

ENHANCEMENT OF THE NUTRITIONAL VALUE OF CEREALS THROUGH GERMINATION

ALBERT A. DIETZ
1618 54th Street, La Grange

The limitations of cereal diets have been known and discussed for many years, and the relative nutritional values of various cereals have been reported many times. Jones, Caldwell, and Widness (1948) reviewed the inconsistencies in the early reports, and in their work found that oats, rice, and rye were superior to the other cereals fed at the same protein levels. Their suggested diets, as well as those used by most workers studying the nutritional properties of cereals, were supplemented with minerals, vitamins, and fats. Thus the relative value of the grains was partly dependent upon the supplement used, and when the diets were sufficiently supplemented to give normal growth, differences in the nutritional value of the cereals could not be seen. Germinated cereals have been used to supplement diets, and reports of their value range from very optimistic (Raybaud, 1929) to those that find them to be of no value (Leitch, 1939). I found no report which compared the unsupplemented germinated cereal directly with the ungerminated. The work reported in the present paper used diets consisting entirely of a single germinated or ungerminated cereal and distilled water. The data show the overall changes in the nutritional properties resulting from germination.

METHODS

Germination. The germination was carried out on an industrial

scale. The cereals were steeped in tap water for 12-14 hours, with or without the addition of lime. They were then placed on wire shelves and a continuous stream of air forced through the grain. The germination was in the dark for 3-6 days, depending upon the cereal, until the sprouts were about 3 times the length of the seeds. During the germination, the grain was kept moist and turned once daily. At the end of the germination, the product was dried at room temperature in a current of forced air and ground in a hammer mill. Adequate samples of the ungerminated grain were ground for the control diets. The protein was calculated from the nitrogen content as determined by Kjeldahl analysis times 6.25.

Feeding Experiments. Wistar rats were raised on the stock diet of Bills *et al.* (1931). The young were put on the experimental diets at weaning or several weeks after weaning. The results were most uniform when the initial weight of the rats was 50-75 g. For a given experiment, one or more litters was divided, half receiving the ungerminated and half the germinated cereal. The rats were kept in false-bottom cages and received the cereal and distilled water *ad libitum*. They were weighed at weekly intervals, and food consumption records were kept. In all cases, the germinated cereal was from the same source as the ungerminated with which it was compared.

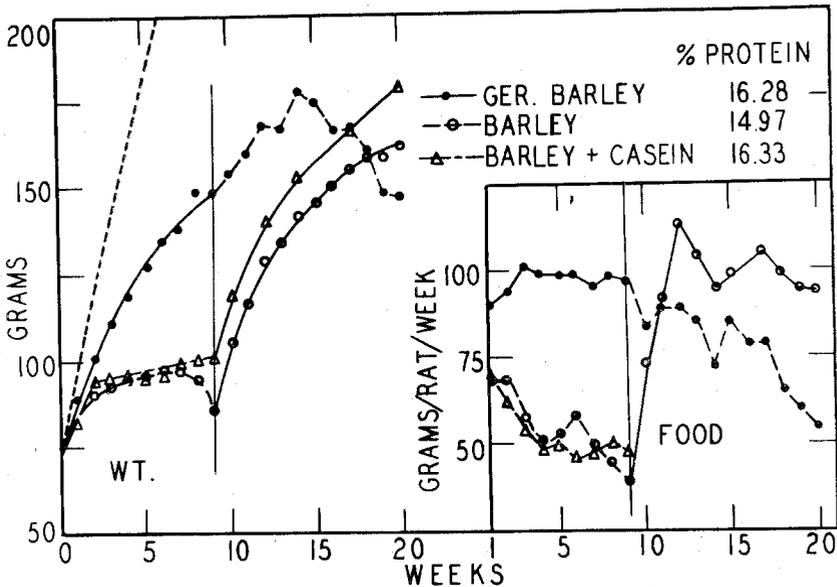


Fig. 1.—Growth and food consumption of rats on diets of barley, germinated barley, and barley supplemented with casein to give a protein content equivalent to that of germinated barley. The values are the averages of four male rats. The symbols represent each group of rats and their diets for the first nine weeks, at which time the diets were reversed. The solid and broken lines represent the germinated barley and barley, respectively. The short dashes represent growth on the stock diet.

