Energy Balance by Carbon and Nitrogen Balance Technique in White Leghorn and Rhode Island Red Hens Fed Maize- and Broken Rice-Based Diets

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ABSTRACT : Carbon (C) and nitrogen (N) balance technique was used to determine energy balance in Rhode Island Red (RIR) and White Leghorn (WL) laying hens fed maize- and broken rice (BR)- based diets. Carbon and nitrogen intake and outgo were determined for three days on *ad libitum* fed diets followed by 2/3 of *ad libitum* intake for next three days. Carbon analysis was done by using four 'U' tubes in which carbon dioxide released during bomb calorimetry was absorbed on drierite in tube 1 and 2 whereas tube 3 and 4 contained sodalime self indicating granule. Carbon in CO_2 was determined by an open circuit respiration system. Energy retention (E, kcal) was calculated as E = 12.386 C (g) - 4.631 N (g). By regressing metabolisable energy (ME) intake on energy balance, maintenance ME requirement of RIR was 128 whereas, that of WL hens was 144 kcal/kg $W^{0.75}$ /d. Efficiency of utilisation of ME for maintenance from BR-based diet in RIR hens was equal but in WL hens it was 11 % less than maize-based diet. (***Asian-Aus. J. Anim. Sci. 1999. Vol. 12, No. 7 : 1080-1084***)

Key Words : Carbon, Nitrogen Balance, Maize and Broken Rice-Based Diet, RIR Hens, WL Hens, Maintenance ME Requirement

INTRODUCTION

Although maize is preferred energy source for expanding poultry industry, its production in India has stagnated at around 8 millions metric tonnes for some decades. New energy sources are being searched to mitigate this higher demand of maize with varying success. Broken rice (BR) is one such source tried extensively in poultry rations (Phalaraksh et al., 1978; Shrivastava et al., 1990; Tyagi et al., 1994).

The carbon and nitrogen (C-N) balance has been used for many years to determine gain or loss of body protein and fat. In this method, carbon and nitrogen are determined in feed, excreta (faeces and urine) and gaseous output. Using equation of Brouwer (1965), energy balance is determined from values of C-N balance. It seems that data on trials to compare energy balances on broken rice-based and maize -based diet in heavy (Rhode Island Red, RIR) and light (White Leghorn, WL) breeds is lacking in literature. The investigation being reported in the paper was undertaken to determine energy balance from carbon and nitrogen balances in WL and RIR hens fed maize- and BR-based diets.

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MATERIALS AND METHODS

Experimental hens, their housing and management and details of the experimental plan has been described earlier (Jadhao et al., 1999a). WL and RIR hens above 72 weeks of age were used for the study and were fed maize- based diet. The composition of diets is given in table 1.

The hens were acclimatized to a room with controlled temperature (20-25℃). First study was done with RIR hens. Following a ten day feeding period, a group of hens (4 to 7) housed individually in cage having capacity of 9 hens (which was easily manageable to transfer in and out of large size chamber actually meant for sheep and goat study) were transferred to a respiration chamber (20-25℃) and after adaptation in chamber for 2 days, carbon loss in excreta (faeces and urine) and as carbon dioxide was determined on *ad libitum* feeding for 3 days followed by 2/3 *ad libitum* feeding level. The study was done for 4 batches of RIR and WL hens on each maize -and BR -based diet except 5 batches of WL on BR based diet. ME bioassay was done during *ad libitum* feeding in respiration chamber (with 21 and 20 RIR hens fed maize -and BR -based diets and 22 and 24 WL hens fed same diets, respectively).

