Studies on the Energy Content of Pigeon Feeds I. Determination of Digestibility and Metabolizable Energy Content

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ABSTRACT The digestibility coefficient and metabolizable energy (ME) content of the most important pigeon feeds (corn, wheat, barley, red and white millet, sorghum, canary seed, peas, lentils, sunflower, and hemp) were determined. The experiment was carried out using 10 adult male homing pigeons. All feeds were fed alone, in a whole-grain form, *ad libitum*. Drinking water and grit were offered to the birds on a continuous basis. Each feedstuff was fed to five pigeons in 1-wk cycles. There was no significant difference between the values determined in pigeons and those reported in the literature for chickens among the digestibilities of the CP of the various feeds. For pigeons, the digestibility of carbohydrates (N-free extracts, NFE) was lower (e.g., 62.37 *vs* 83.00% for barley and 63.45 *vs* 77.00% for peas), whereas the ether extract (EE) was higher (e.g., 75.58 *vs* 61.00% for barley and 82.59 *vs* 80.00% for peas) in pigeons compared with chickens. As a result, the AME_n values determined in pigeons did not differ significantly from those reported for chickens but tended to be slightly higher. For feeds of high-oil content, that difference may be somewhat larger. The correlation between the CP, EE, crude fiber (CF), and NFE contents of the feeds and the ME values determined in this experiment were calculated by multivariate linear regression. It was concluded that it was more accurate to determine and tabulate the ME contents of other potential pigeon feeds directly by experimental methods rather than using an equation.

(*Key words*: pigeon, feed, digestibility, energy, prediction)

1999 Poultry Science 78:1757–1762

INTRODUCTION

Experiments necessary for determining the nutrient requirements of pigeons are rendered difficult because of several characteristic features of these birds (Waldie *et al.*, 1991): 1) Young pigeons continuously stay in the nest and are dependent on their parents for feed intake; 2) Initially, the parents feed the squabs with a special feed, so-called "crop milk"; and 3) Parents are strictly monogamous, and the pair remain together throughout their lives.

The scarcity of experimental data available on the nutrient requirements of pigeons is likely attributable to the above factors. The greatest amount of available information is related to protein requirements; however, the reported values show rather wide variation. At the same time, numerous indirect data exist on the breed-related weight and weight gain (Pelzer, 1990a,b) as well as the feed conversion ratio (Rizmayer, 1969) of young meat-type pigeons. Total annual feed consumption per pair has been measured directly in large-scale trials, and based upon the measured data, recommendations have been formulated for the nutrient content of mixed feeds (Morice, 1970; Levi, 1972, 1974; Klein, 1974; Orban, 1975; Csontos, 1981; Böttcher *et al.*, 1985).

Vandeputte-Poma and Van Grembergen (1967) and Hegde (1972) published valuable data on the amino acid composition of pigeon crop milk. From the digestive physiological point of view, the observations reported on the passage of feed through the crop are especially interesting. For instance, 15 g of wheat leaves the crop in 11 to 17 h, whereas the same quantity of barley takes 18 to 23 h (Kakuk, 1991). In that context, an interesting comparison was made possible by the experiments of Bokori (1968) on growing chickens, which revealed that labeled corn was completely excreted from the crop by the end of the fourth hour after feeding.

The digestive tract of pigeons in relation to body size is shorter than that of fowl (7:1 *vs* 8:1; Kakuk, 1991), presumably because of their flying ability, which requires that the body be as light as possible. At the same time, because of their lively temperament and high meta-

Received for publication March 29, 1999.
Accepted for publication September 1, 1999.
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Abbreviation Key: CF = crude fiber; DC = digestibility coefficient; EE = ether extract; NFE = N-free extract; OM = organic matter.

bolic rate, pigeons require a larger quantity of feed in proportion to their body weight. Because of the faster intestinal passage resulting from this metabolism, the efficiency of digestion is assumed to decrease. However, only few data, determined by specific digestion experiments, are available to support these concepts (Engelmann, 1963). An accurate knowledge of the nutrient requirements is only one of the conditions necessary for formulating pigeon diets that are nutritionally adequate. The other basic precondition would be to know the nutrient digestibility and ME content of individual feed ingredients. The relevant tabulated values have been derived from experiments on chickens and, because of lack of more precise data, these values are being used in the formulation of pigeon diets. Therefore, the objective of the present experiment was to determine the apparent digestibility coefficients (DC) and AME_n contents of grains regarded as the most important pigeon feeds. Our aim was to provide basic data for more precise formulation of mixed feeds and to determine whether the tabulated values obtained for chickens could be used in the formulation of pigeon diets.

