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EFFECT OF HEATING ON THE NUTRITIONAL VALUE OF GRAINS

Robert W. Seerley

Temperature is a part of the environment and it undoubtedly has some influence on all grains. The term heating is rather vague to us because there are several types of heat and there is not a definite temperature at the start of heating. Also, destruction of the nutritional value of grain may occur in the case of fire or normal heating after harvesting. On the other side of the coin, the nutritional value of grains may be improved by heat treatment. Heat is used in a variety of ways as a part of the total process of improving feed grains for animals. For example, toasting of soybeans and peanuts has a direct relationship to their nutritional value. Heat is used in pelleting to change the physical form of the feed. The merit of cooking grains for ruminants is under investigation.

The number of detailed reports in the literature on the effects of heating is relatively small. Therefore, a few reports will be presented in the areas of heating after harvest, artificial drying and heat treatment. The reports in these three areas are useful to make some judgments on the effect of heating.

There are more reports on the effects of heat on soybeans, but it is felt that a discussion on soybeans is not the main concern in this report. However, a report by Milner and Geddes (1946) on soybeans illustrates the effect of spontaneous heating on grain. Table 1 shows the changes over time in temperature, chemical, microflora and germination values on soybeans stored at 23% moisture (equilibrium relative humidity approximately 92%). The authors stated that total sugars decreased in the initial biological phase of heating followed by a sharp rise in the initial phase of spontaneous chemical heating. This increase may only be an apparent one since it might well be due to thermal cleavage of large carbohydrate molecules such as sucrose, stachyose, raffinose, and pentosans to yield numerous small reducing sugar fragments. The succeeding heating then brings about a rapid decline in total sugars. Nonreducing substances calculated as sucrose show a slow decline in the biological stage of heating and a marked decline as chemical heating sets in. Reducing substances similarly declined slightly in the biological heating phase but increased drastically at the expense of the nonreducing carbohydrates in the region of spontaneous chemical heating. The slight increase noted in the protein content was probably a reflection of a decrease in sample dry matter weight due to selective respiratory utilization of carbohydrates. The crude fat did not change much until the end of biological respiration, then the extractable oil dropped from 20.3% to 10.5%. The amount of microflora increased up through 49.3° C. and then decreased rapidly at the higher temperatures.

Zeleny (1954) reviewed the subject of changes of grain during storage. The report indicated that a complexity of interactions of moisture, temperature, oxygen supply, microflora, insects and other factors influence the effect on grains. Total protein content as calculated from the nitrogen content is generally assumed to remain unchanged during storage. There are cases of a

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Table 1. Influence of Spontaneous Heating on Chemical Composition, Microfloral Infection, and Germination of Illini Soybeans

Days	Temp.	Chemical analyses							Microflora	Germination
		Crude protein (N x 6.25 dry basis)	Non-protein nitrogen	Sugars				Crude ether extract (dry basis)	Seeds infected with fungi[2]	
				Total[1]	Non-reducing as sucrose	Reducing as glucose	Reducing as % of total			
	°C	%	mg/10 g	mg/10 g	mg/10 g	mg/10 g	%	%	%	%
0	24.4	35.4	22.4	444	400	44	10.0	21.6	3	93
3	29.4	35.4	21.2	410	378	32	7.8	19.5	11	73
5	37.1	35.8	21.2	405	373	32	6.9	20.2	16	52
7	44.4	35.1	22.2	378	347	31	8.1	20.2	27	30
8	49.3	35.2	23.6	433	382	51	11.8	20.3	64	0
10	53.7	35.4	28.2	417	334	83	19.9	19.4	40	0
12	55.1	35.7	34.7	491	245	246	50.1	15.3	14	0
13	55.2	35.8	32.4	438	251	187	42.6	14.9	13	0
15	59.7	36.1	32.3	443	226	217	48.9	13.6	9	0
17	67.3	36.3	35.7	432	172	260	60.3	12.0	0	0
19	77.0	36.6	35.0	291	27	264	90.8	10.5	0	0
Dewar[3] flask	77.0	36.6	37.7	310	59	251	81.0	11.2	0	0

[1] Sum of sucrose and glucose.
[2] The majority of the fungi were *Aspergillus* spp.
[3] Sample analyzed after 19 days.

