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Ration Formulation and Compound Feed Preparation: A Review

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Abstract: Feed represents a large percentage of the cost of production; therefore, ration formulation is a very important aspect of animal production. Diet formulation allows nutritionist to develop that can be eaten and utilized by the animal to provide an economically feasible level of production. For diets contain few feedstuffs and in which the nutritional parameters, such as energy and protein. Compound feed is mixtures of feed materials, for oral animal feeding in the form of complete or complementary feedstuffs. The present reviews covers information on ration formulation and how to prepare compound feed.

Key words: Compound feed, energy, protein and ration formulation

INTRODUCTION

Diet formulation is a very important aspect of animal production. The success of any animal production enterprise depends to a large extent on proper nutrition and feeding based on economical diets. The owner or animal production practitioner should have a good knowledge of nutrition, feeding, the physical and chemical characteristics of feedstuffs and feedstuffs interactions and limitations as well as the economics of production. Feed formulation is task that matches nutrient requirements of the animal with combinations of ingredients (Pond *et al.*, 1995).

In ration formulation is a process by which different feed ingredients are combined in a proportion necessary to provide the animal with proper amount of nutrients needed at a particular stage of production. It requires the knowledge about nutrients, feedstuffs and animal in the development of nutritionally adequate rations that will be eaten in sufficient amounts to provide the level of production at a reasonable cost. The ration should be palatable and will not cause any serious digestive disturbance or toxic effects to the animal. Different species, strains or classes of animals have different requirements for energy (carbohydrates and fats), proteins, minerals and vitamins in order to maintain its various functions like maintenance, reproduction, egg production, lactation and/or growth (Concepcion, 2008). It involves determining the qualities of individual feedstuffs to feed to the animal to the animal in order to supply nutrients i.e. the energy, protein, minerals etc required by the animal. The formulation of a ration is thus different from the formulation of a diet which in this context is defined in terms of the proportions of the constituent feedstuffs and is formulated to have specified concentrations of individual nutrients (Glen, 1980).

The objective in diet formulation is to design diets to meet the animals' nutrient requirements and provide the maximum or optimum economic return to the livestock producer. In case of animals raised for exhibition purposes or as pets, the economic factor is not as critical. In general, though, people would like to feed their animals adequately at a reasonable cost. It is important to note the distinction between diets that provide the maximum economic return and diets that have the lowest cost. The lowest cost diet, even though it may be nutritionally adequate, may not be the most economical. It is the net return from the use of the diet that indicates efficiency. The almost universal use of computer technology has eliminated most of need to formulate diets by hand calculation. Some of the more simple calculations will be described, but is should be recognized that there is abundant computer software available for diet formulation (Cheeke, 1999).

To supply all the needs for maintenance, growth, finishing, reproduction, lactation, work (exercising), egg production and wool production, the different classes of animals must receive sufficient feed to furnish the necessary quantity of energy, proteins, minerals, vitamins and water. A ration that meets all these needs is said to be balanced (Ensminger *et al.*, 1990).

Objectives

1. To identify information needed for diet formulation
2. To indicate the mathematical manipulations needed to formulate diets
3. To describe general process involved in preparation of compound feed for livestock

Consideration of ration ingredients

Concentrates: Most of the protein and energy of the ration is supplied by the concentrate feeds. For ruminants in heavy production like finishing, lactation and almost all non ruminants the concentrates portion of the ration constituents most of the DM (Dry Matter) intake. Amino acid composition of feedstuffs and protein digestibility are especially critical for animals with non functional ceaca. Hence, many livestock producer routinely use more than one high protein feed so that the amino acid deficiencies of one ingredient can be corrected by another. In non ruminant animal rations levels of non protein nitrogen must be monitored to avoid ammonia toxicity (Ensminger *et al*., 1990).

Roughages: The amount of roughage incorporated in ration depends largely upon intensity of production of the particular animal being fed. Non ruminants without functional caeca utilize very little roughage. But in case of ruminants and animals with functional caeca are generally given at least a small amount of roughage to maintain healthy, functional gastro intestinal activity. Animals with non functional caeca, such as swine, can utilize limited amounts of forage. When swine are fed at maintenance levels, forage can be included in the formulation to reduce costs. Some forage, such as high quality like alfalfa, is frequently added to swine and poultry rations for its high vitamin content. Ruminants and animals with functional caeca can be maintained relatively easily on high roughage rations. In this case, a micro nutrient supplement containing minerals and vitamins may be all that is additionally required. As production pressures increase that means for high producing animals, roughage is replaced by concentrate feed. The concentrate can be fed separate and apart from the roughage or mixed with the roughage, along with any supplements, to make a complete feed. Beef cattle have been successfully fed finishing rations with no roughage. However, when on high concentrate rations, they still need a little roughage to promote good ruminal activity (Ensminger *et al*., 1990).

