Rapid Techniques for Feed Evaluation: Scope and Limitations

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ABSTRACT

Poultry diets are formulated primarily using cereals and protein meals (corn, wheat and soybean meal) as the main ingredients. There is noted shift in using coproducts from cereals and oilseeds in poultry diets due to availability and relatively lower cost. However, there is wide variation in the nutritional values of both conventional feedstuffs and coproducts, which creates a necessity of developing routine evaluation techniques to detect these variations in order to formulate balanced diets and achieve optimal animal performance. Currently, the approaches being used to evaluate the nutritional values of ingredients in animal diets are based on values obtained from a) wet chemistry b) tables, c) predictive equations, d) in vitro studies, e) near infrared spectroscopy (NIRS), and f) in vivo studies. Wet chemistry analysis is the basis of some nutritional analysis. In vivo studies are considered the best method to get the nutritional value of any feedstuff. However, using an animal model for routine evaluation is not practical due to logistical limitations such as costs and time involved and ethical concerns. Hence, there is the utmost need for rapid feed evaluation techniques that is reliable and logistically practical. The in vitro methods to determine the nutritional value and digestibility have been found to be more reliable than the table values and predictive equations, especially for grains. However, the accuracy of these in vitro methods in determining the digestibility of the co-products is not very high. In vitro fermentation study can provide some functional characteristics of feedstuffs which are not well considered presently, but has potential to be used.

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The NIRS is being used widely and can serve as a better feed evaluation technique not only in determining the nutritional value of feedstuffs and feed but also in diagnosing the differences between the results of the in vitro and in vivo methods. Although NIRS method is expensive in setting up the instrument and developing calibration, it delivers reliable outputs along with high economic efficiency once the method is established. Moreover, collaboration among the industry partners to provide services on calibration data and results are making it as the most practical tool for rapid feed evaluation technique at present. In conclusion, each of these tools has some advantages and disadvantages. Thus, it is not easy to make a clear recommendation on which one is the best method for rapid feed evaluation that can be applied in all conditions.

FEED EVALUATION

Poultry diets are formulated based primarily using cereals and protein meals (corn, wheat and soybean meal (SBM)) as the main ingredients. The competition for food, feed and fuel of these conventional feedstuffs has forced animal nutritionist and feed industry to formulate animal diets using alternative feedstuffs like coproducts from cereals and oilseeds. In addition, a large range in nutrient content exists within and between these feedstuffs because of variable agronomic conditions, genetic variation and processing techniques in these feedstuffs and coproducts. The wide variation among the nutritional values of these coproducts creates a necessity of developing routine evaluation techniques to detect these variations in order to formulate balanced diets and achieve optimal animal performance.

Feed quality information is essential as feed accounts for 65-70% of the total cost involved in the monogastric animal production (Woyengo et al., 2014). The basis of any commercial farming system is to formulate a diet combining ingredients with the least cost in order to give a better return on investment. However, the nutritional content varies widely within and between crops depending upon the type of feedstuffs (Jha et al., 2011a, Jha et al., 2011b), within and between fibrous and starchy feedstuffs (Tiwari and Jha, 2016), and harvesting condition and processing method (Hernot et al., 2008). Conventional feed ingredients like corn, wheat and SBM used in poultry feeding program might give the best result in term of performance but might not be the cost effective. Hence, the poultry industry is shifting towards alternative feed ingredients, mainly agro-industrial coproducts. The major limitation

in the use of such coproducts in the poultry feed is the variation in their nutritional composition even if those were obtained from the same source but in different batches. One of the possible ways to minimize the effect of such variation is by routine analysis of each batch coming out from the processing industry. Nutrient evaluation of such feedstuffs has to be carried out before they are supplemented in the animal diet. However, traditional methods like wet chemistry and animal studies to evaluate the feed can be very time consuming. Thus, there is a need for rapid feed evaluation techniques in place for routine practice. The goal is to quantify the nutrient value of feed ingredients to provide a basis for formulating the diet close to the desired nutrient requirements quickly and accurately. Accuracy is very important, as poor prediction of digestible nutrient content can result in high feed cost and poor performance of the animals.

