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Review Article

The Different Methods of Measuring Feed Digestibility: A Review

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Abstract

Review was carried out on the different Methods of Measuring Feed Digestibility to feed animals at different treatment to evaluate the nutritional and chemical composition of digestibility of a feed determines the amount that is actually absorbed by an animal and therefore the availability of nutrients for growth, reproduction. The animal relative intake more importance than digestibility in determining overall nutritive value food/feed stuff of the ruminant because highly digestible feeds are of little value. However, digestibility usually provides a fairly reliable index of nutritive value of feed/food stuff because more digestible feeds are normally consumed to a greater extent than less digestible feeds in ruminant nutrition. Nutritive value of feeds is affected by a lot of factors, such as composition, odor, texture and taste (Schneider and Flat, 1975). Digestibility measurement has numerous advantages. One of the most significant is determining the nutritive value of a feed and to predict animal performance [1]. Digestibility data can offer an insight into the proper feeding and management of animals. different techniques used to measure the digestibility of the feed samples in reliable method up-to-date sample collection is very crucial. However, some feed/food has some the some anti-nutritional factors results in characteristically bitter taste making an unacceptable for consumption.

Different strategies (processing methods) have been used to reduce/eliminate many positive effects in terms of growth and reproductive efficiency, comparable with supplements of other feeds and which is better than the maintenance requirements of the animals.

Keywords: *Feed; Digestibility; Animals*

Introduction

The digestibility of a feed determines the amount that is actually absorbed by an animal and therefore the availability of nutrients for growth, reproduction etc. (FAO, 2013) in normal condition, the digestibility and intake directly related with nutritive value of food/feed. major two factors, intake is relatively more important than digestibility in determining overall nutritive value because highly digestible feeds are of little value. However, digestibility usually provides a fairly reliable index of nutritive value because more digestible feeds are normally consumed to a greater extent than less digestible feeds. Nutritive value of feeds is determined by a lot of factors, such as composition, odor, texture and taste (Schneider and Flat, 1975). Digestibility measurement has numerous advantages. One of the most significant is determining the nutritive value of a feed and to predict animal performance [1]. Digestibility data can offer an insight into the proper feeding and management of animals. Of the various techniques that have been used to date the total collection is the most reliable method of measuring feed's digestibility. The portion feed which is soluble or is rendered soluble by hydrolysis or some other chemical or physical change in the body of an animal can be taken up into the circulation and assist in supplying the animal body with material for building and repair of tissue or supply the energy necessary for body functions [2].

Aim of the Study

This paper aims to review the different techniques used for the estimation of digestibility of animal feed.

Ways of digestibility determination

Conventional methods of digestibility determination

Total collection technique (conventional digestion trial) is the most reliable method of measuring a feed's digestibility. Unfortunately, however, it is somewhat time consuming, tedious, and costly. Basically, the feed in question is fed in known quantities to an animal [3]. Usually, the animal is restrained in an individual cage so that a quantitative collection of feces can be made. Accurate records of feed intake, refusals and fecal output are kept, and a sub sample of each (usually 10% of daily output in the case of feces) is retained for analysis. When estimates of nitrogen balance are desired, urine output is also measured. Three animals per feed are required as a minimum but maximum is increase the accuracy [2]. The animals are usually allowed from 7 to 21 days (d) to adjust to the feed offer, followed by a collection of feed samples for analysis and the samples can then be dried, ground, and analyzed for the nutrients of evaluation [2].

Digestibility of any given nutrient can be calculated as follows:

$$\text{Nutrient digestibility (\%)} = \frac{\text{Nutrient intake - Nutrient in feces x 100}}{\text{Nutrient intake}}$$

The most common arrangement for collecting the excreta of animals for digestibility experiments is through the use of metabolic crates [2]. A metabolic crate is actually a stall or box large enough for the animal set on legs from 50 cm to 1m high. The space allowed to the animal must be large enough to permit considerable freedom of movement to respect the animal welfare issue. Some individual animals are temperamentally not fit to be used in such experiments and are too nervous to be used in digestion trials the sex the animal is difficult to fix the carte [2]. Mostly captive wild animals fall into this category. Even though conventional digestion trials are the standard with which all other measures of digestibility are compared, the values obtained still vary ± 1 to 4 % as a result of animal-to-animal variation, sampling procedures and analytical errors [4].

Special methods of digestibility determination

Difference technique

Calculation of digestibility of a nutrient in a test diet is based upon the assumption that digestibility of a mixed diet is equal to the summation of the proportions of the diet supplied by each ingredient when fed alone. The digestibility of a nutrient in the experimental feed stuff being fed in form of mixed feed is calculated as follow.

$$\text{Digestibility of nutrient in test feed (\%)} = \frac{\text{(A) - (B) (C) X 100}}{\text{D}}$$

Where, A = Digestibility of nutrient in total diet; B = Digestibility of nutrient in basal diet (usually already determined when fed alone; C = Proportion of total nutrient in diet supplied by basal diet; (D) proportion of total nutrient in diet supplied by test feed.