Table 1. Composition of diets (g/kg)

Ingredients		
Maize or broken rice (BR)	500	
Soybean meal	100	
Groundnut meal	100	
Deoiled rice bran	170	
Fish meal	50	
Limestone powder	60	
Dicalcium phosphate	15	
Salt	3	
Vitamin premix[1]	1	
Mineral premix[2]	1	
Total	1,000	
Analyses	Diet I (Maize-based)	Diet II (Rice-based)
Crude protein	180.8	173.2
Gross energy (kcal/kg)	3,930	3,890
Metabolizable energy (kcal/kg)	2,864 (in RIR)	
	2,878 (in WL hens)	3,018 (for both breeds)
Carbon (g/kg)	389.0	388.6
Calcium (g/kg)	30.1	29.0
Phosphorus* (g/kg) (available)	5.4	5.2

[1] The vitamin premix supplied per kg diet: retinal acetate 8000 IU, cholecalciferol 800 ICU, dl-α-tocopheryl acetate 1.2 mg, menadione 11 mg, thiamin 2.2 mg, riboflavin 5.5 mg, calcium pantothenate 14.3 mg, biotin 45 mg, cyanocobalamin 11 μg.

[2] The mineral supplied (mg/kg diet): Magnesium sulphate 195, ferrous sulphate 180, zinc sulphate 160, copper sulphate 14 and potassium sulphate 0.3.

* Assuming 30% availability of phosphorus from plant origin feedstuffs.

Analysis of carbon content

C content in feeds and excreta (faeces and urine) was estimated by soda lime absorption method recommended by van Es and described by Chandramoni et al. (1999). While determining gross energy of samples by bomb calorimeter, after noting down rise of temperature, the gas content of bomb was led through a suitable set of 4 absorption tubes (calcium chloride 'U' tubes). Tubes 1 and 2 contained drierite ($CaSO_4$) for absorbing moisture.

The gas stream from the bomb was led through this absorption system at a flow rate of 100-120 bubbles per minute. After passing the gas content once, oxygen was filled in the bomb to a pressure of about 1.8 kg/cm^2 (10 lb/sq inch) and the gas content was led again through the absorption system for washing. The difference in two weights (initial and after passing the gas) of 3rd and 4th tube was added together to obtain the amount of CO_2 in the sample from which carbon content per g dry matter was calculated.

Carbon dioxide

Carbon content of CO_2 produced was calculated from the values obtained in respiration calorimetry, using factors recommended by Brouwer (1965).

Nitrogen balance: After estimating nitrogen (N) content of feed and excreta (pooled sample of excreta of birds housed in chamber at a time was used for carbon nitrogen balance study) by Kjeldahl's method, the N balance was calculated by subtracting the total N outgo from total N intake.

Carbon balance

It was calculated by subtracting the total C outgo in excreta (faeces plus urine) and carbon dioxide from the total carbon intake in feed.

Energy balance from carbon (C, g) and nitrogen (N, g) balance was calculated according to equation proposed by Brouwer (1965).

Energy balance (kcal) = 12.387 C - 4.631 N

Protein energy retained was calculated as retained $N \times 6.25 \times 5.6$. The value of 5.6 kcal/g used for energy content of protein is that quoted by Znaniecka (1967). Retention of fat energy was calculated as the difference between total energy balance and energy retained as protein.

Statistical analysis was done as per Snedecor and Cochran (1967).

RESULTS AND DISCUSSION

Data related to carbon and nitrogen balances ME intake, energy balance and energy retained as protein (ERp) and as fat (ERf) are given in table 2.

The relationship of ME intake (X, kcal/kg $W^{0.75}$/d) and energy balance (Y, kcal/kg $W^{0.75}$/d) by carbon-nitrogen balance for RIR and WL hens fed maize-and BR-based diets is shown in figure 1, 2, 3 and 4, respectively. Statistical analysis indicated that the relationships of ME intake and energy balances for all equations were highly significant (p<0.01). The figures indicate that, when energy intake i.e. Y = 0, X gives ME required for maintenance (ME_m) and slope of the line gives efficiency of utilization of ME for maintenance (k_m) from that diet. Thus, in RIR, on maize-based diet, ME_m was 127.9 kcal/kg $W^{0.75}$ and k_m was 0.913 units and on BR - based diet, ME_m was 127.6 kcal/kg $W^{0.75}$ and k_m was 0.80 units. In case of WL, on maize-based diet, ME_m was 139.3 kcal/kg $W^{0.75}$ and k_m was 0.933 units, whereas on BR-based diet ME_m was 149.2 kcal/kg $W^{0.75}$ and k_m was 0.928 units. However, on an average, carbon and nitrogen balance method overestimated ME_m by 4.3% and heat production by 2.64% than calorimetry (Jadhao et al., 1999a). In studies with sheep, we (Chandramoni et al.,