MATERIALS AND METHODS

Experimental Design

The experiment was carried out in the animal facilities of the Department of Animal Breeding, Nutrition and Laboratory Animal Science, University of Veterinary Science, Budapest, Hungary in January and February, using 10 adult (2- to 3-yr-old) male homing pigeons with an average BW of 460 g. The birds were housed individually in metabolic cages suitable for quantitative measurement of the diet consumed, as well as the excreta produced. A room temperature of 15 to 18 C and a relative humidity of 60 to 75% were maintained throughout the experiment. The concentration of CO_2 was less than 0.2 vol %, whereas that of NH_3 was less than 0.002 vol %.

The test feeds included corn, wheat, barley, red millet, white millet, sorghum, canary seed, peas, lentils, sunflower, and hemp. All feeds were consumed alone, in grain form, *ad libitum*. Drinking water and grit were offered to the birds on a continuous basis. All birds were cared for according to the Canadian Council on Animal Care guidelines (CCAC, 1993).

Sample Collection and Chemical Analysis

Each feedstuff was fed to five pigeons in 1-wk cycles. The experimental phase consisted of two parts, the prefeeding period (3 d) and the main feeding phase (4 d). During the main phase, the amount of feed consumed was measured daily on an individual basis. Excreta were collected from each bird twice each day and were stored at −20 C until laboratory analysis. The 4-d excreta of one bird constituted one sample.

The gross energy (GE) content of feed and excrement samples was determined using an IKA C-400[2]-type adiabatic calorimeter. Separation of the N content of excreta into N of urinary and fecal origin was done by a chemical method (Jakobsen *et al.*, 1960). The DM, ash, CP (N × 6.25), crude fiber (CF), and ether extract (EE) contents of feed and excrement samples were determined according to the AOAC (1975).

Calculations and Statistical Analysis

Correlation among the CP, EE, CF, and N-free extract (NFE) contents of the feeds and the AME_n values experimentally determined by us were analyzed by multivariate linear regression (SPSS for Windows 5.0.1., 1992). Statistical evaluation of the DC and the ME values was done by the two-tailed *t*-test by SPSS for Windows 5.0.1. (1992) software.

This study was approved by the Animal Use and Care Administrative Advisory Committee of the Hungarian Scientific Chamber and complied with European Union directives regarding the use of experimental animals (CECAE, 1992).

RESULTS AND DISCUSSION

The chemical composition of the feeds and gross energy content were determined with a bomb calorimeter and are presented in Table 1. The data indicate that, the cereal grains, of the red-hulled variety of millet contains a somewhat higher amount of protein and energy than the white-hulled variety, although the difference was not significant. Canary seed contains a higher level of protein and more oil than millet. Peas and lentils are important protein sources, are low in EE, and most of their energy content comes from starch. Sunflower and hemp are good protein sources and provide considerable amounts of energy because of their oil content.

Table 2 shows the feed consumption values measured during the 4-d experimental cycles. The apparent digestibility and AME_n values of the nutrients of the test feeds, determined by a metabolic trial, are summarized in Table 3. Of all the feeds tested, corn had the highest dry and organic matter (OM) digestibility, but other cereal grains also had high digestibilities. In contrast, the digestibilities of lentil and hemp were of medium level. Interestingly, the digestibility of CP was excellent for all feeds, and that of the EE was similarly good for all feeds, except wheat and barley. At the same time, the digestibility of NFE could be considered only moderately good. The data seem to confirm the findings of Goodman and Griminger (1969), who suggested that pigeons could more efficiently utilize lipids than carbohydrates as energy sources.

