THE NUTRITIONAL VALUE OF WHEAT MILLING BY-PRODUCTS FOR THE GROWING CHICK

I. Availability of Energy[1]

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ABSTRACT

Four experiments were conducted to determine the relative energy value of a series of wheat by-product fractions and of wheat germ meal. When supplemented by only a vitamin-mineral mix, bran samples were unable to support life; the other wheat by-products supported only a poor rate of growth. Growth and feed efficiency of chicks were good when they were fed either wheat shorts or wheat germ meal diluted with 50% of a corn-soybean meal ration. Feed intake and growth appeared to be limited by the gluten content and/or fineness of wheat middlings fed in the form of mash. Growth was restricted by the low nutrient value of bran. The results indicate that because of the difficulty with which certain wheat by-products at high levels are consumed by chicks, the only satisfactory way in which they can be compared is in the form of pelleted or crumbled feed. High-pressure steam pelleting of rations containing 50% of wheat by-products improved growth and feed efficiency markedly. The level of feed intake was increased for all rations and the metabolizable energy values of bran, shorts, and wheat germ meal were increased by 30, 17, and 15%, respectively.

The nutritive value of wheat by-products has been investigated by Fraps (1) and Halnan (2,3); Bailey (4) has reviewed many reports on the physical and chemical properties of wheat and wheat products; more recently, Hill *et al.* (5), Potter and Matterson (6), and Sibbald and Slinger (7) have studied the metabolizable energy values of these feed sources with chickens.

Wheat milling by-products are relatively low in available energy and high in fiber content. The chick is able to increase its intake of nutrients to compensate for the low energy (8), but its ability to increase the amount of bulk ingested is limited physically. However, the chick's capacity to increase the consumption of fibrous feeds is greater for those of high moisture-absorbing capacity such as wheat bran (9).

If fed at too high a level in the ration, wheat by-products impair growth (10). Wheat bran has been fed to laying hens and turkeys at levels as high as 30% with no lowering of egg production; however, the body weights of these birds declined throughout the laying period (11,12). The reason for lower growth of chicks fed on wheat by-products is primarily the low energy values associated with these feeds,

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but this is exacerbated by the relatively low digestibility of the fat (1,13).

Pelleting of feed has frequently been shown to increase intake of the feed, and so enhance rate of growth (14). This improvement in weight gain is usually greater for feeds of higher fiber content (15,16,17). Since pelleting has produced little improvement of rations high in fat content (18,19,20), it has been suggested that the beneficial effect is a result of increased density raising the intake of nutrients. However, further experimental work, in which feed intake was controlled, indicated that greater ingestion of pelleted feed is not solely responsible (21); also, where reground pellets have been fed to chicks there is an indication that pelleting has more than a physical effect in enhancing chick growth (19). Allred *et al.* (19) proposed that there is a chemical effect, due to pelleting at high temperature and pressure, which either improves the availability of some of the nutrients or destroys a toxic factor present in the feed. No differences in chemical composition between pelleted and nonpelleted feed were found by Bolton (22). However, Reddy *et al.* (23) and McIntosh *et al.* (24) found that values for metabolizable energy (ME) were enhanced by pelleting certain feeds.

The experiments reported here were carried out as part of a study to assess the nutritional value of wheat by-products and to investigate means of improving their nutrient availability to the chick.

Characterization of Wheat By-Products

The wheat by-products under study were derived simultaneously from the same sample of No. 1 Northern Canadian hard wheat. The proximate analyses of these are presented in Table I. Analysis for protein (N × 6.25) was by a semimicro-Kjeldahl method, and analysis for fiber by the AOAC (25) method. Fat content was determined by refluxing with petroleum ether for 16 hr. in a Soxhlet apparatus. Moisture was determined from the loss in weight when the wheat by-products were heated in an oven at 105°C. for 24 hr. Dry density was calculated from the volume of a known weight of the wheat by-product, in a measuring cylinder; wet density was determined by filling to the mark, a graduated cylinder containing a weighed amount of the sample and calculating, from the amount of water added, the water displaced by the sample of wheat by-product (26).

