A NEW, RAPID METHOD FOR DETERMINING THE METABOLIZABLE ENERGY OF POULTRY FEEDSTUFFS

D.J. Farrell

Department of Biochemistry and Nutrition,
University of New England, Armidale, N.S.W. 2351

Measurement of metabolizable energy (ME) is a standard procedure for evaluating the energy concentration in poultry feeds and feedstuffs. There are numerous reviews of the subject, but more recently a critical appraisal of the methods of determination were discussed by Miller (1974). Recognising that the ME value represents the difference between the heat of combustion of feed consumed and the heat of combustion of faeces and urine attributed to the amount of feed eaten, it is surprising that there is often discrepancy between values obtained for similar feed ingredients. Indeed, variation in ME between laboratories for the same feed has been reported (Sibbald, 1975a).

The object of this review is not to look backwards and examine many of the classical studies on ME determination except to refer to them only where necessary, but to look forwards in order to assess the usefulness of new methods of determination.

Unfortunately, some misunderstanding arose from the early work of Hill and Anderson (1958), and of Davidson, McDonald and Williams (1957) in which ME and productive energy (Fraps, 1946) comparisons were made. Because productive energy values showed greater variation than ME values for the same diet, the authors concluded that the latter should be used as the measure of choice for chicks. Consideration of the productive energy, or net energy of diets has shown that biological variation is to be expected for a number of reasons (Farrell, 1974).

In Australia there is often a dilemma as to what ME value should be used for a particular feedstuff in formulating diets for poultry. This dilemma has stemmed from normal variation in a feedstuff, method of determination, and often a low inclusion rate of the test ingredient such that it is not possible to partition out a precise ME value. In addition, there is error frequently associated with diets that may be poorly acceptable to poultry; these result in a range of intakes, and as will be discussed later at low intakes, may often give a spuriously low ME value.

There is variation in the amount of protein nitrogen consumed in diets, and the amount retained will depend on the quality of the feed protein as well as the stage of growth of the test bird. Consequently ME values of feeds, corrected to N equilibrium, are often calculated on the assumption that all nitrogenous end products are in the form of uric acid with an energy value of 8.2 kcal/g. It is debatable whether such a correction is necessary or even valid (Kleiber, 1961; Vohra, 1972). All excreted urine nitrogen is not as uric acid but may appear in variable amounts as other chemical compounds (Ekman, Emanuelson and Fransson, 1949).

Chromic Oxide Vs. Total Collection Method

Miller (1974) reported that the indicator method gave consistently higher estimates of the energy excreted per g of food intake, hence lower values for ME compared with the total collection method, only 90% of the ingested Cr_2O_3 was recovered in excreta. Pryor and Connor (1966) showed that for some grains, particularly barley, Cr_2O_3 gave a lower ME figure than did total collection. Pym (personal communication) also found that Cr_2O_3 was not a satisfactory indicator. Comparisons made with Cr_2O_3 and polyethylene with the total collection method showed that polyethylene was the superior indicator. This is probably due to the electrostatic properties of Cr_2O_3 which are not overcome by mixing with wheat flour to form a dough which is subsequently dried and ground (Vohra, 1972).

The method of determination of Cr_2O_3 in feed and excreta involves a number of steps each of which may be subject to error. One step involves quantitatively transferring the ashed material from a crucible to a receptacle; this step may be particularly subject to error. It is to be expected that the indicator method would show more variation than total collection, but in addition appears to have a bias.

Level of Substitution

Although it may be argued that level of substitution per se of a test ingredient in a diet may change the ME value, with very few exceptions there is little experimental evidence to support this. In other words, the effects of substitution, even at high levels appear to be additive and not associative (Sibbald, 1977a). One notable exception is that of wheat. Prior and Connor (1966) found that a higher ME value of wheat was obtained when substituted at 40% of a basal diet than when fed as the entire diet. Payne and Jalil (unpublished observations) have confirmed this anomaly. Annison (1974) discussed digestibility of dietary fats and cited studies that showed that unsaturated fatty acids were better digested than the saturated fatty acids, and the addition of the former enhances the digestibility of the latter. Thus the ME value of tallow is increased by the addition of oil to the diet.