Defining feed evaluation

Traditionally the definition of feed evaluation was limited to testing feed quality i.e. evaluating or quantifying nutrient composition of feed or feed ingredients. Composition refers to how much energy (fats, oils and carbohydrates), protein (amino acids), vitamins and minerals are provided by the feed. Cereals (corn, wheat, barley, and oats) are the major sources of energy, whereas coproducts of oilseeds and legumes (SBM and canola meal) are primary protein sources. Therefore, feed formulation is mainly based on mixing different ingredients and forming a uniform mixture that would provide all the nutrient requirements of poultry at various stages of life (starter, grower and finisher). Diet for any animal can be formulated after the feed is evaluated for their nutritional composition and their digestibility, and evaluation is done as per the requirement of animal. Carbohydrates, fats, proteins, minerals and vitamins are important nutrients provided by the feed ingredients as well as their roles at the functional benefit level. Currently, the main approaches being used to evaluate the nutritional values of ingredients in animal diets are based on values obtained from a) wet chemistry b) tables, c) predictive equations, d) in vitro studies, e) near infrared spectroscopy (NIRS), and f) in vivo studies. Of these techniques, some are time demanding while others can provide results rapidly. Each of these approaches has some advantages and disadvantages and at present time, it is not easy to make a fair recommendation on which one is the best.

Re-defining feed evaluation

Current feed formulation considers not only meeting the nutrients requirements of animals from particular feedstuffs, but also targets for obtaining functional benefits from the feedstuffs. Thus, feed evaluation needs to broaden the scope by not only determining the nutrient profile but also its functional characteristics. As the animal feed industry is moving towards utilizing more and more coproducts (which are typically rich in fiber) in feeding program, the functional benefit of these fibers in different types of feedstuffs have to be considered. For example, fermentation of fiber in the hindgut produces volatile fatty acids (VFA), primarily acetate, propionate and butyrate. These fermentation metabolites are taken up by the cells in the intestines and used for bacterial growth and energy to host animal. Acetate diffuses and provides energy via glycolysis, whereas propionate goes to liver and provides energy via gluconeogenesis. Butyrate is the principal oxidative fuel for colonocytes and induces growth of the colonic epithelium, colonocyte differentiation and improvement of immune-system response. The energy produced from VFA may contribute up to 25.0% of the maintenance energy requirements of pigs (Yen et al., 1991). However, the fermentation characteristics of fibers vary widely, mainly due to their physico-chemical properties (Jha et al., 2011b, c). Thus, fibrous feedstuffs need to be evaluated for their fermentation characteristics to gain such functional benefits from these feedstuffs. In vitro fermentation characteristics have been measured in an array of feedstuffs (Williams et al., 2005). Also, several alternative feedstuffs have been evaluated for their functional benefits such as hulless barley and oats (Jha et al., 2011b), legumes (Jha et al., 2011c; Woyengo et al., 2014) and canola coproducts (Woyengo et al., 2015). Evaluating fermentation characteristic of other fibrous feedstuffs before using in feed formulation will be helpful to consider the functional benefits of those feedstuffs in addition to the basic nutritional value provided by the feedstuff to animals.

FEED EVALUATION TECHNIQUES

Traditionally feedstuffs are subjected to different protocols of laboratory analysis for nutrient profiling from representative samples to be analyzed followed by digestibility and energy utilization determination using animal studies to determine their inclusion level, effects and negative effects (if any) on the performance of animals. The new feedstuff is then incorporated in the commercial feeding program if is found to be comparable to the conventional feedstuffs. Also, several published table values and perdition equations have been used to determine the nutrient profile before incorporating in feeding programs traditionally.

Wet chemistry

Wet chemistry so far has been the best method in terms of determining the nutrient content of feedstuffs. However, feeds are formulated based on standardized ileal digestibility and metabolizable or net energy values, which is not explained by the wet chemistry only. Noblet and Prez (1993) evaluated the digestible energy value of pigs using chemical analysis with reasonable accuracy (R^2 = 0.75). The longer time required to get results and the use and disposal of hazardous chemical(s) used in analysis are the major limitations in the use of wet chemistry routinely.

Table values

Table values or reference values of the nutrient profile of feed ingredients are available from different sources like NRC (National Research Council), INRA (French National Institute for Agricultural research), CVB (from the Netherlands), Fedna (Fundación Española para el Desarrollo de la Nutrición Animal from Spain) (Mateos et al., 2016). It's the easiest method of getting nutrient value of feedstuffs but the table values vary widely within and between the tables as the source of data differs. It also varies among batches and countries due to several factors including agronomical conditions and genetic variations. This discrepancy among tables makes it poor in accuracy and of limited value for getting quality outcomes. As an example, table values and analyzed values of same feed ingredients were found to vary widely, as presented in Table 1. Lower accuracy is the limiting factor in the use of table

values. Due to this variation, potential lower safety margin in using table values for feed formulation can affect performance of poultry.