There were two samples of bran, of which bran 2 was the coarser; two samples of middlings, of which middlings 2 was much the finer; and four samples of shorts, making a total of eight wheat by-product samples. Of the shorts, 2 was the coarsest, 4 was akin to fine bran, 1 and 3 were finer. For commercial purposes these would ordinarily be combined

TABLE I

DRY AND WET DENSITY, AND PROTEIN, FAT, AND FIBER CONTENTS OF WHEAT MILLING BY-PRODUCTS

WHEAT BY-PRODUCT	DENSITY		COMPOSITION [a]			
	Dry	Wet	Moisture	Protein	Fat	Fiber
	g./cc.	g.[b]	%	%	%	%
Bran 1	0.411	1.25	11.3	18.0	5.3	12.0
Bran 2	0.421	1.73	11.3	16.5	4.7	12.7
Shorts 1	0.434	1.58	11.3	18.0	6.3	6.0
Shorts 2	0.537	1.54	11.9	21.0	6.6	5.0
Shorts 3	0.445	1.68	11.7	18.3	6.1	7.1
Shorts 4	0.414	1.48	12.7	19.4	5.3	8.8
Midds. 1	0.409	1.60	10.1	18.0	5.2	1.2
Midds. 2	0.543	2.45	11.3	16.5	3.5	3.6
WGM	0.516	1.71	11.5	29.0	9.8	2.1

[a] Analyses reported are on basis of 14% moisture.
[b] Material per ml. of water replaced.

into one bran, one shorts, and one middlings. It was considered possible that differences in the nutritive values of the narrower streams might be found which would indicate that recombination of the streams was advisable, or that an increase in the number of products marketed was desirable. Wheat germ meal was also included in the study. For this, the amount available from the milling process was inadequate for all experiments, and thus wheat germ meal from another wheat sample was used in certain trials.

Experiment 1

The purpose of the first experiment was to rank the eight wheat by-products according to their nutritional worth for chicks.

Methods. For each ration, one of the wheat by-products was essentially the sole source of protein and energy and was supplemented only by 4% of a vitamin-mineral premix (Table III). These rations were fed *ad libitum* to chicks from hatching to 28 days of age. Both bran samples were ground moderately fine for this and subsequent experiments before they were included in rations, since previous studies had indicated that young chicks experienced great difficulty in consuming unground bran. Three replicates of 12 and three replicates of 11 White Leghorn male chicks 1 day old were started for each treatment, using a randomized complete block design. The chicks were housed in electrically heated battery brooders with raised wire floors. The chickens were weighed at 14 and 28 days of age, and feed intake was recorded. The data obtained were analyzed statistically by the method of analysis of variance as described by Steel and Torrie (27), and tests of significance of treatment effects were made, using multiple comparison tests as indicated by Robinson (28).

TABLE II

WEIGHT GAINS AND FEED:GAIN RATIOS OF CHICKS FED WHEAT BY-PRODUCTS AS THE SOLE SOURCE OF ENERGY AND PROTEIN (EXPT. 1)[a]

WHEAT BY-PRODUCT	WEIGHT GAIN		FEED:GAIN RATIO[b]		MORTALITY[c]
	(0–2 Weeks)	(0–4 Weeks)	(0–2 Weeks)	(0–4 Weeks)	(0–4 Weeks)
	g.	g.			
Shorts 2	78	207	2.25	2.56	1
Shorts 1	46 a	151 a	2.92 a	3.21 a	7
Shorts 3	42 a	137 a	3.16 a	3.36 a	5
Midds. 1	34 a	106 b	3.39 a	3.55 a	6
Shorts 4	26	100 b	4.32	4.21	19
Midds. 2	19	43 c	5.26	4.94	19
Bran 2	5	47 c	8.29	...	64
Bran 1	..	...	...	...	68
$S_{\bar{x}}$	3.8	8.9	0.22	0.13	
DF	24	24	24	24	

[a] Treatments followed by the same letter are not significantly different ($P = <0.05$).
[b] Feed:Gain Ratio = (g. feed consumed by chicks)/(g. gain in body weight of chicks).
[c] Of 69 chicks started.