Supplements: When ration are formulated, supplements are considered after the macro nutrients like protein and energy have been balanced. The ration is then checked for any deficiencies or imbalances of micronutrients and supplements are needed to correct the deficiencies. The supplements can be in the form of either a premix that means combination of many micronutrients or individual micronutrients like lysine (Ensminger *et al*., 1990).

Information needed to formulate diets

Nutritional requirements: The first step is to know the nutrient requirements of the particular animal species for particular physiological function like growth, reproduction, gestation and lactation. Nutrient requirement expressed in terms of energy, fat, protein and amino acids, mineral elements and vitamins. And it expressed as amount per unit of diet (%, mg/kg) or as amount per animal per day. These figures are the minimum requirements for maximum production and do not include a margin of safety. Many nutritionists use their judgment to provide a margin of safety by increasing the figures by 5 or 10% or more. Environmental conditions, stress, animal housing conditions, breed or strain of animal, disease incidence and projected length and conditions of feed storage are factors that might influence selection of an appropriate margin of safety (Pond *et al*., 1995; Cheeke, 1999; Coleman, 2008).

In the United States, the National Research Council (NRC) recommendations are the most commonly used guides for nutrient requirements of farm animals, dogs, cats and horses (National Research Council, 1981, 1982, 1984, 1985a, 1985b, 1993, 1994, 1995). It has also been traditional belief in the United States that a well-formulated diet is one that meets NRC requirements and will support maximum animal performance. Preston and Leng (1987) are proponents of the viewpoint that application of this philosophy in developing countries in inappropriate and that; instead the objective should be to optimize the use of available resource and minimize the use of imported ingredients. Under these conditions, NRC requirements generally cannot be economically achieved and optimal production is less than maximal.

Generally these should be known for the particular class of animals for which a ration is to be formulated. Also, it must be recognized that nutrient requirements and allowances must be changed from time to time, as a result of new experimental findings (Ensminger *et al*., 1990).

The purpose of providing feedstuffs and formulating diets is to provide animals with the nutrients they require. Energy is the major nutritional need. At least 80 % of the total feed intake of most animals consists of sources of calories. Feed intake is regulated according to energy need; animals eat to satisfy their energy requirements (Perry *et al*., 2003). A much smaller proportion of the total diet is protein. The protein requirement varies with animal species, stage of growth and type of production, but generally less than 20 percent of the diet. For example, for mature beef cattle, the protein requirement is about 6% of the, for a growing pig 13-15% and for a mature ewe 9% (Cheeke, 1999). The requirement for minerals can be met in approximately 3 to 4% of the diet. Salt is added at a level of 0.25 or 0.5%, calcium and phosphorus requirements for most species are in the 0.5 to 1% range and the requirements for trace elements are met with less than 0.5 to 1% of the total diet. Vitamins are needed in trace amounts, much less than 1% of the diet. Thus a typical diet for livestock contain 10 to 20% protein, 80 to 90% energy yielding nutrients, 3 to 4% minerals and trace of vitamins. The cost of nutrients sources will vary in a similar manner. Thus most of the cost of diet ingredients is for energy sources and to a lesser extent for protein supplements (Cheeke, 1999).

Nutrient composition of feed ingredients: The next step is to list all the variable feedstuffs to be considered in the diet for the particular animal. It is best to obtain the laboratory analysis of the feed ingredients. Commercial laboratories specializing in such analyses are also common. The nutrient analysis of the feed ingredient also can be estimated from published values. How satisfactory the diet will be depends on the reliability of the feedstuff analysis. Updated analytical data on feedstuffs are preferred when available, if not; average composition data can be used from the NRC tables or composition from any other reliable source. Diets are only as the analytical information used to formulate them. In the case of feedstuffs utilized for non ruminants, it may be appropriate to include available nutrients as opposed to total nutrients. Some feedstuffs may be limited in use because they are indigestible or unpalatable. Therefore, both the feedstuff analysis and the maximum percentage allowances of a particular feedstuff for a diet can be considered in formulation (Pond *et al*., 1995).

Tables of feed composition using average or typical values may be used but chemical analysis of a representative sample should be used if available (Coleman, 2008). Extensive tables of composition of feedstuffs are available (NRC, 1982). As with requirement figures, the composition data can be placed in computer files. In the future, it is likely that standardized computer lists of ingredient composition will become available commercially. Most feed companies have proprietary files of ingredient composition for use in ration formulation. It is important not to be dazzled or intimidated by lengthy computer printouts. Feedstuffs are inherently variable products; their composition is greatly influenced by harvesting conditions, environmental factors, fertilization and irrigation practices and so on. Thus considerable judgment is needed in assessing whether an apparent deficiency of a particular nutrient is truly important (Cheeke, 1999).

Nutrient availability: For most feedstuffs, the nutrients are not completely released during digestion. This is particularly true with energy fraction and for this reason, digestible energy (DE), metabolizable energy (ME), or net energy (NE) values should be used rather than gross energy (GE). These values vary between animal species, especially for fibrous feeds. For instance, the DE value for alfalfa meal is higher in dairy cattle than in swine. Ideally, species specific values for energy (DE, ME, or NE), protein and amino acids should be used in formulation, along with the requirements expressed on the same basis. For poultry, ME values are used, while for swine either DE or ME are satisfactory. For ruminants ME, or NE values should be used because of the variability energy losses in rumen gases (Cheeke, 1999).