Glucose is often used in the basal diet, and then replaced by the test ingredient. Sibbald (1975b) argued that the value of 3.64 kcal/g applied to glucose (Anderson, Hill and Renner, 1958) should be 3.75 kcal/g, and this would change appreciably the ME value of many ingredients. Sibbald and Slinger (1963) concluded that it is more practical to use a basal diet of practical ingredients rather than a synthetic diet with glucose to be replaced. Miller (1974) presented a table giving the precision of estimate of ME for a test ingredient substituted at different levels in a basal diet for either a standard ingredient or a portion of the basal diet. The data are shown in Table 1.

It is obvious that substitution of anything less than 10% of the test ingredient is not likely to give accurate results, and it seems that only at levels of from 30 to 40% would precise ME values be expected for the test ingredient. Sibbald and Price (1975) also found that inclusion levels of less than 50% of a dietary ingredient resulted in high variation in its ME value. Alternatively, regression analysis

TABLE 1: Precision of estimate of ME value for an ingredient calculated from measured values of basal diet supplied with and without test ingredient: Relative standard deviations' for different levels of ingredient substitution

Percentage of diet	Substitution for standard ingredient	Substitution for complete diet
5	28.3	27.6
10	14.1	8.7
20	7.1	6.4
30	4.7	4.1
40	3.5	2.9
50	2.8	2.2
100	...	1.0

The evaluation of an ingredient with equal precision as for complete diet requires approximately an eight-fold increase in replication when substitution is made for standard ingredient and five-fold increase when substitution for portion of whole diet.

[1] Computed from variance factors for linear regression coefficient and predicted regression value by formulae given in Snedecor (1967) or in most standard textbooks on statistics.

(From Miller, 1974)

---

can be used to calculate the ME value of an ingredient when included in multi-level assays. Again these levels should encompass a wide range.

True Metabolizable Energy (TME)

It has long been recognised that birds, like mammals void excreta that is both exogenous and endogenous and metabolic in origin. Thus the energy content of excreta includes a component which is not directly related to the feed, consequently distinction can be made between apparent and true metabolizable energy of a feed. The latter is higher than the former.

Guillaume and Summers (1970) found that during starvation daily excreta amounted to 5.2 kcal per kg of bodyweight of adult roosters. They concluded that if feed intake is much below 40 g/d, then endogenous and metabolic excreta can influence the apparent ME value of the diet. It follows that precise determination of ME of a feed ingredient must be made above a minimum feed intake. This of course will vary with weight of bird.

Sibbald and Price (1975a)convincingly rationalized the use of adult cockerels for the measurement of ME of diets. Firstly, it should not be necessary to correct values to N-equilibrium since adult birds would be in approximately N balance; secondly, they can be used for long periods for such measurements; and finally they can tolerate diets which may be imbalanced, or contain large amounts of a single ingredient. There is no evidence to suggest that values thus obtained do not have wide application.