Source: Milner and Geddes (1946), Cereal Chem. 23:449.

slight increase in total nitrogen; however, the proteolytic enzymes in grain and organisms associated with grain hydrolyze the proteins into polypeptides and finally into amino acids. These reactions ordinarily proceed very slowly and are not readily measurable until the grain has reached an advanced stage of deterioration. Protein digestibility may decrease with storage time, especially at higher temperatures. Oxidative breakdown of fat is not a problem under normal conditions. However, lysolytic activity of lipase can cause the breakdown of fats into free fatty acids and glycerol during storage, particularly when the temperature and moisture contents are high and thus favorable to deterioration. No appreciable changes normally occur in the mineral content of grains or their products during storage. It is possible for the percentage of total mineral matter in grain as measured by ash content to increase because of the loss of other constituents. Phosphorus may be more available by liberation from phytin by phytase and selenium content of grain grown on seleniferous soils will decrease. Carotene content in corn gradually deteriorates in time, but the B vitamins are fairly stable under normal conditions.

Wornick (1959) reviewed in some detail the effects of moisture and temperature on vitamins in relationship to pelleting. There was little information on grains, but the author relied on limited data on rations and more information from manufacturers of vitamins. He postulated that the entire group of fat soluble vitamins were fairly sensitive to moisture, high temperature, oxidation and minerals. Consequently, conditions that decompose vitamin A will also destroy vitamins D, E and K. Vitamin C is quite sensitive to moisture, temperature and trace metals. B vitamins vary widely in feed and pellet stability. Choline and niacin are rather stable under higher temperatures, whereas some of the sources of calcium pantothenate and thiamine are unstable in the presence of moisture and temperature. Stability of various manufactured sources of B_{12} varied from poor to good, but the effect of temperature on B_{12} and riboflavin in grains was not stated.

Artificial Drying

Gausman *et al.* (1952) studied the effects of artificially drying high moisture (24 to 74%) corn at high (181° F.), medium (129° F.), low (110° F.) and normal temperatures with controlled humidity and air velocity. Artificial drying rendered corn brittle; corn harvested at a high moisture content and dried at 180° F. was the most brittle. Brittleness decreased as the corn matured and there was little change in brittleness caused by artificially drying corn with less than 50% moisture. High-moisture corn dried at high temperatures contained relatively high sugar and low starch. Reducing sugar and total sugar were both high in samples dried at high temperatures. No significant changes were found in protein and ash content except they were higher when the initial moisture was above 40% and dried at high temperature. Oil content was consistently higher in all samples of corn artificially dried than in comparable samples dried at room temperature. Differences in biotin and carotene contents were not significantly changed due to the drying conditions. Pantothenic acid and pyridoxine decreased while riboflavin and niacin increased with high drying temperatures. However, pantothenic acid and riboflavin were the only constituents which showed significant differences when the corn contained less than 40% initial moisture.

Hathaway *et al.* (1952) found that drying temperatures up to 240° F. did not affect nutrients of the corn as determined by chemical analysis, but rats did not gain as fast when fed diets with corn dried at the higher temperatures.

Scientists at the South Dakota Experiment Station (1953) conducted an extensive study on soft corn. According to chemical analysis they postulated that soft corn should give about the same results in feeding (on a pound for pound basis) as mature corn. After feeding trials with beef cattle, dairy cattle, sheep, swine and poultry they concluded that soft corn had the same value as hard corn when figured on a dry matter basis. In two trials soft moldy corn proved to be palatable to lambs and there were no death losses due to spoiled corn in these trials. However, the feeding value appeared to be best in the winter before the grain molded. Also swine, dairy cattle and lambs made good use of corn dried at approximately 155° F. when compared with naturally dried mature corn.

Albert and Neumann (1955) compared corn field dried to 16% moisture before harvesting with corn harvested at 30% moisture, shelled and dried at 180° F. to 16% moisture. The two groups of heavy cattle had essentially si .ilar daily gains and feed utilization.

Clanton et al. (1960) studied the nutritive value of dried corn in beef cattle rations. Corn was harvested at 25% moisture, which decreased to 20% after shelling. One batch of corn was dried to 13% moisture by unheated forced circulating air. Other batches were dried at 130, 160 and 190° F., respectively. Digestion trials with four steers were conducted. No significant difference in digestibility or metabolizable energy between rations was observed in either the growing or fattening phases of the experiment. A decrease in crude fiber digestibility at the higher drying temperatures approached significance in the growing phase.

In a series of trials, Benjamin and Jordan (1960) compared high moisture corn (25 to 35% moisture) in three forms: (1) dried at 100° F., (2) ensiled and (3) dried, then water added and ensiled. There was no significant difference in nutritive value of the shelled corn or ground ear corn for feeder lambs when stored under the various conditions. Carcass grades were similar on the various treatments. Microbiological analysis revealed that the number of aerobic bacteria, yeasts and molds was much higher in the ensiled corn.

