THE EFFECT OF GRINDING ON THE DIGESTIBILITY OF CORN BY PIGS AND ON ITS CONTENT OF METABOLIZABLE ENERGY

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INTRODUCTION

The effect of grinding on the value of corn (Zea mays) as a feed for pigs has been studied mainly in feeding experiments, the results being measured by the rapidity and feed economy of the gains secured. In the United States it has in general been found, according to Morrison, that for young pigs ground corn is not appreciably superior to whole corn, but for older pigs, variable percentage advantages in economy of gains may result from the feeding of ground corn. However, a more recent summary by Crampton indicates no advantage due to grinding at any weight of pig. In sharp contrast to the American experiments are the results of Hansson in Sweden, who calculated from his own feeding experiments on pigs that the productive value of maize was increased by fine grinding by as much as 15 to 18 percent.

Such findings as are obtained in feeding experiments are the resultants of a number of factors, including effects of grinding on the digestibility of the corn, on its palatability, and, as Crampton points out, on its wastage at the feed trough: "Shelled corn lost from the feeder is salvaged by the hogs but ground feed is not... Feed rooted out of the trough and lost to the pig is, of course, still charged to the gains made." A complete understanding of the problem, therefore, demands a consideration of each of these factors.

PREVIOUS INVESTIGATIONS

The factor most amenable to quantitative study, and perhaps the most fundamental factor of all, is the effect of grinding corn on its digestibility. However, very little study seems to have been made on this point. A summary of such work as has been found in the literature is embodied in table 1.

The corn in Jordan's experiment was a flint variety. The experimental pig weighed about 50 pounds and received in each of the two digestion trials 787 g of corn daily. The collection period was of 5 days duration.

1 Received for publication Feb. 18, 1935; issued July 1935.
2 HENRY, W. A., and MORRISON, F. B. FEEDS AND FEEDING; A HANDBOOK FOR STUDENT AND STOCKMAN. Ed. 18, 770 pp., illus. Madison, Wis. 1923.
In Haberhauffe’s experiment, the degrees of fineness of the ground corn studied can be roughly characterized by the percentages passing through a 1-mm round-hole sieve, i.e., 42, 63, and 98. The two pigs weighed initially 87.5 kg. They received daily 4 kg of the corn mixed with water, except that the whole corn was fed mixed with the coarsely ground corn in even proportions. The digestibility of the whole corn was then computed indirectly. Apparently the pigs were not fed or confined separately during the collection period of 7 days.

<table>
<thead>
<tr>
<th>Condition of corn</th>
<th>Number of pigs</th>
<th>Digestion of coefficients obtained</th>
<th>Authority and reference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Organic matter</td>
<td>Crude protein</td>
</tr>
<tr>
<td>Whole kernels</td>
<td>Whole kernels</td>
<td>1</td>
<td>83.4</td>
</tr>
<tr>
<td>Finely ground</td>
<td>Finely ground</td>
<td>1</td>
<td>91.2</td>
</tr>
<tr>
<td>Whole kernels</td>
<td>Whole kernels</td>
<td>2</td>
<td>88.8</td>
</tr>
<tr>
<td>Coarsely ground</td>
<td>Coarsely ground</td>
<td>2</td>
<td>90.4</td>
</tr>
<tr>
<td>Medium ground</td>
<td>Medium ground</td>
<td>2</td>
<td>93.7</td>
</tr>
<tr>
<td>Finely ground</td>
<td>Finely ground</td>
<td>2</td>
<td>94.9</td>
</tr>
</tbody>
</table>

See footnote 5. See footnote 6.

The experiment of Jordan in particular indicates a marked improvement in the digestibility of corn by grinding it to a fine meal, possibly because a flint variety of corn was used. In Jordan’s study, grinding improved the digestibility of the organic matter 9.4 percent, that of protein 25.3 percent, and that of nitrogen-free extract 6.1 percent. The results obtained by Haberhauffe indicate less improvement for the finely ground meal, i.e., 5.9 percent in the digestibility of the organic matter, 10.9 percent in the digestibility of the protein, and 3.0 percent in the digestibility of the nitrogen-free extract. The meals of intermediate fineness show an intermediate but graded improvement.

It appears from these two experiments, constituting the only published work on the problem, that the effect of grinding on the digestibility of corn has not yet been precisely measured. Since the nutritive advantages of the grinding of corn must be balanced against the cost of grinding in deciding whether and when this method of preparing corn is economical, the need of more work of this character seems evident. The experiment reported below is a further contribution to this problem.

**PLAN OF EXPERIMENT**

The subjects of the experiment were 5 Chester White barrows and 1 Hampshire barrow (pig 4), weighing initially from 135 to 196 pounds. Each of the pigs received daily either 1,300 g or 1,500 g of corn, depending upon appetite, with no other feed. The digestibility and metabolizable energy content of the whole corn and of the same corn after grinding was determined with 5 of the 6 pigs, 1

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pig refusing to consume the whole corn in adequate amounts after a feeding period on ground corn. Three of the pigs received the whole corn first, and three received the ground corn first. In an immediately following period, the rations were reversed, each pig continuing, however, on the same amount of feed.

Each feeding period consisted of from 14 to 17 days, during the last 10 days of which both feces and urine were collected. The animals were confined throughout in metabolism crates very similar in size and design to the crate described by Forbes. The feces of the collection periods were separated from those of adjacent periods by giving ferric oxide (equal in weight to 3 percent of the morning feed) to the pigs on the morning of the first day of the collection and again on the morning of the day following the termination of the period. The feces were dried at a low temperature and analyzed for moisture, nitrogen, crude fiber, and gross energy (heat of combustion), while the urines (with washings) were analyzed for nitrogen and gross energy.