Table 1. Comparison of nutrient profile of wheat byproducts between analyzed values (Jha et al., 2012) and Table values (NRC, 2012)

	Analyzed values						Table values		
	Shorts		Millrun		Middlings	Bran	Shorts	Middlings	Bran
	A	B	A	B					
Dry matter	90.1	89.9	89.1	90.4	88.6	91.0	87.9	89.1	87.3
Ash	7.3	5.5	6.5	6.2	5.3	6.7	NA	2.1	4.2
ether extract	2.9	3.4	4.8	4.1	4.1	3.0	4.6	3.2	4.7
Crude protein	27.8	24.9	18.7	19.0	22.1	15.9	16.7	15.8	15.1
Crude fiber	7.9	5.2	8.3	9.9	7.1	12	NA	5.2	7.8

*NA- not available

Prediction equations

Several equations have been developed to predict the energy values of feedstuffs in swine and are found to predict with very high accuracy (R^2 = 0.97) (Noblet and Perez, 1993; Noblet et al., 1994). All the prediction equations are based on basic nutrient values of feedstuffs. Obtaining basic nutrient values using wet chemistry can be time consuming and cause a delay in decision making of purchase of feed ingredients or feed formulation. Analytical error and time required to obtain the data from developing quality prediction equations are the main challenges to using prediction equations accurately. Different prediction equations have been proposed to calculate different nutritional value, like nitrogen corrected apparent metabolizable energy (AMEn) in poultry. An example of prediction equation to determine AMEn content in poultry is: 39.78 × CP + 69.68 × Ether extract + 35.4 × Nitrogen free extract (Rostagno et al., 2005). Under practical conditions, most of the nutritionists and feed companies use table values often modified based on their practical experience or on analyses conducted in their laboratories by NIRS technology (Mateos et al., 2016).

Animal studies

The in vivo method is so far the best and most robust model to determine the digestibility of feedstuffs in animals. However, the accuracy of digestibility of the in vivo method depends upon the marker used and the method by which the amount of marker is quantified. Also, there has been wide variation reported by different researchers while determining nutritional value of feedstuffs using animal studies. For eg., AMEn of wheat was found to be in the range between 2.03-2.97Mcal/kg by Wiseman (2000), 1.84-3.32 Mcal/kg by Garnsworthy et al. (2000) and 3.01-3.34 by (Rafuse, 2005). These variations can be attributed to the source and type of wheat samples and the methods used to determine the AMEn content. Moreover, logistical limitations, skilled expertise required, and longer time and higher costs involved to conduct animal studies are the limiting factors in using animal studies in routine feed evaluation program.

RAPID FEED EVALUATION TECHNIQUES

There is a need for rapid feed evaluation technique because of the practical limitation of the commonly used approaches (wet chemistry, table values, prediction equations, and animal studies) used for the determination nutrient profile and digestibility of feedstuffs. The limitations are in the form of cost, logistics, time etc., making is less practical to be applied in routine feed evaluation by industry. Some methods (such as in vitro digestion and fermentation and NIRS technology) have been developed and used, and are getting more attention by nutritionists and feed industry for their capability to evaluate feedstuffs relatively quickly and cost-effectively.

In vitro digestion

In vitro methods simulate the activity taking place in the GI tract of animals to determine the digestibility of nutrient (Boisen and Fernández, 1997). Briefly, finely-ground samples are digested in 3 steps using a water bath. In step 1, gastric digestion is mimicked using pepsin. In step 2, small intestine digestion is mimicked using pancreatin. In step 3, large intestine digestion is mimicked using viscozyme (a multienzyme complex obtained from *Aspergillus aculeatus* containing cellulase, β-glucanase, arabinase, xylanase, mannanase, and pectinase;

Novozymes, Bagsvaerd, Denmark). In vitro digestion techniques can be used to screen large set of samples in short period of time and are non-invasive to animals and relatively very cheaper than in vivo methods.