Sibbald and Price (1975), like Miller (1974) (Table 1), not

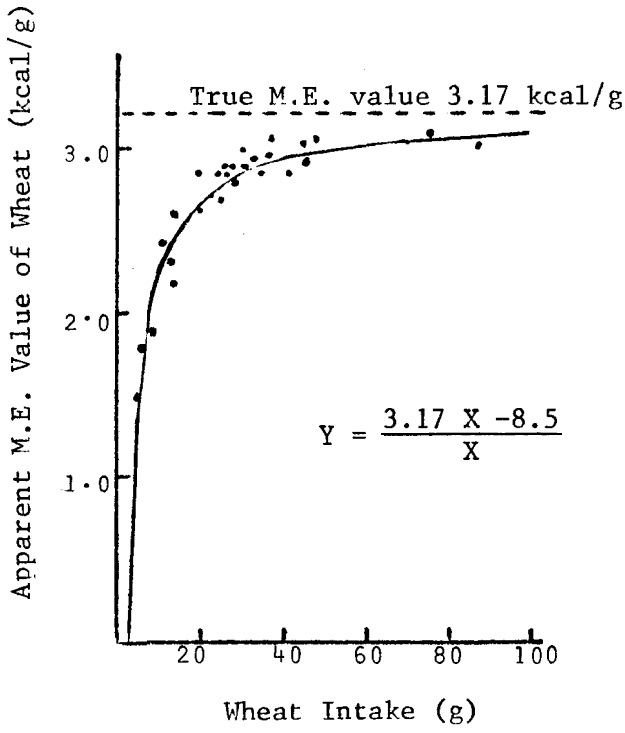

Fig. 1. *The effect of level of intake on the apparent M.E. value of wheat.*

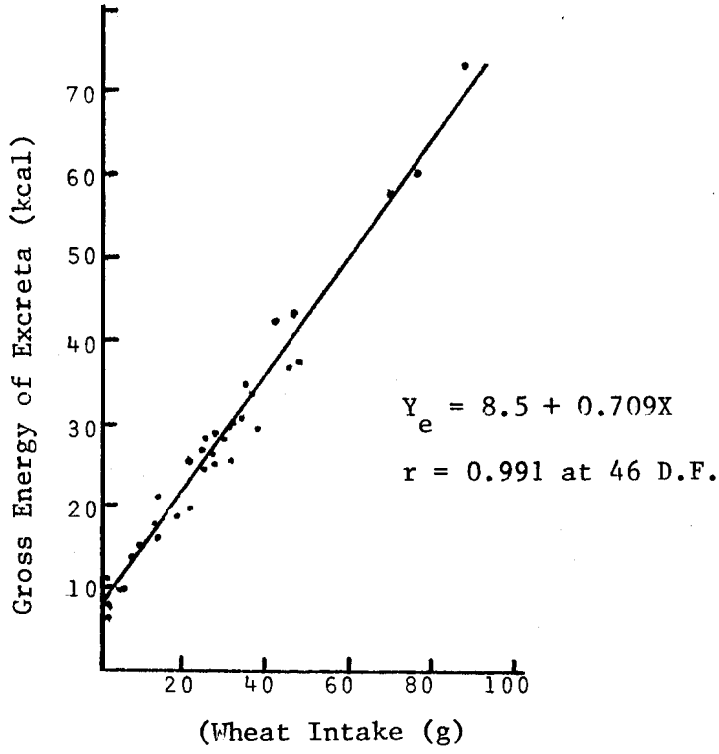

Fig. 2. *The relationship between wheat consumption and the gross energy voided as excreta.*

only showed that a substitution level of much less than 50% leads to high variation in ME values, but the method of total collection carried out for a period of 5 d on 5 roosters markedly reduced variation in ME values derived.

In a subsequent paper Sibbald (1975b) allowed starved, adult roosters to consume various amounts of whole wheat by controlling feeding time. During the next 24 h excreta were collected. The effect of level of intake on the apparent ME of wheat is shown in Figure 1, and illustrates that different values are obtained when intake falls below about 80 g of intake. Above this intake, ME values were some 3.0 kcal/g but if correction is made for metabolic and endogenous excreta energy then a value of 3.17 kcal/g results. This value is termed the true metabolizable energy (TME) of the wheat.

Another way of looking at the influence of metabolic and endogenous excreta is shown in Figure 2. Again these data relate to Sibbald's (1975a) study of feeding graded amounts of whole wheat to starved adult roosters. Wheat intake (S) is plotted against gross energy of the resultant excreta. Extrapolation of the linear regression line indicates a value of 8.5 kcal of endogenous and metabolic excreta energy at zero intake. The slope of the line indicates that for each gram of wheat consumed an additional 0.709 kcal was voided as excreta. The gross energy of wheat was 3.88 kcal/g, thus 3.88 -0.71 kcal gave a value of 3.17 kcal/g; this then is' the TME of wheat. Thus one basic assumption of TME is its linearity with level of intake.

On the basis of his previous studies, Pibbald (1976) modified his TME assay. Instead of feeding graded levels of a particular test feed, he tube-fed a similar amount (20 to 25 g) to adult cockerels starved for 21 hours. Excreta was then collected for the next 24 hours. For each experimental cockerel fed, a cockerel of similar weight was starved for the 24 hour period and excreta collected. The energy of this excreta was subtracted from the energy of the excreta voided by the paired cockerel, and a TME value then calculated.