RESULTS

Barley. In an initial experiment, the average weight gain of 14 rats receiving only barley (15.13% protein) was 20.3 g. in 10 weeks, whereas 14 rats fed germinated barley (16.20% protein) gained an average of 60.4 g. in the same interval. Half of the rats receiving barley died in the tenth week, and one survived 25 weeks. Five of the animals fed germinated barley were still alive in the 38th week when the experiment was terminated.

The higher protein content of the germinated cereal, according to Bartlett (1917), is due to the loss

of carbohydrate during germination. To test whether the higher protein content of the germinated cereal was responsible for the more rapid growth, barley was supplemented with commercial casein to increase its protein content to that of the germinated grain. The results of the feeding and the analyses of the diets are given in Figure 1. For nine weeks, three groups of four rats each received barley, barley-casein, or germinated barley diets. At the end of this period, those receiving the germinated barley had gained an average of 80 g., whereas those on the barley or barley-casein

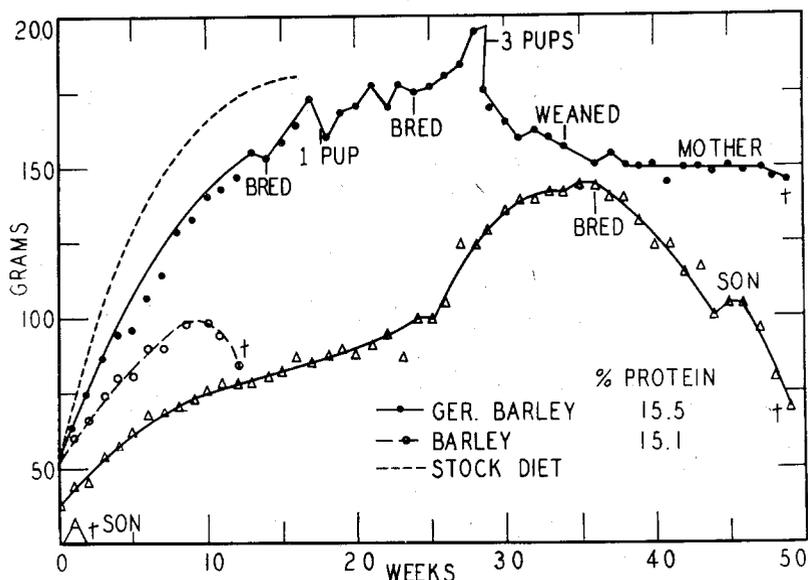


Fig. 2.—Growth and longevity of rats receiving barley and germinated barley. The protein analysis of the diets was 15.08 and 15.50%, respectively. The triangles represent the second generation on germinated barley. The short dashes represent growth on the stock diet.

diets gained an average maximum of 30 and 35 g., respectively. At nine weeks, the four rats fed the casein-supplemented barley showed a slight but not significant beneficial effect of the casein. At this time, two of the rats receiving barley died. The diets were reversed at the end of nine weeks so that the rats that had received the germinated barley were then fed barley and those on the other two diets then received the germinated cereal. In all cases, the rats grew, but after six weeks on the new diets, the rats now receiving barley began to lose weight. The experiment was terminated in the 20th week when two of the rats receiving barley died. Thus, the total protein is not the determining fac-

tor in the enhancement of the value of the cereal through germination.

A study of the food consumption on the three diets (Fig. 1) showed that the rats ate considerably more of the germinated barley at a rather constant rate throughout the experiment. The food consumption of the rats on the barley or barley-casein diets fell almost continuously.

As already noted, the animals fed germinated barley not only grew more rapidly but they survived longer than those eating the ungerminated cereal. Although most experiments were terminated before the animals on the germinated barley died, in eight cases, rats survived for over one year with germinated barley as the sole nutrient, one as

long as 76 weeks. Ten female rats that had been on germinated barley for more than 10 weeks were bred with males from the stock colony. Attempts were made to breed four of them three times. In three cases, litters were cast, but only one mother was able to wean her young. The cycle of the mother and her pups is shown in Figure 2. The mother had received only germinated barley from the time she was a month old. She was bred in the 14th and 24th week on the diet. With the first breeding, one pup was born but it died the next day. As a result of the second breeding, three pups were cast, but only two survived until weaning. They were weaned at the age of 37 days when they weighed 37 and 21 g. (normal weight at this age is 65 g.). The diet of germinated barley was continued. The smaller of the young died during the second week after weaning. The other pup grew slowly until the 36th week on germinated barley. At this time, an attempt to breed him to a female from the stock colony was unsuccessful. Thereafter, he lost weight. He died in the 49th week, at about the same age as had his mother. In addition, five attempts to breed male rats that had received germinated barley for over ten weeks were without success.

