Studies on the Metabolizable Energy Content of Ground Full-Fat Flaxseed Fed in Mash, Pellet, and Crumbled Diets Assayed with Birds of Different Ages

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ABSTRACT Four experiments were carried out to determine the AME_n of ground flaxseed in chickens of different ages and to study the effect of feeding flaxseed in pelleted or crumbled diets on flaxseed AME_n. A corn-soybean meal basal diet was prepared, in which the energy-yielding ingredients were substituted with ground flaxseed at 5, 10, 15, or 20%. Experiments 1, 2, and 3 consisted of these five dietary treatments replicated six times using 9-d-, 6-wk-, and 79-wk-old birds, respectively. A total collection procedure was used to measure diet AME_n, and linear regression analyses were used to calculate the AME_n value of flaxseed for birds at different ages. Experiment 4 involved birds fed either a basal or a 10% ground flaxseed diet prepared as mash, pellets, or crumbles. The flaxseed AME_n values obtained with 9-d- and 6-wk-old chickens were 2,118 and 2,055 kcal/kg, respectively. These values contrast with those of Experiments 3 and 4, in which mature roosters were fed mash diets with AME_n values of 3,560 and 3,654 kcal/kg, respectively. In Experiment 4, a significant improvement in flaxseed AME_n was observed when diets were pelleted or crumbled (4,578 and 4,277 kcal/kg, respectively). We concluded that the difference in AME_n of flaxseed observed in young birds vs. that found in mature birds was likely due to a greater tolerance of the latter to flaxseed, with less evidence of diarrhea. Feeding flaxseed in pellet or crumbled diets can significantly increase AME_n value.

(*Key words*: metabolizable energy, linseed, flaxseed, chickens, feed form)

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INTRODUCTION

In the last decade, there has been interest in increasing the omega-3 fatty acid (n-3) content of human diets. It is known that feeding n-3-enriched diets to poultry increases the n-3 content of eggs and meat and thus, enriched poultry products offer consumers an alternative to enhance their n-3 daily intake (Leskanich and Noble, 1997).

Flaxseed is a rich source of protein (22.4%) and lipids (37.4%) for poultry (Lee et al., 1995). Recently, flaxseed has gained popularity as an ingredient due to its content of linolenic acid, which is an n-3 fatty acid. However, reduced performance has been reported in birds fed flaxseed (Ajuyah et al., 1990, 1991, 1993). Caston et al. (1994) reported increased feed consumption in laying hens attributable to differences in the ME of experimental diets containing no flaxseed or 10 and 20% flaxseed. These researchers estimated the AME_n of a 20% flaxseed diet used in the trial to be 2,906 kcal/kg, in contrast to the subsequently determined AME_n of 2,440 kcal/kg. Increased feed intake was observed in our laboratory (data not published) in broilers fed diets containing 10% flaxseed for 7 and 14 d compared with that of birds fed a diet without flaxseed. In this trial, the dietary ME could have affected, at least partially, the feed intake of the birds.

The information reported on the ME content of flaxseed is conflicting. Lee and Sim (1989), in a trial involving mature Single Comb White Leghorn roosters (WLR), used diets containing 30% ground flaxseed and determined the TME_n value of flaxseed to be 3,774 kcal/kg. Barbour and Sim (1991), also using mature WLR, calculated the TME_n of flaxseed to be 3,957 kcal/kg. More recently, Lee et al. (1995) calculated the AME_n of flaxseed and a reconstituted mixture of flaxseed meal + flaxseed oil in adult WLR. The AME_n value obtained for flaxseed was considerably lower than that of the reconstituted mixture (3,750 vs. 4,910 kcal/kg, respectively). These workers suggested that the AME_n value of flaxseed may be influenced by the presence of some deleterious compounds in the raw

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Abbreviation Key: WLR = Single Comb White Leghorn roosters.