Jensen et al. (1960) also compared the effect of heating temperatures on corn and the performance of pigs. Drying temperatures and times with an on-the-farm portable batch drier of 375-bushel capacity were, respectively: 140° F., 2 hours, 30 minutes; 180° F., 1 hour, 27 minutes; 220° F., 55 minutes. Average corn moisture before and after drying was 21.5% and 12.2%, respectively. Average gain and feed efficiency on the different corns were very similar within each experiment. In a 5-week palatability test 50-pound pigs showed a very slight preference for 200° F. shelled corn. When corns were roller ground, the choice was definitely and consistently for the 140° F. corn. Viability tests, used to measure possible milling quality, showed decreasing viability with increasing temperature above 140° F. Increased temperature did not appear to affect the organic solubles portion but the starch became slightly less susceptible to malt amylase digestion. Vitamin assays showed no effect of temperature on content of riboflavin, niacin and carotene. However, pantothenic acid values for 140° F., 180° F. and 220° F. drying temperatures were 2.58, 2.40 and 2.31 mg. per pound, respectively.

Emerick et al. (1961) studied the nutritional value of dried high moisture corn in chick and rat diets. One source of high moisture corn dried at temperatures of 70 to 250° F. was incorporated into complete diets and fed to chicks and rats. Another source of high moisture corn was dried at temperatures of 70 to 450° F. and fed in similar diets to rats. Only small differences in the chemical composition of the corn were found and these did not appear to be related to the drying temperatures (table 2). Drying the corn at temperatures as high as 250° F. for chicks and 350° F. for rats caused no significant differences in weight gains or feed efficiencies despite a mild scorching of the grain which occurred at the higher temperature. When corn was severely burned at 450° F., a significant reduction in weight gain (16.4%) and a trend toward reduced feed efficiency (12.6%) occurred.

Essentially the same results were found by Taylor et al. (1964). There was no difference in growth rate of pigs when fed a ration using crib corn or corn dried at 140° F. or 190° F. Pigs fed corn dried at 290° F. gained slower than pigs fed the corn dried at the lower temperatures. Analysis of the corn showed that the carotene value of the corn decreased slightly with increased temperatures or drying time; however, the carotene content of the crib corn was as low as all batches except the corn dried at 290° F.

Heating Feedstuffs and Rations

Heat has been used in many ways to affect the nutritive value of feedstuffs; therefore an extensive review could be made on this section. However, only general comments and a short review of papers will be used to illustrate the effects of heating on grains.

As mentioned earlier, heating of soybeans and peanuts has been used for a number of years to improve the nutritional value of these grains. Some scientists have suggested that pelleting causes changes in the ration. Seerley et al. (1962) found a faster rate of food passage when pelleted rations were fed to growing-finishing pigs. However, heating is only one of several phases in the pelleting process and the effects of each phase, such as steaming, heating, cubing and so forth, have not been made clear. Perry (1963) showed that certain conditions in heating to make gelatinized corn can be related to a higher incidence of gastric ulcers in pigs. Recently, there is more interest in heating complete rations for livestock, especially for ruminant animals.

Mitchell et al. (1949) studied the effects of heat on several protein sources and corn. They found that cooking cut corn for from 20 to 45 minutes at a steam pressure of 45 to 50 lb. in preparation for flaking decreased digestibility of the protein from 90 to 76% and the biological value decreased 3% when fed to rats; however, subsequent toasting in another trial at 350 to 400° F. increased protein digestibility from 74% to 80%, but the biological value remained the same as the untoasted corn flakes.

Newland et al. (1962) studied the effects of steamed-cooking ground shelled corn at 250° F. for 30 minutes, then rolled into ribbons and dried, on steers and lambs. The treatments did not affect daily gain, but the palatability was decreased and the various corn processings improved feed efficiency in lamb trials from 7 to 16%. The various kinds of processed corn significantly narrowed the ruminal acetate:propionate ratio in both species. Jordan (1965) also observed that heat processed flaked corn adversely affected grain consumption by lambs