Marker technique

There has been considerable interest among animal nutritionists in methods of reducing the time and expense involved in digestion experiments by the use of methods where total feces are not collected and weighed but are merely analyzed [5]. This departure from the former method of determining digestibility has been designated as the indicator or index method (Kotb and Luckey, 1972). In this method, in addition to the chemical analysis of the usual proximate nutrients, the content in the feed and feces of an indigestible reference sub-

stance is determined. The substance may be a natural constituent of the feed (internal indicator) or it may be added to the feed (external indicator). Substances used for this purpose include ferric oxide, chromic oxide, lignin, silica, chromogen, acid-insoluble ash (Van Keulen and Young, 1977) and indigestible acid detergent fiber (Waller., *et al*. 1980). A good marker must be strictly non-absorbable, must not affect or be affected by the gastrointestinal tract or its microbial population, must be physically similar to or intimately associated with feed material and its method of estimation in digesta samples must be specific and sensitive and not interfere with other analyses. A characteristic of this method is that the digestibility is calculated from the relation between the nutrients and the indicator substance in the feed and in the feces. This method had been called a qualitative method, although this name is not strictly accurate. The digestion coefficient is computed by using the change in the ratio of each nutrient with reference to the special indigestible substance in the feed and in the feces. An example of this is the determination of the digestibility of the dry matter of a feed by the following equation:

$$\text{Digestion coefficient of dry matter} = 100\text{-}100 \text{ X } \frac{\% \text{ Indicator in feed DM}}{\% \text{ Indicator in fecal DM}}$$

By chemical analysis of a suitable feed sample, the ratio of the concentration of the inert substance to that of any nutrient in the feed can also be established. The face and digestibility it can be calculated without measurement of feed consumed, orts and feces defecated. Thus, if the percentage of any nutrient in this feed and feces is known and the percentage of the indicator substance is also determined in the feed and feces, the digestibility of that nutrient can be found by means of the following formula:

$$\text{Digestion coefficient of a nutrient} = 100\text{-}100 \text{ X } \frac{\% \text{ Indicator in feed X } \% \text{ Nutrient in feces}}{\% \text{ Indicator in feces X } \% \text{ Nutrient in feed}}$$

When determining the coefficients of digestibility of nutrient by the indicator method, it is assumed that the reference substance passes through the alimentary tract at a uniform rate. If its rate of excretion during the day is vary with time and intake, special sampling plans is followed to adjust for diurnal variation. If on the other hand, the ratio of the indicator and the nutrients is the same throughout 24h period, only a small amount of feces collected at any time of the day or night should be sufficient to give an estimate of digestibility. However, it is advise to collect samples more than once for sample for digestibility calculation. The animal should always be allowed an adequate adaptation period before actual experiential feed tested. The fecal samples should be collected for several consecutive days to collect adequate sample and pooled for subsequent analyses in appropriate sampling store. This method of determining digestibility will hopefully minimize much of the time, labor and expense to conduct digestion trials.

Apparent digestibility of a diet can be estimated using a natural constituent of the feed as an indicator. Acid insoluble ash (AIA) can be used in this way (van Keulen and Young, 1977). The ratio between the concentration of AIA in the feed and the concentration of AIA in the faeces gives an estimate of digestibility (Osuji P., *et al.* 1993).

Nylon bag technique

In sacco method, also named as nylon bag or *in situ*, is based on depositing separately foodstuff into bags which are incubated into the rumen of an animal fitted with a rumen cannula. The main objective is to measure the disappearance of dry matter and/or other nutrients [6].

The technique provides a means of ranking feeds according to the rate and extent of degradation of dry matter, organic matter, nitrogen or other nutritional parameters. It involves incubating samples of feeds in the rumens of fistulated animals for periods of from 6 to 120 hours and subsequent determination of the disappearance of the different feed components. The nylon-bag technique uses bags (6.5 x 14 cm) made of nylon mesh (30 - 50 mm). A sample of known weight is tightly sealed in the nylon bags and placed in the rumen of a fistulated animal. After the required period of time, the sample is removed, washed, dried and weighed (ILCA).

In this procedure, nylon bags are filled with 2 to 3g of the grinded feed sample prepared for experimental feed and incubated in the rumen of a cannulated animal kept for the experimental purpose. In general, bags are secured to a weighted cord to prevent surfacing on the rumen and to ensure adequate exposure to microbial digestion of the tested feed sample [2].