Results. The ranking of the wheat by-products, based on both weight gain and feed efficiency, was identical; their relative positions at 14 and 28 days of age were unchanged, although there were slightly fewer differences between means which were significant at the earlier age (Table II).

The two bran rations were inadequate to sustain life; at 28 days all but five chicks (of 69) fed on bran 1, and all but one on bran 2, were dead. The shorts rations gave the most rapid growth and lowest feed:gain ratio; middlings 1 was intermediate, and middlings 2 gave very low growth with a high feed:gain ratio. Consumption of middlings 2 was severely limited, presumably because of its fineness and/or its gluten content which pasted the beaks, causing them to become necrotic. Cannibalism was noted toward the end of the experiment in the groups fed middlings 2. Shorts 1 and shorts 4 may have had an adverse effect on the digestive tract of the chicks, as bloody droppings were noticed prior to the early deaths of several of the chicks fed these diets.

Experiment 2

The purpose of the second experiment was to determine the ME content of the eight wheat by-products used in experiment 1 and of the wheat germ meal milled simultaneously.

Methods. The basal ration (Table III) was compounded with nutrient levels sufficiently high so that these would not be growth-limiting when the ration was fed, diluted with 50% of the various wheat by-products. The nine rations, containing 50% basal and 50% wheat by-products, were fed to five replicate groups of 11 White Leghorn male chicks, from hatching to 28 days of age, in a random incomplete block

design. The chicks were raised in electrically heated battery brooders with raised wire floors.

During the final 6 days of the assay, samples of excreta were collected on alternate days, pooled, freeze-dried, and ground. These, together with samples of feed, were analyzed for moisture, gross energy, chromic oxide, and nitrogen, as indicated by Sibbald and Slinger (29), to permit calculation of the ME values of the wheat by-products.

Results. The ranking of the wheat by-products, based on growth and feed efficiency (Table IV), was identical with that in the previous experiment, with the exception that shorts 4 gave greater weight gains than middlings 1, whereas both middlings 1 and 2 gave lower feed:gain ratios than shorts 3 and 4. As was the case in the previous experiment, the middlings rations caused pasting of the beaks; this appeared to limit feed consumption, compared to the shorts and bran rations. The wheat germ meal resulted in values for weight gain and feed efficiency which were higher than those of all the wheat by-products except shorts 2.

Metabolizable energy values (Table IV) showed little correlation with growth data. Middlings 2 had the highest ME value, but the weight gain on this ration was little greater than that of the brans. Middlings 1 had a relatively high ME value but gave smaller weight gains than did shorts 1 and 3; shorts 4 had the lowest ME value, but weight gain with this by-product was greater than that of the brans and middlings 2.

TABLE III
COMPOSITION OF BASAL DIET

INGREDIENT	AMOUNT
	%
Ground yellow corn	27.25
Soybean oil meal (50% protein)	56.0
Dehydrated alfalfa meal (17% protein)	4.0
Meat meal (50% protein)	2.5
Fish meal (60% protein)	2.5
Dried whey (55% lactose)	2.5
Ground limestone	2.0
Dicalcium phosphate	2.0
Iodized salt	0.5
Vitamin-mineral premix[a]	0.75

[a] The vitamin-mineral premix supplied the following nutrients per 100 g. of diet:

Vitamin A, 1,008 IU	Niacin, 0.55 mg.
Vitamin D_3, 124 ICU	Manganous oxide, 14.81 mg.
D-calcium pantothenate, 0.622 mg.	Zinc oxide, 10.58 mg.
Menadione sodium bisulfite, 0.22 mg.	3-Nitro-4-hydroxy phenylarsonic acid, 5.0 mg.
Riboflavin, 0.70 mg.	
Vitamin B_{12}, 0.0030 mg.	DL-methionine, 50.04 mg.
Choline chloride, 18.80 g.	Penicillin, 1.1 mg.

Chromic oxide indicator was added to provide a level of 0.3% in the assay diets.