The recognized value of chemical analysis, it is not the total answer. It doesn't provide information on the availability of nutrients to the animals, it does not tell anything about the associated effect of feedstuffs for example the apparent way in which beet pulp enhances the value of ground milo and it does not tell anything about taste, palatability, texture or undesirable physiological effects, such as bloat and laxative effect. Never the less, a chemical analysis does give a sound basis on which to start the evaluation of feeds. Also with chemical analysis at hand and bearing in mind that it is the composition of the total feed (the finished ration) that counts, the person formulating the ration can more intelligently determine the quantity of protein to buy and the kind and amounts of minerals and vitamins to add (Ensminger *et al*., 1990).

It is necessary that all the available ingredients are listed along with the unit cost, as long as the number does not exceed some practical figure which the machine is capable of handling. Ration specifications this generally represents the nutrient requirements and ingredient limits. In each case, the formulator specifies either a lower limit and/or an upper limit for each item.

Non nutritive characteristics: One of the most obvious non nutritive characteristics of importance is palatability. Certain ingredients such as molasses and other sweet materials are highly palatable others, such as feather meal, are somewhat unpalatable. The experience and judgment of nutritionist are important factors in the evaluation of palatability characteristics. Other non nutritive qualities include palatability, handling qualities (will the ingredient flow freely or bridge in bins), associative effects and the presence of toxins such as gossypol in cotton seed meal. Associative effects refer to the interactions between feedstuffs that can influence their nutritive value. They may be positive or negative. The DE content of forage, for instance, may be less if the forage is fed along with a concentrate than if fed alone. Thus there may be negative associative effect between fibrous feeds and concentrates in ruminants. A positive associative effect is the improvement in utilization of low quality roughage when it is supplemented with alfalfa (Cheeke, 1999).

Contamination from foreign substances such as dirt, sticks and rocks can reduce feed quality, as can aflatoxins, pesticide residues and variety of chemicals. Often, the value of feed can be either increased or decreased by processing. For instance heating some types of grain makes them more readily digestible to livestock and increases their feeding value on the other hand; there may be destruction of heat liable nutrients, such as vitamin A (Ensminger *et al*., 1990).

The presence of anti-nutritional factors in the feed, such as anti-trypsin factor in soybean meal, affects the digestion of some nutrients by making them unavailable to the animal. Some feed ingredients may also contain toxic substances, which may be detrimental to the animal when given in excessive amounts. The inclusion of these feed ingredients should therefore be limited or eliminated from the formulation (Coleman, 2008).

Cost of available feedstuffs: Costs of ingredients vary according to a number of factors. The ingredient in largest supply will often dictate prices for other ingredients. The least cost diet formulation; the prices of available ingredients are entered into the computer. These prices may change on readily or weekly basis. The computer solves an array of simultaneous equations to provide the solution for the least expensive combination of ingredients to satisfy the requirement for each nutrient (Cheeke, 1999).

The ideal ration is one that will maximize production at the lowest cost. A costly ration may produce phenomenal gains in livestock, but the cost per unit of production may make the ration economical infeasible. Likewise the cheapest ration is not always the best since it may not allow for a satisfactory level of production. Therefore, the cost per unit of production is the ultimate determinant of what constitutes the best ration at any given time. Awareness of this fact separates successful producers from marginal or unsuccessful ones. Not only should the cost of the feed be considered, but also the cost of processing, transportation and storage some feeds requires antioxidants and/or refrigeration to prevent spoilage. Other loses nutritive value when stored for extended periods (Ensminger *et al.*, 1990).

The requirement of the animal can be met through several combinations of feed ingredients. However, when the costs of these ingredients are considered, there can only be one least-cost formulation. The least-cost ration should ensure that tile requirements of the animal are met and the desired objectives are achieved (Coleman, 2008).

Adjusting moisture content: The simplest way to avoid errors in ration formulation is to formulate on a 100% DM basis. Correction factor on Table 1 may be used to convert feeds of various moisture contents to 100% DM basis. The majority of feed composition tables listed on as fed basis while most of NRC nutrient requirement tables are on either a 90% DM or moisture free basis (Waller, 1982):