It is imperative that any simulation should be reproducible and should correlate well with in vivo parameters for diverse feedstuffs. A close linear relationship (R^2 = 0.94, RSD = 3.4, CV = 4.4) between the in vitro enzyme digestibility of organic matter and in vivo total tract digestibility of energy was found for 90 samples of 31 different feedstuffs (Figure, 1; Boisen and Fernández, 1997). Similar finding was reported by Regmi et al. (2009) for single samples of 8 feedstuffs (R^2 = 0.97). Within feedstuff variability was predicted well for cereal grains and but poorly for canola meal and corn DDGS (Regmi et al., 2009). For multiple samples per feedstuff, in vitro energy digestibility was the best single predictor (R^2 = 0.71) compared with proximate analyses (R^2 = 0.63). Prediction accuracy of the in vitro technique was similar to using proximate analyses (R^2 = 0.71 vs. 0.75; SE of prediction = 5.5 vs. 5.0; respectively). However, energy and organic matter digestibility of corn DDGS (R^2 = 0.29 and R^2 = 0.63, respectively) was poorly predicted by in vitro digestion method (Anderson et al., 2009). There was a high correlation (r = 0.96) of in vitro starch digestion (up to the second step) with in vivo ileal digestibility of starch in poultry using cereals and potato (Weurding et al., 2001), and a linear relationship in pigs (R^2 = 0.76) with peas (Montoya and Leterme, 2011) and highly correlated (r = 0.98) when the mixture of potato starch and wheat bran raw and extruded form was used (Sun et al., 2006). Also, a high and positive correlation was seen in digestibility of nitrogen (r = 70) and essential amino acids (r = 0.92) in peas for pigs (Montoya and Leterme, 2012). However, there was a poor correlation for SBM (R^2 = 0.59) and rapeseed meal (R^2 = 0.33) for poultry (Swiech et al., 2001). A medium to poor correlation and prediction accuracy was found when other coproducts (canola meal, corn DDGS, SBM and wheat millrun) were evaluated (combined average R^2 = 0.69, Figure 2), with highest for wheat millrun (R^2 = 0.79) and lowest for corn DDGS (R^2 = 0.29) (Wang, 2014). These information combined indicates that different in vitro digestibility techniques might be required for each feedstuff or feedstuff category to predict the digestibility of energy accurately as opposed to a single technique for the entire range of feedstuffs (Boisen and Fernández, 1997). Another limitation with the use of in vitro methods can be the presence of anti-nutritional factors, which may affect negatively when fed to animals. The different physiological stages of the birds (starter, grower and finisher) influence the nutrient

digestibility. Thus, any change or adjustment of enzymes or time during simulation of gastrointestinal tract would change the digestibility. Further refinement in the in vitro digestibility study, as initiated by some workers (Regmi et al., 2008; Regmi et al., 2009; Wang, 2014) might be helpful to get better prediction using this model.

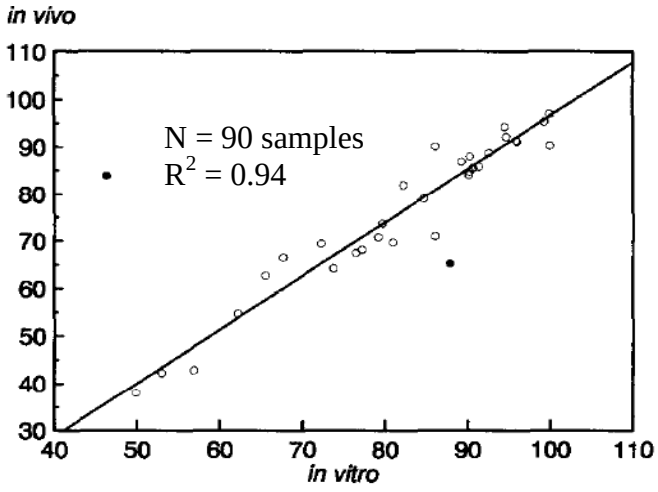

Figure 1. The relationship between in vitro enzyme digestibility of organic matter and in vitro total tract digestibility of energy in slaughter pigs determined in 90 samples of 33 different feedstuffs (Boisen and Fernández, 1997)

