Feed input and excreta collection time in metabolisable energy assays for ducks

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ABSTRACT: Three experiments were conducted to determine the optimal feed input and excreta collection time by a bioassay of dietary true metabolisable energy (*TME*) for ducks. In experiment 1 and experiment 2, the time for the unabsorbed feed passage through the alimentary canal was determined by measuring the DM and energy of excreta and feed residues in the alimentary canal at different periods. In experiment 3, the feed input of force-feeding was studied and a total of 70 mature Pekin drakes were allotted to 7 groups, each group containing 10 birds. After fasting for 36 h, one group served as a negative control to measure metabolic faecal energy plus endogenous urinary energy and the drakes of the other 6 groups were force-fed pelleted feed 30 g, 50 g, 70 g, 90 g, 110 g, and 150 g per bird, respectively. Energy excretion of the periods of 16–28 h after force-feeding was significantly higher than that of the periods after 32 h, and the total energy excretion of the periods after 32 h ($P < 0.05$). When the feed input increased from 30 g to 70 g, the value of *TME* was constant ($P > 0.05$). Metabolisable energy decreased significantly with an increase in feed input when the feed input was higher than 70 g ($P < 0.05$). It was concluded that the optimal time of feed withdrawal before tube-feeding and during excreta collection would be 32–36 h. The optimal feed input was 50 g to 70 g per drake.

Keywords: metabolisable energy; bioassay method; force-feeding

Metabolisable energy is most frequently used to evaluate the available energy of chick feed. Due to relatively limited information on energy utilization in feed ingredients by ducks (Elkin, 1987), the chick *ME* values were usually used when a duck diet was formulated. However, there was a significant difference in nutrient requirements and energy utilization between ducks and chickens (Muztar et al., 1977; Ostrowski-Meissner, 1983; Mohamed et al., 1984), so it is questionable to use the nutrient bioavailability data from chicks to formulate diets for ducks. At present, there are few reports on the bioassay method of duck feeds. Feed input and excreta collection time are two key factors influencing the accuracy of bioassay for true metabolisable energy of poultry feeds (Sibbald, 1975, 1976; Yaghobfar and Boldaji, 2002). Feeding and excreta collection techniques for ducks were developed by Adeola et al. (1997) and modified by Hong et al. (2002) based on ducks' specific physiology. However, in their study ducks suffered force-feeding twice to get a higher feed intake, which may cause more stress to ducks. Moreover, the collection of highly liquid excreta was also difficult even according to their methods, so the collection time should be reduced as much as possible.

The objective of the present study was to determine optimal feed input and excreta collection time in a bioassay for true metabolisable energy (*TME*) of duck feeds.

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Table 1. The composition of ingredients and nutrients in feed mixture

Ingredient	Content	Nutrient analysis	Nutrient content
Maize	59.6	*AME* (MJ/kg)	11.02[2]
Wheat bran	10.0	crude protein	16.94
Leese	10.0	crude fibre	3.00
Soybean meal	16.0	calcium	0.90
Premix[1]	4.0	salt (%)	0.40
Salt	0.4	NNP[3]	0.41

[1]providing: 10 mg of Cu, 60 mg of Fe, 60 mg of Zn, 80 mg of Mn, 0.3 mg of Se, 0.2 mg of I, 0.15 mg of Cr, 750 mg of choline chloride, 8 000 I.U. of vitamin A (retinyl acetate), 3 000 I.U. of vitamin D3, 20 I.U. of vitamin E (DL-α-tocopheryl acetate), 2 mg of vitamin K3, 1.5 mg of thiamine, 8 mg of riboflavin, 3 mg of pyridoxine, 0.02 mg of vitamin B12, 10 mg of pantothenic acid, 50 mg of nicotinic acid, 1 mg of folic acid, 0.2 mg of biotin per kilogram of total diet

