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Influence of level of feed input and procedure on metabolisable and endogenous energy loss with adult cockerels

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ABSTRACT

Two experiments were performed to study the relationship between apparent metabolisable energy (AME) and true metabolisable energy (TME) values at different levels of feed intake. Rhode Island Red (RIR) adult cockerels were used in two bioassays, under standard conditions. In the first experiment the birds were starved for 72 hours and then various quantities of corn were fed, the feed ration quantities ranging from 10 to 100 g per bird in 10 g increments, without any regurgitation. There were 6 replicates per treatment. Excreta voided during the 48 hours of the experimental period were collected, their quantity was recorded and samples were assayed for gross energy and nitrogen. In the second assay, after a 4-day adaptation period each bird was starved for 24 hours and during the third experimental period corn was fed ad libitum, in the same rations as those used in the first assay. The birds were then fasted for 24 hours. During the 4 days of the experimental period excreta was collected and frozen for chemical analysis. The main purpose of the experiment was to compare the force feeding procedure for the determination of apparent metabolisable energy, nitrogen correction of AME, true metabolisable energy and N correction of TME with the ad libitum feeding (Conventional Addition Method). The results show that mean metabolisable energy values obtained by the force feeding procedure with high positive intercept were repeatedly higher than those obtained by the ad libitum (CAM). The EEL determined by the force feeding was lower than that given by the ad libitum method; this may be due to the response of the birds to the methodology applied. It was concluded that procedures of feeding do not influence metabolisable energy of corn at different ration levels. Differences among intercepts of the regression line have been reported as evidence that the metabolic plus endogenous energy loss varies at difference corn intake levels. The optimum feed ration quantity proved to be approximately 35 to 40 g for adult Rhode Island Red (RIR) cockerels with both procedures.
(Keywords: apparent metabolisable energy, EEL, procedure, feed level, N correction)

ÖSSZEFOGLALÁS

A takarmányfelvétel és az etetési módszer hatása a metabolizálható, valamint az endogén energiaveszteségre kifejlett kakasokban

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Két kísérletet állítottunk be, hogy különböző takarmányozási szinteken tanulmányozzuk a kukorica AME és TME értékének változását. Mindkét esetben standard körülmények között tartott, kifejlett Rhode Island Red kakasokat használtunk. Az első kísérletben 72 órás éheztetést követően eltérő mennyiségű (10 és 100 g között, 10 grammonként növelt adag) kukoricával kényszeretettük az állatokat. A kezeléseket 6 ismétlésben végeztük. A 48 órás kísérleti szakaszban gyűjtöttük majd megmértük az ürüléket, valamint meghatároztuk az energia- és nitrogéntartalmát. A második kísérletben 4 nap adaptációt követően a kakasokat 24 órán át éheztettük, majd 4 napos kísérleti szakaszban, az első kísérletben ismertetett mennyiségben ad libitum etettük a madarakat. Az ürüléket gyűjtöttük, fagyasztottuk, majd a minták kémiai analízisre kerültek. Ezután újra24 órás éheztetés következett. A kísérletek fő célja az volt, hogy összehasonlítsuk a kényszeretetés hatását az ad libitum etetés hatásával az AME, az AMEn, a TME és a TMEn értékére. Az eredmények szerint a kényszeretetett állatokkal mért ME érték nagyobb volt, mint az ad libitum takormányozott madarakkal mért érték. A kényszeretetés csökkentette az endogén energiaveszteséget az ad libitum takarmányozáshoz képest. A regressziós vizsgálatok eredményei értelmében a takarmányadag növelése fokozza az endogén energia ürítést. Kifejlett Rhode Island Red kakasok esetében mind a kényszeretetés mind az ad libitum etetés módszerének használata során megközelítően 35-40 g az etethető optimális takarmányadag.

(Kulcsszavak: látszólagos metabolizálható energia, endogén energiaveszteség, módszer, takarmányozási szint, nitrogén korrekció)

