Chapter 1

Introduction to Feeding of Livestock: Importance of Scientific Feeding; Feeding Experiments

INTRODUCTION

We have studied the different nutrients that are required by the animal body and the metabolic changes, which they undergo in serving its (the body's) various functions.

A knowledge of the quantitative needs of the body for these nutrients and of the relative value of feeds as sources of them is the basis of scientific feeding. This knowledge has been gained gradually by means of research and experience over many years. An understanding of the methods by which it has been attained and which are still being employed to augment it is essential for the student of nutrition.

Let us visit into the history of these developments. Science is the study or theoretical explanation of natural phenomena that happen in the nature. Our environment is governed by natural laws that control everything from gravity to the weather. These laws also control the way plants and animals live and grow on our planet. As animals were domesticated, people reasoned that there were certain methods they could use to grow the animals more efficiently. Through the use of trial and error, the best ways of caring for the animals were discovered and passed along from parents to children. Thus, most of the knowledge about growing plants and animals had been passed from generation to generation and represented people's beliefs rather than proven knowledge.

Scientific Method

Progressive scientific research began in the United States about the middle of the 1800s, and in 1862 United States Department of Agriculture (USDA) was established. To create new knowledge through a systematic process of scientific investigation, Experiment Stations were established from 1872. These experiment stations put to use what has come to be known as the **scientific method of investigation**. The scientific method is a systematic process of gaining knowledge through experimentation. The method is used to make sure that the results of an experimental study did not occur just by chance and that something caused the change. This process involves formulating a hypothesis, designing a study, collecting data, and drawing conclusions based on an analysis of the data (Fig.1.1).

A scientist begins by identifying a problem that needs to be solved. The scientist may have an idea or suspicion of what causes the problem or what might solve the problem. This suspicion is called a **hypothesis** and serves as the basis for investigating a problem. The hypothesis is then subjected to a test called an **experiment** that attempts to isolate the problem in question and determine the solution. Thus, the scientific method has been used thousands of times to develop the methods that are in use to produce animals to meet the demand for animal products. The several types of feeding experiments that have been conducted are explained here in the following pages.

Recognising a problem
↓
Develop hypothesis
↓
Design an experiment
↓
Conduct the experiment
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Collect data
↓
Analyse data
↓
Draw conclusions
↓
Make recommendations

Fig. 1.1: The scientific method requires several steps (*Source*: p 4, The Science of Animal Agriculture by Ray V Harren 2nd edn, 371pp, Delmer Publishers, 2000)

FEEDING EXPERIMENTS

Trial and experience were the means by which the art of feeding animals was originally developed. A feeding trial with the species in question still remains the most useful method of obtaining results, which have a direct application to feeding practice. Minimum number of animals per group should be 4. Completely randomized design (CRD) or randomised block design (RBD) may be followed.

1. Comparative Feeding Trials

A feeding trial, in its simplest form, is a record of the results produced in a feeding experiment in terms of growth, milk production, or other function from a given feed or ration. Two or more rations may be compared with each other on this basis. In case of two rations 't' test is used while in case of three or more rations 'analysis of variance' test is applied to analyse the data-feed consumed per day, average daily gain (ADG), feed consumed per kg gain (feed efficiency), etc. for statistical significance. A comparison was made between fish meal and linseed meal as protein supplement for swine (Maynard et al. 1979). This shows that fish meal is a better protein supplement for swine than linseed meal. But it tells nothing as to why the fish meal was better. Is it due to higher percent of protein, or higher biological value of protein or large amount of calcium supplied by FM or presence of certain vitamins?

It is important to know the specific nutritive quality, which makes one feed better than another. For example, if the superiority of FM ration is due to the extra calcium, the addition of ground limestone to the linseed meal ration would be cheap. The

Comparison of fish meal with linseed meal as protein supplement for swine

	ADG, kg	Feed for 100 kg gain, kg
Ration I		
200 kg corn, 100 kg wheat middlings 75 kg fish meal (FM)	0.5	390
Ration 2		
200 kg corn, 100 kg wheat middlings 75 kg linseed meal	0.32	440

comparison of two feeds with respect to a specific nutrient such as Ca, or protein requires that all other nutritive factors be held alike and adequate in the two rations. However, this can never be achieved absolutely. But feeding trials can be set up to get the specific information desired.

2. Feeding Trials with Laboratory Animals

Today many of the problems of nutrition are being studied with small animals, such as rat. The processes of growth, reproduction and lactation can be effectively investigated.

