# Effect of Heat-Treatment on the Metabolizable Energy Value of Wheat Germ Meal and Other Wheat Milling By-Products[1]

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**ABSTRACT**

Wheat bran, middlings, and shorts were steam-pelleted and reground. To compare the metabolizable energy (ME) values of products so processed with those of the original materials, the products were mixed with a basal ration and these diets were fed to young chicks and adult roosters. The roosters utilized the unprocessed bran better than the chicks. Steam-pelleting increased the ME value for both chicks and roosters, but the increase was greater for chicks. Steam-pelleting reduced the ME value of the middlings and the shorts.

Wheat germ meal was toasted or autoclaved for 20, 45, or 90 min. and these samples were compared with one of raw wheat germ meal by way of a series of diets containing each of the various processed wheat germs. These diets were fed to young chicks, roosters, and adult turkeys. The ME values of the raw wheat germ for both young chicks and roosters were similar. Toasting caused an increase for roosters but had no effect for young chicks. Autoclaving resulted in an increased ME value for roosters but a decrease for chicks. The ME values of the raw and toasted wheat germ meals for turkeys were similar to that of the toasted wheat germ meal for roosters. However, autoclaving the wheat germ meal reduced its utilization by turkeys.

Wheat milling by-products represent a large quantity of good-quality protein which could be used in animal and human foods. However, their high fiber content and the consequent low availability of energy limits their usefulness to monogastric animals. In the milling process it is possible to separate various fractions from wheat which have different levels of fiber, and efforts are being made to characterize these fractions in terms of their nutritional worth and to examine various ways in which their value may be enhanced. Cave *et al.* (1) studied the utilization of the energy-yielding components of wheat milling by-products by young chicks and reviewed the relevant literature. Moran *et al.* (2) studied the effect of heat-treatment on the nutritional value of the protein in wheat germ meal. Young chicks, mature roosters, and turkey toms were used in the present studies, since adult birds may utilize fibrous feeds to a greater extent than young chicks. If adult birds do utilize fibrous feed ingredients to a greater extent, then the metabolizable energy (ME) values obtained with these birds would better represent the nutritional worth of the feed, since the greater proportion of poultry feed is fed to adult birds and finishing broilers.

The earlier report (1) from this laboratory described the effects of steam-pelleting complete rations containing high levels of wheat by-products, but recent evidence from our laboratory indicated that there are interactions between the components of mixed feeds during the pelleting process. In the first experiment to be described, wheat bran, shorts, and middlings

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were steam-pelleted separately, reground, and then mixed with a basal diet. This technique avoided the possibility of occurrence of interactions during pelleting between the other ingredients in the diet and the wheat by-product being studied. The second experiment investigated the effects of heating wheat germ meal. This fraction of wheat contains little fiber and a high level of protein and fat. It is thus potentially valuable for use in livestock feeds and as a human food. However, it has been reported that its use in chick diets resulted in a depression in growth, and it was suggested by Creek *et al.* (3) that the depression is due to the presence of a thermolabile factor which appeared to impair the utilization of fat and protein. Parrish and Bolt (4) repeated the observation of Creek *et al.* (3) but explained the reduced performance as a result of the lower feed consumption due to the birds' difficulty in prehending and swallowing the sticky glutinous rations. They explained the reduced digestibility as the result of the birds' scraping the sticky feed from their beaks on the wire floors of the cage and thus contaminating the excreta.

## MATERIALS AND METHODS

The dry matter, crude protein, crude fiber, and ether extract in the wheat milling by-products used in these experiments were determined by the methods described by the AOAC (5), and the results are described in Table I.

TABLE I
COMPONENTS OF WHEAT MILLING BY-PRODUCTS

| By-Product | Dry Matter | | Crude Protein[a] | Crude Fiber[a] | Ether Extract[a] |
|---|---|---|---|---|---|
| | Before Processing | After Processing | | | |
| | *% of sample* | *% of sample* | | | |
| Wheat bran | 88 | 85 | 17.7 | 9.8 | 4.5 |
| Wheat shorts | 87 | 85 | 20.8 | 5.8 | 4.8 |
| Wheat middlings | 88 | 82 | 19.7 | 3.2 | 4.1 |
| Wheat germ meal—raw | 86 | | 29.0 | 3.4 | 10.3 |
| Toasted | | 95 | 30.5 | 3.0 | 9.6 |
| Autoclaved 20 min. | | 93 | 28.6 | 3.2 | 9.5 |
| Autoclaved 45 min. | | 94 | 28.7 | 3.0 | 9.8 |
| Autoclaved 90 min. | | 93 | 29.0 | 2.9 | 9.7 |

[a] 90% Dry-matter basis.