TABLE IV

WEIGHT GAINS, FEED CONSUMED, AND FEED:GAIN RATIOS OF CHICKS FED RATIONS CONTAINING 50% OF WHEAT BY-PRODUCTS OR WHEAT GERM MEAL, AND METABOLIZABLE ENERGY VALUES OF THE WHEAT BY-PRODUCTS AND WHEAT GERM MEAL (EXPT. 2)[a]

WHEAT BY-PRODUCT	WEIGHT GAINS		FEED INTAKE	FEED:GAIN RATIOS		METABOLIZABLE ENERGY
	(0–2 Weeks)	(0–4 Weeks)	(0–2 Weeks)	(0–2 Weeks)	(0–4 Weeks)	
	g.	*g.*	*g.*			*Kcal./g. DM*
Shorts 2	100 a	264	231 abc	1.93 ab	2.35 ab	2.71 a
WGM	93 a	244 a	202 d	1.79 a	2.27 a	3.19 b
Shorts 1	84 b	240 a	217 cd	2.12 bc	2.59 bc	2.47 c
Shorts 3	82 b	234 ab	223 bc	2.28 cd	2.65 c	2.30 c
Midds. 1	74 c	209 c	216 cd	2.45 a	2.60 bc	3.49 c
Shorts 4	84 b	224 b	239 ab	2.37 d	2.81 c	1.27
Midds. 2	44 c	206 c	200 d	2.27 cd	2.61 c	3.35 b
Bran 2	65	194 c	247 bc	2.81 e	3.20 d	1.91
Bran 1	68 c	194 c	224 a	3.05 e	3.31 d	1.61
$S_{\bar{x}}$	2.9	6.1	58	0.07	0.08	0.78
DF	34	34	34	34	34	34

[a] Treatments followed by the same letter are not significantly different ($P = <0.05$).

Experiment 3

It was apparent from the previous experiment that the chicks had difficulty in prehension of some of the rations. So that hindered prehension should not limit growth rate on any of the rations, they were fed in pellet form in the present trial.

Methods. The rations fed in this experiment were mixed, as for experiment 2, and then pelleted in a cold-press-type machine. These rations were fed to five replicate groups of 10 White Leghorn male chicks, from hatching to 2 weeks of age. At the termination of this period, the chicks were weighed and the feed intake was recorded.

TABLE V

WEIGHT GAIN, FEED CONSUMED, AND FEED EFFICIENCY OF CHICKS FED COLD-PELLETED RATIONS CONTAINING 50% WHEAT BY-PRODUCTS (EXPT. 3)[a]

WHEAT BY-PRODUCT	WEIGHT GAIN (0–2 Weeks)	FEED CONSUMED (0–2 Weeks)	FEED:GAIN RATIO (0–2 Weeks)
	g.	*g.*	
Midds. 2	129 a	221 a	1.72 a
Shorts 1	125 ab	236 ab	1.88 b
Shorts 2	120 bc	211 a	1.76 a
Shorts 3	119 bcd	223 a	1.90 b
Midds. 1	118 cd	221 a	1.87 b
Shorts 4	112 cd	234 ab	2.10
Bran 2	114 cd	257 b	2.29 c
Bran 1	111 cd	261 b	2.35 c
$S_{\bar{x}}$	26	11	0.13
DF	32	32	32

[a] Treatments followed by the same letter are not significantly different ($P = <0.05$).

Results. Although there was considerable variability in the degree to which the pellets of the various rations held together, the feed consumption was higher and consequently weight gains (Table V) were much greater for all treatments than those in experiment 2; these differences were more marked for some treatments than others. The rankings of the wheat by-products, based on weight gain and feed efficiency, were similar to those of the previous experiments, with one notable exception; middlings 2 produced greater weight gains than in the previous experiments, and in fact this feedstuff was superior to all other wheat by-products except shorts 3.

It was concluded that the reason for the marked improvement of middlings 2 was that the pelleting process overcame the problem of beak necrosis, and thus the birds were able to consume a greater amount of feed.