TABLE 1. Composition of experimental diets

	Basal diet	Flax inclusion			
		5%	10%	15%	20%
Ingredients[1]					
Yellow corn, g/kg	545.7	517.2	488.5	460.0	431.4
Soybean meal (48%), g/kg	377.4	357.7	338.1	318.4	298.8
Animal-vegetable fat, g/kg	31.7	30.0	28.4	26.8	25.1
DL-methionine, g/kg	2.2	2.1	2.0	1.9	1.8
L-lysine HCl, g/kg	0.4	0.4	0.4	0.3	0.3
Flaxseed (ground), g/kg	0.0	50.0	100.0	150.0	200.0
Limestone, g/kg	16.9	16.9	16.9	16.9	16.9
Dicalcium phosphate, g/kg	12.0	12.0	12.0	12.0	12.0
Salt, g/kg	3.7	3.7	3.7	3.7	3.7
Mineral-vitamin premix, g/kg[2]	10	10	10	10	10
Calculated analysis					
AME_n, kcal/kg	3,050	3,071	3,090	3,113	3,135
Crude protein, %	23.0	22.9	22.8	22.7	22.6
Lysine, %	1.35	1.33	1.30	1.27	1.25
Methionine − cystine, %	0.95	0.94	0.93	0.92	0.91
Calcium, %	1.0	1.0	1.0	1.0	1.0
Available phosphorus, %	0.45	0.45	0.45	0.44	0.44

[1]Yellow corn, soybean meal (48%), animal-vegetable fat, DL-methionine, and L-lysine HCl were considered to be the energy-yielding ingredients.

[2]Provides per kg of diet: vitamin A, 8,800 IU; (retinyl palmitate)l cholecalciferol, 3,300 IU; vitamin E, 40 IU (dl-α-tocopheryl acetate); thiamin, 4 mg; riboflavin, 8.0 mg; pyridoxine, 3.3 mg; biotin, 0.22 mg; pantothenic acid, 15.0 mg; vitamin B_{12}, 12 mg; niacin, 50 mg; choline, 600 mg; vitamin K, 3.3 mg; folic acid, 1 mg; ethoxyquin, 120 mg; manganese, 70 mg; zinc, 70 mg; iron, 60 mg; copper, 10 mg; iodine, 1 mg; and selenium, 0.3 mg.

seed. There is currently no information on the AME_n of flaxseed determined with young birds, or what effect pelleting may have on flaxseed utilization. Thus, four experiments were designed to 1) determine the AME_n value of ground flaxseed in 9-d-old chicks, 6-wk-old broilers, and mature WLR, and 2) to study the influence of the feed's physical form on the AME_n value of flaxseed for mature WLR.

MATERIALS AND METHODS

A practical corn-soybean meal basal diet (Table 1) was used for the determination of ME of flaxseed. The basal diet was formulated to meet the NRC (1994) requirements. Ground flaxseed was included in the basal diet at the expense of the energy-yielding ingredients at 5, 10, 15, and 20% using the procedure described by Ali and Leeson (1995). Four experiments were conducted with birds at different ages.

Experiment 1

One-hundred 20-d-old male broilers of a commercial strain were randomly assigned to 30 groups of four birds each. The chicks were reared in a battery brooder located in a mechanically ventilated room with 24-h light. The temperature was maintained at 32.5 C from 0 to 5 d and then was gradually reduced according to standard brooding practices. Mash feed and water were available for consumption ad libitum. A basal diet (Table 1) was fed to birds from 1 to 5 d of age. At 6 d of age the 30 groups of birds were randomly assigned to five experimental treatments using six replicates each and comprising birds fed the basal diet and diets with graded levels of ground flaxseed (5, 10, 15, and 20%, Table 1).

Experiment 2

Thirty 18-d-old broilers from the previous experiment were randomly allocated individually to cages measuring 61 × 50 cm and 16 cm height, skipping alternate cages to prevent excreta contamination, and each cage was equipped with separate feeders. Birds were fed mash diets for consumption ad libitum, and water was also provided at all times. Birds were kept in a temperature-controlled room under a 23-h light:1-h darkness daily program. At 6 wk of age, birds were randomly assigned to five treatments using six replicates each and consisting of birds fed a basal diet or diets containing 5, 10, 15, and 20% flaxseed (Table 1).

Experiment 3

Thirty 79-wk-old WLR were randomly allocated to five dietary treatments with six replicate birds each. Roosters were fed mash diets either without flaxseed (Table 1) or with graded levels of flaxseed (5, 10, 15, and 20%). Birds were housed in individual cages equipped with separate feeders, skipping alternate cages to avoid excreta contamination. Room temperature was 22 C, and light was provided for 16 h/d.