INTRODUCTION

Energy, representing the link between the biological and the physical. In addition, energy intake is implicated in the physiology of appetite and satiety and in the control of the consumption of human food or animal feed. For economic reasons it is important to be able to describe the energy content of foods and foodstuffs. Apparent metabolisable energy is the most widely used measure of feed energy available to birds. The central assumption made in all assays for ME is that the energy voided as excreta is linearly related to energy input. In the TME system the intercept value of this line is positive and corresponds to the EEL (endogenous energy losses). The AME value determined is dependent on EEL per unit of feed intake. Variations in this ratio clearly explain the effects of feed intake on AME values (*McNab*, 1990). The AME values relating to diets fed to adult cockerels were profoundly affected by the amount of feed eaten during the assay (*Guillaume* and *Summers,* 1970). The lower the feed consumption, the lower the AME value of the diet. This effect was attributed to the contribution made to the excreted energy by the EEL. There is a widespread belief that FEm+UEe losses in birds will vary with the nature and quantity of feed ingested and, as pointed out elsewhere, if this is true any correction would be invalidated. The calculation of EEL is a prerequisite for the determination of TME, and its measurement in AME assays is strongly recommended. Apparent dietary metabolisable energy values should vary with the level of feed intake, as, under standardised conditions, the quantity of excreta composed of metabolic faecal energy (FEm) plus endogenous urinary energy (UEe) is constant. When feed energy intake is high the resultant energy loss in the form of FEm+UEe is relatively small, but as energy intake decreases these energy losses become increasingly significant and tend to reduce the apparent ME value. *Guillaume* and *Summers* (1970) explained this hypothesis. However, *Sibbald* (1975) reported that energy voided as excreta increased linearly as wheat intake increased. Excretion increases with the duration of starvation, but the difference diminishes with advancing age of the birds examined (*Sibbald,* 1981). Also, FEm+UEe varies among birds, but there is evidence that it is characteristic of bird species (*Sibbald* and *Price*, 1980). Variation in retained nitrogen (RN) contributes to variation in AME and TME values and nitrogen correction is intended to reduce this variation. *McNab* and *Fisher* (1981) suggest the possibility that the feeding of small rations to starved birds may lead to abnormal digestion. At high levels of feed intake FEm+UEe losses have only a slight effect on apparent ME value (*Sibbald*, 1975; 1976). Therefore, *Härtel* (1986) argued that the *Sibbald* procedure was less precise than the Conventional Addition Method (CAM), and that the *Sibbald* procedure gave incorrect TME and AME values, the reason for this being the use of starved birds. The objective of this study of these two research works was to determine: first, the influence of different levels of corn on the AME, AMEn, TME and TMEn values for this energy source. Second, test the hypothesis that AME and TME values decrease when energy consumption is reduced, all other conditions remaining constant.

MATERIALS AND METHODS

Two experiments were conducted using Rhode Island Red (RIR) line mature cockerels, by both the conventional addition method (CAM) and the *Sibbald* procedure. The cockerels were housed individually in metabolic cages in a temperature-controlled room with 14 hours of light per day in both experiments. Each cage was fitted with an individual feeder and a water nipple. A total of 88 birds, drawn from the same population, were used for the two procedures. Between assays the birds were fed a maintenance diet *ad libitum* and fresh water was available at all times, including the starvation period and the excreta collection period. A fixed aluminium tray was placed under each cage to allow droppings to be collected separately. In both experiments, modified plastic bags were used for the collection of faeces. Also, before the start of each experiment, the 88 birds were fasted for 24 hours to ensure that no feed residues remained in their alimentary tract. For the force feeding (*Sibbald* procedure) the experimental period was 72 hours and excreta were collected during the final 48 h. In the case of the Conventional Addition Method (CAM), the experimental period was 6 days: a 3-day pre-collection period and a 3-day collection period. Each experiment was designed with 10 levels of corn fed to 6 groups of adult RIR cockerels. The level of corn input was increased in 10 g increments in both experiments; the level of input (10 to 100 g) and the weight of corn consumed were recorded.

Additional 6 birds were given no feed and served as the controls in the measurement of metabolic faecal and endogenous urinary energy output. In the first experiment (force-feeding) the birds were fed various amounts of corn, each sample being placed directly in the crop from a pipe to ensure that a known amount of feed was ingested at a specific time. In the second experiment, performed with the CAM, the duration of the feeding period was altered in such a way that the adult cockerels voluntarily consumed all the corn offered. After this precision feeding, bags were immediately attached to each bird. The excreta voided during the 48-hour period were collected and their quantity recorded subsequent to which the samples were frozen to prevent microbial growth. Prior to analysis the frozen excreta samples were removed from the freezer, taken out of the bags and placed in an oven, to be dried at 90oC overnight. Samples of ground corn and excreta were assayed for gross energy by means of an adiabatic oxygen bomb calorimeter. When sufficient excreta samples remained after the determination of energy they were assayed for nitrogen in accordance with the method of *Kjeldahl* (AOAC, 1990). The experiment was conducted on the basis of a completely randomised design, with 10 levels of corn and 6 replicates, mean values for each corn level input also being determined for each replicate. Total intake of feed energy (IE), nitrogen (IN), total excreta energy (FE+UN) and nitrogen (FN+UN) were measured for each bird, and all data from the two experiments were evaluated by means of the formulae given below.