The possibility is limited for comparing the data obtained in the present experiments with those of the literature, because very little relevant data have been pub-

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TABLE 1. Chemical composition and gross energy content of the feedstuffs

Feedstuff[1]	DM	Ash	OM	CP	CF	EE	NFE	GE
	(%)							kcal/kg
Corn	89.89	1.32	88.57	10.10	1.95	3.70	72.82	4,167
Wheat	90.28	1.69	88.59	13.70	2.06	1.73	71.10	4,084
Barley	89.56	3.08	86.48	11.40	3.91	2.13	69.04	3,869
Millet (red)	90.18	2.98	87.20	12.40	6.79	4.13	63.88	4,379
Millet (white)	86.83	2.71	84.12	11.55	6.64	3.95	61.98	4,110
Sorghum	86.68	1.76	84.92	11.65	2.65	4.08	66.54	3,924
Canary seed	89.10	5.21	83.89	16.90	4.63	6.30	56.16	4,241
Peas	90.21	2.80	87.41	23.40	3.72	1.10	59.19	4,220
Lentils	89.16	2.80	86.36	26.15	2.90	1.20	56.11	4,067
Sunflower	95.25	3.55	91.70	17.77	13.46	44.38	16.16	6,391
Hemp seed	94.68	5.06	89.62	24.13	20.72	32.38	12.39	5,597

[1]OM = organic matter; CF = crude fiber; EE = ether extract; NFE = nitrogen-free extract; and GE = gross energy.

lished for pigeons. Table 4 presents the values obtained by Engelmann (1963) in experiments comparing the digestibility of the OM content of some grains fed to chickens and to pigeons. In the present experiment, the OM digestibility of wheat was found to be practically identical, that of barley higher, and those of peas and lentils were lower than the respective values reported by Engelmann (1963).

The data reported in the literature for chickens offer somewhat more opportunity for comparing our findings in pigeons. This comparison is intriguing because, as mentioned earlier, the length of the digestive tract relative to body size is shorter in pigeons (7:1) than in fowl (8:1; Kakuk, 1991). The relative shortness of the pigeon's intestinal tract is, however, partially compensated for by the well-developed network of intestinal villi covering the intestinal mucosa, as well as by the more acidic character of all portions of the intestinal tract (crop, gizzard, intestines) compared with that of the fowl. In view of the above theoretical considerations, it would be interesting to know whether there are any differences between the two species in the digestibility and ME of the same feeds.

Table 5 presents those feeds for which reference data determined in chickens are available in the literature. As shown in the table, the pigeon diet includes many feeds that are seldom used in conventional poultry feeding; thus, the literature contains no data for them. Comparison is rendered difficult because the values published in tables represent the average of several experiments and because the analyzed samples are not identical. After this preliminary remark, it is shown that corn, wheat, peas and sunflower are the feeds for which the DC of CP measured in pigeons are the closest to those found in chickens. The finding applies to the digestibility of EE for peas and sunflower. With the exception of sunflower, the digestibility of NFE of all feeds was lower in pigeons. From this result, lower energy utilization can be expected. The comparison of the ME values shows that the values contained in the European Table (Janssen, 1989) tend to be lower than those of the NRC (1994). The values obtained from pigeons are closer to the figures of the cited European Table but are usually slightly higher than the latter. This comparison seems to contradict the statement concerning the digestibility of the NFE. It is striking, however, that in pigeons the DC of the EE of feeds are higher. This result suggests that pigeons can probably utilize lipids more efficiently than carbohydrates as an energy source. Although the pigeon, like the horse and rat, does not have a gallbladder, the lack of that organ does not prevent the utilization of fat contained in oilseeds, because bile production in the liver can adapt to the changing demands in a versatile manner.

TABLE 2. Average feed consumption of pigeons in different stages of the experiment (g)

Feed intake rank	Mean[1]	SD	%
1. Peas	132.00	5.96	100.00
2. Millet (white)	106.68	18.31	80.82
3. Canary seed	106.10	21.78	80.38
4. Lentils	105.95	29.06	80.26
5. Hemp seed	101.90	18.45	77.20
6. Barley	92.40	9.57	70.00
7. Corn	90.62	17.89	68.65
8. Millet (red)	86.46	10.38	65.50
9. Sunflower	76.80	17.89	58.18
10. Wheat	69.62	15.96	52.74
11. Sorghum	64.30	26.78	48.71

[1]Grams per 4 d; n = 5.