Advantages

i. Much small cost in terms of animals, feed and labour and the much shorter time involved for a given experiment, in view of the short lifecycle of the lab animal.
ii. The influence of individual variability (it is a seriously disturbing factor in large animal experimentation) can be reduced to a minimum by the use of animals of similar generic and nutritional history, by using large number of animals and by close environmental control.
iii. Slaughter for chemical and histological examinations, a desirable feature of many feeding trials, presents little difficulty with small animals, compared with the economic and other considerations involved in the case of farm animals.

The result obtained in feeding trials with small animals, however, cannot be considered to have direct application to the various species of farm animals, because of the differences in physiology and other considerations. Even here studies with small animals serve as pilot experiments, by means of which much preliminary information can be obtained more quickly and at much less cost. Final test can be done with the large animals.

3. Purified Diet Method

Purified diets were used in conducting feeding trials with lab animals. Purified diets consist of purified sources of the various nutrients. For example, *protein* is supplied as casein, purified soybean protein, or urea; *carbohydrates* as starch, glucose, or sucrose; *fat* as lard or some oil; *minerals* as chemically pure salts and *vitamins* as pure crystalline compounds. Such a diet makes it possible to include or withdraw a given nutrient with a minimum of disturbance of any of the other nutrient relations.

In 1816, Magendie fed diets of pure sugar and of pure fat to dogs to ascertain whether or not N was required in the food. Later JB Boussingault, the famous French chemist carried on nutrition studies with various species, involving the use of diets consisting in part of purified nutrients. Later McCollum and Davis and Osborne and Mendel used this method.

Purified diet method became responsible for much of our modern knowledge of nutrition, including the physiology of the vitamins, the establishment of differences in protein quality and more exact information regarding many of the minerals. Studies of the role of an element needed by the body in small amounts can be effectively carried out only with basal diets, which may be freed from it and to which it may be added in known amounts. This is only possible with purified diets, because a diet cannot be prepared from natural foods, which will be free from the element in question.

Limitations

1. The ingredients of these diets cannot be considered pure in the absolute sense. For example, starch cannot be entirely freed from mineral elements. Some of the vitamins were identified as 'impurities'.
2. Some of the constituents, notably protein, in purified diets may be altered from their natural state in the process of purification.
3. The kind of pure carbohydrate used affects the significance of the results in the case of certain vitamins because of the effects of various carbohydrates on vitamin synthesis in the alimentary tract.
4. All the nutrient requirements of species should be known to prepare a completely successful purified diet.
5. The diet must be of suitable physical nature and sufficiently palatable so that it will be consumed as per the need.

The method has been developed to its highest degree of usefulness in the case of rat and chick because of the lesser problem involved in preparing purified nutrients on a small scale and many years of experiments with these species. As regards farm animals, the use of purified diets has contributed greatly to the modern knowledge of poultry nutrition. Other applications of the method have made important contributions to our knowledge of the nutritional needs of lambs, sheep, cattle and pigs.

4. Germ-free Technique

Contribution of intestinal organisms to the nutrition of the host complicate the interpretation of data obtained in feeding trials on dietary reuirement of various vitamins. Thus, the nutrition scientist has a special interest to obtain germ-free animals at birth and to rear them in an uncontaminated environment thereafter. Germ-free means free of contamination by bacteria, yeasts, moulds, fungi, protozoa and parasites in general, that is, free of all other life.

The newborns are obtained by caesarean section and reared in specially designed apparatus by appropriate techniques using sterilized diets, etc. Success has been reported with rats, rabbits, hamsters, mice, chickens, turkeys and monkeys. Techniques have been developed for obtaining "specific pathogen-free" (SPF) baby pigs by hysterectomy. These were used for nutrition experiments.

5. Group Feeding versus Individual Feeding

Feed records are a desirable feature of all feeding trials. In many feeding experiments, particularly those with farm animals, the animals have been fed as a group. This is the simplest procedure from the standpoint of equipment needed and labour cost. But in many experiments, it introduces complications in the interpretation of results.

Such complications arise when there is a wide variability in the individual behaviour within the group, as to its production, feed consumption, etc. The difficulty is increased when an animal, owing to accident or other unavoidable cause, has to be removed from the lot. The performance of the animal can be eliminated from consideration, but the food which it ate cannot.