Table 2. Carbon, nitrogen (g/kgW$^{0.75}$) and energy balance (kcal/kgW$^{0.75}$) in hens fed maize and broken rice (BR) based diet

Breed:	Rhode Island Red hens						White Leghorn hens					
Diets:	Maize			BR			Maize			BR		
Level of intake	*Ad lib.*	2/3 *ad lib.*	SEM	*Ad lib.*	2/3 *ad lib.*	SEM	*Ad lib.*	2/3 *ad lib.*	SEM	*Ad lib.*	2/3 *ad lib.*	SEM
Body weight (kg)	13.08	10.41	0.97	10.95	10.03	0.55	8.22	8.22	0.45	8.80	8.70	0.48
kg W$^{0.75}$	5.860	5.787	0.23	6.012	5.627	0.23	4.847	4.845	0.19	5.099	5.504	0.21
ME intake	212.4	144.9	8.22	244.6	169.6	9.01	223.6	139.4	3.99	301.4	201.2	11.97
C intake	28.61	18.82	0.65	31.32	21.66	1.09	30.35	19.15	1.39	9.18	25.84	2.56
C in feces & urine	7.44	3.97	0.32	6.92	4.53	1.13	7.30	4.21	0.30	8.80	5.10	0.54
C- CO_2	14.61	13.56	0.18	16.57	14.75	0.39	12.30	14.71	0.65	18.79	16.18	0.92
C balance	6.56	1.28	0.44	7.85	2.98	0.52	6.75	0.23	0.25	11.59	4.56	1.18
N intake	2.13	1.40	0.05	2.23	1.54	0.09	2.25	1.40	0.10	2.77	1.85	0.35
N outgo	1.31	0.83	0.03	1.26	0.88	0.09	1.38	0.83	0.19	1.62	1.03	0.10
N balance	0.81	0.57	0.02	0.97	0.66	0.19	0.87	0.57	0.06	1.15	0.82	0.06
Energy retained (ER)	77.50	13.22	6.80	93.9	33.85	9.04	79.58	0.21	9.04	138.40	52.68	8.60
ER as protein	28.60	20.12	5.94	34.25	23.30	1.28	30.72	20.13	1.28	4.12	28.05	1.27
ER as fat	48.90	-6.9	4.95	59.65	10.55	8.05	48.86	20.34	9.73	97.0	23.73	12.43
Heat production	134.9	131.68	5.81	150.7	135.75	4.51	144.0	139.61	4.51	163.2	148.5	4.09

SEM (pooled standard error of means): four observations for each level of intake except WL hens on BR based diet which was for five observations at each level of intakes.

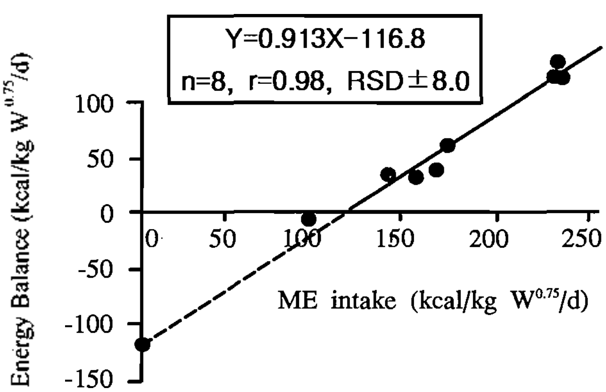

Figure 1. The relationship between ME intake and energy balance in RIR hens fed maize-based diet