For the first experiment, samples of wheat bran, shorts, and middlings were divided into two portions. One portion was pelleted in an experimental pelleting machine in which the feed passed through a conditioning chamber, where it was heated to approximately 90°C. by injection of steam at a pressure of 40 p.s.i. The feed passed through the conditioning chamber in approximately 4 sec. and was then extruded through 3/16-in. dies. The experimental pelleting machine has been described in more detail (6). The pellets were reground and will be referred to as the "processed" samples; the other portion will be referred to as the "control." For the second experiment one sample of wheat germ meal was heated in a rotating drum at 121°C. for 45 min.; the moisture content was reduced to 5%, and this sample will be referred to as "toasted." A different sample was divided into four portions;

one was left in the original state and will be referred to as "raw," and the three others were autoclaved at 121°C. for 20, 45, or 90 min. The processing of the wheat germ meal has been described in more detail (2).

TABLE II

COMPOSITION OF BASAL DIET

| INGREDIENT | AMOUNT | COMPOSITION | AMOUNT |
|---|---|---|---|
| | % | | % |
| Ground corn | 65.75 | (Determined) | |
| Soybean oil meal (50% protein) | 30.00 | Dry matter | 90.0 |
| Dicalcium phosphate (21% Ca, 20% P) | 2.20 | Crude protein | 22.0 |
| Ground limestone (38% Ca) | 1.00 | Crude fiber | 2.6 |
| Iodized salt | 0.30 | Ether extract | 2.8 |
| Vitamin and mineral supplement[a] | 0.75 | | |

[a] The vitamin mineral supplement supplied the following levels of nutrients per kg. of ration: vitamin A, 3,400 USP units; vitamin $D_3$, 1,300 ICU; riboflavin, 55 mg.; calcium *d*-pantothenate, 10 mg.; vitamin $B_{12}$, 7γ; 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.

A basal diet was made up as shown in Table II and a series of diets was prepared from this. An equal quantity of the by-product being investigated was mixed with the basal diet, which contained sufficient vitamins and minerals to supply the birds' requirements even after dilution with the by-products. Young chicks and adult roosters of a light hybrid strain were used in the first experiment, and in the second, mature turkey toms (Large Whites) were used in addition. Each diet was fed to four pens of ten chicks in electrically heated tier brooders. The chicks all received the same well-balanced diet from 1 day of age for 7 days, when the experimental diets were introduced; balances of total feed intake and excreta output were made between 21 and 25 days of age. Five roosters and turkeys were used; they were housed in individual cages which allowed feed intake and excreta output to be determined for each bird. The experimental diets were fed for 14 days, and balances of feed intake and excreta output were made in the last 4 days.

The excreta were collected each day during the balance period, frozen, freeze-dried, weighed, and ground for analysis. The lipid content of the excreta was determined by extraction with a mixture of chloroform and methanol as described by Bligh and Dyer (7). Gross energy values of feed and excreta were determined by combustion in oxygen with a bomb calorimeter (Parr Inc., Moline, Ill.). The ME value of each diet could thus be calculated. If it is assumed that the presence of the by-product did not affect utilization of energy in the basal diet, it is possible to calculate the ME value of the added by-product by the expression:

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

Sibbald and Slinger (8) discuss the determination of ME values more fully. It should be noted that although each of the values used in the calculation has a standard error associated with it, there is no simple way of describing the variance associated with the derived value for the by-product itself.

Analyses of variance of each parameter were carried out, and the standard errors of the means ($S\bar{x}$) for all the parameters studied were used as a basis for comparison of means by either LSD (experiment 1) or Duncan's new multiple range test (experiment 2). The 5% level of probability was used as a basis for statistical significance. The statistical procedures used are described by Steel and Torrie (9).

## RESULTS

The results of the first experiment are shown in Table III. It should be noted that the basal diet and those containing the three different by-products contained different levels of nutrients; this limited valid comparisons to the control and processed forms of a by-product. Comparisons of parameters for young and adult birds could not be evaluated statistically. Feed

