, cottonseed meal, linseed meal, peanut meal, rapeseed meal, safflower meal, sesame meal, and sunflower seed meal. Oil is extracted by solvent extraction, hydraulic, or expeller extraction.

Soybean meal

Soybean meal has the highest nutritive value of any plant protein source and is the most widely used protein supplement in poultry rations.

In the past, oil was extracted by the solvent, hydraulic, and expeller processes. Today, almost all soybeans are solvent extracted. Soybean meal normally contains 41, 44, 48, or 50% protein, depending on the amount of hull removed. Because of its well-balanced amino acid profile, the protein of soybean meal is of better quality than other protein rich supplements of plant origin. However, it is low in calcium, phosphorus, carotene, and vitamin D. Because raw soybeans contain several antinutritional factors they should never be fed to poultry. However, heat processed soybean products are very acceptable poultry feeds.

Hull-less meals are often used in broiler rations because of their lower fibre and higher energy contents. Methionine may be slightly marginal in diets where SBM constitutes the major protein source.

In some circumstances unextracted SBs may be desirable to use in broiler rations, but the beans must be processed by either extruding or roasting. This will result in a product which can be utilized by poultry with up to 19% fat and 38% protein. Care must be exercised not to overheat SBs because this renders lysine and other AAs unavailable.

Cottonseed meal

The protein content of cottonseed meal varies from about 22% in meal made from undecorticated seed to 95% in flour made from seed from which the hulls have been removed completely. Thus, by screening out the residual hulls, which are low in protein and high in fiber, the processor is able to make a cottonseed meal of the protein content desired usually 36, 41, 44 or 48%.

Cottonseed meal is low in lysine and tryptophan and deficient in vitamin D, carotene, and calcium. But, cottonseed meal is rich in phosphorus. It can be fed to growing chickens provided free gossypol levels are below 0.03% and supplemental lysine is provided.

CSM may be used to replace up to half of the usual amount of SBM in grower poultry rations, but further use must be restricted because of the content of gossypol and sterculic acid. Gossypol levels of more than 0.04% will cause an olive green yolk color, particularly with eggs subjected to storage. Thus even with lower gossypol levels, the use of CSM for layers is restricted to a maximum of 10% of the diet. The addition of 0.05 to 0.1% of ferrous sulfate will alleviate the gossypol problem partially; there are also biologically tested meals that have been developed for use with poultry. Further sterculic acid, a cyclopropenoid FA present in cottonseed oil causes pink albumens. Morison (1959) mentioned, that by treating ordinary CSM several hours before feeding it, with a solution containing 3.4 lbs of ferrous sulfate per 100 lbsof CSM, it was made safe for pigs. This treatment destroyed the free gossypol or changed it into the inactive form. In Mississippi tests merely mixing 0.3 Ib of dry ferrous sulfate with each 100 Ibs of a feed mixture high in CSM made it safe for pigs.

Today, glandless cottonseed, free of gossypol, is being grown and improved. Someday, meal made from it may replace conventional cottonseed meal in poultry rations and alleviate (1) many of the restrictions as to levels of meal, and (2) the need to add iron to tie up free gossypol.

Linseed meal

Linseed meal is the finely ground residue (known as cake, chips, or flakes) remaining after the oil extraction of flax seed. It averages about 35% protein content (33 to 37%). Linseed meal is lacking in carotene and vitamin D, and is only fair in calcium and the B vitamins. It is laxative, and can depress growth in poultry. Hence, linseed meal levels should be no higher than 5% of the poultry ration.

LSM proves toxic when fed to poultry in excess of 2-3% of the diet. The inhibitor (linatine) results in reduced growth. Water treatment by soaking and drying largely inactivates the inhibitor, as do high levels of pyridoxine, but the meal processed in this manner is not used because of the cost involved.

Peanut meal

Peanut meal, a by-product of the peanut industry, is ground peanut cake, the product which remains after the extraction of part of the oil of peanuts by pressure or solvents. It is a palatable, high-quality vegetable protein supplement used extensively in poultry feeds. Peanut meal ranges from 11 to 50% protein and from 4.5 to 8% fat. It is low in methionine, lysine, and tryptophan, and low in calcium, carotene, and vitamin D.

Since peanut meal tends to become rancid when held too long-especially in warm, moist climates it should not be stored longer than 6 weeks in the summer or 2 to 3 months in the winter.

Rapeseed meal (canola meal)

Rape is grown extensively in Canada. When processed, rapeseed yields about 40% oil and 50% oil meal which ranges from 32 to 44% protein. The amino acid profile of rapeseed meal is very comparable to that of soybean meal, thus making it a rather high quality plant protein source.

Although rapeseedmeal is not recommended for poultry starter rations, it can be used at levels up to 10% of the total ration for fattening birds or layers, provided the iodine level is carefully monitored.