The question arises whether an applicable equation can be formulated from the experimental data for assessing the ME content of the hitherto unanalyzed pigeon feeds. While investigating that possibility, the following correlations were found by multivariate linear regression between the CP, EE, CF, and NFE content of the feeds and the ME values experimentally determined by us:

$$AME_n = 7.494 \times EE + 1.885 \times CP - 0.310 \times CF + 2.387 \times NFE + 1268,$$

where AME_n is expressed in kilocalories per kilogram, and EE, CP, CF, and NFE are as grams per kilogram of feed.

TABLE 3. Digestibility and AME_n content of the feeds analyzed (n = 5)

Feed	Dry matter	Organic matter	Crude protein	Ether extract	N-free extract	AME_n
	(%)					(kcal/kg)
Corn	81.25	82.38	85.15	82.33	77.27	3,527
SD	2.83	2.31	1.80	7.39	2.88	114
Wheat	75.52	77.80	85.75	73.20	70.85	3,325
SD	2.62	1.24	1.50	3.71	1.43	29
Barley	71.25	71.84	86.30	75.58	62.37	2,955
SD	2.38	3.14	1.89	4.90	4.10	107
Millet (red)	67.35	73.83	84.16	90.44	65.43	3,530
SD	3.86	2.88	1.76	1.98	3.62	100
Millet (white)	70.86	75.18	85.35	90.69	68.21	3,284
SD	2.66	3.29	1.71	2.49	4.34	143
Sorghum	76.81	82.13	86.02	93.32	77.57	3,315
SD	4.42	1.62	1.55	0.42	2.05	48
Canary seed	69.32	74.53	85.75	94.10	68.57	3,508
SD	5.97	5.23	2.98	2.60	6.32	155
Peas	71.71	71.20	85.70	82.59	63.45	3,348
SD	2.97	3.14	1.41	5.97	4.18	98
Lentils	64.65	65.51	85.48	93.64	56.21	3,057
SD	1.32	4.16	1.71	1.93	5.31	117
Sunflower	69.28	68.98	85.97	98.10	57.56	5,301
SD	5.17	5.46	3.11	0.46	7.70	167
Hemp seed	58.58	63.95	86.86	98.44	51.62	4,308
SD	5.12	5.75	1.79	0.45	7.82	243

AME_n = Apparent metabolizable energy corrected to zero nitrogen retention.

For the equation, $r^2 = 0.95$, the correlation was highly significant ($P < 0.001$). These favorable values, however, do not mean that no doubts arise regarding the validity and applicability of the above equation. One of the problems is that, of the coefficients of the independent variables, only the ether extract has an acceptable significance level ($P < 0.05$). In addition, the standard error is rather high as compared with the coefficients (EE: 3.22, CP: 3.77, CF: 5.06, and NFE: 3.75). Furthermore, based upon the correlation calculated according to Snedecor and Cochran (1967), there is a very close correlation between the individual independent variables (e.g., NFE – CF: r = 0.93; NFE – EE: r = 0.94). Because of the similarly strong correlation for AME_n and EE (r = 0.96), the question arises as to how much that close correlation can be attributed to the combined effect of the other variables. By calculating the partial correlation coefficient, it became clear that AME_n and EE are closely correlated (r = 0.69) even if the effects of the other variables are disregarded. Subsequently, we calculated the multivariate linear regression by the stepwise method (Hochberg and Tamhane, 1987). Only one factor, i.e., the EE, proved to have a significant effect. Therefore, the answer to the original question (whether an applicable equation can be formulated from the experimental data for assessing the ME content of the hitherto nonanalyzed pigeon feeds) is no, at least on the basis of the available data. A possible solution would be to expand the feed database by results from further experiments. This solution is, however, restricted by the limited number of different feeds usually fed to pigeons. In addition, increasing the number of samples in itself will not guarantee the reliability of the equation. Härtel (1977) could not obtain reliable results even after analyzing as many as 40 poultry feeds. According to his statement, the assessment of ME on the basis of crude nutrient content is markedly hindered by the fact that their digestibility may markedly differ depending on the feeds in which they occur. Excluding some "extreme" feeds, which would reduce the accuracy of correlation, can increase the reliability of the equation, which would set a limit to general applicability. In view of all these considerations, a feasible solution would be to increase the number of analyzed feeds up to a rational limit and to tabulate the results obtained, which could then be used for the formulation of pigeon feeds without applying the assessment equation.