- Conversion of ration from as fed basis to moisture free basis

To convert as fed ration to moisture-free basis, the following formulas can be used:

$$\left[\begin{array}{c}\text{% nutrient in dry}\\ \text{diet (total)}\end{array}\right]=\frac{\left[\begin{array}{c}\text{% nutrient in}\\ \text{wet diet (total)}\end{array}\right]}{\text{% DM in diet (total)}}\times 100 \quad (1)$$

$$\left[\begin{array}{c}\text{Amount of ingredient}\\ \text{in dry diet}\end{array}\right]=\frac{\left[\begin{array}{c}\text{% of ingredient}\\ \text{in wet diet}\end{array}\right]}{\text{% DM wanted in diet}}\times\left[\begin{array}{c}\text{% DM in}\\ \text{ingredient}\end{array}\right] \quad (2)$$

$$\text{Parts on wet basis}=\left[\begin{array}{c}\text{% of ingredient}\\ \text{in wet diet}\end{array}\right]\times\left[\begin{array}{c}\text{% DM of}\\ \text{ingredient}\end{array}\right] \quad (3)$$

- Conversion of ration from moisture free basis to as fed basis

$$\left[\begin{array}{c}\text{Parts of ingredient}\\ \text{in wet diet}\end{array}\right]=\frac{\left[\begin{array}{c}\text{% of ingredient}\\ \text{in dry diet}\end{array}\right]\times\left[\begin{array}{c}\text{% DM desired}\\ \text{in diet}\end{array}\right]}{\text{% DM in ingredient}}$$

Methods of formulating rations

Square method: The square method is relatively simple and easy to follow, direct and easy way in which to figure proportions between two ingredients. It satisfies only one nutrient requirement and uses only two feed ingredients. It permits quick substitution of feed ingredients in keeping with market fluctuation without disturbing the protein content (Coleman, 2008).

To compare rations by the square method, or by any other method, it is first necessary to have available both feeding standards (nutrient requirement and feed composition table) (Ensminger *et al.*, 1990).

But, now a day frequently it is necessarily to blend two or more feeds into a mixture containing a certain percentage of some major nutritive factors. For this purpose a procedure generally referred to as the square method may be used.

When only two feeds are involved: Sometimes it is necessary what combination of two feeds will create a mixture with a specific nutrient content (Perry *et al.*, 2003).

Example: A swine producer may need to know what combination of ground shelled corn and 40% complete swine supplement will produce a mix suitable for self-feeding a group of pigs averaging 30 kg (66 lb) in weight. From nutrient requirement table (NRC, 1998), it is determined that pigs of this weight need 18% crude protein ration. What combination of ground shelled corn and 40% protein supplement will provide an 18% protein complete mixture? This can be calculated utilizing the square method. The steps involved in square method for the above purposes are as follows:

a. Draw a square at the left side of the page
b. Insert the % crude protein desired in the final mixture (18%) in the middle of the square

c. Place "corn" with its crude protein 8.5% in the upper left corner and "40% supplement" with its % crude protein 40.0 in the lower left corner. (For this method to work, one feed must be above the desired level of protein and the other below)
d. Subtract the % crude protein in corn 8.5 from the % crude protein desired in the mix 18 and place the difference 9.5 in the corner of the square diagonally opposite from the corn. This amount is supplement
e. Subtract the % crude protein desired in the mix 18 from the % crude protein in the supplement 40 and place the difference 22 in the corner of the square diagonally opposite from the supplement. This amount is corn

The above remainders represent the proportions of the two feeds that will provide a mix containing the desired % crude protein. The amounts are then converted to a percentage or a per hundred weight basis and then to other weight bases as desired for mixing purposes.

When three or more feeds are involved: Frequently it is desirable to use more than two feeds in formulating a feed mixture (Perry *et al*., 2003).

Example: A swine producer may desire to use a mixture of corn, wheat bran and a 40% complete supplement in formulating a 12% crude protein mix for his pregnant sow The following steps would be involved using the square method.

a. Draw a square as in the previous example
b. Place the% crude protein desired 12 in the middle of the square
c. Separate the feeds into two groups, specify the proportion of each feed in each group and calculate the weighted average % protein each group. For this example, let us assume that corn and wheat bran grouped together in the proportion of 2:1 with the supplement being used alone. The average % protein in the corn and wheat bran must then be calculated as follows:

$$2 \times 8.5 = 17.0$$
$$1 \times 15.7 = 15.7$$
$$32.7 \div 3 = 10.9\%$$

d. Place "2 corn+1 wheat bran" with its calculated % of crude protein 10.9 in the upper left corner of the square and "40% supplement" 40.0 in the lower left corner. (For the method to work the figure in one left-hand corner of the square must be above and the one in the other corner below the level of protein desired)
e. Subtract diagonally and proceed with the calculations as in the previous example
f. Divide the final figure for "corn+wheat bran" into 2/3 corn and 1/3 wheat bran. (The proportion of each feed in each group must always be indicated initially and complied with in the final mixture)

With a fixed percentage one or more ration components: sometimes a feeder desires to formulate a mixture containing a certain percentage of some