$$AME=[IE-(FE+UE)]/I \qquad (1)$$

$$AMEn=[(IE-(FE+UE)-K(IN-(Fn+Un)]/I \qquad (2)$$

$$TME=AME+EEL/I \qquad (3)$$

$$TMEn=AMEn+\frac{EEL+(RNo\times 8.73)}{I} \qquad (4)$$

$$RN=IN-(FN+UN) \qquad (5)$$

RESULTS

The results, in the form of AME, AMEn, TME and TMEn values, are shown in *Table 1*. These results are in agreement with the theories put forward by *Guillaume* and *Summers* (1970) and *Sibbald* (1975). As the data indicate, AME, AMEn, TME and TMEn values for corn vary in a with change in level of intake. The metabolisable energy and N-correction of metabolisable energy values obtained with the force feeding were higher than those determined by the *ad libitum* (CAM) according to mean amounts of feed intake level for corn. However, despite there being large differences between the methods, it is worthy of note that at low levels of feed consumption the AME and N-corrected metabolisable energy values derived by the force feeding method were lower than those obtained by the ad libitum (CAM). Besides this, the two procedures were not different with respect to feed ration quantity. More substantial was the differences observed between intercepts of both methods and is particularly magnitude to TME values for force feeding methods. Judging by the coefficient of determination (r^2) value adjustment and residual standard deviation (SD) it can be seen that the differences due of inherence of force feeding methods.

Values relating to corn quantity, body weight loss, feed energy, excreta energy, N balance and nitrogen correction is shown in *Table 2*. The correction to zero N-balance was reduced at all levels of corn quantity, and thus distinction has to be made between the two procedures. Therefore, correction to zero N-balance was reduced at all levels of corn input and values became less negative when corn intake was raised. The EEL obtained by means of force feeding method were lower than those produced by the ad libitum feeding (CAM). The EEL were among of methods at zero corn intake was differences, it is really characteristic of birds. Alternatively, these differences could be due to alterations in physiological systems. Thus, correction energy voided (EELn) of fast birds for both methods were positive and lower than uncorrected values. However, corrected excreta energy voided gradually reduced when corn intake increase. There was a general decline in body weight loss, although weight reduction did not follow a similar pattern for every feed ration level, an evident decrease in mean values was observed.

Table 1

Apparent and true metabolisable energy and N correction of metabolisable energy with different levels of corn input

Procedure(1)	Feeding rate(2)	AME	AMEn	TME	TMEn
CAM	10	8.73	13.09	16.53	16.07
	20	10.13	12.22	14.18	14.30
	30	13.09	14.34	15.77	15.31
	40	14.10	14.69	16.02	15.40
	50	13.16	13.51	16.15	14.10
	60	14.81	15.19	16.15	15.06
	70	14.31	14.64	15.40	15.19
	80	14.60	14.85	15.56	15.31
	90	14.64	15.02	15.52	15.23
	100	14.77	14.94	15.56	13.84
	Mean (kJ/g)(3)	13.23	14.25	15.68	14.98
	Intercept(4)	9.83	12.84	15.72	15.15
	Coefficient regression (slope) (5)	0.067	0.029	-0.0008	-0.0002
	S	2.31	1.14	0.97	0.93
	r	3.31	2.81	0.10	0.02
	r squared	2.56	1.81	-0.13	-0.13
	SE	0.51	0.30	0.35	0.33
Sibbald	10	6.85	12.83	14.01	15.43
	20	13.42	15.31	17.01	16.61
	30	14.89	15.44	17.28	16.28
	40	15.59	15.95	17.39	16.60
	50	14.94	15.94	16.36	16.44
	60	14.77	15.31	15.94	15.73
	70	15.06	15.90	16.10	16.28
	80	15.23	15.23	15.69	15.56
	90	15.10	15.02	15.90	15.30
	100	15.90	16.28	16.61	16.56
	Mean (kJ/g)	14.18	15.33	16.23	16.08
	Intercept	11.09	14.42	16.11	16.23
	Coefficient regression (slope)	0.059	0.018	0.0023	-0.0029
	S	2.63	0.99	1.24	0.62
	r	2.56	2.03	0.22	0.52
	r squared	1.49	0.90	-0.10	-0.04
	SE	0.72	0.30	0.43	0.21