Fortunately, a new low glucosinolate rapeseed has been developed. Up to 20% of this improved meal may be included in layer rations, and up to 10% in starter feeds. The meal is only slightly goitrogenic, because its glucosinolate content is low. Furthermore, sufficient heat during the early extraction process destroys the enzyme myrosinase, which is responsible for the conversion of progoitrin to goitrin, the principal goitrogenic factor in canola meal. Incomplete destruction of myrosinase, or myrosinase getting into mixed feed as a grain contaminant, does not affect poultry seriously. The levels of canola meal should not exceed 10, 15, 15, 20 and 20% in the rations of laying-breeding chickens, broilers, turkey breeders, market turkeys and waterfowl respectively.

Inclusion of canola meal in rations of brown egg layers is not recommended. Brown egg layers are apparently unable to oxidize trimethylamine (THA), which has a fishy odor, to odorless THA-oxide rapidly enough to prevent THA from being deposited in eggs.

Safflower meal

A large proportion of the safflower seed is composed of hull about 40%. Once the oil is removed from the seeds, the resulting product contains about 60% hulls and 18 to 22% protein. Various means have been tried to reduce this high-hull content. Most meals contain seeds with part of the hull removed, thereby yielding a product of about 15% fiber and 40% protein. Safflower meal is deficient in lysine and methionine. Decorticated meal may be used successfully in layer rations at levels up to 15%.

Sesame meal

The oil meal is produced from the entire seed. Solvent extraction yields higher protein (45%) but lower fat levels (1%) than either the screw press or hydraulic methods which produce meals containing about 38% protein and 5 to 11% oil. Sesame meal is extremely deficient in lysine. It is generally recommended that some soybean meal, along with added lysine be fed with sesame meal to achieve optimum utilization.

Alfalfa meal

They are used in poultry rations as a source of vitamins, protein, and skin or yolk pigmentation (xanthophylls). They also contain toxic substances which influence growth and mortality of chicks when levels exceed 10 percent of the diet. The toxic substances are related to saponins since alfalfa meal contains a relatively high level of fiber, it usually is not.

Sunflower oil meal

It varies considerably depending on the extraction process and whether the seeds are dehulled. Meal from prepressed solvent extraction of dehulled seeds contains about 44% protein, as opposed to 28% for whole seeds. Screw pressed sunflower meal ranges from 28 to 45% protein. When sunflower meal is used in poultry feeds, it should be combined with high lysine supplements, such as meat scrap or fish meal, and/ or lysine should be added. When sunflower meal constitutes all, or most, of the protein supplement, the ration should be pelleted or crumbled to prevent stickiness and necrosis of the beak.

Animal Proteins

Protein supplements of animal origin are derived from (1) meat packing and rendering operations, (2) poultry and poultry processing, (3) milk and milk processing, and (4) fish processing. Before the discovery of vitamin Bi2, high protein feeds of animal origin have become less essential, although they are still included to some extent in rations for most monogastric animals.

With further improvement in the protein quality of plants, such as the development of high lysine corn, the use of animal proteins may decline in the future. The cost of such proteins will need to be more competitive than they are at the present time if they are to be included in any major quantity in animal rations. Blending several proteins with complementary balances of amino acids and supplying more concentrated sources of industrial amino acids may also be a factor affecting the future role of animal proteins in poultry rations.

Many protein supplements of animal origin are difficult to process and store without some spoilage and nutrient loss. If they cannot be dried, they must usually be refrigerated. If not heated to destroy disease-producing bacteria, they may be a source of infection. On the other hand, protein availability will be reduced and some nutrients lost if the feed is heated excessively.

Meat Packing By-Products

Although the meat or flesh of animals is the primary object of slaughtering, modern meat-packing plants process numerous and valuable by-products, including protein-rich poultry feeds.

Tankage and meat meal

In 1975, nearly 2 million tons of tankage and meat meal were fed to livestock. Tankage and meat meal are made from the trimmings that originate on the killing floor, inedible parts and organs, cleaned entrails, fetuses, residues from the production of fats, and certain condemned and parts of carcasses.

The end products and the methods of processing of each are:

1- **Tankage (or digester tankage, meat meal tankage, feeding tankage)** is produced by the older wet-rendering method, in which all of the material is cooked by steam under pressure in large closed tanks; hence, the derivation of the name tankage. Tankage may also be made by the dry-rendering method (in which case it is known as "meat meal"), or by mixing products containing both wet-rendered and dry-rendered materials.

The level of protein of tankage (generally 60%) is often standardized during manufacturing by the addition of enough blood to raise the total protein to the desired level.

2- **Meat meal (or meat scrap)** is produced by the newer and more efficient dry-rendering method, in which all of the material is cooked in its own grease by dry heat in open steam-jacketed drums until the moisture has evaporated.

