A Nutritional Evaluation of Corn Wet-Milling By-Products with Growing Chicks and Turkey Poults, Adult Roosters, and Turkeys, Rats, and Swine

H. S. BAYLEY, J. D. SUMMERS, and S. J. SLINGER[1], University of Guelph, Guelph, Ontario

ABSTRACT

The absorbabilities of the energy-yielding components of three corn wet-milling by-products were measured with young growing chicks and turkeys, adult roosters and turkey toms, swine, and laboratory rats. The corn fiber remaining after corn wet-milling, corn fiber to which the soluble material removed during wet-milling had been re-added, and a commercial corn gluten feed were assessed. The effects of steam-pelleting the first two products on the nutrient absorbability were examined. The by-products were substituted for 50% of a basal diet to allow estimation of metabolizable and digestible energy values. None of the animals utilized the corn fiber well and steam-pelleting resulted in no improvement. The addition of the soluble material to the fiber resulted in a product with a lower crude fiber content which was better utilized by the experimental animals. However, this product was not improved by steam-pelleting. The commercial product was not well utilized by the chickens, roosters, or young turkeys, but could be a valuable ingredient in rations for turkey breeding stock and swine.

Examination of the results of the proximate analyses of corn gluten feed (1) indicates that it is a valuable feed for ruminants but there is little information concerning the nutritional value of the by-products of corn wet-milling for monogastric animals. In the corn wet-milling process, two main by-products are produced: insoluble fibrous residues and a solution of low-molecular-weight compounds. To fully exploit these materials, it is necessary to investigate their nutritional values. This study was designed to measure the availability of the nutrients, which upon absorption and catabolism could supply energy to the animal. Samples of the fibrous material and of the fiber to which the soluble products had been re-added and the resultant mixture dried were evaluated along with a commercially produced sample of corn gluten feed. Bayley et al. (2) have shown that the nutritional value of wheat bran could be increased by steam-pelleting and so the effect of steam-pelleting the corn wet-milling by-products was evaluated. The results of the earlier study indicated that it was difficult to extrapolate the results obtained with young chicks to adult roosters and so in this study a variety of monogastric animals were employed: young growing chicks and turkey poults, adult roosters, turkey toms, swine, and laboratory rats. Nutrient digestibility, digestible and metabolizable energy (ME) values were used as criteria to evaluate the products.

MATERIALS AND METHODS

In the commercial corn wet-milling process, whole corn is steeped in a 0.2% solution of sulfur dioxide at 50°C., and after 36 to 48 hr., the steep water is removed from the corn. The corn is then coarsely ground and the starch separated

[1]Respectively: Departments of Nutrition, Poultry Science, and Nutrition.

from the germ and other fibrous residues. Samples of these fibrous residues were either dried and are referred to as "corn fiber," or the steep water-solubles and the fiber were combined (1:3) and are referred to as "corn fiber plus solubles." The commercial product was similar to the corn fiber plus solubles but was steam-pelleted during manufacture. The proximate components of the by-products were determined as described earlier (2) and the results are shown in Table I. Part of the sample of corn fiber and the corn fiber plus solubles was steam-pelleted as described in (3). All the by-products were then ground to the same degree of fineness. A basal diet was prepared as shown in Table II which was adequately fortified so that the experimental diets made by substituting 50% of the basal diet with 50% of corn by-product still contained sufficient levels of critical nutrients.

Balance studies were carried out with light hybrid chicks, Large White turkeys, specific-pathogen-free Yorkshire swine, and Wistar rats. The young birds were placed in electrically heated tier brooders at day of age and received a well-balanced

TABLE I. COMPONENTS OF CORN WET-MILLING BY-PRODUCTS

	Corn Fiber[a]		Corn Fiber Plus Solubles[b]		Commercial Product[c]
	Not Pelleted	Reground Pelleted	Not Pelleted	Reground Pelleted	
Dry matter (%)	92.9	88.9	91.8	84.9	90.3
Crude protein (% N X 6.25)[d]	11.0	10.5	20.8	21.8	21.2
Crude fiber (%)[d]	15.7	14.6	10.8	10.4	8.8
Ether extract (%)[d]	2.7	3.4	3.3	3.6	4.1

[a]Fibrous by-product of corn wet-milling.

[b]The water-soluble material extracted during corn wet-milling added back to the fibrous by-product and dried.

[c]"Buffalo Kracklets," CPC International, Inc. brand of corn gluten feed.

[d]Values presented on a 90% dry-matter basis.