There were few differences between means of weight gains which were statistically significant; however, there were clear-cut differences between means in feed efficiency. The data on weight and feed efficiency from this experiment corresponded fairly well with the ME values obtained in the previous experiment. It was concluded from these results that all experiments comparing wheat by-products should be conducted with pelleted feed, to minimize the differences due to difficulties associated with prehension.

Experiment 4

The purpose of the fourth experiment was to determine the effect of commercial steam pelleting on the growth-promoting abilities and on the ME values of certain of the wheat by-products and wheat germ meal.

Methods. Four rations containing 50% of wheat bran 2, shorts 3, middlings 2 or wheat germ meal, and 50% of the basal diet (Table II), and a fifth treatment of basal, alone, were fed either as mash or as crumbled steam pellets, in a factorial arrangement in a randomized complete block design. A commercial starter ration was fed to all the White Leghorn male chicks from hatching to 14 days of age, and the assay rations were fed to five replicate groups of 10 chicks from 14 to 28 days of age. Samples of feed and excreta were collected for analysis to permit calculation of ME values, as described in experiment 2.

Results and Discussion. The wheat germ meal, which was of different origin from that in experiment 2, gave poorer growth than the samples used in previous experiments. The other rations were ranked in the same order as in the previous experiment with cold, pelleted

TABLE VI

WEIGHT GAINS, FEED:GAIN RATIOS OF CHICKS FED STEAM-PELLETED RATIONS CONTAINING 50% OF WHEAT BY-PRODUCTS OR WHEAT GERM MEAL AND METABOLIZABLE ENERGY VALUES OF THE WHEAT BY-PRODUCTS AND WHEAT GERM MEAL (EXPT. 4)[a]

WHEAT BY-PRODUCT	WEIGHT GAIN (2–4 Weeks)	FEED CONSUMED (2–4 Weeks)	FEED:GAIN RATIO (2–4 Weeks)	METABOLIZABLE ENERGY
	g.	*g.*		*Kcal./g. DM*
Mash				
Bran 2	98 a	409 a	4.17	2.00
Shorts 3	101 ab	347 b	3.44 ab	2.25
Midds. 2	123 b	358 b	2.91 bc	3.48 a
WGM	81 a	298	3.64 a	2.79 b
Pellets				
Bran 2	149 c	464 c	3.11 abc	2.60 c
Shorts 3	163 cd	455 c	2.88 bc	2.64 bc
Midds. 2	176 d	407 a	2.31 d	3.54 a
WGM	124 b	324 b	2.00 cd	3.21
$S_{\bar{x}}$	7.7	12.4	0.18	0.08
DF	36	36	36	36

[a] Treatments followed by the same letter are not significantly different ($P = <0.05$).

feed, with respect to both growth rate and feed efficiency (Table VI). In all cases, both growth rates and feed efficiencies were greatly improved by pelleting the rations. In contrast to the previous experiment, the improvement in growth rate was greatest for the shorts ration and less for the middlings ration. Feed intake for the shorts was increased by pelleting to a greater extent than for any other ration. However, the improvement of feed efficiency, caused by pelleting, was greater for the bran and wheat germ rations than for the shorts ration.

The ME values for the samples fed in mash rations showed close agreement with the values of experiment 2, except for the wheat germ meal which, as mentioned earlier, was from a source different from that of the previous wheat germ sample. Agreement with ME values published by Hill and Dansky (8) and Sibbald and Slinger (7) is quite reasonable for what were poorly defined fractions of wheat by-products.

By comparison with the values for mash rations, the ME values of the samples fed as crumbled pellets were considerably enhanced. This effect was most marked for the high-fiber wheat bran, and least for the considerably lower-fiber wheat middlings. The ME value of the bran was increased by 29.9%, the wheat germ meal by 15.0%, the shorts by 17.1%, and the middlings by only 1.5% by the pelleting process.

It appears from the data presented here that the effect of pelleting these rations was both physical and chemical; feed intake was increased by 10 to 31% with the various by-products. A change was

induced in the feeds containing bran, shorts, or wheat germ, which increased their metabolizability. Further studies are being made to investigate the effects of pelleting on the digestibility of the various components of wheat by-products.

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