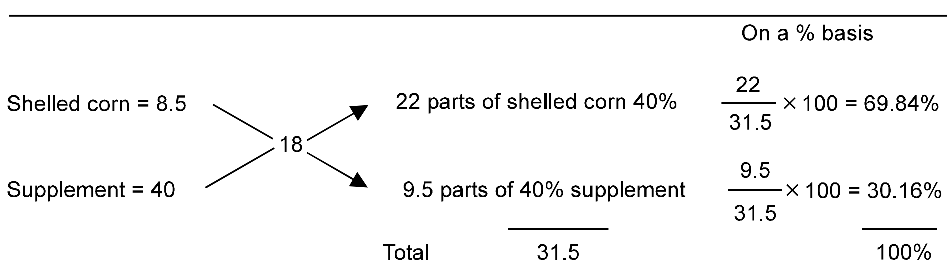

Fig. 1: Application of the square method using only two feeds. Sources: (Perry *et al*., 2003)

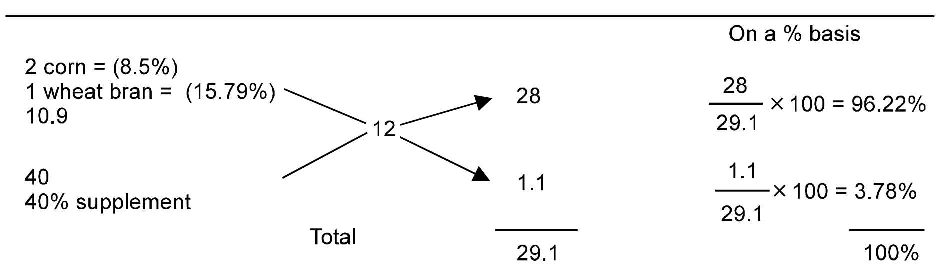

Fig. 2: Application of the square method using only two feeds. Sources: (Perry *et al*., 2003)

		On a % basis
Corn = (8.5)	12	36.99 ÷ 40 = 92.48% × 77 = 71.21 lb corn
SBM = (48.5)		31÷ 40 = 7.52% × 77 = 5.79 1b SBM

Final ration mixture		Proof of 12% protein in final ration
Wheat bran	20.00%	×0.157 = 3.14 lb
Mineral vitamin upplement	3.00%	×0.000 = 00.00 lb
Ground shelled corn	71.21%	×0.085 = 6.05 lb
oybean meal	5.79%	×0.485 = 2.81 lb
Total	100.00%	12.00 lb (protein per 100 lb mix)

Fig. 3: 12% protein in final ration

nutrients, such as protein, but with a fixed percentage of one or more ration components (Perry *et al*., 2003).

Example:

a. A swine producer might wish to formulate a 12% crude protein mixture for pregnant sows using corn, oats, soybean meal and a mineral and vitamin supplement. He wants to include in the mixture exactly 20% wheat bran and 3% mineral and vitamin supplement. He then needs to know what combination of corn and soybean meal can be used to make up the other 77% of the mixture and give an overall mixture that contains exactly 12% crude protein. An adaptation of the square method may be used this purpose
b. It is known that a protein level of 12% is desired for overall mixture. This means there will be 12 lb of protein per 100 lb of mixture. Since 20 lb of each 100 lb is wheat bran (20%), then the wheat bran in each 100 lb of the mixture will supply 3.14 lb of crude protein (15.7% x 20 lb) (Perry *et al*., 2003). The mineral and vitamin supplement essentially is protein free. Thus, the combined 20 lb wheat bran and 3 lb mineral and vitamin supplement would provide 3.14 lb of protein. The remainder of the 12 lb protein required, per 100 lb total mix (12.00-3.14 = 8.86lb), must come from the 77 lb of corn and soybean meal. To determine what combination of corn and soybean meal is needed in the 77 lb remaining, an adaptation of the square method can be used
c. To do this, it is necessary to calculate what % protein will be needed in the corn and soybean meal combination to provide 8.86 lb of protein per 77 lb, as follows:

$$8.86 \div 77 \times 100 = 11.51\%$$

This figure is then used in conjunction with the square method as seen in Fig. 3.

Algebraic equations method: This is an alternative method for the square method using a simple algebraic equation. Here, a particular nutrient requirement is satisfied using a combination of two feed ingredients (Coleman, 2008).
Those who enjoy a mathematical approach to the solution of problems may find the use of algebraic equations preferable to the square method for formulating feed mixtures. In fact, appropriate algebraic methods may be used in the place of the square method in each of the preceding illustrations, as outlined below (Perry *et al*., 2003; Kline *et al*., 2007).