TABLE II. COMPOSITION OF BASAL DIET

Ingredient	Amount	Composition	%
		(Determined)	
Ground corn	65.75	Dry matter	87.9
Soybean oil meal (50% protein)	30.00	Crude protein (% N X 6.25)[b]	20.8
Calcium phosphate (21% Ca, 20% P)	2.20	Crude fiber[b]	2.9
Ground limestone (38% Ca)	1.00	Ether extract[b]	3.5
Iodized salt	0.30		
Vitamin and trace mineral supplement[a]	0.75		

[a]The vitamin and trace mineral supplement supplied the following levels of nutrients per kg. of diet: vitamin A, 3,400 USP units; vitamin D-3, 1,300 ICU; riboflavin, 55 mg.; calcium d-pantothenate, 10 mg.; vitamin B-12, 7 γ; niacin, 11 mg.; choline chloride, 290 mg.; menadione sodium bisulfite, 0.45 mg.; ethoxyquin, 290 mg.; manganese, 53 mg.; zinc, 50 mg.; copper, 9 mg.; iron, 19 mg.

[b]Values presented on a 90% dry-matter basis.

diet for 7 days, at which time they were individually weighed and distributed to the experimental groups so that the mean weight of each group was similar. Each diet was fed to four groups of ten chicks and to five groups of six poults. The feed consumed was measured between the 21st and 23rd days of age and the droppings produced during this time were collected, freeze-dried, weighed, and ground for analysis. The adult birds (12 months old) were housed in individual cages and five roosters and four turkey toms received each experimental diet for 14 days. Feed consumption was measured during the last 4 days and the droppings produced were collected, weighed, thoroughly mixed, and duplicate subsamples freeze-dried and ground for analysis.

Eight cages were available for measuring the feed consumption and collection of the feces produced by the swine. Two sets of eight barrows were used in the evaluation of the diets; in each set two pigs each received the basal diet, the two diets containing the corn fiber, and the diet containing the commercial product. The pigs were brought into the laboratory and were introduced to the experimental diets in individual pens. The day's allotment of feed (1.5 kg.) was divided into two approximately equal meals and was fed as a wet paste. When the pigs had learned to consume their full allocation of feed, they were weighed and transferred to the cages, and after they had become accustomed to the cages and consumed all of the day's allotment of feed for 10 days, the feces voided from 4 consecutive days' feed were collected, weighed, thoroughly mixed, and duplicate subsamples freeze-dried and ground for analysis. The rats were housed in individual cages and were allowed 10 days to become accustomed to the experimental diets. Feed consumption was then measured for 4 consecutive days and the feces produced during this time were again freeze-dried, weighed, and ground for analysis.

The analyses of feed, droppings, and excreta were carried out as described earlier (2) and the ME value of the by-products were calculated from the ME values of the basal diet and the diets containing the by-products by the expression:

$$\text{ME of by-product} = 2\left[\text{ME of diet containing by-product} - \frac{\text{ME of basal diet}}{2}\right]$$

To compare ME values obtained with birds retaining different amounts of nitrogen, Hill and Anderson (4) corrected ME values to zero nitrogen retention by assuming that the retained nitrogen, when excreted, would be oxidized to uric acid and thus contribute 8.22 kcal. per g. of nitrogen to the energy value of the excreta. To facilitate comparisons between the young birds which were retaining nitrogen and the adult birds which were in nitrogen equilibrium, both the classical and nitrogen-corrected ME values are presented.

Analyses of variance of each parameter were carried out, and the standard error of the means ($S\bar{x}$) calculated. These were used as a basis for comparison of the results by Duncan's multiple range test. The 5% level of probability was used as the basis for statistical significance. The experiments were analyzed as simple randomized block designs, except for the experiment with the pigs, which was analyzed as a split-plot design with the split factor being the time of the experiment (first and second). The statistical analyses of the data were carried out as described by Steel and Torrie (5).

RESULTS AND DISCUSSION

Table III summarizes the effects of adding corn by-products to the basal diet for young chicks and roosters. The digestibility of the dry matter was significantly depressed by the addition of all the products for both the chicks and roosters. Diets containing the added solubles were better digested than those containing the fiber. Steam-pelleting did not improve the digestibility of either product. The young chicks digested the commercial product significantly better than the other products, but the roosters utilized it only as well as the corn fiber plus solubles.

TABLE III. UTILIZATION OF A BASAL DIET AND DIETS CONTAINING 50% CORN WET-MILLING BY-PRODUCTS BY YOUNG CHICKS AND ADULT ROOSTERS