The level of protein of meat meal (generally 50 to 55%) was originally established because the normal proportions of raw materials available for rendering resulted in a product which, after being pressed and ground, contained approximately 50% protein. The protein content of meat meal is adjusted up or down by raising or lowering the quantity of bone and fat in the raw material.

Protein content alone is not an infallible criterion of the feeding value of tankage or meat meal, for they vary considerably according to the kind of raw material from which they are produced. For this reason, the poultry man should (1) purchase tankage or meat meal from a reputable source, and (2) mix these products with other protein supplements, especially when the birds are confined.

Meat and bone meal tankage, and meat and bone meal

When, because of added bone, tankage or meat meal contain more than 4.4% phosphorus (P), the word "bone" must be inserted in the name; and they must be designated, according to the method of processing as either (1) meat and bone meal tankage, or (2) meat and bone meal. Thus, when such high-phosphorus products are prepared by the older wet-rendering method, they are known as meat bone meal tankage. Likewise, when products in excess of 4.4% phosphorus are prepared by the newer dry-rendering method, they are designated as meat and bone meal.

Meat and bone meal tankage and meat and bone meal, or other similar bone-containing products, contain less protein than tankage or meat meal, usually 45 to 50%.

Blood meal

Blood meal is ground, dried blood. When prepared by a special process and reduced to a fine powder, the end product is called blood flour. It contains 80 to 82% protein, more than any other packinghouse product, and it is an excellent source of the amino acid lysine, of which about two- thirds is available to the bird. However, due to the high temperature of processing, the protein is less digestible and of lower quality than that in high-grade tankage or meat meal, being especially low in the essential amino acid isoleucine. Also, blood meal and blood flour differ from tankage and meat meal in that they are low in calcium and phosphorus.

In recent years, new methods of drying blood, such as flash drying, have shown considerable promise in producing a uniform high-lysine product.

Poultry Wastes

Byproduct feedstuffs are derived from all segments of the poultry industry from hatching all the way through processing for market; and they come from the broiler and turkey segments of the industry as well as from egg production. Centralization of these industries into large units with enough volume of wastes to make it feasible to process the potential feeds have opened new markets for what was previously a disposal problem. Certain precautions have had to be included to make the products most useful and safe, but considerable amounts of poultry products are currently being used in poultry rations.

The three most extensively used high-protein by-products of the poultry industry are hatchery by products, poultry by-products, and poultry feathers. Cull birds, unsalable eggs, eggshells, and slaughter wastes are also used in poultry feeds.

Hatchery by-products

Of the various by-products from poultry, the most valuable is hatchery by-products consisting of infertile eggs, eggs with dead embryos, and unsalable sexed male chicks. However, these products deteriorate quite rapidly if not cooled promptly a factor which is true of most poultry, fish and meat products.

Poultry by-product meal

Poultry by-products consist of nonrendered clean parts of carcasses of slaughtered poultry such as heads, feet and viscera free from fecal content and foreign matter except for such trace amounts as are unavoidable in good factory practice. The meal is the dried, rendered, and ground poultry byproduct.

Because of the heads and feet, poultry byproducts are lower in nutritional value than the flesh of animals, including poultry. The biological value of the proteins is lower than the other animal proteins and the better plant proteins. They may be successfully used in animal rations, however, provided they are not the sole source of proteins.

Hydrolyzed poultry byproducts aggregate is the product resulting from treatment under pressure of all byproducts of slaughtered poultry clean and undecomposed, including such parts as heads, feet, undeveloped eggs, intestines, feathers and blood.

Feather meal

Feathers, a by-product that is nearly all protein, can be used in rations after they are hydrolyzed with heat and pressure to make the proteins available. Hydrolyzed feather meal is defined as the product resulting from the treatment under pressure of clean, undecomposed feathers from slaughtered poultry, free of additives, and/or accelerators. Not less than 75% of its crude protein content must be digestible by the pepsin digestibility method. Although hydrolyzed feather meal is high in protein (from 85 to 90%), it is rather low in nutritional value, being low in the amino acids histidine, lysine, methionine, and tryptophan. Those amino acids which are present are readily available.

Because of the deficiencies of several amino acids, care must be used when incorporating feather meal into poultry feed. The addition of fish meal or meat meal tends to complement feather meal and facilitates its use. In practice, feather meal rarely exceeds 5% of poultry rations.

Poultry manure

Dried poultry manure consists of freshly collected feces from commercial layer or broiler flocks not receiving medicants. It is thermally dehydrated to a moisture content of not more than 15%. It must not contain any substances at harmful levels, and it must be free of such extraneous materials as wire, glass, and nails.

It may be used in broiler and layer feeds, as well as an ingredient in cattle and sheep feeds.