[2]The values are calculated according to the *AME* of chickens

AME = apparent metabolisable energy; NNP = non-phytate phosphorus

MATERIAL AND METHODS

Three experiments were carried out to determine the optimal feed input and excreta collection time by a bioassay of dietary true metabolisable energy for ducks. In all experiments adult Pekin drakes, aged approximately 30 weeks, were used. The birds had an average body weight of 4.50 ± 0.10 kg. The drakes were randomly assigned to individual cages (0.50 × 0.50 m) and housed in an environmentally controlled room at a temperature of 25°C. The excreta collection apparatuses were prepared according to the method developed by Adeola et al. (1997) and Hong et al. (2002) one week before experiments for experiment 1 and experiment 3. In the adaptation time, the birds had an *ad libitum* access to water and common diet, the composition of which is given in Table 1.

In experiment 1, 20 drakes had their food withdrawn and were allocated to 4 groups, each group containing 5 birds. In experiment 2, 28 drakes were randomly allocated to 7 treatment groups, each containing 4 birds. Birds of each group were tube-fed 50 g common feed, approximately 48 h after food withdrawal. The subsequent operations were conducted according to Table 2.

In experiment 3, 70 adult drakes were allocated to 7 treatment groups. All birds were fasted for 36 h prior to force-feeding. One group was continually fasted to serve as a negative control to measure metabolic faecal energy plus endogenous urinary energy and the drakes of the other 6 groups were force-fed pelleted feed 30 g, 50 g, 70 g, 90 g, 110 g, and 150 g per bird, respectively. The excreta voided during the exact of each drake were collected for 36 h after force-feeding. The excreta of each group were collected for another 36 h to measure the *EEL* of different groups.

Excreta samples were dried in an oven at 65°C for 96 h soon after collection and ground through a 0.5-mm screen prior to the analysis. Dry matter was determined by the method described in AOAC (1984). The energy contents of the feeds and excreta samples were determined with a bomb calorimeter with benzoic acid as a standard (Parr, Moline, Il).

The *AME* and *TME* contents of the feeds were calculated using the methods described by Sibbald (1976). *AME* and *TME* in kJ/g were calculated as follows:

$$AME = (EI - EO)/FI;\ TME = AME + (EEL/FI)$$

where:

EI = gross energy intake (kJ)

EO = gross energy output in the excreta (kJ)

FI = feed intake (g)

EEL = fasting energy loss from the group of feed-deprived ducks (kJ)

Data were analyzed by one-way analysis of variance with ANOVA procedure of SAS software (SAS, 1996). Means were compared by Duncan's multiple-range test when *P*-value was significant ($P < 0.05$).

RESULTS

Excreta energy and dry matter of different periods are shown in Table 3; DM excretion increased

Table 2. The procedures of experiment 1 and experiment 2

Day	Time	*Hours	Operation	
			experiment 1	experiment 2
1	0800	48	drakes were tube-fed 50 g test diet, plastic bags placed through the bore of plastic bottle, screwed to retainer rings sutured to the vents	drakes were tube-fed 50 g test diet
1	1200	52	excreta collected and dried in an oven at 65°C for 96 h by replacing the plastic bags, and the dry excreta were sorted by the group and collecting time	birds of one group were killed by an intravenous dose of sodium pentobarbitone and residues in the alimentary canal were collected and dried in an oven at 65°C for 96 h
1	1600	56	the operation as mentioned above	the operation as mentioned above.
1	2000	60	the operation as mentioned above	
1	2400	64	the operation as mentioned above	the operation as mentioned above
2	0400	68	the operation as mentioned above	
2	0800	72	the operation as mentioned above	the operation as mentioned above
2	1200	76	the operation as mentioned above	
2	1600	80	the operation as mentioned above	the operation as mentioned above
2	2000	84	the operation as mentioned above	
2	2400	88	the operation as mentioned above	the operation as mentioned above
3	0400	92	the operation as mentioned above	
3	0800	96	the operation as mentioned above	the operation as mentioned above
3	1200	100	the operation as mentioned above	
3	1600	104	excreta collected and dried in an oven at 65°C for 96 h	