Individual feeding eliminates these disadvantages. It makes possible the correlation of individual performance record with the feed consumption. It preserves the identity of the individual. Certain species which are fed together may consume somewhat less than when fed individually. This may be due to "competition in the feed lot". Individual records are highly desirable in studies where only small differences are to be expected and where quantitative data are of special importance.

Individual records are much more useful from the standpoint of statistical treatment.

6. Controlled versus *Ad Libitum* Feeding

Ad libitum feeding is the most commonly used procedure in farm animal investigations and gives unbiased results for direct practical application. In growth trials, *ad libitum* feeding is to be given. Feed per kg gain can be calculated.

Ad libitum feeding method does not provide the controlled conditions required for certain purposes; for example, the determination of digestibility. Osborne and Mendel from their studies of protein quality recognized that *ad libitum* feeding frequently gave rise to variable results. Thus in many instances, there is an advantage in using some system of controlled feeding. Food intake was adjusted in accordance with increase in weight. In digestion and metabolism trials controlled feeding is allowed; 90% of feed intake is offered.

7. Equalized Paired Feeding or Paired Feeding

Feed intakes are completely controlled. In this method of comparing two rations, the animals are fed alike in a preliminary period. Then animals are selected by pairs and are kept on ration A and B, and are fed same quantity of feed limiting the intakes of both to that of the animal consuming the lesser amount.

The two animals of the pair are similar in size, age and previous history. But such qualities are not essential from pair to pair. The equalization of feed intake is also limited to within the pair. Minimum of four pairs of animals are to be used to carry out statistical analysis, e.g. Dicalcium phosphate, A; Bone meal, B are compared as sources of phosphorus for bone growth (in rats). When it is desired to compare three rations at the same time, the animals can be selected in trios. This may involve complications in comparing more than three rations.

Limitations

1. The faster-growing animal is penalized because of restricted feeding. As the animal on the superior ration increase in weight over its mate, its maintenance requirement becomes greater than that of its mate. Under these conditions, as equal feed intake for both means that the larger animal must be using a larger proportion for maintenance and less remains for growth promotion. That is how the faster-growing animal is penalized.
2. The frequent effect of a nutritionally deficient ration is to decrease feed consumption. By limiting feed intake, the full effect of the better ration cannot express itself.
3. The method is not suitable for finding out how much superior one ration is to another for growth. Lactation studies which adjust the feed of each animal on the basis of body weight and production represent a special type of controlled-feeding experiment.

Lucas (1943) designed an equalized feeding system, which reduced the variability of responses of lactating cows that are fed individually.

8. Slaughter Experiments

Relative value of the two mineral supplements was measured in terms of calcium and P content of bones because the growth of the animals as a whole would not have given definite information as to bone development. Such a procedure, which involves the killing of the animals and the analysis of certain specific tissue or of the body as a whole, is commonly referred to as a slaughter experiment.

In many feeding trials, it is desirable to obtain more specific information regarding the effect of a given ration than is furnished by the common measures of weight and size. For example, in studies of the optimum energy and protein requirements for growth, it is important to know the specific effect of the ration in terms of the composition of the tissue formed, since the increase in the body weight as a whole may be due to water, fat, minerals as well as protein, the relations of which may vary. Lawes and Gilbert have used this slaughter method.

To study the effect of a given diet on changes in body composition a group of like animals are selected and a part of them are slaughtered and analyzed at the start of the experiment. The others are fed different experimental diets for a given period and then slaughtered and analyzed. The difference in their composition from that of the animals killed at the start reveals the effect of the diet fed.

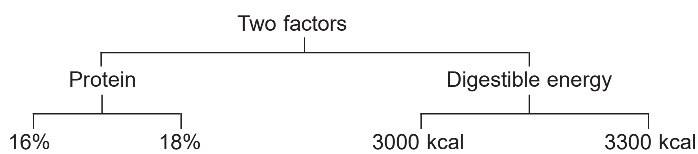
Limitations

1. It required much more time and labour than is involved in merely weighing feed and animals.
2. Difficult problems are presented in the selection of representative samples of tissues and in their preparation for analysis. Similarly, utmost care has to be taken in taking truly representative sample of the carcass after thorough mixing of minced carcass. The author conducted these experiments in pigs and sheep in a research project on prediction of body composition of live meat animals using isotope techniques (Reddy and Prasad 1983, Prasad et al. 1983).

EXPERIMENTAL DESIGNS

The statistician refers to those feeding trials, which are set up in such a way as to allow statistical analysis as experimental designs, e.g. CRD and RBD. In addition, there are certain specific designs with which the student should be familiar.