1. táblázat: A takarmányadag hatása az AME, AMEn, TME, TMEn tartalomra

Módszer(1), Takarmányadag/állat(2), Átlag(3), Metszéspont(4), Regressziós együttható(5)

Table 2

Feed ration quantity levels, excreta energy, nitrogen balance and N correction

Feed input (g)(1)	Weight loss (g) (2)	Excreta energy voided (kJ/g)(3)		Corrected energy voided (kJ/g)*(4)		Nitrogen balance (g)(5)		N correction (kJ/g)(6)	
		Sibbald	CAM	Sibbald	CAM	Sibbald	CAM	Sibbald	CAM
0	129	66.61	72.68	24.18	30.25	-4.85	-5.10	42.38	44.60
10	148.50	101.42	83.85	45.81	43.60	-6.36	-4.60	55.56	55.56
20	155.25	80.12	136.77	44.98	99.08	-4.02	-4.31	35.10	37.66
30	125.00	79.75	136.77	64.35	103.85	-1.76	-3.77	15.36	32.89
40	101.00	80.06	134.22	66.90	109.33	-1.50	-2.55	13.10	22.30
50	96.50	130.92	194.56	83.72	180.29	-5.40	-1.63	47.15	14.23
60	116.75	165.98	152.72	136.27	131.50	-3.40	-2.43	29.66	21.21
70	151.75	174.35	217.86	120.21	194.10	-6.19	-2.72	54.10	23.77
80	71.00	219.95	226.06	187.02	208.87	-3.77	-1.97	32.89	16.78
90	26.66	221.08	254.22	214.14	224.60	0.79	-3.39	6.95	29.62
100	94.00	170.79	266.14	135.69	250.04	-4.02	-1.84	35.10	16.07
Mean	110.49	135.55	170.53	102.12	143.23	-3.68	-3.12	33.40	28.61
∑	1215.4	1491.03	1875.85	1123.28	1575.49	-40.46	-34.31	367.36	314.68
Var.	1488.7	796.30	1028.94	905.64	1285.26	1.11	0.34	63.27	40.76
SD	38.58	57.72	65.61	61.56	73.33	2.16	1.19	16.27	13.06

*Excreta energy corrected to zero nitrogen balance. (*Ürülék energiája 0 nitrogénmérlegre korrigálva*.)

2. táblázat: A takarmányarány mennyiségi és minőségi szintjei, valamint az ürülék energiája, a nitrogénmérleg, továbbá a nitrogén korrekció

Takarmánybevitel(1), Súlyveszteség(2), Ürülék energiatartalma(3), Korrigált energia(4), Nitrogén egyensúly(5), Nitrogén korrekció(6)

There was a linear relationship between the gross energy (kJ/g) voided as excreta and the amount of corn consumed. Therefore at zero energy content of corn zero energy voided as EEL was dieffent for force feeding and ad libitume feeding (58,53 to 77,11 kJ/g). In the cause, intercept value as EEL (77,11 kJ/g) by CAM higher than force feeding method (58,53 kJ/g). When corn intake is high the energy loss as EEL is relatively small but as the energy intake is reduced these energy losses as EEL become increasing.

Both methods showed excreta weight (Y) to increase in a linear manner as corn consumption of the cockerel's (X) increased. The results indicate that with both methods 6 to 6.3 g excreta was voided by the birds unfed corn (the control group). It was observed that during the experimental period an additional 0.1 to 0.12 g excreta was voided for each gram of corn fed; these values were approximately the same for both procedures. There was a correlation coefficient for the *Sibbald* method, which is 0.53, and the CAM method, which is 0.8.

The effect on metabolisable energy of level of corn intake indicates that AME depends on EEL per unit of feed intake. The TME values for corn was 16.24 kJ/g, but apparent ME value (14,18 kJ/g) was lower. The relationship between the latter two parameters proved to a hyperbolic curve with the apparent ME value approaching the true ME value at high levels of intake.

The data given in *Table 3* indicate that there was no significant (P>0.05) difference between the two methods (force feeding and ad libitum) with respect to values for apparent metabolisable energy (AME), nitrogen-corrected AME, TME or TMEn obtained for corn diets. Therefore, it seems that method of feeding has no effect on AME, AMEn, TME and TMEn values.