*time after feed withdrawal

and then decreased as the fasting time increased after tube-feeding. DM excretion between 4 h and 8 h after feeding is significantly higher than that of the other periods ($P < 0.05$). Eight hours after feeding, DM excretion began to decrease. However, energy excretion did not parallelize with DM excretion. Energy excretion of the periods 16–28 h after force-feeding was significantly higher than that of the periods after 32 h ($P < 0.05$), and the total energy excretion of the periods after 32 h.

With an increase in the fasting time, residues in the alimentary canal decreased to a relatively low weight and remained stable after 24-h time point (Table 4).

The effect of feed input on metabolisable energy is shown in Table 5; when the feed input increased from 30 g to 70 g, *AME* increased ($P < 0.05$) while the value of *TME* was constant ($P > 0.05$). Metabolisable energy decreased significantly with an increase in the feed input when it was higher than 70 g ($P < 0.05$).

Table 3. Excreta energy and dry matter of different periods[1]

Time (h)	0–4	4–8	8–12	12–16	16–20	20–24	24–28
DM (g/bird)	$2.14^{a} \pm 0.11$	$4.66^{b} \pm 0.07$	$1.70^{c} \pm 0.05$	$1.31^{d} \pm 0.06$	$0.70^{e} \pm 0.04$	$0.66^{e} \pm 0.04$	$0.68^{e} \pm 0.03$
Energy (kJ/bird)	$27.82^{a} \pm 1.13$	$58.20^{b} \pm 1.99$	$22.10^{c} \pm 0.72$	$17.03^{d} \pm 0.77$	$9.60^{e} \pm 0.45$	$9.39^{e} \pm 0.49$	$9.70^{e} \pm 0.39$
Time (h)	28–32	32–36	36–40	40–44	44–48	48–52	52–56
DM (g/bird)	$0.68^{e} \pm 0.03$	$0.60^{e} \pm 0.05$	$0.66^{e} \pm 0.02$	$0.65^{e} \pm 0.06$	$0.61^{e} \pm 0.05$	$0.62^{e} \pm 0.05$	$0.60^{e} \pm 0.06$
Energy (kJ/bird)	$9.07^{ef} \pm 0.58$	$8.04^{f} \pm 0.42$	$7.97^{f} \pm 0.35$	$7.90^{f} \pm 0.31$	$7.79^{f} \pm 0.37$	$7.78^{f} \pm 0.29$	$7.88^{f} \pm 0.43$

[abcdef]values with no common superscript are significantly different ($P < 0.05$)

[1] values means ± SD

[2]DM = dry matter

Table 4. The change of residues in the alimentary canal with fasting time[1]

Time (h)	4	8	16	24	32	40	48
DM (g/bird)	23.43[a] ± 3.98	11.40[b] ± 0.24	8.38[c] ± 0.41	7.50[c] ± 0.37	6.60[c] ± 0.54	6.70[c] ± 0.61	6.63[c] ± 0.38
Energy (kJ/bird)	421.74[a] ± 23.55	193.8[b] ± 17.46	134.08[c] ± 10.04	108.75[cd] ± 7.39	99.00[d] ± 7.22	100.50[d] ± 6.21	99.45[d] ± 5.97

[abcd]values with no common superscript are significantly different ($P < 0.05$)

[1]values means ± SD

Table 5. The effect of feed input on metabolisable energy[1]

FI (g)	30	50	70	90	110	150
AME (kJ/g) DM	10.07[b] ± 0.47	11.16[a] ± 0.31	11.48[a] ± 0.30	11.12[ab] ± 0.36	10.47[b] ± 0.32	9.59[c] ± 0.73
TME (kJ/g) DM	12.55[a] ± 0.48	12.45[a] ± 0.39	12.47[a] ± 0.36	11.83[b] ± 0.43	11.18[b] ± 0.49	10.31[c] ± 0.82

[abc]values with no common superscript are significantly different ($P < 0.05$)

[1]values means ± SD

FI = feed input; *AME* = apparent metabolisable energy; *TME* = true metabolisable energy

The effect of feed input on an endogenous energy loss is shown in Table 6. The *EEL* changed insignificantly when the feed input increased from 0 to 70 g, but it increased significantly when the feed input reached 70 g ($P < 0.05$).