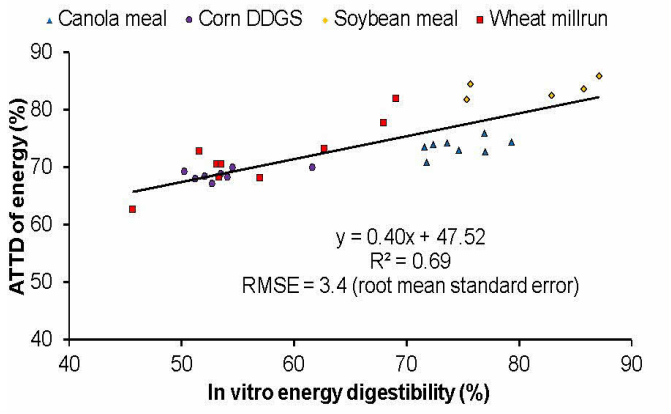

Figure 2. Relationship between in vivo apparent total tract digestibility (ATTD) and in vitro energy digestibility among co-products in 30 samples (Wang, 2014)

In vitro fermentation

Nutritionists and feed industry is using more and more coproducts in poultry diets. Coproducts are typically rich in fiber content, which needs to be considered while using in monogastric animal feeding program. The fiber in feedstuffs negatively affects the nutrients digestibility (Jha et al., 2010) but it may also play an important role in improving gut health of host animals (Jha and Berrocoso, 2015). The fibers which are not digested by endogenous enzymes of monogastric animals become available for microbial fermentation, primarily in the large intestine and produce metabolites like VFA. The fibers are degraded by microbial enzymes in the large intestine in vivo, which is simulated in vitro either by using purified fiber-degrading enzymes or by using live microbes as inoculum. It is hypothesized that gas produced and fermentation kinetics and metabolites produced during in vitro fermentation reflects the same kinetics and metabolites production as in vivo fermentation of fiber in the large intestine of animal. The microbial inoculum to initiate the fermentation in vitro can be obtained either from the cecum, rectum, or feces in swine while cecal content is used as inoculum for in vitro fermentation study in poultry. Digestible energy and digestible organic matter can be determined using purified enzymes, whereas microbial inoculum has to be used to determine the fermentation characteristics. The VFA, main end products of microbial fermentation, can be used to predict the extent of energy digestion in the large intestine (McBurney and Sauer, 1993). Using purified enzymes are promising (Regmi et al., 2008; Regmi et al., 2009) for the purpose; however their validation with in vivo study is important. In vitro fermentation models using pig fecal inoculum (Jha et al., 2011b; Jha et al., 2011c, Jha et al., 2012) and poultry cecal content (Guo et al., 2003; Dunkley et al., 2007; Malabad et al., 2016) have been used to determine both fermentation metabolites and intestinal microbiota. In vitro fermentation method is validated with high correlation in pigs for non-starch polysaccharide degradation ($r = 0.96$) (Anguita et al., 2006) and organic matter ($r = 0.77$) (Christensen et al., 1999). The fermentation characteristics of hullless and hulled barley and oat samples were studied both in vivo and in vitro (Jha et al., 2010; Jha et al., 2011b) and had similar fermentation characteristics and metabolites produced. Thus, in vitro fermentation models can serve as an option for rapid technique while considering evaluation of functional properties of any feedstuff. However, the in vitro model does not consider simultaneous production-absorption of the metabolites as happens in the large intestine in vivo. Thus, it may overestimate the energy contribution from VFA in animals.

Near infrared spectroscopy

The NIRS has been adopted widely by the nutritionists and feed industry as a rapid feed evaluation technique and is becoming increasingly popular. The use of NIRS technology to determine basic nutrients such as moisture, protein, fat, and fiber of major feed ingredients and finished feeds has been around for many years (Valdes and Leeson 1992). With advancement in technology, NIRS is being used for a range of measurements that are based on using laboratory methods to provide reference values for establishing calibration. For nutritionist that rely on digestible as opposed to total nutrient values for feed formulation, the additional cost of obtaining a large sample set with determined digestibility values has been cost prohibitive to establish NIRS calibrations, but some research calibrations have been established (Zijlstra et al., 2011). Also, industries have been working to develop a rapid NIRS technology based tool to estimate bioavailability of nutrients from different feedstuffs. The idea is to assist the industry to adopt and use standards based on the functional utility of the grain purchased rather than relying on the current grain physical grades to determine value in use. Every feed ingredient has their spectral properties which can be utilized to determine the nutritional value. Thus, it is important to have good calibration database to have better prediction equations. Moreover, NIRS penetrated deeper into the sample because of its wavelength; however, depth of penetration depends upon the particle size, particle density (DeThomas and Brimmer, 2002). Thus, not only the feed ingredient or complete feed type but also their other physical properties need to be considered.