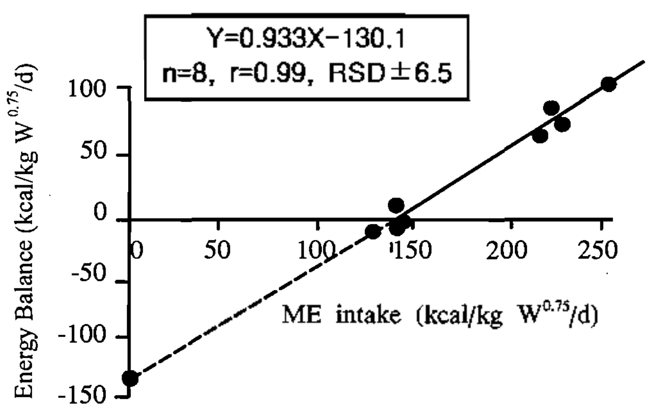

Figure 3. The relationship between ME intake and energy balance in WL hens fed maize-based diet

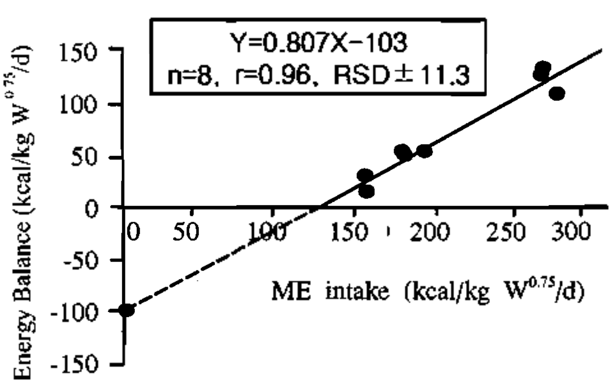

Figure 2. The relationship between ME intake and energy balance in RIR hens fed broken rice-based diet

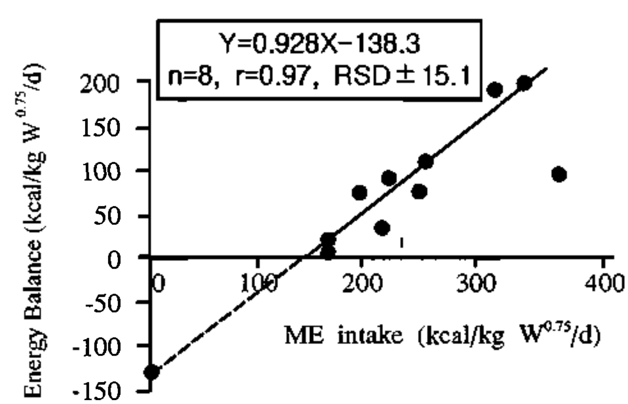

Figure 4. The relationship between ME intake and energy balance in WL hens fed broken rice-based diet

1999) have found 8.6% higher value of heat production by C-N technique than calorimetric estimates.

The k_m value of BR-based diet in RIR hens was almost 11% less than maize-based diet, whereas it was similar for WL hens. Farrell (1975) found 79 and 84% k_m of the feed for heavy (Black Australorp) and light (WL) breeds of hens. Similarly, Leeson et al. (1973) found 54 and 72% net availability of ME for maintenance and production in heavy and light breed of hens. These reports support to the result that heavy breed utilise energy less efficiently than the light breed like WL from some diets. The effect on k_m may also be due to either more heat increment which may be breed specific or the reason that surplus energy was diverted to fattening (as such intakes were such to cause energy retention) resulting in less energy utilisation. The growing cockerels (Bagel and Netke, 1982), quails (Shrivastava et al., 1990) and also RIR hens (Jadhao et al., 1999b) are more responsive to broken rice, which is a lipogenic feedstuff. The heat production in WL, but not in RIR was significantly higher on *ad libitum* than 2/3 of *ad libitum* fed BR-based diet is indicative of better thermo-regulatory mechanism of heat dissipation in WL than RIR hens. Heat dissipation has relation with process of energy deposition as fat, ultimately affecting efficiency values. As such the role of heat dissipation on different diets in different breeds in modifying dietary effects on body composition has received little experimental attention in birds. The responses in the form of energy deposition as fat without regulatory variation of energy dissipation as heat (MacLeod, 1991) may be breed and diet specific. The energy balance values observed on *ad libitum* and 2/3 of *ad libitum* in the experiment may have disproportionately influenced the derived regression equation. Also the extrapolation towards zero energy balance may have had effect on regression coefficient. However, k_m values of two diets in calorimetric study were not much different either in RIR or WL hens. In that calculation, lowest level of energy balance was of fasting heat production (i.e. the ME intake was zero kcal). This could have considerably influenced slope of the equation. Hoffmann and Schieman (1973) has reported ME_m of 99 kcal/kg $W^{0.75}$/d by carbon and nitrogen balance and pointed out that k_m is based on the level of egg production and the net energy balance of the hens but theoretically it should not be less than 75% and frequently higher depending on contribution of body reserves of energy.