Oats. The results of feeding trials with oats were similar to those with barley. Three experimental groups involving 26 rats were followed. For one group of eight rats (Fig. 3), the protein content of the oats and germinated oats was 13.28 and 14.56%, respectively. The four rats fed the oats failed to grow and were dead by the 13th week, but the four

animals receiving germinated oats grew almost as rapidly as rats on the stock diet (dotted line) during the first seven weeks. After the 7th week, their rate of growth was less but they attained a maximum weight of about 80% of that of normal mature rats. They were still healthy when the experiment was terminated in the 20th week. In another experiment, the oats and germinated oats contained 15.15 and 16.01% protein, respectively. Each diet was fed to five rats. In this experiment, the animals grew almost as rapidly on the oats diet as did those fed germinated oats, but in neither case did the rats approach the weight of the control animals on the stock diet, or the weight achieved by the rats on the germinated oats in Figure 3. A difference in growth on the two

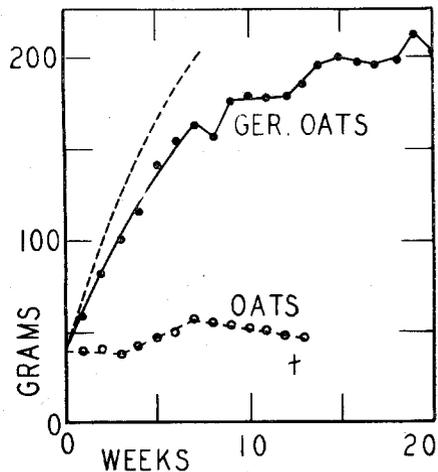


Fig. 3.—Growth of rats on oats and germinated oats. The protein content was 13.28 and 14.56%, respectively. The values are the averages of 4 male rats on each diet. The short dashes represent growth on the stock diet.

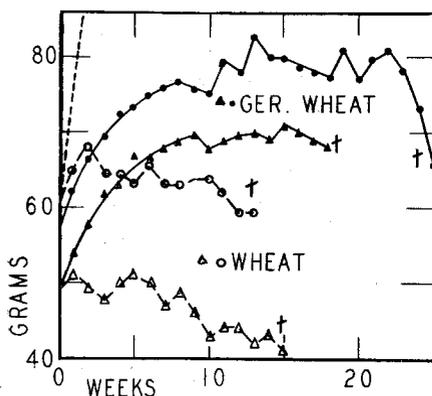


Fig. 4.—Growth of rats on wheat and germinated wheat diets. Each line represents the average weight of four female rats. Wheat from two different seasons is represented. The analysis is in the text. The short dashes represent growth on the stock diet.

diets was not noted until the 18th week when the animals on each diet averaged 110 g. The five rats receiving the oats then lost weight and died by the 22nd week. At the 22nd week, the rats on germinated oats attained their maximum weight (120 g.) which they maintained until the 45th week when they began to die. One rat lived until the 52nd week.

Wheat. Three different experiments with a total of 34 rats were completed with wheat and germinated wheat diets. The results of two of these experiments are graphed in Figure 4. Each represents a winter wheat grown in different years. Each line represents the average weight of four female rats. The rats with an initial weight of 50 g. received wheat and germinated wheat containing 14.9 and 15.8% protein, respectively. The protein

content of the diets of the rats with an initial weight of 60 g. was 10.66 and 11.53%, respectively. In both experiments, the rats fed wheat did not grow significantly, and none survived longer than 15 weeks. Those rats receiving germinated wheat grew slowly for about eight weeks, maintained their weight for an additional 10-14 weeks, and then died. In a third experiment with seven rats on each diet, no difference in the growth rate was found. A comparison of the curves in Figure 4 with those in Figures 1-3 shows that rats on the wheat diets had a slower growth rate than those fed barley or oats.