As an energy source, in comparison with No.2 corn which is arbitrarily assigned a feeding value of 100, poultry litter (manure plus bedding) has a relative feeding value, pound for pound, ranging from 10 to 40; and it may replace up to 15 to 25% of the grain ration. As a protein source in comparison with 41% soybean meal which is arbitrarily assigned a feeding value of 100, poultry litter has a relative feeding value, pound for pound, ranging from 50 to 55; and it may replace up to 25% of the protein supplement.

Dairy Products

The superior nutritive values of milk by-products are due to their high-quality proteins, vitamins, and good mineral balance, and the beneficial effect of the milk sugar, lactose. In addition, these products are palatable and highly digestible. They are an ideal supplement for balancing out the deficiencies of the cereal grains. The chief limitation to their wider use is price.

Marine By-Products

On a worldwide basis, some 25 million metric tons of fish are processed into fish meal for animal feed each year but less than ½ million metric tons of this amount is consumed in the United States. Nevertheless, fish by-products are generally considered by poultry producers to be excellent sources of nutrients. Proteins, vitamins, and minerals are all readily available in most fish products.

Fish meal

Fish meal a byproduct of the fisheries industry consists of dried, ground whole fish or fish cuttings either or both with or without the extraction of part of the oil. If it contains more than 3% salt, the salt content must be a part of the brand name. In no case shall the salt content exceed 7%.

The feeding value of fish meal varies somewhat, according to:

a- **The method of drying:** It may be either vacuum, steam, or flame dried. The older flame drying method exposes the product to a higher temperature. This makes the proteins less digestible and destroys some of the vitamins.

b- **The type of raw material used:** It may be made from the offal produced in fish packing or canning factories, or from the whole fish with or without extraction of part of the oil.

Fish meal made from offal containing a large proportion of heads is less desirable because of the lower quality and digestibility of the proteins. Although few feeding comparisons have been made between the different kinds of fish meals, it is apparent that all of them are satisfactory when properly processed raw materials of good quality and moderate fat content are used.

c- **The amount of oxidation:** Much of the variation in the efficiencies of fish meal is due to the oxidation. Today, ethoxyquin is being added to many fish meals to prevent oxidation.

It is of interest to poultry producers to know the sources of the commonly used fish meals. These are:

1- **Menhaden fish meal:** This is the most common kind of fish meal used in the eastern states. It is made from menhaden herring (a very fat fish not suited for human food) caught primarily for their body oil. The meal is the dried residue after most of the oil has been extracted.

2-**Sardine meal or pilchard meal:** This is made from sardine canning waste and from the whole fish, principally on the West coast.

3-**Herring meal:** This is a high-grade product produced in the Pacific North West and Alaska.

4- **Salmon meal:** This is a byproduct of the salmon canning industry in the Pacific Northwest and Alaska.

5- **White fish meal:** This is a byproduct from fisheries making cod and haddock products for human food. Its proteins are of very high quality.

Fish meal should be purchased from a reputable company on the basis of protein content. It varies in protein content forming 57 to 77% depending on the kind of fish from which it is made. When of comparable quality, fish meal is superior to tankage or meat meal as a protein supplement for poultry. The protein of a good-quality fish meal is 92 to 95% digestible. If fish meal is poorly processed or improperly stored, the digestibility of protein decreases dramatically. Since fish meals are cooked, there is danger that certain amino acids-notably lysine, cystine, tryptophan, and histidine will be denatured, but these losses are minimized when proper processing techniques are used.

Fish meals containing high levels of fat are considered to be low quality. If they are incorporated into poultry feeds, they lend to impart a fishy flavor to poultry products. Also, problems of rancidity are greater in high fat fish meals.

Fish meal is not a particularly source of vitamins. Most of the fat-soluble vitamins are lost during the extraction of oil, but a fair amount of the B vitamins remain. However, fish meal is one of the richest sources of vitamin B_{12} and unidentified growth factors.

III- Yeasts

(Note: Herein, yeasts are listed as protein supplements. But they may also be classed as vitamin supplements).

Three forms of dried yeast are used in poultry feeding: (1) dried yeast which is a byproduct of the brewing industry, (2) torula yeast, resulting from the fermentation of wood residue and other cellulose sources, and (3) irradiated yeast which is used because of its vitamin D_2 content. Of these, only brewers dried yeast, which must contain not less than 35% crude protein, is used to any extent in poultry feeds.

Yeast proteins are generally of good quality, although they are deficient in methionine. They are good sources of lysine. Yeasts are excellent sources of the B complex vitamins.

IV- miscellaneous ingredients

Feed ingredients that are particularly rich in vitamins, AAs, and minerals tend to fall in the category of supplements. Vitamin supplements include sun- cured and dehydrated alfalfa meals, corn gluten meal, distillery and brewery byproducts, fish soluble, and brewer’s yeast, as well as crystalline or highly concentrated forms of individual vitamins. Synthetic sources of AAs currently include Met, MHA, Lys, Threonine, and Try (or Trp). A wide variety of mineral supplement may be used involving Ca, P, Na, Mn, and Zn.