Type of By-Product (Steam-Pelleting Treatment)	Age of Bird	Basal Diet[b]	50% Basal Diet + 50% Corn By-Product[b]: Corn Fiber, Not Pelleted	Corn Fiber, Steam Pelleted	Corn Fiber Plus Solubles, Not Pelleted	Corn Fiber Plus Solubles, Steam Pelleted	Commercial Product	$S\bar{x}$[a]
Dry-matter digestibility (%)	Young	74	48	49	54	55	58	0.4
	Adult	67a	44b	45b	54c	51c	51c	1.9
Nitrogen retention (mg./g. of feed)	Young	18a	12b	11b	15c	15c	13b	0.5
	Adult	3a	0a	0a	3a	4a	−1a	1.8
Classical metabolizable energy value (kcal./g.)	Young	3.07a	2.16b	2.10c	2.41d	2.43d	2.50e	0.014
	Adult	2.97a	2.13b	2.06b	2.51c	2.40d	2.35d	0.058
Nitrogen-corrected[c] metabolizable energy value (kcal./g.)	Young	2.92a	2.06b	2.01b	2.31c	2.30c	2.39d	0.017
	Adult	2.94a	2.13b	2.05b	2.48c	2.37c	2.36c	0.053

[a]Error mean square degrees of freedom: 15 for young chicks and 18 for roosters.

[b]Means on the same line followed by the same letters do not differ at the 5% level of probability.

[c]Corrected to nitrogen equilibrium by allowing 8.22 kcal./g. for the excretion of retained nitrogen.

The young growing birds were retaining nitrogen, whereas the nitrogen retention of the adult roosters was not significantly different from zero. For the chicks, the inclusion of any of the corn by-products in the diet reduced the nitrogen retention. The classical ME values are shown, but since the nitrogen retentions of the young growing birds and of the adults were so different, it is more meaningful to study the ME values corrected to zero nitrogen retention. These ME values exhibit the same pattern as the dry-matter digestibility values. Both the young birds and the adults metabolized the basal diet and the diet containing the commercial product equally well, but the adults appeared to metabolize the diets containing the nonpelleted fibrous materials to a greater extent than did the young chicks.

The results obtained with turkeys are shown in Table IV. The young poults digested the dry matter to a similar extent,as did the young chicks; however, the adult turkeys digested the fibrous material better than the roosters. Both the young, growing poults and the adult turkey toms were retaining nitrogen; nitrogen retention of the poults was significantly depressed by substitution of the by-products for part of the basal diet, but this effect was not significant for the adult birds. The nitrogen-corrected ME values of the whole diets show that the

TABLE IV. UTILIZATION OF A BASAL DIET AND DIETS CONTAINING 50% CORN WET-MILLING BY-PRODUCTS BY YOUNG TURKEY POULTS AND ADULT TURKEY TOMS

Type of By-Product (Steam-Pelleting Treatment)	Age of Bird	Basal Diet[b]	50% Basal Diet + 50% Corn By-Product[b] Corn Fiber Not Pelleted	Corn Fiber Steam Pelleted	Corn Fiber Plus Solubles Not Pelleted	Corn Fiber Plus Solubles Steam Pelleted	Commercial Product	$S_{\bar{x}}$[a]
Dry-matter digestibility (%)	Young	74a	48b	48b	56c	55c	56c	1.2
	Adult	72a	49b	51b	62c	58c	59c	1.6
Nitrogen retention (mg./g. of feed)	Young	19a	12b	12b	19a	15c	15c	0.5
	Adult	8a	5a	6a	10a	6a	3a	1.7
Classical metabolizable energy value (kcal./g.)	Young	3.00a	2.08b	1.99b	2.40c	2.35c	2.36c	0.045
	Adult	3.05a	2.22b	2.20b	2.73c	2.55d	2.31b	0.051
Nitrogen-corrected metabolizable energy value (kcal./g.)	Young	2.84a	1.98b	1.89b	2.24c	2.21c	2.24c	0.042
	Adult	2.98a	2.18b	2.15b	2.65c	2.50d	2.53cd	0.041

[a]Error mean square degrees of freedom: 15 for young poults and adult turkey toms.

[b]Means on the same line followed by the same letters do not differ at the 5% level of probability.

reduction in ME values was greater for corn fiber and that steam-pelleting the products caused no improvement in ME value. The ME values of the fibrous diets, determined with the adult turkeys, were greater than those determined with either young birds or adult roosters, even though all classes of birds utilized the low-fiber basal diet to a similar degree.

The standard errors associated with the determinations made with the adult roosters or turkeys are comparable for the four parameters studied; however, the standard errors of the determinations with the groups of chickens are approximately one-third of those for the adults, whereas those obtained in the same circumstances with turkey poults are no less than those of the adults. This probably reflects the greater uniformity of young chickens and the greater ease with which they can be raised in experimental batteries.

The apparent digestibilities of the main proximate components of the experimental diets, determined with both rats and swine, are shown in Table V. These results indicate that the commercial product and the mixture of fiber and soluble material are more readily digested than the fibrous materials, but that steam-pelleting causes no significant improvement in nutrient utilization (with the exception of the increase in apparent fat digestibility of the diet containing the fiber for the rats). The swine digested the diets to a greater extent than did the rats, as would be expected on the basis of the observation of Elsden et al. (6) that there is a much greater microbial activity in the large intestine of the pig than in the rat.