Degradability (or disappearance) of the substrate is determined by the weight loss during the incubation periods. The major factors which affect nylon-bag degradation include how the bags are placed in the rumen, particle size of sample *vis-à-vis* the pore size of the nylon bag, loss of feed particles through the bag cloth (a function of fineness of grinding, cloth pore size and feed material), method of washing, the length of time that the samples are incubated in the rumen and the rumen environment in which degradability is determined. The nylon-bag technique is a very simple and useful biological tool for *in vivo (in sacco)* animal nutrition studies (ILCA).

Another method of estimating digestibility of feeds is the nylon bag technique. Bags are then removed, washed under tap water, dried and the weight of residue determined to determine the amount of nutrient in feed digested. An empty bag should be incubated that serve as a blank for the experimental conditions [2] during the use of the nylon bag, the pore size of the nylon material, which should be small enough to prevent passage of feed from the bag, but large enough to permit microbial entry to the sample. A pore size of 50µ or less is desirable as the stranded [2]. In addition, the sample to bag size ratio is quite relevance, and a ratio of ~10 mg/cm^2 of bag surface is probably enough. The disadvantage of the nylon bag technique is that fewer samples can be run at one time than with the Tilley and Terry method, and a donor animal with large diameter postulated animal is desirable. Nylon bag (or *in situ*) techniques, are, however, quite useful for evaluating kinetic aspects of digestion in ruminants. by using multiple incubation times and computer models, rates of nutrient digestion can be calculated.

Laboratory methods (*in vitro* methods)

Studies with live animals *(in vivo)* to determine the digestibility of feeds are time-consuming, laborious and expensive and require large quantities of feed. Such experiments are not suited for the rapid and routine feed evaluations undertaken by commercial laboratories that provide feed information to livestock producers and feed manufacturers [3].

Tilley and Terry IVDMD

In vitro digestibility techniques provide a quick, inexpensive, and precise prediction of *in vivo* or conventionally determined digestibility in ruminants.

The two stage Tilley and Terry method is a laboratory test used as a plant quality index for animal feed. The method includes two consecutive digestion phases [7]. During the first digestion phase in Tilley and Terry IVDMD, plant materials will be incubated under anaerobic conditions with rumen microorganisms for 48 hours at 39°C [3]. This will followed by a 24 hour acid-pepsin digestion phase at 39°C, under anaerobic conditions [7].

The Two-Stage Tilley and Terry IVDMD procedure is quite simple, but nonetheless subject to a number of variables that may influence the results obtained. Basically, a small of graded feed sample (~0.5g) is weighed into a 50 mL centrifuge tube. McDougall's buffer and ruminal fluid from a donor animal are added, and the tube is allowed to incubate for 48h at 39°C [7]. There are different types of buffers which are used to maintain pH during fermentation as Ohio buffer, Kansas buffer and Van Soest buffer [4]. The fermentation is then stopped up, tubes are centrifuged, and supernatant fluid discarded. Acidified pepsin is added, and the tube is allowed to incubate for another 48 h at 39°C [7]. Finally, the contents are filtered, and the residue is oven dried (105°C for 12 hours). Ash contents will be determined by combustion (550°C for 2 hours) and these data used to correct plant sample weight for potential contamination with soil so that, care should care at this every moment of the experimental phase [7].

Calculations can be made using the following equation: %IVDMD = (1 - wd - wb/ws) × 100, where wd = weight of dry plant residue, wb = weight of dry residues from blank, and ws = dry weight of original plant sample.

It produces values that are numerically similar to *in vivo* values for many types of forage but the data statically there is difference. However, the method requires fistulated animals to obtain rumen fluid and long incubation periods and conditions of rumen will affect the result. The technique is based on the premise that the final residue is similar to the feces voided by animals eating the forages. This assumption is not strictly true, because metabolic fecal N, which is present in *in vivo* but not *in vitro* residues, can cause lower protein digestibility *in vivo* [7].

The Tilley and Terry method is widely adopted due to its relative simplicity and usefulness. The major limitation of the method is that it's less accurate for tropical forages (poor quality roughages in general) possibly due to slow rates at which poor quality feeds are digested (Olivera RM 1998).

Two-stage Van Soest IVDMD

The two stage Van soest IVDMD involves incubation of ruminal fluid with feed in buffer followed by extraction of undigested residue in neutral detergent, drying NDF residues and finally weighing [1]. The Single and two-stage T and T IVDMD measures apparent DM digestibility while the Two-stage Van Soest IV measures true DM digestibility.