Intrinsic and extrinsic deleterious substances

1- Barley awns

With rough-awns varieties, the hull-awn portion of the seed is very rough and abrasive, making the grain distinctly unpalatable, unless incorporated into pelleted feed.

2- Silica

Rice hulls are high in silica and are abrasive to both feed mill equipment and the digestive tract.

3- Condensed tannins

They are polyphenolic compounds. They are quite significant nutritionally. Most of the biological effects of tannins are associated with their ability to react with proteins. This effect begins in the mouth, where tannins react with taste receptors to produce the sensation of astringency. Thus, one effect of tannins is to reduce palatability of feedstuffs. In the digestive tract, tannins may react with digestive enzymes, reducing nutrient digestibility. They also react with dietary proteins, forming indigestible complexes.

In sorghum presence of tannins confers a brown pigmentation of the seed, although the color is not a reliable indicator of tannin content. Varieties of sorghum differ widely in tannin content, and varieties selected have enough tannin to provide adequate bird resistance (against wild bird predation) without markedly reducing their nutritional value.

Various processing methods can be used to at least partially overcome the effects of sorghum tannins. Treatment with an alkali, such as sodium or ammonium hydroxide, or anhydrous ammonia, is effective. Polyethylene glycol, which forms complexes with tannins, has also been shown to be an effective additive to improve the feeding value of high tannin sorghum.

4- β-glucans

Barley contains water-soluble carbohydrates, called β-glucans, which are poorly digested and thus lower the digestible energy content. This is particularly true in poultry and to a lesser extent in swine. The glucans and other gums are found in the hull, in the aleurone, and in the endosperm cell walls. They are composed of glucose molecules linked together by chemical bonds that are different from those found in starch. Animals do not secrete glucanases to break these bonds, so they cannot digest β-glucans. The glucans are viscous, hydroscopic, gummy materials. The viscosity reduces intestinal flow rate & thus feed intake. The viscous glucans also inhibit the formation of lipid micelles and reduce fat absorption. In poultry, the hydroscopic nature 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 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, it may cause a pasty vent, condition, in which the sticky excreta dries on the vent blocking the gut. This makes it impractical to use barley in diets for young chicks. The β-glucan content is influenceby genetics and environment (waxy gene & hot dry conditions). The glucans are digested by microbial action in the rumen. The effect can be largely overcome by:

- Incorporating a source of β-glucanase in the feed. Various bacterial and fungal enzyme sources are useful. Developments in the commercial availability of enzyme preparations containing β-glucanase and other complex- carbohydrate digesting enzymes (e.g. pentosanases, βglucansolubilase) may result in increased utilization of barley in swine and poultry feeding. β-glucans are soluble fiber have favorable effects on lowering serum cholesterol (of interest in human nutrition). Refer to "oats".

- Soaking in water activates β-glucanases in the seed.

5- Insoluble starches

Raw potato starch is poorly digested and should be cooked prior their use as a feed. Cooking breaks down the structure of the starch granules and improves digestibility and palatability.

6- Trypsin inhibitors

Of particular importance in nutrition is trypsin inhibitors which reduce the value of protein by reducing peptide digestion. For ruminant animal the inhibitor is not important and toasting is unnecessary while toasted meals are preferred for simple stomached ones.

The inhibitors inhibit the pancreatic enzymes as they bind with them irreversibly. Both are excreted, causing reduction in protein digestibility and an increase loss of enzyme protein. The pancreas gland attempts to compensate for the reduction in protein digestion by enlarging. The increased production of pancreatic enzymes is a factor in the growth depression (increased loss of EAAs).

Potatoes contain trypsin & chymotrypsin -inhibitors throughout the tuber and in the peel, cooking destroys these protease inhibitors. Cull sweet potatoes tubers contain trypsin inhibitors, and so must be cooked before using as feed.

Solanine is present in the skin of potatoes which have been left exposed to the light and allowed to turn green. When green potatoes are boiled the poisonous principle is extracted by water so that, although the tubers are fit to eat, the water in which they have been boiled is poisonous and must be discarded. It is also advisable to dilute green potatoes by adding normal potatoes before they are boiled.

7- Alkaloids

They are toxins containing N in a carbon ring. Potatoes contain solanine which is bitter, and is an irritant of the mucous membranes of the gut, and inhibits nerve function (it is a cholinesterase inhibitor). Normally the solanine content is not of concern, but in tubers exposed to sunlight, either pre- or post-harvest, solanine is synthesized and may be present at toxic levels. Solanine and chlorophyll are synthesized under similar conditions:, thus green potatoes are green because of their chlorophyll content, but they are also high in solanine.