Corn. The growth of rats on corn and germinated corn was less satisfactory than their growth on the other cereals. An experiment which shows that corn can be improved by germination is given in Figure 5.

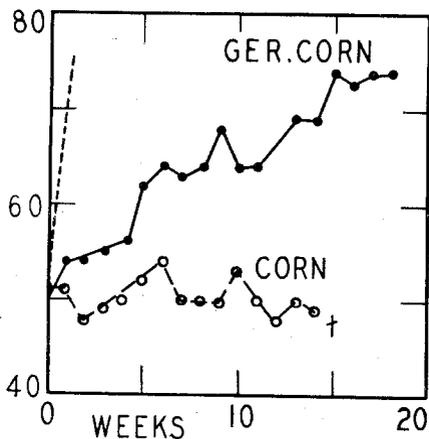


Fig. 5.—Growth of rats on corn and germinated corn diets. The protein concentration of the diets was 9.34 and 9.50%, respectively. The values are the averages of four male rats on each diet. The short dashes represent growth on the stock diet.

TABLE 1.—Weight gain, food consumption, and CER (g. food/g. gain) of rats on germinated and ungerminated cereals.

(Rats on the wheat diets were females, others males.)

Cereal	% N	No. Rats	1st 4 weeks			1st 8 weeks		
			Gain, g.	Food, g.	CER	Gain, g.	Food, g.	CER
Barley.....	14.97	8	26.7	239.7	8.98	26.6	458.1	17.2
Ger. Barley...	16.28	8	44.9	343.0	7.64	69.6	710.0	10.2
Difference.....			18.2	103.3	5.68*	43.0	251.9	5.9*
Barley.....	13.81	4	21.	247.	11.76	31.	530.	17.1
Ger. Barley...	14.35	4	27.	307.	11.37	44.	655.	14.9
Difference.....			6.	60.	10.00*	13.	125.	9.6*
Barley.....	15.13	4	19.	199.	10.47	17.	444.	26.1
Ger. Barley...	16.70	4	21.	261.	12.43	43.	722.	16.8
Difference.....			2.	62.	31.0*	26.	278.	10.7*
Oats.....	10.17	5	5.	221.	44.2	12.	480.	40.0
Ger. Oats.....	13.00	5	13.	244.	18.8	20.	536.	26.8
Difference.....			8.	23.	2.88*	8.	46.	5.7*
Wheat.....	10.66	4	1.	127.	127.	-2.	229.	.....
Ger. Wheat...	11.53	4	15.	175.	11.7	20.	308.	154.
Difference.....			14.	48.	3.44*	22.	79.	3.6
Corn.....	9.34	4	-1.	141.	.....	-1.	284.	.....
Ger. Corn.....	9.50	4	8.	160.	20.0	13.	288.	12.3
Difference.....			9.	19.	2.11*	14.	4.	0.3*

* The rows labeled "difference" were obtained by subtracting the growth and food consumption on the ungerminated cereal from those on the germinated cereal. The CER was recalculated from these values.

The average weights of four males on corn and germinated corn with protein contents of 9.34 and 9.50%, respectively, are graphed. The four rats fed corn were able to maintain their weight for about 14 weeks when they died. Those receiving germinated corn grew slowly to a maximum weight of 74 g. in 15 weeks, but failed to grow beyond this time and were killed in the 18th week. In two other experiments with other sources of the cereal, the growth of the animals on the corn

and germinated corn was insignificant, and the curves were similar to that of the rats receiving the ungerminated cereal in Figure 5. A comparison of Figure 5 with Figures 1-4, as well as the values in Table 1, suggests that corn and germinated corn give the lowest growth rates of the cereals tested when used as the sole source of nutrient.

Food consumption. Food intake data for the first four and the first eight weeks on the various cereal diets are given in Table 1. At-

TABLE 2.

Effect of heat on the nutritional properties of barley and germinated barley.

(Values for the first four weeks on the diets.)