When only two feeds are involved: Algebraic equations may be used in place of the square method for determining what combination of two different feeds will give a mixture containing a certain percentage of some particular nutrients. To illustrate, let us return to the swine feeder who wanted to know what combination of ground shelled corn and 40% complete pig supplement would provide a mixture that contained 18% crude protein. Through the use of the square method, it was determined that a mixture of 69.84% corn and 30.16% supplement would give the desired level 18% of protein. Algebraic equations can be used to make these same determinations as follows:

- x = lb corn per lb mix
- y = lb supplement per 100 lb mix
- x+y = 100 lb mix
- 0.085x+0.400y = 18.0 (lb protein/100 lb mix)
- (Subtract) 0.085x+0.085y = 8.5
- 0+0.315y = 9.5
- y = 9.5/0.315 = 30.16% supplement in mix
- x = 100-30.16 = 69.84% corn in mix

Table 1: Correction factor to use when converting feeds of various moisture contents to 100% DM basis (0% moisture)

% Moisture	Dry to as fed	As fed to dry	% Moisture	Dry to as fed	As fed to dry	% Moisture	Dry to as fed	As fed to dry
10	1.11	0.90	38	1.61	0.62	66	2.94	0.34
12	1.13	0.88	40	1.66	0.60	68	3.12	0.32
14	1.16	0.86	42	1.72	0.58	70	3.33	0.30
16	1.19	0.84	44	1.78	0.56	72	3.57	0.28
18	1.22	0.82	46	1.85	0.54	74	3.84	0.26
20	1.25	0.80	48	1.92	0.52	76	4.17	0.24
22	1.28	0.78	50	2.00	0.50	78	4.54	0.22
24	1.31	0.76	52	2.08	0.48	80	5.00	0.20
26	1.35	0.74	54	2.17	0.46	82	5.55	0.18
28	1.39	0.72	56	2.27	0.44	84	6.25	0.16
30	1.43	0.70	58	2.38	0.42	86	7.14	0.14
32	1.47	0.68	60	2.50	0.40	88	8.33	0.12
34	1.51	0.66	62	2.63	0.38	90	10.00	0.10
36	1.56	0.64	64	2.78	0.36			

Source: (Waller, 1982)

When three or more feeds are involved: The use algebraic equation to formulate a feed mixture containing a definite percentage of some nutrient using three or more feeds, it is first necessary, as with the square method, to separate the feeds into two logical groups, to specify the proportion of each feed in each group and to calculate the weighted average % of nutrient under consideration in each group. One is then ready to set up the appropriate equations and solve for the unknowns.

Using the same problem as was used in illustrating the square method (formulating a 12% crude protein mix using corn and wheat bran in the ratio of 2:1 along with a 40% supplement), one would then proceed as follows:

- x = lb corn+lb wheat bran per 100 lb mix
- y = lb supplement per 100 lb mix
- x+y = 100 lb of mix
- 0.109x+0.400y = 12.00 (lb protein/100 lb mix)
- (Subtract) 0.109x+0.109y = 10.90
- 0+0.2910y = 1.10
- y = 1.10/0.2910 = 3.78% supplement in mix
- x = 100-3.78 = 96.22% corn and wheat bran (2:1) mix

With a fixed percentage of one or more ration components: Let's use algebraic equation to solve the same problem as was illustrated using square method formulating a 12% crude protein mix using corn and 44% soybean meal along with a fixed 20% wheat bran and 3% mineral and vitamin supplement). As with the square method the amount of protein provided by 20 lb of wheat bran and 3 lb of mineral and vitamin supplement per 100 lb of mix must first be calculated (3.14 lb) and subtracted from the 12 lb desired in the overall mix (12.00-3.14 = 8.86 lb). This is the amount of protein that must come from the 77 lb (100-23) of corn and soybean meal per 100 lb of overall mix. The lb of corn and soybean meal, respectively, are then calculated using appropriate equations as follows:

- x = lb of corn per 77 lb of corn and soybean meal and per 100 lb of overall mix
- y = lb of soybean meal per 77 lb of corn soybean meal and per 100 lb of overall mix
- x+y = 77.0 lb corn and soybean meal
- 0.085x+0.485y = 8.86
- (Subtract) 0.085x+0.085y = 6.55 (77.0 x 0.085)
- 0+0.400y = 2.31
- y = 2.31/0.400 = 5.79 lb soybean meal/77 lb corn and soybean meal
- x = 77-5.78 = 71.21 lb corn/77 lb corn and soybean meal

Final ration mixture	%
Ground shelled corn	71.21
48.5% soybean meal	5.79
Wheat bran	20.00
Mineral and vitamin supplement	3.00
Total	

Formulating computerized least-cost rations: A great deal of interest has been demonstrated by feed manufacturers and livestock feeders over the past few years in the computer formulation of least-cost rations. Such rations differ from conventionally formulated rations only in that a computer is used in their formulation. Like conventionally formulated rations, computerized least-cost rations are balanced with respect to nutritional adequacy using the most economical, satisfactory sources available for supplying the various critical nutrients in the amounts needed. The advantage of the computer is that it will do almost instantly what otherwise would be a long, laborious, almost impossible task done by hand calculation (Perry *et al*., 2003).

There are several basic requisites necessary for the computer formulation of least-cost rations. They are:

- Computer facilities
- Personnel trained in the use of computer facilities

- Information on nutritional requirements
- Information on feed suitability
- Information on feed composition
- Information on prevailing prices of available feeds

Computer facilities and their use: Computers are available with almost unlimited capabilities. Almost all companies, most nutrition consultants and a large percentage of livestock producers have computers and are knowledgeable in their operation. Private programmers offer programs suitable for use in calculating least cost formulations.