8- N-propyl disulfide

Onions contain n-propyl disulfide, which can induce hemolytic anemia.

9- Prussic acid

Broom corn must not be given while still immature and not hardened in the brush, otherwise poisoning may ensure. Cassava leaves and roots contain toxic cyanogenic glycosides. Glycosides contain substances linked by an ether bond (-O-) with a carbohydrate fraction. The noncarbohydrate portion is called an aglycone. Glycosides are metabolized by enzymatic action to release aglycone from the carbohydrate. The aglycone may then be metabolized further. Cyanogenic glycosides are those that contain cyanide as part of the aglycone. When they are metabolized, free cyanide, a deadly poison, is released. Cyanide is extremely toxic to cellular metabolism. Plants containing glycosides also contain enzymes to hydrolyze them, but in different compartments of the plant cell. Thus cyanide is not released until the plant cells are disrupted in some way.

Cassava is processed to reduce its cyanide content. When the roots are chopped, pulped, or mashed, the cell structure is macerated and the glycoside and enzymes come together, releasing cyanide.

The HCN is hydrocyanic or prussic acid; the ionic form is cyanide (CM). Cyanide is volatile, so when cassava roots pulped and sun dried, free cyanide is formed, much is then volatilized into the air. Extraction of the pulped root with water will also wash out much of the cyanide.

Adequate processing of the cassava will prevent acute poisoning. However, small amount of residual cyanide remain. Methionine and vitamin B_{12} function in the detoxification and excretion of cyanide, so the requirements are elevated with cassava-based diets.

The commonest example of a feed such cyanogenic glycosides is linseed. The prussic acid is liberated when dampened meal is allowed to stand but can be removed by boiling. For this reason, although linseed meal is a valuable food, it should not comprise more than 3% of the diet unless it is boiled before it is fed and should never be included unboiled in a wet mash.

Cattle and sheep are affected by the poison, but horses and swine are apparently not injured, or only very rarely. Glucose in the rumen checks the rate of formation of the prussic acid, and it has been found that it is wise to give cattle or sheep a starchy feed, such as corn or the grain sorghums, before allowing them to graze. The starch in the grains form glucose in the digestive tract and thus aids in preventing trouble.

10- Gossypol

A major constraint to the use of whole cottonseeds or cottonseed meal in feeding animals is gossypol which is a phenolic compound contains aromatic (benzene) rings with hydroxyl groups attached (it is an aromatic aldehyde). Its name is derived from Gossypium phenol. It is a yellow pigment that occurs in pigment glands scattered throughout the seed. Gossypol likes most toxins in plants, is a natural pesticide. Cottonseed meals contain about 0.03 to 0.20% gossypol, and to be used with safety in any large proportion it should not have more than 0.04% free gossypol in swine rations, and in poultry rations not more than 0.02%.

Gossypol has a number of adverse effects in mammals and poultry. One unique effect is olive-green yolks in stored eggs (when GSM is given at more than 5-10% of the diet) caused by a chemical reaction between gossypol and iron in the egg yolk, li also causes reduced growth and feed intake. When large amounts of the untreated meal are included in the diet, the yolks have a brown mottled appearance and the albumen assumes a pinkish tint.

The toxicity of CSM is associated with nonbound or free gossypol. It has profound effect on simple-stomached animals, being toxic at low levels e.g. at 0.016% of diet of young chicks. For nonruminants the level of free gossypol in the diet should not exceed 0.01%, or approximately 9% CSM. Ruminants are more tolerant of gossypol, but, even in ruminants, prolonged feeding of whole cottonseeds can cause heart and liver damage. Gossypol damage is cumulative, and adverse effects may not be observed until after many weeks or months of feeding livestock cottonseeds. Signs encountered in dairy cattle include liver lesions, ascites, edema, heart lesions, lung damage, and cardiac failure. Because gossypol reacts with iron, it causes anemia by lying up iron in an unavailable form. An outbreak in a dairy calf-rearing facility occurred. Ruminants show no ill effect even when fed on large quantities of CSM.

An interesting application of gossypol is in the development of a male birth control pill. It is a potent contraceptive agent in the human male, and, at levels than those implicated in cardiac and lung lesions, blocks sperm production. There do not seem to be any fertility problems in livestock that are fed CSM.

The toxic effect of gossypol can be reduced by the addition of iron salts to the diet. It reacts with iron and thus becomes "bound" or physiologically inactive. Iron sulfate 4 parts/1 part of free gossypol, and up to a maximum of 400 ppm will overcome the problem of yolk discoloration. The tolerance level of gossypol in food is 200 ppm in broilers and 50 ppm in layers and 0.1% ferrous sulfate.