Experiment 4

Thirty 81-wk-old WLR were randomly housed in individual cages and kept under the conditions outlined in Experiment 3. Five birds were randomly assigned to each

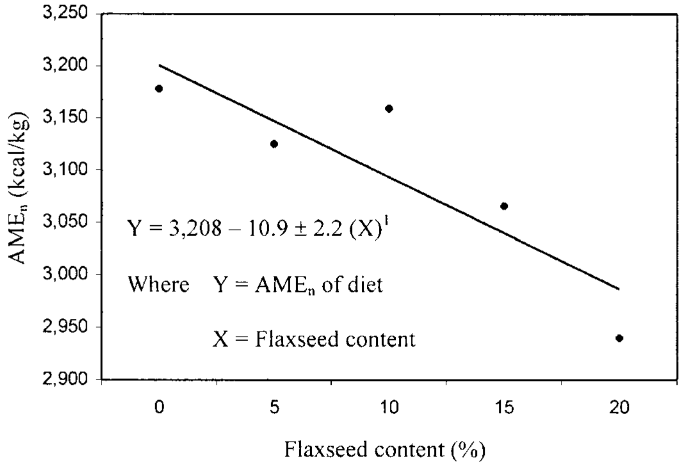

FIGURE 1. AME_n content of experimental diets assayed with 9-d-old broilers (note: when X = 100%, the AME_n value is 2,118 ± 220 kcal/kg). [1]$P < 0.01$; $r^2 = -0.66$.

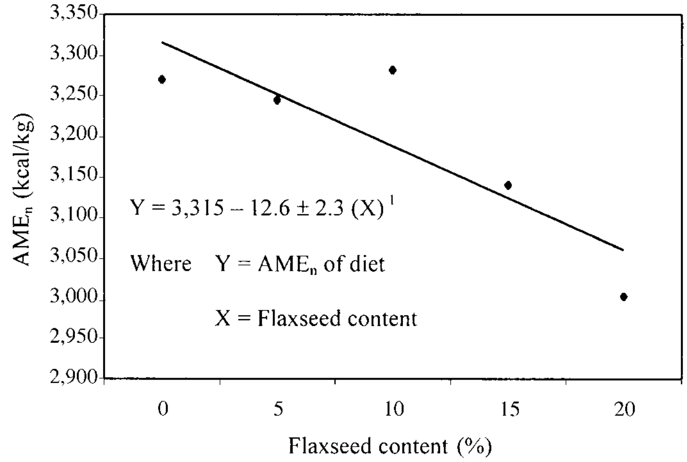

FIGURE 2. AME_n content of experimental diets assayed with 6-wk-old broilers (note: when X = 100%, the AME_n value is 2,055 ± 230 kcal/kg). [1]$P < 0.01$; $r^2 = -0.74$.

of six treatments involving mash, pelleted, or crumbled diets that contained 0 or 10% ground flaxseed (Table 1). Diets were fed to allow consumption ad libitum, and each treatment was represented by five replicate birds.

General Procedures

In all experiments, an adaptation period of 4 d was used, during which experimental diets were fed to birds prior to starting the excreta collection. Over the next 4 d, all excreta were collected on aluminum foil trays. During this period, feed was maintained at low levels to avoid spillage. Feathers, down, and feather scales were removed daily. All spilled feed was weighed and carefully removed from the excreta. The feed intake of each group was measured. At the end of the collection period, the excreta were wrapped in the foil and dried in an oven[3] at 50 C for 3 d. The excreta and feed samples were ground using a commercial blender.[4] The ground samples were allowed to come to equilibrium with the atmosphere for 3 d, and excreta were weighed for each group, and then stored for further analysis. Gross energies of feed and excreta from each group were assayed by the complete combustion of the samples in a C5003 ika adiabatic bomb calorimeter.[5] The nitrogen contents of feed and excreta were determined using a Leco nitrogen analyzer.[6] The AME_n of flaxseed for Experiments 1, 2, and 3 were calculated using the total collection technique described by Leeson et al. (1974) and, subsequently, using regression analysis (Potter et al., 1960). For Experiment 4, the AME_n of flaxseed was determined using the total collection method. All values obtained were corrected for nitrogen retention using the correction factor of 8.22 kcal/g as described by Hill and Anderson (1958).

RESULTS

In Experiments 1 and 2, the AME_n of the experimental diets decreased when flaxseed was added to the basal diet (Figures 1 and 2). This effect is described by the equations Y = 3,208 − 10.9 ± 2.2 (X) and Y = 3,315 − 12.6 ± 2.3 (X), where Y is equal to the AME_n of the test diet (kcal/kg) and X is the percentage of ground flaxseed included in the experimental diet. The AME_n of flaxseed was calculated when the basal diet was fully substituted by flaxseed (X = 100). These values are 2,118 and 2,055 kcal/kg for 9-d-old birds and for 6-wk-old birds, respectively, and represent the AME_n of flaxseed.