Nutritional considerations: From the standpoint of nutritive requirements, such information takes on the form of so called restrictions. These restrictions for the various critical nutrients are expressed as minimum and/or minimum values, depending on the nutrient under consideration. Generally speaking, the fewer the restrictions and the wider the restriction range consistent with acceptable ration quality, the better.
For certain critical nutrients such as salt, the trace minerals and the vitamins, which usually are supplied at minimum allowance levels independent of the amounts provided by the major ration components, no formal restrictions ordinarily, are provided. The rations simply are formulated with consideration given to protein, energy, fat, fiber, calcium and phosphorus. The trace minerals, critical vitamins and salt are added per ton as needed to meet the minimum requirements. In fact, sometimes the calcium and phosphorus restrictions also are omitted and supplemental sources of these two nutrients are added as required based on the amounts of each supplied by the major ingredients as calculated by the computer.

Individual feed restrictions: In formulating rations, whether it is by conventional or computer procedures, frequently it is necessary or desirable to place certain limitations on the use of one or more potential ration components. These may be either minimum or maximum limitations, depending on the circumstances. For example, sometimes a feed may be used in the ration for a particular class of livestock up to certain level, but it cannot be used in unlimited amounts without possible complications. In other instances, circumstances sometimes dictate that a certain minimum amount or some fixed amount of a feed be used in ration. As with the various critical nutrients, such limitations are effected in computerized ration formulation through the use of appropriate restrictions. As indicated earlier, these restrictions may be in the form of minimum and/or maximum values. Should it be desirable to include a fixed level of some nutrient or feed in the ration, this would be accomplished ordinarily by using minimum and maximum restriction values of the same magnitude for the feed or nutrient in question.

Net weight 50 pounds

PROCEDURS 24

OMMERCIAL
BROILER STARTER
MEDICATED
To be used as a medicated for chicken only:
To aid in the prevention of coccidiosis

ACTIVE DRUG INGREDIENTS
Sulfaquinoxaline--------------------------------------0.015%

WARNING
Do not treat chickens withing10 days of slaughter
Do not feed laying chickens in production for food

GUARANTEED ANALYSIS
Crude protein, not less than-----------------------24.0%
Crude fat, not less than-----------------------------7.0%
Crude fiber, not more than--------------------------2.0%

Ground corn, soybean meal, fish meal, corn gluten meal, stabilized fat, alfalfa meal, ground limestone, dicalcium phosphate, salt, ethoxyquin, manganous oxide, vitamin A palmitate, D-activated animal sterol, choline chloride, niacin, calcium pantothenate, riboflavin.

MANUFACTURED BY ÿ FEEDS
TIGERTOWN S.C.

Fig. 4: Example of a feed tag

Feed composition and prices: Once appropriate restriction values have been established for the various critical nutrients and feeds, this information is fed into computer along with information on the composition and prices of the various alternative feeds available in the area. It should remembered that the list of alternative feeds and ingredients must be of such a combination as will permit the computer to comply with the program restrictions on a reasonable basis in the formulation of the desired ration. Also, of course, the composition figures used for the various feeds and products under consideration must be accurate for the computer to turn meaningful results.
For effective least cost ration formulation, there also must be available reliable, realistic prices on potentially available feed ingredients. In addition, only products should be included in the list of alternative feed possibilities that can be handled with the user's existing facilities. Otherwise, the cost of providing any additional facilities to use such an ingredient should be given appropriate consideration (Perry *et al.*, 2003).
Virtually all commercial diets are now formulated by computer using linear programming techniques. Linear programming involves the simultaneous solution of many linear equations to determine the optimum allocation of feed ingredients to meet an objective, which

usually is to satisfy a set of nutrient requirements. Generally, the optimum allocation means the least expensive selection of ingredients. Thus most diets are formulated on a least-cost basis. In essence, the computer calculates the combination of available ingredients that will meet all the specified requirements at the lowest cost. Many computer programs for diet formulation are available from commercial sources. The selection of the best one to use is based on the computer available and the particular objectives desired (Cheeke, 1999).

Linear programming method is a method of determining the least-cost combination of ingredients using a series of mathematical equations. There are many possible solutions to each series of equations, but when the factor of cost is applied, there can only be one least cost combination. An electronic computer is capable of making thousands of calculations in a very short time. However, the machine is incapable of correcting errors resulting from incorrect data and errors in setting up of the program. Therefore, the resultant rations obtained from linear programming will be no better than the information and values which are entered into the programming (Coleman, 2008).