Considerable control of gossypol content is possible by heating, but this in turn leads to denaturation of the protein and a lowering of the nutritive value. Fortunately the shearing effect of the screw press in the expeller process is an efficient gossypol inactivator at temperatures which do not reduce protein quality. In the presence of heat, gossypol reacts with proteins to produce "bound gossypol". The reaction, resulting in a lowered lysine availability, is mainly with the AA lysine.

By treating ordinary CSM several hours before feeding it with a solution 3.4kg of ferrous sulfate per 100kg of CSM, it was made safe for pigs and poultry. This treatment destroys the free gossypol. In other tests merely mixing 0.3kg of dry ferrous sulfate with each 100kg of a feed mixture high in cottonseed meal is safe for pigs.

11- Cyclopropene fatty acids

Cottonseed oil contains these acids that have unique nutritional properties, including a synergistic effect on the carcinogenicity of aflatoxin. They inhibit desaturase enzymes which are involved in increasing the unsaturation of fatty acids. Thus CSM prepared by the expeller process, containing residual oil, tends to cause a hard body fat in pigs and other nonruminants. A unique effect in poultry is the production of pink egg albumen.

12-Gylcinin and conglycinin

Soybeans contain storage proteins (glycinin and conglycinin) which may cause allergic reactions in animals, particularly in preruminant calves, and baby pigs, resulting in atrophy of intestinal villi and impaired nutrient absorption. Gastrointestinal hyper-sensitive reactions arising from absorption of SB antigens are well known. SB products used in milk replacers should be heated sufficiently to denature antigenic proteins. Baby pigs fed creep diets containing soy products may become sensitized to the soy proteins and exhibit gastrointestinal distress when exposed to the same ingredients after weaning.

13- Oligosaccharides

SBM contains approximately 5-6% oligosaccharides, short-chain polysaccharides containing a number of different sugars. Nonruminant especially poultry, are unable to digest the oligosaccharide fraction efficiently. As a result, this CHO material is fermented in the hindgut and, because it is soluble, it has an osmotic effect in increasing fecal moisture content, causing diarrhea and wet droppings. This is particularly important in the nutrition of young turkey poults. Because of the high protein requirement of poults, the SBM content of the diet may be as high as 50% and the indigestible oligosaccharides cause significant wet-litter problems. In addition, the ME content of the SBM is lower than if the oligosaccharides were a digestible component. Ethanol extraction of SBM removes the oligosaccharides and increase the energy and protein content of the meal.

Commercialization of this process would produce a superior quality SBM, especially for turkeys and fish, which are fed diets high in protein.

14- Mycotoxins

They are toxins elaborated by molds (fungi) growing in or on feedstuffs. They may be produced while the crop is growing or during storage. In general, toxigenic fungi grow best under warm, humid, aerobic conditions. The major mycotoxin of concern especially with corn is aflatoxin, produced by the mold Aspergillusflavus. Drought and insect damage promote infection of the developing grain in the field. Warm, humid storage conditions can promote explosive formation of aflatoxin. The conditions are typical of the areas where peanuts are produced and stored. Groundnut meal played an important role in the identification of aflatoxins. The molds develop best in cereals and ingredients rich in vegetable protein.

Infected grain is not necessarily visibly moldy. Aflatoxin fluoresces under ultraviolet light, so its presence can be detected by examining grain under "black light".

Other moulds than A. flavus, which have been shown to produce toxins are A. clavatus, Penicilliumcitrinum, P.rubrum and Stackybotrysatratoxicmoulds can grow in litter and in food and careful attention to both is needed if losses are to be avoided.

Other mycotoxins sometimes associated with corn and other grains are zearalenone (F-2 toxin), ochratoxin, T-2 toxin, vomitoxin, and citrinin. Zearalenone causes estrogenic effects. It is also produced commercially and is marketed as an estrogenic implant for cattle under the trade name Ralgro. Corn often contains zearalenone.

Corn (and other grains, to a lesser extent) may be harvested at a moisture content too high for storage as dry grain stored grains must contain less than 15% moisture, or else molding and/or rotting will occur. Corn may be dried with heat, ensiled, or preserved moist by the addition of preservatives and mold inhibitors. Propionic acid, urea, anhydrous ammonia, and sulfur dioxide are substances that have been employed for preservation of moist grains. Increased dietary levels of methionine and protein help to protect against aflatoxin toxicity in swine.

Aflatoxin causes reduced feed intake, poor growth, and diarrhea: chronic exposure causes liver damage. It is the most potent carcinogen known: at dietary levels as low as 1 ppb. It causes liver cancer in rainbow trout, a widely used experimental animal in mycotoxin studies, as it is the most sensitive to the carcinogenic effects of aflatoxin. Vomitoxin and T-2 toxin cause vomiting and feed refusal in swine and oesophygeal lesions in poultry.