TABLE III

UTILIZATION OF A BASAL DIET AND DIETS CONTAINING 50% OF EITHER CONTROL OR PROCESSED WHEAT BRAN, SHORTS, OR MIDDLINGS BY YOUNG CHICKS AND ADULT ROOSTERS: FEED INTAKE, DRY-MATTER DIGESTIBILITY, AND METABOLIZABLE ENERGY VALUE[a]

| | Class of Bird[b] | Basal Diet | 50% Basal Diet + 50% Wheat By-Product | | | | | | $S\bar{x}$ |
|---|---|---|---|---|---|---|---|---|---|
| | | | Bran | | Shorts | | Middlings | | |
| | | | Control | Processed | Control | Processed | Control | Processed | |
| Feed intake (g./bird, 21–25 days) | C | 44 | 49 | 50 | 37 | 46* | 41 | 46* | 1.7 |
| (g./bird/day) | R | 100 | 85 | 95 | 50 | 63 | 68 | 40 | 9.0 |
| Dry-matter digestibility (%) | C | 73 | 53 | 55* | 62 | 62 | 66 | 66 | 0.7 |
| | R | 70 | 50 | 51 | 62 | 57* | 63 | 63 | 2.1 |
| Metabolizable energy value of diet (kcal./g.) | C | 3.05 | 2.19 | 2.34* | 2.60 | 2.56 | 2.82 | 2.76* | 0.028 |
| | R | 3.05 | 2.25 | 2.30 | 2.77 | 2.60 | 2.85 | 2.76 | 0.060 |

[a] Error mean square degrees of freedom: 18 for young chicks, 24 for adult roosters.
[b] C = chick; R = rooster.
* Difference between pairs exceeds LSD.

intakes by chicks were increased by processing all the ingredients, and these increases were significant for the diets containing the shorts and middlings. Processing the bran increased the dry-matter digestibility and ME value of the diet containing the bran; the increase was significant for the chicks. In contrast, processing the shorts and middlings depressed the ME values of the diets; the decrease was significant for the young chicks receiving wheat middlings.

The results of the second experiment are shown in Table IV. The effectiveness of the heat-treatments was assessed by comparing the means for

TABLE IV

UTILIZATION OF A BASAL DIET AND DIETS CONTAINING 50% OF EITHER RAW, TOASTED, OR AUTOCLAVED WHEAT GERM MEAL BY YOUNG CHICKS, ADULT ROOSTERS, AND TURKEY TOMS: FEED INTAKE, DRY-MATTER DIGESTIBILITY, METABOLIZABLE ENERGY VALUE, AND LIPID DIGESTIBILITY[a]

| | Class of Bird[b] | Basal Diet | 50% Basal Diet + 50% Wheat Germ Meal | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Autoclaved | | | |
| | | | Raw | Toasted | 20 Min. | 45 Min. | 90 Min. | $S_{\bar{x}}$ |
| Feed intake | | | | | | | | |
| (g./bird, 21–25 days) | C | 59 | 48a | 53b | 53b | 52b | 53b | 1.2 |
| (g./bird/day) | R | 82 | 75a | 81a | 59b | 79b | 65b | 6.8 |
| (g./bird/day) | T | 338 | 334 | 321 | 335 | 295 | 297 | 20.0 |
| Dry-matter digestibility | C | 72 | 64 | 66 | 64 | 64 | 65 | 0.5 |
| (%) | R | 68 | 62a | 66b | 68b | 65b | 66b | 1.6 |
| | T | 68 | 68 | 64 | 67 | 66 | 64 | 1.7 |
| Metabolizable energy | C | 2.95 | 2.90a | 2.90a | 2.82b | 2.86a | 2.84b | 0.018 |
| value of diet | R | 2.93 | 2.95a | 3.06b | 3.23c | 3.06b | 3:15bc | 0.055 |
| (kcal./g.) | T | 2.86 | 3.06a | 3.07a | 3.03a | 2.97a | 2.77b | 0.050 |
| Apparent lipid digestibility (%) | R | 75 | 77a | 84b | 80c | 84b | 82bc | 0.7 |

[a] Error mean square degrees of freedom: 15 for young chicks, 20 for roosters and turkeys. Means on the same line followed by the same letters do not differ at the 5% level of probability.

[b] C = chick; R = rooster; T = turkey.

the diets containing the different samples of wheat germ meal. The feed intakes by the chicks were significantly greater for the diets containing the heated wheat germ meal than for those containing the raw product. This observation supports the suggestion of Parrish and Bolt (4) that the stickiness of the raw wheat germ reduces feed intake. However, heating the product did not have this effect for the roosters, and for two of the autoclaved samples intake was lower than for the diet containing the raw wheat germ meal. The feed intakes of the turkeys were very variable as shown by the standard error of the means, but the results suggest that they consumed less of the diets containing the wheat germ meal which had been autoclaved for 45 or 90 min. than of the diet containing the raw product. There were no significant differences between the over-all digestibilities of the diets for the chicks and turkeys; however, for the roosters, the diets containing the heated wheat germ meal were more digestible than the diet containing the raw meal. The heat-treatments had different effects on the ME values for the different classes of birds: for young chicks, toasting had no effect but autoclaving caused a reduction; for roosters, toasting and autoclaving caused an increase, with a large increase for the sample autoclaved 20 min.; for turkeys, toasting had no effect, but autoclaving caused a reduction which was significant for the sample autoclaved 90 min. The apparent digestibility of the lipid to the roosters was determined, and these results indicated that the heat-treatment had increased the digestibility; but these values do not distinguish between the effects of toasting and autoclaving as clearly as the ME values.