Table 3

Effect of procedure on metabolisable energy and nitrogen correction (kJ/g)

Procedure	AME	AMEn	TME	TMEn	Corrected energy voided	N correction
Sibbald	14.17±0.2	15.31±0.07	16.23±0.07	16.07±0.04	102.09±4.43	33.39±1.17
CAM	13.22±0.16	14.22±0.07	15.69±0.05	14.98±0.05	143.22±5.28	28.6±0.94

3. táblázat: A módszer hatása a metabolizálható energiára és a nitrogén korrekcióra (kJ/g)

DISCUSSION

The relationship between apparent ME values and corn consumption proved to be a hyperbolic curve, with the apparent ME value approaching the true ME value at high levels of intake. The results of this experiment clearly demonstrate that the apparent ME of corn was affected by level of intake (*Guillaume* and *Summers,* 1970; *Sibbald* 1975). This effect was attributed to the contribution made to the excreted energy by the EEL. The combined FEm+UEe losses may exceed energy input at low levels of feed consumption, thus yielding lower apparent ME values. At high levels of feed intake FEm+UEe losses have decreased and less effect on apparent ME value. There is a widespread belief that FEm+UEe losses in birds will vary with the nature and quantity of feed ingested.

Nitrogen retention in the cockerels also proved negative with both procedures at all levels of intake. Consequently, with respect to the corn intake levels used with the CAM, and in force feeding the values determined for AME were lower than those for AMEn, while the values for TMEn were lower than those for TME *Wolynetz* and *Sibbald* (1984). The values for metabolisable energy and N-corrected metabolisable energy obtained by the *Sibbald* procedure were higher than those determined by the ad libitum (CAM). More important that the different observed between intercept which determine particularly tendency to increase amount of TME values. Apparent dietary metabolisable energy values should vary with the level of feed intake because, under standardised conditions, the excretion of metabolic faecal energy (FEm) plus endogenous urinary energy (UEe) is constant. The intercepts of the regression equations determined by the *Sibbald* procedure were markedly different from those determined by the CAM (*Härtel*, 1986). The results obtained were not in agreement with those of *Härtel* (1986), who found that AME and nitrogen correction of TME were affected by the method of feeding.

The TMEn estimates were slightly lower than the TME values, and were independent of the feed ration quantity. As the result of among methods there were predicted energy excreted of unfed birds was lower (66,6 and 72,7 kJ/g) than the mean energy excreted by the fed birds. Thus, the data indicated that the effect of N-correction did indeed depend on the method of determination used (*Sibbald* 1976; *Sibbald* and

Morse, 1983). Therefore, correction to zero N balance was reduced at all levels of feed ration quantity; also, a distinction has to be made between the two procedures, as reduction of N-correction to zero was more precise with the CAM than with the *Sibbald* procedure. The progressive increase in feed ration quantity reduced negative N balances, and the *Sibbald* method produced lower EEL values than the CAM (*Sibbald*, 1975, 1981). However, the standard deviation and coefficient of determination (r^2) were low (0.32) for both procedures, but the ad libitum (CAM) was more favourable in this respect than the force feeding procedure. Both procedures showed substantial differences between intercepts and regression coefficients, and could influence the true metabolisable energy (TME) values, since for given TME value, AME depends on EEL per unit of feed intake (*Sibbald*, 1975). The weight of excreta (dry weight) produced by the cockerels increased in a linear manner as corn consumption increased with both methods (*Sibbald*, 1975).

This experiment showed the relationship between cumulative excreta energy and corn input: with both procedures the variation about the mean values increased with input level. When corn intake is high the energy loss as EEL is relatively small but the energy intake is reduced these energy losses as EEL become increasing and depressed AME values, (*McNab* and *Fisher,* 1981, *Sibbald* 1976, 1986). According the data EEL arrived of starvation and intercept of both procedures were had differences values. An intercept of 58.57 kJ/g was produced by the ad libitum (CAM) method; this value was higher than the value obtained by force feeding (*Sibbald* method). Consequently, in this case the CAM determined higher nitrogen retention than the *Sibbald* method. At high levels of corn intake FMe+UEe losses exert only a slight effect on apparent ME values. Furthermore, with both procedures AME values remained constant with increasing feed ration quantity. Also, the TMEn value of these feeds does not depend on the feed ration quantity (*Wolynetz* and *Sibbald*, 1984; *Sibbald* and *Wolynetz*, 1985).

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