In the context of energy requirements, several researchers have studied which energy sources can be considered most favorable for pigeons. It is accepted that

TABLE 4. Comparison of some grain feeds for the digestibility of organic matter in chickens and pigeons

Feed	Organic matter digestibility (%)		
	Chicken[1]	Pigeon[1]	Pigeon[2]
Wheat	81.1	78.1	77.8
Barley	72.8	64.1	71.8
Oats	73.2	61.9	. . .
Peas	80.0	77.9	71.2
Lentils	87.0	74.6	65.5
Broad beans	89.0	70.0	. . .

[1]Engelmann (1963).

[2]Present data.

TABLE 5. Comparison of the digestibility coefficients (DC) of feeds obtained in these experiments for pigeons with reference values reported in the literature for chickens[1]

	DC (%)						AME_n (kcal/kg)		
	CP		EE		NFE				
Feeds	I	II	I	II	I	II	I	II	III
Corn	85.15	84.00	82.33	92.00	77.27	90.00	3,527	3,501	3,346
Barley	86.30	68.00	75.58	61.00	62.37	83.00	2,955	2,871	2,637
Sorghum	86.02	72.00	93.32	83.00	77.57	91.00	3,315	3,379	3,208
Peas	85.70	86.00	82.59	80.00	63.45	77.00	3,348	2,802	2,566
Sunflower	85.97	85.00	98.10	96.00	57.56	12.00	5,301	3,425	. . .

[1]I = present data; II = Janssen (1989); III = NRC (1994); and AME_n = apparent metabolizable energy corrected to zero nitrogen retention.

fat is the main energy source for breast muscle function during prolonged flight. According to George and Jyotti (1955), in pigeons 77% of the energy necessary for muscle function is derived from the oxidation of lipids. Pigeon's crop milk is also known to contain much fat. These results prompted researchers to study what nutrients (lipids and carbohydrates) would be needed as an energy source for enhancing the performance of racing pigeons. Goodman and Griminger (1969) conducted five experiments with racing homing pigeons to observe the effect on performance exerted by the energy source. In each experiment in which fat supplementation was used (the fat content of the feed was raised from 3.4 to 8.4%, from 3.7 to 8.7%, and from 3.7 to 6.8%), the pigeons receiving the fat-supplemented feed surpassed the control pigeons in performance. Twice as many experimental pigeons as controls could travel a distance of 200 miles or more. From these results it was inferred that flying pigeons are likely to utilize fat more efficiently than carbohydrates as an energy source. Borghijs and De Wilde (1992) and Janssen *et al.* (1998) also stated that carnitine supplementation of the feed had a favorable effect on racing pigeons; it helped maintain the oxidative processes and prevent muscle damage during prolonged flight.

Summarizing our experimental findings, there was no appreciable difference between pigeons and chickens in the DC of the CP content of feeds. Although carbohydrates (NFE) have lower digestibility, EE has higher digestibility in pigeons than in chickens. As a result, the ME values determined in pigeons did not differ markedly from those found in chickens but tended to be slightly higher. This difference may be slightly more pronounced for seeds rich in oil. The DC and ME values as determined by this experiment may serve as reference data for the manufacture of pigeon feeds.

ACKNOWLEDGMENTS

The authors wish to thank the Hungarian Academy of Sciences (OTKA T 26606) and the Ministry of Education (FKFP-0644/97) for financial support for this study, and the Emese Andrasofszky for assistance in lab analyses.

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