Gas production technique

The gas production technique was developed to predict *in vivo* digestibility by simulating the *in vivo* fermentation of feedstuffs. different gas production technique and its variants are superior to digestibility and degradability techniques because they account for contributions from soluble and insoluble feed fractions while providing information on the dynamics of forage fermentation in postulated animal and under laboratory conditions. However, the use of the gas production technique as an index of the nutritive value is vulnerable by the dependence of total gas production on sample size, sample form and the composition of the end products of fermentation [7]. A marked shift in the proportions of volatile fatty acids produced can occur when feeds with different composition are fermented and the ratio of fermented to degraded carbohydrate and yield of gaseous products per mole of hexose fermented are not constant. The production of gas by the reaction of fermentation end products with the buffer also complicates interpretation of gas production profiles; especially as such indirect gas Production is rarely accounted for Khan., *et al* [2]. Caution is therefore required when interpreting gas production profiles and accounting for the end products of the fermentation should ensure the validity of any interpretations. Another, problem in using gas production measurements to estimate ruminal fermentation is that the profile must be described with an 'appropriate' model to enable the estimation of the parameters of the curve. Several better-fitting models have been recently proposed (Merchen, 1988). Usually a closed system:

- Buffers do not work well and pH drops after 12-24 hr.
- Used to measure fermentation curves - Assume that production of fermentation gas is proportional to DM disappearance.

The problem of the laboratory technique of digestibility estimation is that, the value tell us the rumen digestibility since we simulate what is happening in the rumen. But digestion occurs from ingestion to excretion.

Applicability and limitations of the different methods of digestibility measurements

Feed intake: The plane of nutrition is one of the primary factors that affect digestibility of any feed. Experiments have showed that livestock usually, digest a larger percentage of the nutrients in their feed when fed restrictedly than when they receive free access of feed (Okin and Mathison 1991). Most data indicate some reduction in apparent digestibility as level of intake is increased. This may be due to a more rapid movement of feed through the tract, thus allowing less time for digestion and absorption.

Particle size: A lot of data exist indicating that forage digestibility is depressed by grinding to a very fine particle size and Fine grinding also apparently increases rate of passage that as result reduces the digestibility.

Chemical composition: One major factor, which affect digestibility is the nutritional composition of the feeds (Sarwar., *et al*. 1985). Digestibility of one feed is believed to differ from that of a similar feed because each may contain different contents of certain nutritional entities, particularly since some of these diminish the opportunity for the digestive enzymes to come in contact with their respective substrates. On the other hand, digestibility of complete feeds can be improves by the additions of relatively small quantities of specific nutrients such as protein or soluble carbohydrates.

Feed processing: Feedstuffs processing is conducted in an attempt to improve digestibility (Sarwar., *et al*. 1992). Changes in physical form can influence digestibility of the dry matter, energy, protein or any of the organic substances in feed products. Such processes as drying, grinding, pelleting and wafering all act to generally affect digestibility. Chemical, biological treatments and chopping improve the digestibility of fibrous feeds (Sarwar., *et al*. 1994).

Climate: The digestibility was higher at higher temperature than in a cold environment which may be due to higher mean retention time of the feedstuffs in the digestive tract (Faichney, 1986). In some studies (Kennedy, 1985), sheep exposed to cold (0ºC) had a lower digestibility than controls in warmer temperatures (22ºC). Increased reticulo-rumen motility in the sheep exposed to cold temperature (Kennedy, 1985) may be responsible for the decreased mean retention time. Increasing passage rate in such circumstances could serve as a strategy for increasing dry matter consumption to meet demands for higher energy imposed by cold climate (Merchen, 1988). Neural and endocrine regulation of ruminal contractions in animals exposed to cold have also been reported, but the precise mechanism is still to be determined (Kennedy., *et al*. 1980).

Age: It is generally felt that animal individuality affects digestibility more than age. However, older animals appear to better digest some nutrients (e.g. fiber, minerals) than do the young of their species. The evidence available showed that, in general, age itself makes little or no difference in the ability of animals to digest nutrients. In the case of ruminant species, the young cannot digest much roughage until their digestive tracts, especially their rumens, are developed. Also the ability of old animals to digest feed is often impaired by poor teeth, which makes inadequate chewing of their feed.

Summary and Conclusion

There are different reliable techniques of measuring a feeds digestibility but time of collection data and handling of the sample is very crucial among technique, the *in vivo* digestibility technique can be minimized the precession by using the indicator method. The digestibility of a feedstuffs may also be predicted from chemical composition of the feed/food underway the trial. This activity involves development of multiple regression formula relating various chemical components to *in vivo* digestibility. *In vitro* digestibility techniques provide a quick, inexpensive, and precise prediction of *in vivo* or conventionally determined digestibility in ruminants. Nylon bag technique s however, quite useful for evaluating kinetic aspects of digestion in postulated ruminants animals.

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