Fasting heat production of RIR was substantially lower for RIR than for WL hens. This would help to explain the lower ME requirement of RIR hens which in turn may be related to more docile nature of this breed as compared to active WL breed.

Higher estimates of ME_m by C-N balance than calorimetric method may be associated with more precision of calorimetry technique. Similar findings have been reported by Boekholt et al. (1994) on studies with poultry. Blaxter (1967) pointed out that because the C-N balance method involves a large number of analytical measurement than the energy balance method, errors of about 30% greater are frequently observed. But, Farrell (1974) reported good agreement between heat production of cockerels by gaseous exchange and C-N balance method and our findings do not corroborate with his report. Based on

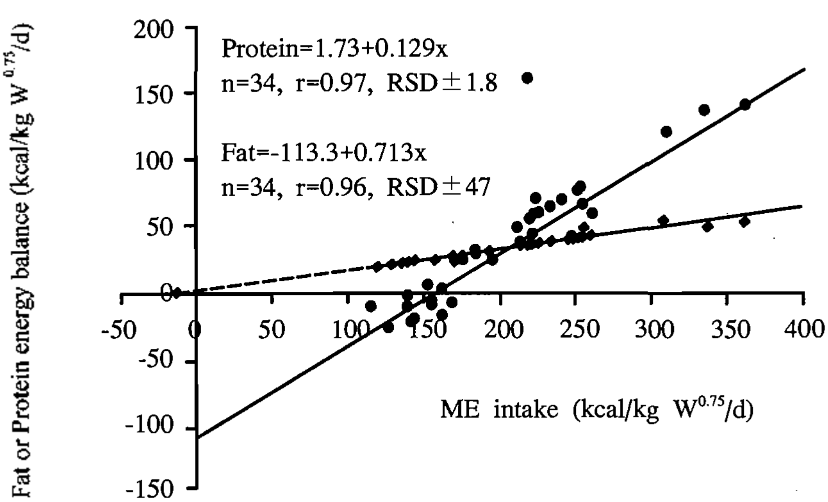

Figure 5. The relationship between ME intake and ME and the simultaneous retention in the body of protein energy (◆) and fat energy (●)

empirical equations, NRC (1994) has given 134 kcal/kg $W^{0.75}$ as ME_m of WL hens not laying egg. Our value is 30 kcal higher than this. The effect on ME_m of hens and k_m of diets is the result of genetical leanness (WL hens) or fatness (RIR hens). It is apparent that propensity to leanness or fatness in poultry relies on fundamental metabolic differences in partitioning of energy from diets (Simon and Leclercq, 1982) in which insulin plays a major role. It is noteworthy to mention here that rice starch induces more glycaemic and insulinemic response than maize starch (Capro et al., 1976, 1977).

The relation between intake of ME (X) and simultaneous retention in the body of protein and fat energy (Y) measured by C-N balance method is shown figure 5. Since p was <0.01 for equation depicted in figure 5, the relations between ME intake and protein or fat energy retentions were highly significant.

The combined equation (figure 5) indicate that hens retains fat only when ME intake exceeds range of 159 kcal/kg $W^{0.75}$, but protein retention occurs evenwhen hens are in negative energy balance. This value is near to 141 kcal/kg$W^{0.75}$ found by Burlacu et al. (1974) for positive energy balance. The finding is also in consonance with Farrell (1974) who pointed out that evenwhen hens are in severe negative energy balance they apparently relies on body protein to supply amino acids and fat reserve to contribute to the balance of energy required for production.

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