The digestible energy value of the diets represents a summation of the digestibilities of the diet components and these results confirm the relative values of the different by-products established with the chickens and turkeys. However, the absolute values again indicate that extrapolations cannot be made from one class of animal to another.

Table VI summarizes the results of the whole survey of the nutritional value of

TABLE V. UTILIZATION OF A BASAL DIET AND DIETS CONTAINING 50% CORN WET-MILLING BY-PRODUCTS BY RATS AND SWINE

Type of By-Product (Steam-Pelleting Treatment)	Animal	Basal Diet[b]	50% Basal Diet + 50% Corn By-Product[b]: Corn Fiber, Not Pelleted	Corn Fiber, Reground Pelleted	Corn Fiber Plus Solubles, Not Pelleted	Corn Fiber Plus Solubles, Reground Pelleted	Commercial Product	$S_{\bar{x}}$[a]
Dry-matter digestibility (%)	Rats	84a	59b	60b	73c	72c	71c	0.9
	Swine	87a	64b	65b	...	...	76b	1.28
Apparent crude protein digestibility (%)	Rats	84a	68b	69b	74c	74c	75c	0.8
	Swine	89a	75b	76b	...	...	82c	1.0
Crude fiber digestibility (%)	Rats	37ac	27b	31b	48d	44de	40ae	2.3
	Swine	52a	38b	40ab	...	...	51a	4.1
Apparent fat digestibility (%)	Rats	89a	73b	77c	83c	84cd	87ad	0.9
	Swine	60a	37b	37b	...	...	55a	2.4
Digestible energy value (kcal./g.)	Rats	3.36a	2.42b	2.42b	3.02cd	2.95c	2.88cd	0.028
	Swine	3.42a	2.61b	2.56b	...	...	3.03c	0.045

[a]Error mean square degrees of freedom: 20 for rats and 3 for swine.

[b]Means on the same line followed by the same letters do not differ at the 5% level of probability.

TABLE VI. GROSS ENERGY VALUES OF CORN WET-MILLING BY-PRODUCTS AND THE EFFECTS OF STEAM-PELLETING ON THEIR METABOLIZABLE ENERGY VALUES IN CHICKENS AND TURKEYS AND ON THEIR DIGESTIBLE ENERGY VALUE IN RATS AND SWINE

	Gross Energy	Metabolizable Energy				Digestible Energy	
		Young Chicks	Adult Roosters	Turkey Poults	Turkey Toms	Rats	Swine
	kcal./g.	kcal./g.	kcal./g.	kcal./g.	kcal./g.	kcal./g.	kcal./g.
Corn fiber:							
control	4.00	1.17	1.29	1.08	1.34	1.43	1.74
reground pelleted	...	1.11	1.19	0.95	1.34	1.50	1.72
Corn fiber plus solubles:							
control	4.08	1.66	1.98	1.61	2.26	2.63	...
reground pelleted	...	1.79	1.90	1.67	2.14	2.69	...
Commercial product	3.95	1.86	1.77	1.63	2.08	2.39	2.63

the corn wet-milling by-products. Since ME or digestible energy values represent the over-all utilization of the feed, this parameter has been calculated for the corn by-product portions of the experimental diets. These values indicate very clearly that the mature birds utilize the fibrous feeds better than the young birds and show the great potential of these corn wet-milling by-products as ingredients for turkey breeding stock and for finishing swine.

Acknowledgments

Financial support for this work from CPC International, Inc., Argo, Illinois, and the Ontario Department of Agriculture and Food is gratefully acknowledged.

Literature Cited

1. NATIONAL RESEARCH COUNCIL. Joint United States-Canadian tables of feed composition, Publ. 1232. National Academy of Sciences-National Research Council, Washington, D.C. (1964).
2. BAYLEY, H. S., SUMMERS, J. D., and SLINGER, S. J. Effect of heat-treatment on the metabolizable energy value of wheat germ meal and other wheat milling by-products. Cereal Chem. 45: 557 (1968).
3. BAYLEY, H. S., SUMMERS, J. D., and SLINGER, S. J. The influence of steam pelleting conditions on the nutritional value of chick diets. Poultry Sci. 47: 931 (1968).
4. HILL, F. W., and ANDERSON, D. L. Comparison of metabolizable energy and productive energy determinations with growing chicks. J. Nutr. 64: 587 (1958).
5. STEEL, R. G. D., and TORRIE, J. H. Principles and procedures of statistics. McGraw-Hill: New York (1960).
6. ELSDEN, S. R., HITCHCOCK, M. W. S., MARSHALL, R. A., and PHILLIPSON, A. T. Volatile acid in the digesta of ruminants and other animals. J. Expt. Biol. 22: 191 (1946).

[Received August 9, 1969. Accepted July 7, 1970]