DISCUSSION

There are differences in the basic metabolism of energy between ducks and chickens (Siregar and Farrell, 1980a,b). Moreover, the rate of the chyme passage from the alimentary canal of ducks is more rapid than in chickens (Li and Li, 1984). These authors also found that residues in the alimentary canal of roosters fasted for 24 h were much higher than those after 48 h. In the present experiments, DM excretion decreased to a stable level in 20 h, and gross energy excretion decreased to a stable level in 32–36 h after force-feeding. The DM and gross energy of residues in the alimentary canal of drakes did not change after 32 h. This was not in agreement with the results of Han and Wu (1984). We can infer that the fasting time before feeding and the time for excreta collection could be shortened to 32–36 h during the bioassay of metabolisable energy of duck feeds. This was not consistent with the results of Shi et al. (1993) for Tianfu ducks. In their trials, ducks were withdrawn from water, which influenced the movement of the chyme.

The apparent metabolisable energy (*AME*) of diets was shown to be affected by the amount of feed intake during the assay (Guillaume and Summers, 1970). The lower the feed intake, the lower the *AME* value of the diet. To avoid the above-mentioned problems the true metabolisable energy (*TME*) system was developed. Even when the feed consumption is too low, a small error can result in higher variation of *TME* values. It was also indicated in Table 5 that the *TME* SD of 30 g feed input was much higher than that of 50 g and 70 g. Tube-feeding was accepted in the determination of the metabolisable energy of poultry feeds to ensure the precision of feed intake. But the feed intake

Table 6. The effect of feed input on endogenous energy loss[1]

FI (g)	0	30	50	70	90	110	150
EEL (kJ/bird)	74.27 ± 3.20[b]	74.37 ± 3.33[b]	74.56 ± 3.52[b]	72.44 ± 2.79[b]	64.54 ± 2.40[c]	79.64 ± 1.05[ab]	89.80 ± 11.90[a]

[abc]values with no common superscript are significantly different ($P < 0.05$)

[1]values means ± SD

EEL = endogenous energy loss; *FI* = feed input

by tube-feeding cannot be too high to avoid any harm to the birds. In the present experiments, the *AME* increased and then declined as the feed input increased. The *AME* decreased significantly when the feed input was higher than 70 g. This was not in agreement with a previous report (Sibbald, 1975), which indicated that apparent metabolisable energy was linear with feed intake. This may be due to different feeding methods, namely *ad libitum* feeding vs. force-feeding. When birds were force-fed, higher feed input needed more time to clear the alimentary canal (Sibbald and Morse, 1982), which means a longer trial time. In the present experiments, duck ingulsives received too much feed were abnormally impact, and the ducks were in depression. Also, a high amount of undigested feed was found in the excreta of the drakes that received too much feed. So we confer that extra feed has a larger volume, which may go beyond the duck physiology capacity and result in abnormal digestion.

The basic assumption in the *TME* bioassay is that under standardized conditions the relationship between energy intake and excreta energy output is linear and the excretion of *EEL* is species specific (Guillaume and Summers, 1970; Sibbald, 1975). In the present experiments, the *EEL* was constant when the feed input was not higher than 90 g, which agreed with it. But when the feed input exceeded 90 g, the *EEL* significantly increased and the values varied. This is partially owed to the undigested feed in excreta. Also, when the feed input was higher than 70 g, more time was needed to clear the alimentary canal (Sibbald and Morse, 1982). Therefore, the values presented here were not proper *EEL*. However, the *EEL* of the control group did not differ from the force-fed groups receiving no more than 70 g feed, which gave another evidence for *TME*. Furthermore, the group of control birds fasted for 36 h can serve as a negative control to provide a measure of the *EEL* so as to reduce the total trial time to 72 h.