Germinated	Heated		No. Male Rats	Average		
	°C	Hours		Gain, g.	Food, g.	C.E.R.
no	none	.....	6	13.8	195.6	14.17
yes	none	.....	6	23.5	231.7	9.86
	Difference	.....		9.7	36.1	3.72*
no	50	48	4	11.5	146.5	12.74
yes	50	48	4	29.8	224.5	7.53
	Difference	.....		18.3	78.0	4.26*
no	60	36	3	19.0	182.4	9.60
yes	60	36	3	26.0	249.0	9.58
	Difference	.....		7.0	66.6	9.51*
no	75	24	5	9.0	141.6	15.73
yes	75	24	5	24.8	215.4	8.69
	Difference	.....		15.8	73.8	4.76*
no	105	24	3	8.	206.0	25.75
yes	105	24	3	2.	278.9	139.9
	Difference	.....		-6.	72.9	-12.15*

* Calculated from differences of weight gain and food consumption of germinated and ungerminated barley.

tempts to extend the data beyond this time were of little value because of the slow rate of growth on diets of ungerminated cereal. Comparisons between the cereal and its germinated counterpart for the first four weeks shows a greater weight gain and a larger food consumption for the germinated grain in all cases. On calculating the cereal efficiency ratio (CER, g. cereal/g. gain), the superiority of the germinated cereal is further shown. The CER for the germinated cereal is lower in all cases except the 3rd experiment using barley at the 4-week period, and is considerably lower in all feeding trials for the first eight weeks. By

taking the difference in weight gain and food consumption on the diets of germinated and ungerminated grain, the CER due to germination can be calculated. These values are given in the third row in each set of three rows in Table 1. With the exception of the above mentioned experiment, the additional food eaten on the germinated cereal diets gave a lower CER than the ungerminated cereal. For six rats on the stock diet, the CER was 4.37 ± 1.81 and 5.17 ± 2.02 at four and seven weeks, respectively.

Effect of Heating. The stability of the enhanced nutritional properties of the germinated cereals was

tested. Storage for a period of a year, either before or after grinding, did not cause a loss of the enhancement. The extra value of the germinated grain was not affected by moderate heating as shown in Table 2. Heating at temperatures as high as 75° C. for 24 hours did not affect the weight gain of rats or the CER on either the barley or germinated barley diets. The nutritional properties of both types of cereals were inhibited by heating 24 hours at 105°. For these experiments, the ground cereals were heated in kilogram quantities, and the temperature is the average measured at the top and bottom of the mass.

DISCUSSION

The use of germinated cereal in diets has been proposed by many. No attempt has been made to review the subject as the literature is quite controversial and has no direct bearing on the testing procedure used here. By feeding the germinated or ungerminated cereal as the sole ingredient of the diet, the value due to germination is not masked by supplements. Germinated cereals do not have values that cannot be supplied with other nutrients. Further, the value of germinated cereal as used in the present experiments may not be compared directly to the practice of using sprouted cereals as winter forage, although both types of germinated grains may have values in common. In the present studies, the seeds were germinated in the dark and not sufficiently long to produce chlorophyll.

The relative value of the individual cereals is shown in the figures and tables in this paper. Barley and oats are much superior to wheat and corn, and the enhancement of the nutritional value through germination is much greater for the first two. In some cases, an enhanced value of the germinated cereal was not found. This was especially true for corn, and can be expected as all cereal crops do not germinate equally (Pollock, 1958) and errors in the process can lead to poor products. The value of the germinated grains cannot be related to the initial protein content, as the cereals with low protein content were frequently found superior to those with higher concentrations. The greater biological value of the lower-protein cereals is consistent with the findings of Hogan *et al.* (1955) and Sauberlich *et al.* (1953)—that the biological value of low-protein corn is higher than that of high-protein corn. Weber *et al.* (1957) have also shown that lysine and methionine levels of different varieties of oats could not be correlated with the weight gain of rats.

SUMMARY

As has been shown many times before, single, ungerminated cereal diets are found to be poor sources for growth and development of rats. The germination of the cereals enhances their nutritional properties, so that rats fed a germinated cereal diet grow and develop faster, consume more food, utilize the food more efficiently for growth, and live much longer than control animals on

an ungerminated cereal diet. The extra value of the germinated cereal is not lost on storage for periods of over one year, and is not destroyed by heating 24 hours at 75° C.

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