Compound feed preparation

Feed compounding: Feed compounding is the process of converting ingredient raw materials into balanced diets that are then sold to producers of livestock and other animals. Manufactured feeds are produced in feed mills that have equipment to process feedstuffs like grinding and extruding for mixing in the desired proportion and to mix the ingredients to produce the finished product. Often the mixed feed is pelleted or mash type feed. In modern animal agriculture, swine and poultry are usually fed manufactured feeds. With swine it is a common practice for farmers to purchase a mixed supplement, to be added to their own grain and mixed at the farm. Dairy cattle are fed manufactured concentrate feed along with hay and/or silage. Beef cows and sheep are primarily grazing animals and generally receive little if any manufactured feed. Calves and lambs may be fed supplementary commercial feed. Feedlot cattle are usually fed diets mixed at the feedlot and so are not major consumers of manufactured feed. Compound feedstuffs may be marketed only if they are wholesome, unadulterated and of merchantable quality (Cheeke, 1999; Revy, 2006).

Specialty feeds: Specialty feeds refer to a number of products that are produced by feed manufacturers for special purposes. The various types and classes of commercial feeds can be designed to take into account specific performance parameters condition of the animals and need for mediation. The determination of what type of class of feed to use depends on a variety of factors including kind of animal fed, level of performance desired and availability and cost of ingredients (Ensminger *et al*., 1990).

The commercial feed manufacturer has the distinct advantages of:

- Purchasing feed in quantity lots, making possible price advantages
- Using computers for purchasing and least cost formulating
- Having the knowledge to manufacture mediated feeds
- Having the knowledge and the facilities to manufacture specialty feeds such as milk replacers
- Processing and mixing economy and control
- Hiring scientifically trained personnel for use in determining the ration and
- Controlling quality

Modern feed mills largely computer controlled. The process begins company nutritionists who formulate diets, using NRC or other recognized nutrient requirements figures, tables of feed composition and current price of ingredients. Many diets are least-cost formulas, in which the ingredients are selected to meet the prescribed nutrient requirement figures at the lowest cost. A least-cost formula is not necessarily optimal. Even though it provides nutrients in adequate quantities, there may be other factors, such as palatability and physical texture that reduce animal performance. A discussion of some methods of formulating optimal return and least-cost gain diets is given by Hertzler *et al.* (1988). The computer formulated diet formula is then put into the mills computer system. The operator provides information as to the quantity of feed desired, mixing instructions and so on. Ingredients are weighed out automatically, the feed mixed, pelleted and discharged into bulk trucks or bags.

Feed labeling: Feed manufacturing is subject to numerous regulations for the protection of the customer and the consumer. Feed labeling requires various information including a list of ingredients and a guaranteed analysis. The following information is required (Revy, 2006):

- The net weight of the feed
- Species or category of animals
- The name or business name and address or registered place of business
- The identifying number for approved or registered establishments
- The net quantity expressed in units of mass or volume
- Guaranteed analysis as state regulations determine to advise the user of the composition of the feed or to support claims made in the labeling. In all cases, the substances or elements must be

determinable by laboratory methods such as the methods published by the Association of Official Analytical Chemists (AOAC). Most feed labels give minimum and/or maximum guarantees of certain nutrients within the feed. The following analyses are listed Dry matter, crude protein, crude fat, crude fiber, ash, NFE, calcium phosphorus and salt and other nutrients. Generally, feeds with more protein and fat and less fiber indicate quality
- Declaration of certain additives
- The minimum storage life
- 'Use before' followed by the date (day, month and year) in the case of microbiologically highly perishable feedstuffs; 'best before' followed by the date (month and year) in the case of other feedstuffs;
- The reference number
- The production date
- The directions for proper use
- The common or usual name of each ingredient used in the manufacture of commercial feed
- Adequate directions for use for all commercial feeds containing drugs and for such other feeds as may be required by regulation as necessary safe and effective use

In conjunction with the particulars listed before only the following particulars may be placed in the same space (Revy, 2006):

- Identification, mark or trade mark of the person responsible for the labeling particulars
- Name or business name and the address or registered place of business of the manufacturer if this is not the person responsible for the labeling particulars.
- The country of production or manufacture
- The price
- The description or trade name of the product
- Recommendations established by the member state for feeds that meet certain analytical characteristics
- Physical condition or specific process undergone
- Certain analytical declarations
- The date of manufacture

Conclusion: Feed represents a large percentage of the cost of production; therefore, diet formulation is a very important aspect of animal production. Diet formulation allows nutritionist to develop that can be eaten and utilized by the animal to provide an economically feasible level of production. For diets contain few feedstuffs and in which the nutritional parameters, such as energy and protein, are fixed, the techniques required are quite simple. In these cases the use of algebraic or Pearson's square can be utilized. When the diets become more complex and the optimum level of production is to be determined, mathematical programming is the technique of choice.

In modern animal agriculture, swine and poultry are usually fed manufactured feeds. With swine, it is common practice for farmers to purchase a mixed supplement, to be added to their own grain and mixed at the farm. Dairy cattle are fed manufactured concentrate feed along with hay and/or silage. Beef cattle and sheep are primarily grazing animals and generally receive little if any manufactured feed. Calves and lambs may be fed supplementary commercial feed. Feed lot cattle are usually fed diet mixed at feed lot and so are not major consumers of manufactured feed.

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