It was concluded that the optimal time of feed withdrawal before tube-feeding and during excreta collection would be 32–36 h. The optimal feed input was from 50 g to 70 g per drake.

REFERENCES

Adeola O., Ragland D., King D. (1997): Feeding and excreta collection techniques in metabolisable energy assays for ducks. Poult. Sci., 76, 728–732.

AOAC (1984): Official Methods of Analysis 14th ed. Association of Official Analytical Chemists, Inc., Arlington, VA, USA.

Elkin R.G. (1987): A review of duck nutrition research. Worlds Poult. Sci. J., 43, 84–254.

Guillaume J., Summers J.D. (1970): Maintenance energy requirement of rooster and influence of plane of nutrition on metabolisable energy. Can. J. Anim. Sci., 50, 363–369.

Han Y.W., Wu C.K. (1984): Metabolisable energy studies for poultry feeds: VI. Empting of alimentary canal and amount of endogenous excreta by chickens and waterfowls. J. Northeast Agric. College, 4, 9–13.

Hong D., Ragland D., Adeola O. (2002): Additivity and associative effects of metabolisable energy and amino acid digestibility of corn, soybean meal, and wheat red dog for White Pekin ducks. J. Anim. Sci., 80, 3222–3229.

Li J., Li L. (1984): Metabolisable energy studies for poultry feeds: V. Comparison of metabolisable energy of diet and wheat bran for chickens and waterfowls. J. Northeast Agric. College, 3, 91–95.

Mohamed K., Leclercq B., Anwar A., El-Alaily H., Soliman H. (1984): A comparative study of metabolisable energy in ducklings and domestic chicks. Food Sci. Technol., 11, 199–209.

Muztar A.J., Slinger S.J., Bueton J.H. (1977): Metabolisable energy content of fresh water plants in chicken and ducks. Poult. Sci., 56, 1893–1899.

Ostrowski-Meissner H.T. (1983): A method of simultaneous measurement of apparent (*AME*) and true (*TME*) metabolisable energy with ducks and comparisons of data obtained with drakes and cockerels. Nutr. Rep. Int., 29, 1239–1248.

SAS (1996): SAS User's Guide Statistics. SAS Institute Inc., Cary, NC. USA.

Shi Y.H., Zhang S.R., Yue G.W. (1993): Bioassay for metabolisable energy in ducks: I. the effect of duration of starvation and excreta collection time on the true metabolisable energy. J. Sichuan Agril. University, 11, 377–387.

Sibbald I.R. (1975): The effect of level of feed intake on metabolisable energy values measured with adult roosters. Poult. Sci., 54, 1990–1997.

Sibbald I.R. (1976): A bioassay for true metabolisable energy in feedstuffs. Poult. Sci., 55, 303–308.

Sibbald I.R., Morse P.M. (1982): The effects of feed input and excreta collection time on estimates of metabolic plus endogenous energy losses in the bioassay for true metabolisable energy (chickens). Poult. Sci., 62, 68–76.

Siregar A.P., Farrell D.J. (1980a): A comparison of the energy and nitrogen metabolism of starved ducklings and chickens. Brit. Poult. Sci., 21, 203–211.

Siregar A.P., Farrell D.J. (1980b): A comparison of the energy and nitrogen metabolism of fed ducklings and chickens. Brit. Poult. Sci., 21, 213–227.

Yaghobfar A., Boldaji A. (2002): Influence of level of input and procedure on metabolisable energy and endogenous energy loss (*EEL*) with adult cockerels. Brit. Poult. Sci., 43, 696–704.

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