In Experiment 3, the AME_n of diets with increasing levels of flaxseed showed a slight increase when assayed with mature WLR (Figure 3). Such change is described by the equation Y = 3,270 + 2.9 ± 1.7 (X). The AME_n value of flaxseed calculated from this equation was 3,560 kcal/kg.

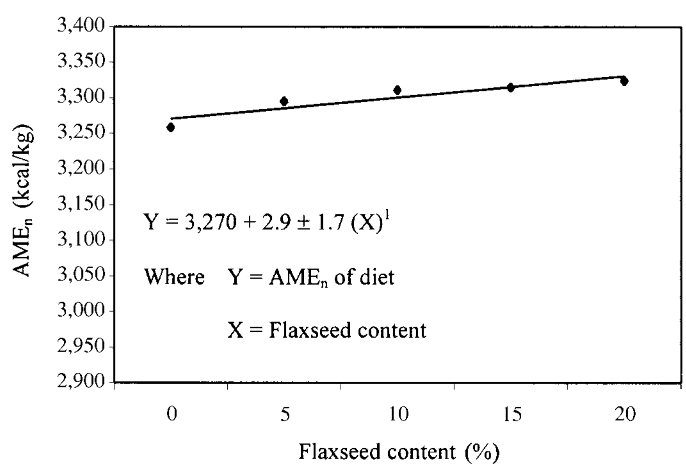

FIGURE 3. AME_n content of experimental diets assayed with 79-wk-old roosters (note: when X = 100%, the AME_n value is 3,560 ± 170 kcal/kg). [1]$P < 0.05$; $r^2 = 0.31$.

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[3]Hotpack, Philadelphia, PA 19154.
[4]Waring Products Division, New Hartford, CT 06057-0000.
[5]GMBIT and CO. KG D-79219, Staufen, Germany.
[6]Leco Instruments, Stockport, Cheshire SK7 5DA, UK.

As shown in Figure 4, the AME_n of flaxseed obtained from mash diets containing 10% flaxseed when tested with mature WLR was 3,654 kcal/kg. However, this value increased significantly ($P < 0.01$) when feed was pelleted or crumbled (4,578 and 4,277 kcal/kg, respectively). There was no difference ($P > 0.05$) in AME_n value between flaxseed fed to roosters as pellets vs. crumbles.

In all trials, flaxseed diets produced diarrhea when fed to birds. The severity of this condition was dependent on the levels of flaxseed, and was most evident in 9-d-old chicks and, to a lesser extent, the 6-wk-old broilers.

DISCUSSION

There are no previous reports on the AME_n value of flaxseed that utilize regression analysis. It is known that the greater the proportion of basal diet substituted by the test ingredient, the greater the accuracy of the AME_n value. The levels of flaxseed used in the current experiments were chosen based on the assumption that it is advisable to measure the AME_n of the test ingredient using concentrations similar to those to be used in practice (Leeson et al., 1974).

The AME_n values of flaxseed obtained with young birds in Trials 1 and 2 were significantly lower than the value obtained with mature WLR (Trial 3). The results of Trial 3 agree with the flaxseed ME values previously reported (all experiments were carried out with mature roosters) (Lee and Sim, 1989; Barbour and Sim, 1991; Lee et al., 1995). This situation implies that digestion and absorption of nutrients from experimental diets were lower in young birds than in roosters. However, it is well known that feeding flaxseed to young broilers increases the n-3 content of their tissues, which implies an active absorption of flaxseed lipids, which are the main energy-yielding compounds of the seed. On the other hand, flaxseed contains phytic acid (Palmer et al., 1980), which is known to adversely affect proteins by forming electrostatic linkages with lysine, arginine, and histidine, and by inhibiting proteolitic enzymes (Caldwell, 1992; Ravindran et al., 1995). In addition, flaxseed contains three cyanogenic glycosides, mainly linamarin, linustatin, and neolinustatin. These substances can form hydrogen cyanide, which is potentially toxic (Chadha et al., 1995). Moreover, in traditional medicine, one tablespoon (i.e., approximately 10 g) of flaxseed soaked overnight is used as a laxative for humans (Rosling, 1993). Scheideler and Froning (1996) also reported a laxative effect in hens fed flaxseed. Other components, such as allergens and mucilage present in flaxseed (Spies, 1974; Palmer et al., 1980), could also affect utilization of nutrients. Thus, the action of several antinutritional factors, along with the diarrhea produced by flaxseed diets, could account for the low AME_n of flaxseed obtained in young birds. This situation probably influenced not only the absorption of nutrients from flaxseed, but also that of the fraction of basal diet contained in the test diets, because rapid passage rate will decrease the digestibility of all components of the diet. However, because of the method of calculation, the decreased ME is attributed to the added ingredient. As mentioned previously, the diarrhea was more evident in 9-d-old chicks and, to a lesser extent, in 6-wk-old birds. Diarrhea was much less severe in mature roosters, which suggests a certain degree of tolerance that develops as the birds age. The antinutritional substances mentioned above, the diarrhea produced in birds, and the apparent susceptibility of younger birds to the negative effects of flaxseed could partially explain the low AME_n values obtained in Experiments 1 and 2 relative to the higher values obtained in Experiment 3.