Of poultry the ducklings and turkeys have been shown to be particularly susceptible. Citrinin and ochratoxin cause kidney lesions. The first sign of mycotoxicosis is poor growth and reduced performance. In poultry mycotoxins cause gizzard erosion. Some 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.

Mycotoxins arc of major concern in animal feeding, causing loss of production efficiency and outbreaks of acute toxicity. The presence of the toxins in the diet increases the vitamin D & K requirement. For vitamin D it has been of practical importance in poultry. Aflatoxin impairs vitamin D absorption and its hepatotoxic effects may interfere with the formation of 25-OHD3 in the liver. Aflatoxins contamination of feeds may also impair xanthophylls absorption, resulting in pale bird syndrome in poultry. Aflatoxin affects the immune system in poultry, increasing the susceptibility to disease. They have a role in field hemorrhagic syndromes in which small hemorrhages may blemish the carcass.

The maximum level of aflatoxin permitted by the Food and Drug Administration (FDA) is 20 ppb in corn and other grains intended for human food use, for immature animals, and for dairy cattle; 100 ppb for corn fed to breeding beef cattle, poultry, and swine: 200 ppb for finishing pigs and 300 ppb for finishing beef cattle.

If stale or musty foods have to be used because there is nothing else, they are best scalded and then used as small percentage only of a wet mash.

Other dietary toxins, such as gossypol and cyclopropenoid fatty acids in cottonseed meal, may enhance the toxicity or carcinogenicity of aflatoxin in trout. Catfish and most other fish species, except trout, are relatively tolerant to aflatoxin.

15- Rancidity products

Refer to "lipids" under hydrolytic and oxidative rancidity.

16- Putrefied foods

When food which have putrefied are fed to stock, the birds die either from ptomaine poisoning or the effects of bacterial toxins.

17-Salt

In small amounts salt is essential for the well-being of birds: in large amounts it has a deletions effect. The signs of acute salt poisoning are excessive thirst and, in some birds, a progressive muscular weakness. Examination post mortem shows an impaction of the crop, where the usual semisour odor is absent, inflammation of the gut and a dark colouredluei. The tolerance of poultry for salt is, however, remarkably high provided adequate drinking water is available. Levels as high as 20% have been fed to adult fowls and as high as 8% to adult turkeys for 4 weeks, without mortality; for fowls even at 30% only a few deaths were reported. Fowls 2 to 3 months old withstood 15% with only a slight mortality but 5% caused a heavy death rate in baby chicks. Addition of salt to the drinking water is not tolerated so well and even 0.9 per cent caused 100 per cent deaths in baby chicks. Baby poults are even less tolerant than chicks of salt in food. When the level of sodium salts, including common salt, is greater than the equivalent of 2% poults up to 21 days old develop ascites and edema and mortality is heavy.

Although birds will withstand high levels of sodium in the diet, feeding diets containing 5g Na/kg diet to chicks aged, 0 to 3 weeks or 4g Na/kg diet to poults of the same age resulted in an incidence of cystic testes. Until the significance of the cysts has been established it is recommended that the sodium levels in the diets should not exceed these concentrations.

18- Deleterious factors in meat products

It is very important that meat and bone meal and other animal by-products be properly heat-sterilized during processing. Contamination of the product with Salmonella species is a potential hazard. In 1988 - 1989, major problems occurred in the United Kingdom from improperly processed renders products. Contamination of meat meal with Salmonella infected poultry by-products resulted in widespread Salmonella contamination of eggs and broiler meat when the meat meal was used in poultry feeds. An even more serious problem also occurred. The disease agent that causes scrapie in sheep was transferred to cattle through the feeding of meat meal prepared from condemned scrapie-infected sheep. This has resulted in a new disease of cattle, bovine spongiform encephalopathy (BSE) or "raging cow disease". The disease turns normally docile cows into dangerously aggressive creatures. There is now concern that the disease agent could enter the human food supply via the consumption of dairy products and meat. As a result, in 1989 the British Ministry of Agriculture banned the use of animal protein in cattle and sheep feeds until the sitation has been resolved, and the animal protein processing sector of Britain's livestock feed industry is resigned to the fact that it has lost this market for good. In 1990 nineteen cases of BSE products, and feeds & feed additives of animal were recorded in Ireland where importation of live animal origin from the United Kingdom was prohibited.

Now corn-soybean meal diets are standard for swine and poultry production. Except for very young pigs, the nutritional needs of all classes of swine can be met by a simple mixture of corn and SBM, supplemented with salt, minerals, and vitamins.

19- Phosphorus

Phosphorus, as phosphate or phospholipid, is an essential food, as zinc phosphide it is a poison and is used in the control of vermin such as rats. If poultry consume this poison the cause of death can usually be diagnosed by an examination of the gut contents. These have a characteristic odour and glow in the dark.