Table 2. Proximate Analysis of Corn Dried Under Various Conditions

			Proximate analysis (Moisture-free basis)				
Temp.	Time	H_2O after drying	Ether extract	Crude fiber	Protein	Ash	Nitrogen free extract
(° F.)	(Hr.)	(%)	(%)	(%)	(%)	(%)	(%)
No Drying		17.06[1]	4.81	2.26	10.81	1.27	82.16
70		10.87	5.02	2.21	10.99	1.24	80.36
100		11.02	5.07	2.31	10.79	1.33	80.16
150		10.40	4.82	2.42	11.05	1.28	80.79
200		8.73	5.35	2.32	11.02	1.49	80.21
250		6.76	4.90	2.33	10.96	1.24	80.34
70		14.09[2]	4.41	2.34	10.59	1.62	81.04
150	5	12.19	4.54	2.41	10.57	1.82	80.66
200	3 1/4	12.54	4.53	2.32	10.68	1.63	80.83
250	2 3/4	9.04	4.62	2.45	10.68	1.73	80.52
350	1 3/4	10.51	4.68	2.35	10.72	1.63	80.62
450	2 1/2	4.91	4.73	2.88	10.76	1.73	79.90

[1] Moisture content at the time rations were mixed. Original moisture content = 21%.
[2] Original moisture content = 26.7%.

Source: Emerick et al. (1961), Poultry Sci. 40:991.

and depressed daily gains, but feed efficiency was slightly improved. The corn was steam cooked at 180° F. for 5 minutes and then flaked. The temperature of the corn raised to 250° F. for about 10 seconds in the flaking process.

Matsushima et al. (1966) reported on the basis of several studies that feed efficiency is improved when steam processed and flaked corn rations were fed to beef cattle. They also observed that the physical nature of the grain had some influence on the eating habits of the cattle. The cattle eat less at any given time but they go to the feeding bunk more times per day.

Erwin and Associates (1966) and workers at the Arizona Experiment Station (1966) make some significant points about the effects of cooking and flaking of grain. In general these two reports illustrate that cooking time, pressure and type of flaking can have much bearing on the nutritional value of grains. It is recommended that readers review the original reports for the details of these studies. Also, cooked grain for ruminants was reviewed at last year's conference (Woods, 1965).

Salsbury et al. (1966) showed that heat treatment affects the starch portion of grains. Their hypothesis in the research was that heating of starch used in ruminant rations increases the ratio of starch dissimilation in the rumen. The results of the research showed that moist heat brings about hydration of the starch and that hydrated starch is digested more rapidly by rumen microorganisms than untreated starch. However, autoclaving ground corn or a commercially heated corn without the addition of water resulted in a decrease in the rate of digestion of the readily hydrolyzable dry matter.

Stored High Moisture Shelled Corn

While this symposium is on high moisture grain, any conclusions made on the effects of heating in this process on the grain *per se* cannot be supported with extensive research. The results of feeding trials have been used to determine the nutritive value of high moisture shelled corn. It has been found that beef cattle utilize high moisture corn 10 to 15% more efficiently than they utilize regular corn on an equal dry matter basis (Culbertson *et al.*, 1957; Beeson and Perry, 1958). Pigs have performed about the same or gained more slowly and required slightly more feed per pound of gain on high moisture corn in comparison with low moisture corn (Conrad and Beeson, 1956; Becker *et al.*, 1959; Beeson *et al.*, 1960; Conrad *et al.*, 1961; Jensen and Becker, 1961).

Lassiter *et al.* (1960) reported that the feeding value of high-moisture corn appeared to be equal to, but not greater than, that of dry corn when compared on a dry matter basis. Also, Benjamin and Jordan (1960) stated that neither shelled corn nor ground ear corn had an increased nutritive value for feeder lambs when it was ensiled.

Summary

Based on the discussion presented the following conclusions seem warranted.

1. Some chemical changes do occur when grains heat in storage or they are influenced by artificial heat. The extent of alteration or deterioration depends on the extent and conditions of the heating process. However, these changes which are due to heat are usually relatively small and the nutritive value remains surprisingly good. The grain must be noticeably damaged for extensive loss of nutritive value. In many instances other factors such as molds or fungus cause more damage to the grain than heating.

2. The protein and ash content of stored or moderately heated grain will remain about the same or increase slightly due to a decrease of moisture. High moisture and heat may cause some breakdown of polypeptides to amino acids. Fat is fairly stable, but high temperature and moisture can cause enzymes to breakdown fats to free fatty acids and glycerol.

3. Cooking grains or rations affects the nutritional value. The effects depend on many conditions, such as the amount of heat, cooking pressure, moisture used, time of cooking and other factors will affect the end product.

4. Heating starch with moist heat in the cooking process causes hydration of the starch and the hydrated starch is more rapidly digested by rumen microorganisms than untreated starch.

5. The effects of heating on ensiled high moisture corn has not been well established by research, but the heating effect *per se* is probably small.

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