### Table 2.—Chemical composition and gross energy value of the corn samples

<table>
<thead>
<tr>
<th>Sample of corn</th>
<th>Dry matter (Percent)</th>
<th>Total nitrogen (Percent)</th>
<th>Crude fiber (Percent)</th>
<th>Gross energy (Calories per gram)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole 1</td>
<td>88.73</td>
<td>1.67</td>
<td>3.80</td>
<td>3.967</td>
</tr>
<tr>
<td>Ground 1</td>
<td>88.99</td>
<td>1.67</td>
<td>3.89</td>
<td>4.053</td>
</tr>
<tr>
<td>Whole 2</td>
<td>89.50</td>
<td>1.66</td>
<td>3.58</td>
<td>4.025</td>
</tr>
<tr>
<td>Ground 2</td>
<td>88.90</td>
<td>1.67</td>
<td>3.70</td>
<td>4.015</td>
</tr>
</tbody>
</table>

The analysis of the corn samples, collected daily at feeding time for the two series of 10-day collection periods, is shown in table 2. The fineness of grinding was determined by passing portions of the ground corn through sieves of three sizes, 12 mesh (2.1 mm), 20 mesh (1.3 mm), and 40 mesh (0.64 mm). Ninety-five percent of the corn passed through the coarsest sieve, 58 percent through the intermediate sieve, and 29 percent through the finest sieve. The fineness of grinding appears to approximate the “medium ground” sample of Haberhauffe (table 1).

### RESULTS OF THE EXPERIMENT

While the pigs were on the whole corn ration an attempt was made to determine what percentage of the consumed kernels appeared unbroken in the feces. By counting a 600-g portion of the corn, it was found to contain 350 kernels per 100 g. For each pig an aliquot of one-fifth of the unground feces for the collection period was carefully inspected and the unbroken kernels were separated and counted. The percentages (by number) of the consumed kernels thus recovered were 0.38 for pig 1, 1.10 for pig 3, 1.10 for pig 4, 0.38 for pig 5, and 37.90 for pig 6. The outstanding position occupied by the last animal is noteworthy, and was probably the result of defective teeth, although the truth of this supposition was not confirmed.

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The most significant results of the digestion and metabolism trials are assembled in table 3. It is evident from the coefficients of digestibility that, except for protein (nitrogen), the constituents of the ground corn were not digested to a markedly greater extent than the constituents of the unground corn. Omitting the incomplete results for pig 2, the average coefficients of digestibility of the whole corn and ground corn were, respectively, 86.6 and 88.4 for dry matter, 84.5 and 86.9 for gross energy, and 70.4 and 79.7 for protein. The percentage improvement in the digestibilities were 2.1 for dry matter, 2.8 for gross energy, and 13.2 for protein. For the four pigs for which the coefficient of digestibility of crude fiber was determined, the averages were 65.5 for the whole corn and 71.8 for the ground corn, but if the atypical results of pig 6 are omitted, the averages are very nearly the same, i.e., 71.8 and 72.2.

It is especially noteworthy that pig 6, which appeared to be passing unbroken and undigested more than a third of all whole corn kernels consumed, digested the whole corn fairly well, except for the crude fiber. While grinding improved the digestibility of corn for this pig somewhat more than for the other pigs, the relative improvement was far less than would be expected from the physical examination of the feces for unbroken kernels, proving the latter method to be quite unreliable as a criterion of completeness of digestion. The apparently unbroken kernels must have been very largely denuded of their digestible contents by the digestive enzymes.

Since corn is preeminently an energy food, the metabolizable energy values of whole and ground corn are of great practical significance. But here also the improvement brought about by grinding is slight, except for pig 6. In fact, for one pig (no. 5) no improvement at all resulted. For all five pigs upon which complete data were obtained, the metabolizable energy per kilogram of dry matter averaged 3,662 calories for the whole corn and 3,791 calories for the ground corn, representing an improvement of only 3.5 percent.
The pigs were in positive nitrogen balance in all periods. The consistently greater digestibility of the protein of the ground corn did not, however, promote consistently higher nitrogen balances, since without exception the urine from pigs on the ground corn ration contained more nitrogen than that from the same pigs on the whole corn ration. In one pig (no. 5) the lesser wastage of nitrogen in digestion on the ground corn ration was more than offset by the greater wastage in metabolism, while for another pig (no. 3) these two tendencies just balanced each other. Thus, the 13-percent improvement in the digestion of the nitrogen of the corn brought about by grinding was largely lost in metabolism, a result suggesting that the digestible nitrogen escaping digestion in the whole corn represents a fraction of the corn protein that is of low value biologically.

SUMMARY AND CONCLUSIONS

The relative digestibility of whole and ground corn and their content of metabolizable energy were determined on five pigs weighing from 135 to 196 pounds.

Grinding corn to a medium degree of fineness (29 percent passing a 40-mesh sieve, 58 percent a 20-mesh sieve, and 95 percent a 12-mesh sieve) increased the digestibility of the protein by 13 percent, but the digestibility of the gross energy of the corn was raised only 2.8 percent. The metabolizable energy was also only slightly improved; i.e., 3.5 percent. Furthermore, the appreciable advantage in protein digestibility occasioned by the grinding of corn was largely lost by greater losses of nitrogen incurred in metabolism, so that the net effect on the nitrogen balance of an animal receiving an exclusive ration of corn was slight and inconstant.

The net effect of grinding upon the nutritive value of corn for pigs of the weights used in this test is to increase its value as a source of energy by 3.5 percent. Its value as a source of protein was not appreciably altered.