Although TME is an attractive method of measuring the energy content of ME it is extremely difficult to validate the technique and therefore to verify the resultant values, particularly as the pure feed is given without any additives. Although the inherent assumption is that the relationship between intake and excreta energy is linear, this cannot be verified over a normal range of intakes of free-fed birds. Furthermore since amounts of excreta voided from such minute quantities of feed are extremely small, errors associated with the technique of collection of excreta are correspondingly large. Addition of foreign material such as feathers and cellular debris will also add to error. These errors are likely to be substantially less under *ad libitwn* intakes. Furthermore regurgitation following tube-feeding is not uncommon (Sibbald, 1975b).

Since the energy of all feeds and feed ingredients are associated with a certain quantity of metabolic and endogenous excreta energy, in practice such a correction to TME is questionable. Finally, feeding standards of energy requirements of poultry (A.R.C. 1975; N.R.C. 1971) are based on apparent ME figures; conversion to TME of feeds would necessitate also changing energy requirements of poultry.

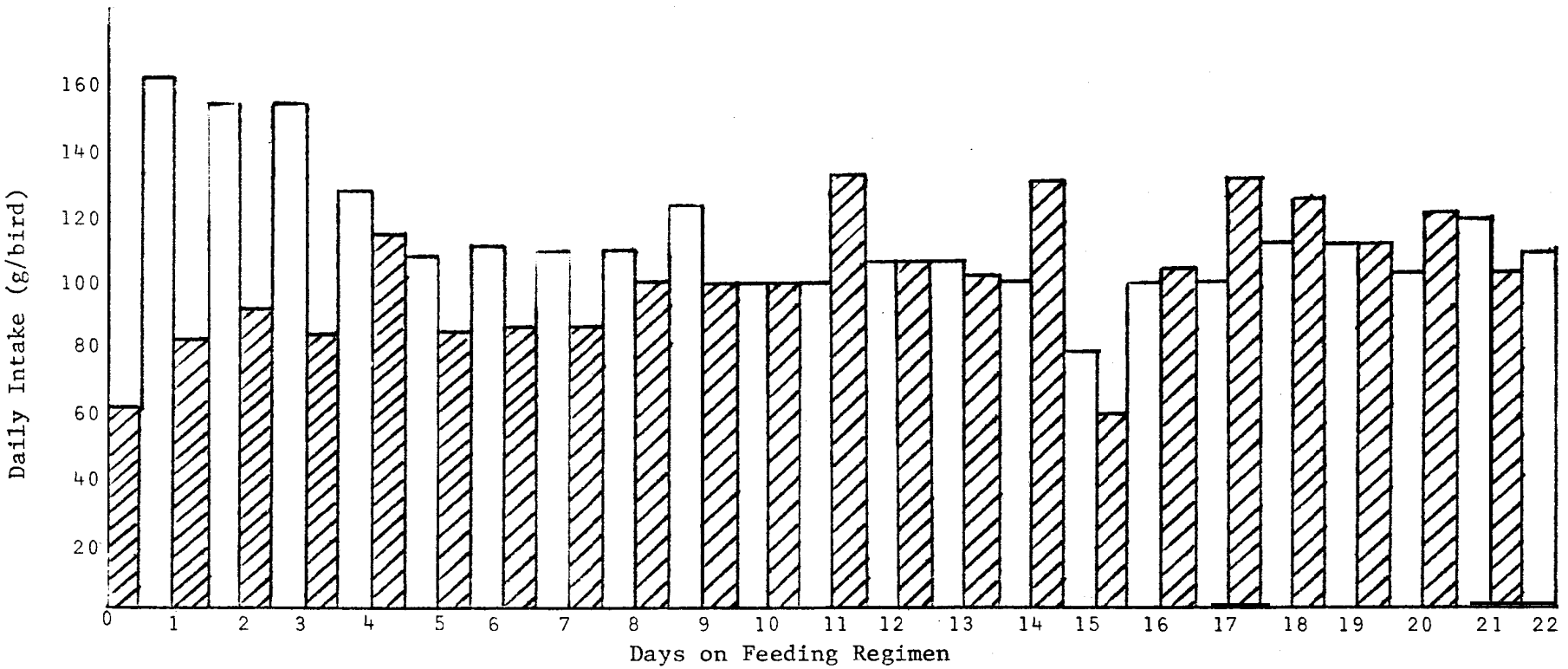

Fig. 3. *Mean Daily intake of six mature cockerels fed for one hour* ▨ *and two mature cockerels fed continuously* □ *the same diet.*