Advantages of using NIRS

The NIRS is undoubtedly the most rapid feed evaluation technique at present and is widely used by nutritionist and feed industry. The sample preparation is easy as it does not require any processing like dilution or derivatization of the sample (e.g. fats to fatty acid methyl esters), thus it is advantageous over other methods. No derivatization for analysis means there is no need for any wet chemistry analysis, which involves use of potential harmful chemicals and their disposal, which is a major concern these days. The main advantage of NIR is that it provides relatively very accurate prediction of nutritional value (given that high quality calibration and method is used). Also, it is economically more efficient than any other analytical methods and is able to determine multiple components of each sample in a single measurement. Additionally, the calibration developed in one NIRS instrument can be

transferred or "cloned" to many other NIRS instruments in the field through a process called calibration transfer (Fernandez-Ahumada et al., 2008; Rao 2012).

Limitations of using NIRS

The main limitation in the use of NIRS technology is the cost involved in the setting up the system. Also, it requires calibration which in turn requires large number of sample set that has been grown under different agronomical conditions and is analyzed using wet chemistry. Both of these obstacles are now solved thanks to internet technology. The data transfer to other NIRS instrument by "cloning" have been practiced by some companies. But, data interpretation after scanning the feed ingredients and reporting the results in real time are the remaining obstacles to overcome. Another main limitation of the technology is that the reference value used in this calibration has to be validated with in vivo data, which makes it dependent on animal studies on continuous basis. Statistical expertise is required to calibrate and validate the results. Also, change in chemical structure of nutrients during digestion process cannot be predicted using NIRS technology.

Calibration

Having robust calibration is the key for quality prediction by NIRS technology. Typically, calibration is developed by data from wet chemistry and after validation with in vivo studies. To make stronger pool of calibration, reference data from in vitro digestion can be used to calibrate NIRS (Regmi et al., 2008); however, in vitro digestion data is useful for cereals but the accuracy with the coproducts is low (Anderson et al., 2009). Thus, the NIRS cannot provide accurate prediction without robust calibration which is possible only with valid reference data. Digestibility of nutrients can be predicted using NIRS such as crude protein (Swift, 2003) and energy (Ziljstra et al., 2011). Protein content in different feed ingredients has been accurately measured using NIRS such as whole maize (Jiang et al., 2007), wheat (Garnsworthy et al., 2000), and napier grasses (Tiwari et al., 2014). Prediction accuracy of fatty acid (saturated/ unsaturated) determination using NIRS was very high (R^2 = 0.99) in edible oils (Sherazi et al., 2009). Standard error of cross validation was found to be low (indicating high prediction accuracy) i.e. 57 Kcal/kg when NIRS was used to predict the digestible energy of barely for pigs (Zijlstra et al., 2011). However, prediction accuracy of AME in broiler chickens was found to be poor (R^2 = 0.52) (Gransworthy et al., 2000).

The spectral data of different feedstuffs, grown at different agronomical conditions that have been generated in different laboratories could be shared to have a better calibration (Rao, 2012). Calibration transfer helps the data generated in one NIRS machine to be transferred to many other instruments anywhere in the world using internet.

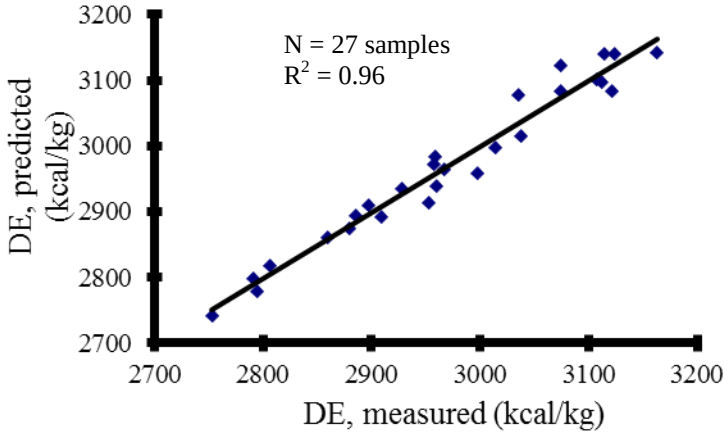

Figure 3. Digestible energy (DE) value grain samples predicted using NIRS calibration model and determined in grower pigs (Zijlstra et al., 2011)