1. Factorial Experiment



2 × 2 factorial experiments:	16 and 3000	18 and 3000
4 ratios	16 and 3300	18 and 3300

2. Latin Square Design (LSD)

In a 4 × 4 LSD four experimental rations (τ1, τ2, τ3 and τ4) can be evaluated using four animals (A, B, C and D) in four periods (preliminary period, 14 days and collection period, 7 days) for their digestibility and nutrient balance. Animals are shifted from one ration to another and at the end of four periods data from four animals are available for each ration.

	Rations			
Periods	r_1	r_2	r_3	r_4
1	A	B	C	D
2	B	C	D	A
3	C	D	A	B
4	D	A	B	C

3. Crossover Design

Crossover design or changeover design is a special class of experimental design in which one group of experimental animals receives different treatments during the different time periods, i.e. the group of animals crossover from one treatment to another treatment. This facilitates conduct of multi-treatment animal experiments and statistical analysis of the data with the availability of only 4–6 animals. Crossover experimental design allows for an increase in precision when less variability is expected within animals than between animals.

Examples

Six metabolism trials were conducted using four male goats (local nondescript breed; BW 13.5 kg) in a crossover design to study the supplementary feeding value of fresh foliage of subabul (*Leucaena leucocephala*), sesbania (*Sesbania grandiflora*), acacia (*Acacia auriculiformis*), jack (*Artocarpus heterophyllus*), yellow gold mohur (*Peltophorum ferrugineum*) and cashew (*Anacardium occidentale*). Respective tree foliages (which include leaves and tender twigs) were supplemented (as first feed) @ 300 g/head/day to goats fed *ad libitum* quantity of Napier Bajra green fodder (chopped to 2–4 cm) as basal feed (Reddy et al. 2009. Each trial period consisted of preliminary period of 20 days, adaptation period of 3 days and the collection period of 5 days. Please refer page 210 for details.

The research data was published in the form of research papers as detailed below for wider dissemination.

- Uma Maheswari D, N Elanchezhian and DV Reddy (2008): Evaluation of nutritive value of cashew nut (*Anacardium occidentale*) tree leaves in goats. Indian Journal of Animal Nutrition 25 (3): 248–51.
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NUTRITIONAL EXPERIMENTS WITH RUMINANT ANIMALS

Nutritional experiments with ruminant animals mostly fall within 2 categories, **continuous design experiments** and **changeover or crossover design experiments** (Hristov et al. 2019; JDS 102:5811–52).

The continuous design experiments (e.g. randomised block design), usually of prolonged duration, allows evaluation of the effects of treatment on variables over a longer study period, with body weight changes being a typical example. The main disadvantage of this design is that variability among individual animals can be high (even after blocked due to body weight, parity) in their feed intake, production, or other responses to treatment in time.

The advantage of changeover designs (e.g. Latin square) is that all animals receive all treatments and can serve as their own control, unless the design is incomplete. Thus, the statistical power of this type of design is almost always greater than that of a continuous design because animal variation is accounted for. The main disadvantage of changeover design is that experimental periods are usually of a shorter duration and animals may change their nutrient metabolism or production parameters (or both) during the experiment (such as the case with lactating dairy cows or growing animals). Another issue is carryover effects of treatments; for example, a milk yield decrease as a consequence of metabolisable protein deficiency, may not fully recover or recover over extended periods, with compensatory growth in cattle being another example.

Comparison of feed intake and milk production responses in continuous and changeover design dairy cow experiments (Huhtanen and Hetta 2012) revealed both the designs are similarly accurate in evaluating the effects of nutritional treatments on feed intake and milk production, except when treatments result in large differences in DMI (>5 kg/d). Analysis of production responses to changing crude protein levels in lactating dairy cows (Zanton 2016) showed that design had no effect on DMI, milk fat and protein yields, or milk N efficiency; but experimental design influenced milk yield and consequently feed efficiency because of the different 'days in milk' of the cows since it is an important variable on production effects of dietary protein.

Changeover design experiments are as suitable as continuous ones for studying protein metabolism in ruminant animals, except when changes in BW or carryover effects due to treatment are expected (Hristov et al. 2019). Adaptation following a dietary change should be allowed for at least 2, preferably 3 weeks, and extended adaptation period may be required if body labile pools can temporarily supply the nutrients studied (due to rumen – N recycling).

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