TABLE V

GROSS ENERGY VALUES[a] OF WHEAT MILLING BY-PRODUCTS AND THE EFFECTS OF HEAT-PROCESSING ON THEIR METABOLIZABLE ENERGY VALUES[a]

| | | METABOLIZABLE ENERGY | | |
|---|---|---|---|---|
| | GROSS ENERGY | Young Chicks | Roosters | Turkey Toms |
| | *kcal./g.* | *kcal./g.* | *kcal./g.* | *kcal./g.* |
| Wheat bran: control | 3.95 | 1.33 | 1.45 | |
| reground pelleted | | 1.63 | 1.55 | |
| Wheat shorts: control | 4.05 | 2.15 | 2.49 | |
| reground pelleted | | 2.07 | 2.15 | |
| Wheat middlings: control | 4.09 | 2.59 | 2.57 | |
| reground pelleted | | 2.65 | 2.47 | |
| Wheat germ meal: raw | 4.48 | 2.85 | 2.97 | 3.26 |
| toasted | | 2.85 | 3.19 | 3.28 |
| autoclaved 20 min. | | 2.69 | 3.53 | 3.20 |
| 45 min. | | 2.77 | 3.19 | 3.08 |
| 90 min. | | 2.75 | 3.37 | 2.68 |

[a] 90% Dry-matter basis.

The ME values of the by-product fraction of the diets, calculated according to the expression shown above, are summarized, along with the gross energy values, in Table V. Young chicks did not utilize the unprocessed wheat bran as well as roosters, but steam-pelleting increased its utilization by both. The shorts and middlings were better utilized than the bran by both young chicks and roosters, but steam-pelleting reduced their ME content; the effect was most marked for roosters, which utilized the control shorts and middlings to a greater extent than young chicks.

Mature birds utilized wheat germ meals better than did young chicks. Toasting caused no change in the ME value for chicks, but resulted in an increase for roosters, whereas autoclaving reduced the ME values of wheat germ meal for chicks but increased them for roosters. The turkeys utilized 73% of the gross energy of raw wheat germ, but prolonged autoclaving reduced this to 60%.

## DISCUSSION

The results indicate that the effects of processing different by-products were different for the three classes of birds used. Steam-pelleting caused a 23% increase in the ME value of bran for young chicks, but the increase was less than 10% for adult roosters, which utilized the control bran better than chicks. Thus the changes which occurred in the bran during steam-pelleting were of greater benefit to young chicks than to older birds, and perhaps, indicate that the rooster is capable of digesting a fraction of the bran which is only available to the chick after the bran has been pelleted. The ME values of the diets containing the wheat germ meal samples were similar to that of the basal for chicks and roosters; however, toasting had no effect and autoclaving reduced the value to chicks, whereas both toasting and autoclaving increased the value for roosters. In contrast, turkeys were capable of making maximum utilization of the raw product, and there was no increase in ME as a result of heating. These results suggest that larger birds with their larger digestive tracts are more capable of digesting fibrous feeds, and that preliminary heat-treatment of the feedstuffs confers less advantage on these birds than on chicks. These observations confirm those of Slinger *et al.* (10), who also found that turkeys were better able to utilize fibrous feeds than chickens.

The results of this study differ from those reported earlier (1) in which complete diets were pelleted in a commercial machine and the ME values of diets containing both wheat bran and shorts were increased, whereas in the present study the increase was confined to bran. This observation indicates the importance of defining the conditions used in preparing feeds.

The ME values of the basal diet for the different classes of birds were very similar within each experiment; this confirms and extends the finding of Sibbald *et al.* (11) that age did not influence the utilization of low-fiber diets. It is of interest to note that the standard errors of the means were lower for the determinations performed on the groups of young chicks than for those determined with individual adult birds. This illustrates the greater ease of experimentation with young chicks, and helps to explain the comparative scarcity of data obtained with adult birds.

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