THE MEASUREMENT OF APPARENT AND TRUE METABOLIZABLE ENERGY IN POULTRY FEEDINGSTUFFS

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There are four basic procedures for measuring the metabolizable energy (ME) values of feeds and ingredients. Each procedure has advantages and disadvantages. No single procedure is entirely satisfactory. The purpose of this report is to identify the limitations of these procedures and to describe a new bioassay which is simple, fast and inexpensive.

Direct Biological Assay

This is the procedure in which a diet of known gross energy content is fed to birds. The resulting excreta is collected and also assayed for gross energy. Examples of this procedure are the assays of Hill _et al._, (1960) and Sibbald and Slinger (1963a). There are numerous variations of the direct biological assay. Variables include: total collection of excreta versus the use of an indicator such as chromium sesquioxide; adding the test material at the expense of glucose in a purified diet, replacing a portion of a semi-practical diet or feeding the test material alone; the use of the correction factor for retained nitrogen, either 8.22 or 8.73 kcal./g. of nitrogen; the species, strain, sex, age and physiological state of the birds; the environment and management practices; the methods of sample preparation and analysis.

Differences in assay technique need not result in differences in ME values (Sibbald, 1975a); however, many small differences attributable to variations in technique have been identified and are a cause for concern (Vohra, 1972; Miller, 1974; Fisher, 1975). Much has been written about the variation associated with the direct biological assay but few have attempted to place the ME differences in persepctive. Generally, the ME differences due to variation in technique amount to less than 4% while differences between the ME values of different lots of the same ingredient may be substantially larger (Hill _et al._, 1960; Sibbald and Slinger, 1962; Matterson _et al._, 1965). The feed manufacturer who uses book values for feed formulation is exposed to so many potential errors due to variation in ingredients, that small errors inherent in the method used to derive the book values are of limited significance. An awareness that such errors exist is important but it should not be allowed to undermine a useful method for describing available energy.

The feed manufacturer needs to know the ME values of his ingredients if he is to formulate the most economical diets. While the direct biological assay yields useful book values it is too slow and too expensive to be used for quality control purposes. These are the important limitations of the assay.

Indirect Biological Assay

This usually takes the form of a growth assay in which a diet deficient in energy is fed. A standard curve is obtained by supplementing the diet with a material of known ME content such as glucose or corn oil. Unknowns are assayed by adding graded levels to the energy deficient diet and comparing growth rates with the standard curve. Examples of this procedure are the assays of Yoshida and Morimoto (1970) and Squibb (1971).

The assay is of little interest to feed manufacturers because it yields data of high variability, is almost as slow as the direct biological assay and is expensive because it necessitates a high labour input. The single advantage of the assay is that it requires no complex laboratory equipment.

Indirect Physical Assay

Most of the attempts to find a close relationship between the ME values of feedingstuffs and their physical characteristics have met with failure. However, Lockhart et al., (1961) observed that the ME values of oats increased with bushel weight. A closer relationship was found between the ME value and the percentage of oat groats in the sample. Sibbald and Slinger (1963b) confirmed the raltionship between the ME value of oats and bushel weight but found that similar relationships did not hold for barley and wheat. Sibbald and Price (1976) found correlations between ME and bulk weight to be 0.746 for 28 samples of oats, 0.338 for 34 samples of wheat, and 0.583 for 40 samples of barley. While indirect physical assays are rapid and inexpensive they are of little value to the feed formulator who requires accurate ME values.

Indirect Chemical Assay

As early as 1940 Fraps showed that it is possible to predict ME values from values for digestible protein, ether extract and nitrogen free extract. Titus (1955) took the work one step further with the derivation of a series of 'percentage multipliers'. More recently Carpenter and Clegg (1956), Bolton (1962) and Sibbald et al., (1963) have developed prediction equations based on protein, ether extract, and available carbohydrate. The most comprehensive set of prediction equations is that published by Janssen and Terpstra (1972).

The indirect chemical assay is being used by some feed manufacturers to estimate the ME values of their ingredients and for testing the quality of their finished products. The assay can be completed in 24 hr. and is relatively inexpensive; however, it does have limitations. The prediction equations are derived by relating chemical data to ME values obtained by the direct biological assay; consequently, accuracy and precision cannot be better than the direct method and will probably be worse because of the variability associated with the chemical measurements. The ME values of some ingredients, particularly those high in crude fibre, are poorly predicted by current equations. The assay is discussed in detail in a recent review article (Sibbald, 1975b).

Bioassay for True Metabolizable Energy

The assays described previously yield apparent ME (AME) values. An AME value is defined as the gross energy value minus the energy voided as feces and urine. The true ME (TME) value is similar but it involves corrections for metabolic fecal and endogenous urinary energy losses.

During an investigation of the effects of feed intake on AME values (Sibbald, 1975c) a procedure for measuring TME was found. The procedure has been refined to the form of a simple bioassay (Sibbald, 1976a) which is currently being tested under various experimental conditions.

The assay may be summarized as follows:

1. Adult SCWL roosters housed in individual wire cages, with free access to water, are starved for 21 hr. to empty their digestive tracts.
2. A bird is selected, weighed and force fed an accurately weighed amount of the feedingstuff under test (20-25 g.).
3. The bird is returned to its cage, a clean plastic tray is placed under the cage and the time is recorded.
4. A bird of similar body weight is selected and returned to its cage without feeding, a plastic tray is placed under its cage and the time is recorded.
5. Steps 2, 3 and 4 are repeated to provide the desired number of replications.
6. The plastic trays are removed 24 hr. after placement, the excreta is collected quantitatively, frozen, freeze-dried, allowed to come to equilibrium with atmospheric moisture and weighed.
7. Samples of the feedingstuff and excreta, ground to pass through a 20-mesh sieve, are assayed for gross energy.

$$\text{TME (kcal./g.)} = \frac{(GE_f \times X) - (Y_{ef} - Y_{ec})}{X}$$

where: GE_f is the gross energy of the feedingstuff (kcal./g.)