TABLE 2: A comparison of the mean metabolizable energy (±SE) of a number of diets determined with cockerels fed for one hour each day, and those accustomed to the diets for at least 3 days and determined during 5 days. Values in parenthesis represent the number of cockerels used in each experiment ME values for each ingredient, calculated from the one day determinations, are also given.

DIET	DATE	ONE-DAY COLLECTION ME (Mcal/kg)	FIVE-DAY COLLECTION ME (Mcal/kg)
	12.1.77	3.89 ± 0.02 (7)	
	13.1.77	3.86 ± 0.03 (7)	
BASAL	19.1.77	3.90 ± 0.01 (8)	3.83 (4)
	9.3.77	3.99 ± 0.02 (8)	
	MEAN	3.91	
FISH MEAL (60%)	25.1.77	4.02 ± 0.04 (8)	3.83 (4)
BASAL (40%)	16.2.77	3.57 ± 0.05 (6)	
	MEAN	3.80	
BRAN (50%)	2.2.77	2.86 ± 0.01 (6)	
BASAL (50%)	3.2.77	2.60 ± 0.02 (6)	2.99 (4)
	15.2.77	2.79 ± 0.04 (5)	
	MEAN	2.75	
SUNFLOWER (50%)	23.2.77	3.48 ± 0.02 (8)	3.42 (2)
BASAL (50%)	7.3.77	3.42 ± 0.04 (7)	
	MEAN	3.45	
MEAT MEAL (60%)	14.2.77	3.39 ± 0.03 (6)	3.25 (2)
BASAL (40%)			
WHEAT (50%)	24.2.77	3.49 ± 0.04 (9)	3.41 (2)
BASAL (50%)			

Ingredient	ME (Mcal/kg dry matter)
BRAN	1.59
FISH MEAL	3.73
MEAT MEAL	3.04
SUNFLOWER MEAL	2.98
WHEAT	3.06

A New, Rapid Method of Determining METABOLIZABLE ENERGY

The new method of rapidly determining the metabolizable energy of poultry feedstuffs depends upon the knowledge that adult cockerels can be trained to consume their daily food allowance in one hour. We have compared daily intake of trained birds with cockerels continuously fed and intake and growth rate are essentially the same after about 10 d, (Fig. 3) and the average daily intake normally exceeded 100 g/d for birds fed for one hour each day. Initially, the 8 cockerels, offered feed for one hour daily, weighed 1547 ± 43 compared with 1662 g for the two continuously fed. After 10 weeks they weighed 2561 ± 63, and 2607 g, and after 15 weeks 2760 ± 76, and 2937 g, respectively. Several different diets had been fed after 10 weeks, which tended to cause differences in bodyweight.

Total collection of excreta from these birds, housed individually and fed for one hour, voided during the next 24 h should represent all the excreta from the food consumed, and thus give an accurate assessment of ME of the diet. Comparisons of ME were made with continuously fed cockerels and collection of the excreta for at least 5 d following acclimation to the diet for at least 3 d.

Birds offered food for 1 h that did not consume at least 70 g were excluded from ME calculations, since amounts of feed of less than 70 g were assumed to be unduly influenced by endogenous and metabolic excreta.

Level of inclusion of the test ingredient in the basal diet (90% ground corn, 8½% fish meal, 1½% bone meal, as well as a mineral and vitamin supplement) was 50 to 60%. The ME of feedstuffs when combined was assumed to be additive and not associative, thereby excluding, at this stage, fats and oils from measurement. Furthermore this method of ME determination assumes that there is no time requirement for birds to adapt to any particular diet; thus carry-over effects of dietary ingredients do not occur.

The results of a number of experiments are shown in Table 2. The ME values determined for six cockerels, fed for 1 h, are in close agreement with those found when two or three birds were on the test diets for at least 3 d and collection of excreta was made over the next 5 d.