The flaxseed AME_n value obtained using mash diets in Experiment 4 confirms values determined in Experiment 3. However, the values obtained with pelleted and crumbled diets were significantly higher ($P < 0.01$). Pelleting is a process in which the ground feed is moistened and passed through a die under pressure to form the pellet. Crumbles are formed by partially breaking up pellets. Two possible mechanisms could explain the improvement in AME_n of full-fat flaxseed fed as pellets or crumbles vs. mash as observed in this trial. It is known that in oily seeds, pressure and heat break the cell in which the oil is stored, and this improves lipid utilization (Calet, 1965). Allred et al. (1957) reported that the fat absorption of crude full-fat soybeans increased from 73 to 91% when fed as mash vs. pellets, respectively. Heating produced by the pelleting process could also destroy some toxic compounds present in the feed (Calet, 1965; Scott et al., 1982). Nikolaiczuk (1950) reported that the adverse effects associated with feeding flaxseed meal to young chicks were partially overcome by pelleting the diet. Madhusudhan et al. (1986) also reported that birds fed a diet in which 20% groundnut protein was replaced with raw flaxseed meal (i.e., 6.5% of total ingredients) had a significantly lower performance than did those fed a diet in which 50% groundnut protein was substituted with water-boiled flaxseed meal (i.e., 13% of total ingredients). The average live body weight of the former group of birds at 8 wk of age was 740 g, vs. 1,280 g for the latter. Possibly, the antinutritional factors contained in

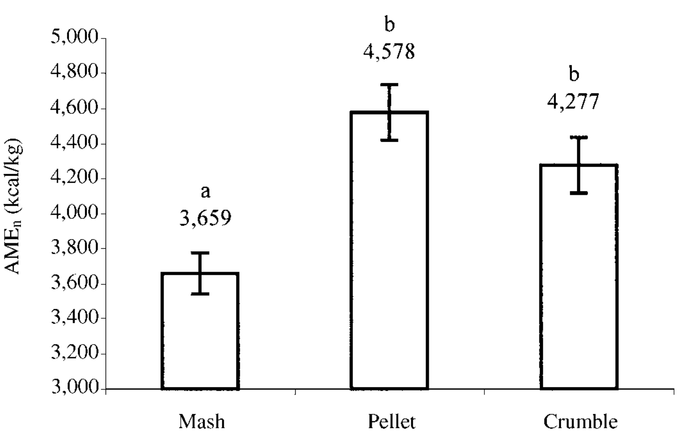

FIGURE 4. AME_n of flax in 79-wk-old roosters included at 10% in mash, pelleted, or crumbled diets. [a,b]Means with different letters differ significantly ($P < 0.01$).

the unprocessed flaxseed meal could account for the remarkable differences in body weights observed in these two groups of birds.

It is concluded that a low tolerance for ground flaxseed fed in mash form is shown in 9-d- and 6-wk-old birds. Consequently, the AME_n of flaxseed diets when assayed with young birds is low compared with that obtained with mature birds. The AME_n contents of flaxseed obtained in mature WLR in Experiments 3 and 4 were 3,560 and 3,654 kcal/kg, respectively. Feeding flaxseed to mature roosters in pellet or crumbled form increased its AME_n from 3,654 kcal/kg to 4,578 and 4,277 kcal/kg, respectively. It would be of interest to test the AME_n of heat-processed flaxseed for younger birds.

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