Y_{ef} is the energy excreted by the fed bird (kcal.)

Y_{ec} is the energy excreted by the unfed bird (kcal.)

X is the weight of feedingstuff fed (g.)

Force feeding is accomplished by insertion of a long stemmed funnel from the beak to the crop. The feed is placed in the funnel and forced into the crop with a rod. The optimal dose is about 1% of body weight; large inputs lead to regurgitation while small inputs magnify errors.

The assay is relatively rapid and inexpensive. The birds can be used for numerous assays, the labour input is small, and the analytical work is minimal. If necessary the assay can be completed in as little as 60 hr.; consequently, it may be suitable for quality control work.

The assay requires further testing before it can be widely recommended but it appears to have advantages beyond speed and cost. The values are independent of feed intake. The small number of operations reduces the chance of errors. The correction for metabolic and endogenous energy losses may eliminate some of the variation associated with AME values. In one experiment involving 12 samples of grain it was found that ME values predicted by the indirect chemical assay were more closely related to TME values than to AME values (Sibbald, 1976b).

Conclusions

The direct biological assay for AME is too time consuming and expensive to be used for quality control work. The indirect biological assay is imprecise and is also time consuming. The indirect physical assay applies only to oats and lacks sensitivity. The indirect chemical assay is used for quality control purposes but it can never be better than a biological assay in terms of accuracy and precision. The bioassay for TME is relatively fast and inexpensive and may be adopted for quality control purposes when it is thoroughly tested.

References

Bolton, W., 1962. Energy value of poultry foods and complete diets. XIIth World's Poultry Congress Section Papers, pp. 38-42.

Carpenter, K. J. and K. M. Clegg, 1956. The metabolizable energy of poultry feedingstuffs in relation to their chemical composition. J. Sci. Fd. Agric. 7: 45-51.

Fisher, C., 1975. Energetic feed evaluation for poultry. Livestock Prod. Sci. 2: 109-119.

Fraps, G. S., E. C. Carlyle and J. F. Fudge, 1940. Metabolizable energy of some chicken foods. Texas Ag. Exp. Stat. Bull. 589.

Hill, F. W., D. L. Anderson, R. Renner and L. B. Carew, Jr., 1960. Studies of the metabolizable energy of grain and grain products for chickens. Poultry Sci. 39: 573-579.

Janssen, W. M. M. A. and K. Terpstra, 1972. Feeding values for poultry. Spelderholt Institute for Poultry Research, Beekbergen, The Netherlands.

Lockhart, W. C., D. W. Bolin, G. Olson, and R. L. Bryant, 1961. The metabolizable energy value for oats of various bushel weights. Poultry Sci. 40: 327-333.

Matterson, L. D., L. M. Potter, M. W. Stutz and E. P. Singsen, 1965. The metabolizable energy of feed ingredients for chickens. Res. Rep. No. 7, Ag. Exp. Stat., U. of Connecticut

Miller, W. S., 1974. The determination of metabolizable energy. Energy Requirements of Poultry, pp. 91-112. Edited by T. R. Morris and B. M. Freeman, British Poultry Science Ltd., Edinburgh

Sibbald, I. R., 1975a. Comparison of metabolizable energy values of cereal grains measured with poultry in three laboratories. Can. J. Anim. Sci. 55: 283-285

Sibbald, I. R., 1975b. Indirect methods for measuring metabolizable energy in poultry feeds and ingredients. Feedstuffs 47 (7): 22-24.

Sibbald, I. R., 1975c. The effect of level of feed intake on metabolizable energy values measured with adult roosters. Poultry Sci. 54: (Nov. issue)

Sibbald, I. R., 1976a. A bioassay for true metabolizable energy in feedingstuffs. Poultry Sci. 55: (January issue).

Sibbald, I. R., 1976b. The effect of cold pelleting on the true metabolizable energy values of cereal grains fed to adult roosters and a comparison of observed with predicted metabolizable energy values. Poultry Sci. 55: (In press).

Sibbald, I. R. and S. J. Slinger, 1962. The metabolizable energy of materials fed to growing chicks. Poultry Sci. 41: 1612-1613.

Sibbald, I. R. and K. Price, 1976. Relationships between metabolizable energy values for poultry and some physical and chemical data describing Canadian wheats, oats and barleys. Can. J. Anim. Sci. 56: (In press).

Sibbald, I. R. and S. J. Slinger, 1963a. A biological assay for metabolizable energy in poultry feedingstuffs together with findings which demonstrate some of the problems associated with the evaluation of fats. Poultry Sci. 42: 313-325.

Sibbald, I. R. and S. J. Slinger, 1963b. Nutritive values of ten samples of Western Canadian grains. Poultry Sci. 42: 276-277.

Sibbald, I. R., J. Czarnocki, S. J. Slinger and G. C. Ashton, 1963. The prediction of the metabolizable energy content of poultry feedingstuffs from a knowledge of their chemical composition. Poultry Sci. 42: 486-492.

Squibb, R. L., 1971. Estimating the metabolizable energy of foodstuffs with an avian model. J. Nutrition 101: 1211-1216.

Titus, H. W., 1955. The Scientific Feeding of Chickens, 3rd Ed., The Interstate, Illinois.

Vohra, P., 1972. Evaluation of metabolizable energy for poultry. World's Poult. Sci. J. 29: 204-214.

Yoshida, M. and H. Morimoto, 1970. Biological assay of available energy with growing chicks. II. Development of a mini-test applicable to the small amount of the sample. Agr. Biol. Chem. 34: 684-691.