Thus the preliminary results shown in Table 2 suggest that this new, rapid method of determining metabolizable energy of feed ingredients during a 24 hour period has much merit. Better agreement could have been expected had dry matter determinations been made on representative feed samples taken at each exoeriment rather than from each batch of mix. Unfortunately large amounts of water were added to some of the feeds prior to pelleting and this no doubt increased the initial water content of the diets, which would have subsequently declined.

Fish meal-based diets showed some variation in ME values between experiments. There were considerable amounts of urine voided with the excreta which proved difficult to handle. A reduction in content of fish meal from 60 to 40% would probably reduce wet droppings and therefore decrease variation. Five day collections of excreta from cockerels on this diet also proved to be difficult, particularly the separation of

feathers and debris from excreta, and this perhaps caused the variation in the ME values. Generally the extremely good agreement between the short and long-term determinations observed on the basal diet indicates the reliability and reproducibility of the rapid method. Furthermore many of the collections made on the basal diet were from cockerels either accustomed to the basal diet for several days, or introduced to this diet without any period of acclimation, yet the resultant ME values were almost identical. Although further work is necessary to validate completely and authenticate this rapid technique for determining ME of feedstuffs there is little doubt that it has potential both in terms of accuracy and cheapness. Furthermore some of the values calculated for individual ingredients are outside those frequently reported for these ingredients. Part of the explanation for this discrepancy lies in the different rates of inclusion. As pointed out previously, a high rate has been shown to be essential in order to obtain precise and meaningful results.

References

ANDERSON, D.J., HILL, F.W. and RENNER, R. (1958) - *J. Nutr.* 65: 561.

ANNISON, E.F. (1974) - *In* "Energy Requirements of Poultry", Ed. T.R. Morris and B.M. Freeman, p. 135. (British Poultry Science Ltd., Edinburgh)

A.R.C. (1975) - Agricultural Research Council. "The Nutrient Requirements of Farm Livestock - No. 1 Poultry". 2nd ed. Revised. (Her Majesty's Stationery Office: London)

DAVIDSON, J., McDONALD, I. and WILLIAMS R.B. (1957) - *J. Sci. Fd. Agric.* 8: 173.

EKMAN, P., EMANUELSON, H. and FRANSSON, A. (1949) - *Ann. R. Agric. Coll. S.* 16: 749.

FARRELL, D.J. (1974) -*In* "Energy Requirements of Poultry", ed. T.R. Morris and B.M. Freeman, p. 1. (British Poultry Science Ltd.: Edinburgh)

FRAPS, G.S. (1946) - Tex. *Agric. Stn. Bull. 678.*

GUILLAUME, J. and SUMMERS, J.D. (1970) - Can. *J. Anim. Sci. 50: 363.*

HILL. F.W. and ANDERSON, D.L. (1958) - *J. Nutr. 64: 587.*

KLEIBER, M. (1961) - *In* "Fire of Life". (John Wiley & Sons, Inc.: New York)..

MILLER, W.S. (1974) - *In* "Energy Requirements of Poultry", ed. T.R. Morris and B.M. Freeman, p. 91. (British Poultry Science Ltd. Edinburgh)

N.R.C. (1971) - National Research Council - "Nutrient Requirements for Domestic Animals. No. 1. Nutrient Requirements for Poultry" 6th ed. (National Research Council: Washington)

PRIOR, W.J. and CONNOR, J.K. (1966) - Aust. *Vet. J. 42:* 141.

SIBBALD, I.R. (1977a) - *Poult.* Sci. 56: 336.

SIBBALD, I.R. (1977b) - *Poult. Sci.* 56: 380.

SIBBALD, I.R. (1976) - *Poult. Sci. 55: 303.*

SIBBALD, I. R. (1975a) - *Can. J. Anim. Sci.* 55: 283.

SIBBALD, I.R. (1975b) - *Poult.* Sci. 54: 1990.

SIBBALD, I.R. and PRICE, K. (1975) - *Poult. Sci. 54: 448.*

SIBBALD, I.R. and SLINGER, S.J. (1963) - *Poult. Sci.* 42: 313.

VOHRA, P. (1972) - *Wld's. Poult. Sci. J. 24: 204.*