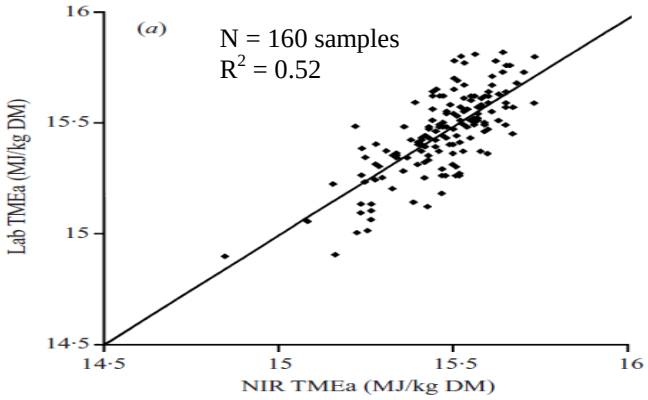

Figure 4. True metabolizable energy (TME) content of wheat samples predicted by near infrared spectroscopy (NIRS TMEa) and determined (Lab TME) in adult birds (Garnsworthy et al., 2000)

Non calibration method of NIRS

Non calibration method of NIRS has been proposed to determine the digestibility of fatty acids based on spectral analysis of digesta and concentration of marker which is also useful (Wang et al., 2014). Wang et al. (2014) determined apparent ileal digestibility and apparent total tract digestibility of fatty acids using ratio of peak intensity associated with the fats and not by spectroscopy. Concentration of total fatty acids was indicated by intensity of methylene stretching peak whereas ether extract concentration was indicated by intensity of peak accumulated in the C=0 region induced by ester and free fatty acids. However, there is very limited information available on this technique to be used in practical condition.

Inter lab collaboration for NIRS use

With the advancement in technology and changing business models, several feed ingredients and additives suppliers are offering the NIRS service to determine the metabolizable energy and the digestible amino acids of feed ingredients which are the two key drivers of practical feed formulation. Evonik industries (Germany) provides AMINONIR and AMINORED to evaluate the digestibility of amino acids to their customer with NIR machine. Evonik standardizes and links it to its NIR network, which allows the customer to get the amino acid digestibility predictions within one hour. Similarly, Adisseo (France) NIR Service provides calibration and technical services for clients with matching NIR machine using internet technology from five regional centers in the world. Also, AB Vista (UK), working with their affiliated company Aunir, provides corn quality report considering protein digestibility to predict and metabolizable energy content using NIRS technology. In most cases, the customer scans the feedstuff using NIRS machine at their location and sent the dataset to these service providers by internet and receives results within few hours (Rao, 2012). This type of collaboration has been found useful to reduce the cost of developing calibration by all and getting better results quickly.

Further collaboration among these companies might be useful, not only to reduce the cost and time of feed evaluation but also getting accurate data as there will be possibility of cross validation. It will also eliminate the need of in-house technician/statistician to calibrate and validate the NIRS instrument. Moreover, introducing a new feed ingredient to the feed formulation may be easier because NIRS calibrations for a large number of feed ingredients may already have been setup by the other company.

SUMMARY AND CONCLUSIONS

In vitro digestion model predicts the apparent total tract digestibility of cereals with higher accuracy; however the prediction with coproducts was poor. The in vitro technique can be improved by finding the difference between the in vivo and in vitro value and solving the discrepancies. The NIR technology is being used to predict the nutrient profile and their digestibility as well as in the QA and QC system of feed ingredients and finished feeds for many years. This technology is becoming increasingly popular in routine practice due to advancement in technology, robust calibration dataset as well as services provided by different companies. The NIRS technology is very compatible with the internet technology to transfer electronic data in both directions, thereby reducing the cost of NIRS data interpretation and report distribution. So, NIRS is the best and most promising rapid feed evaluation technique available for routine use at present. However, prediction of NIRS is based on data from wet chemistry, in vivo and in vitro studies. Thus, there is no single technique which can be referred independently as the best method for rapid feed evaluation. Further collaboration among the nutritionists, feed industries and NIRS service providers can make it more practical, real time or near real-time feed formulation.

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