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Studies on Feed Spoilage . . .

Heating in Simple and Complex Feed Mixtures

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R. D. LEWIS, DIRECTOR, COLLEGE STATION, TEXAS

DIGEST

Studies described in this publication are: (1) heating in mixtures containing two ingredients; (2) heating in mixtures containing five or more ingredients; (3) heating in pelleted feeds; (4) sodium propionate as a heat inhibitor in mixtures containing 2.5 to 5.0 percent of ingredients with 45 to 50 percent moisture; and (5) action of various materials tested as possible heat inhibitors.

Heating in mixtures depended on the moisture content and concentration of each individual ingredient present. A mixture containing two ingredients always heated when both ingredients were above the critical moisture level. When one ingredient was above and the other below the critical level, the mixture usually heated when the concentration of the high moisture ingredient was high enough.

In general, heating in mixtures containing five or more ingredients depended on the moisture content of the ingredient which was present in the largest amount. When an ingredient contained 45 to 50 percent moisture, the addition of 2.5 to 5.0 percent of this ingredient usually caused the mixture to heat, even though the mixture did not heat before the ingredient high in moisture was added.

With present federal moisture standards for grains, it is practically impossible to add 10 percent of blackstrap molasses or 2.5 to 5.0 percent of fish solubles or condensed corn fermentation solubles without the feeds being highly susceptible to heating. Feeds containing 16 to 17 percent moisture were safe from heating when pelleted and the pellets were allowed to cool while exposed to air. Pelleted feeds cooled in a closed container, heated in the same time as unpelleted mixtures. Sodium propionate at a level of 0.3 percent prevented heating in mixtures containing 16 percent moisture. Therefore, sodium propionate could be used to an advantage to prevent heating in feeds high in moisture or when stored at above 85°F.

The moisture content of mixed feeds may be misleading with regard to its susceptibility to heating. A feed containing animal fat and 11.5 percent moisture heated as readily as one without fat and containing 13.5 percent moisture.

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Studies on Feed Spoilage . . .

Heating in Simple and Complex Feed Mixtures

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CRITICAL MOISTURE LEVELS of more than 30 individual feed ingredients, including grain and grain by-products, protein concentrates, dehydrated alfalfa meals, and bonemeal have been reported by Halick and Richardson (1953) and by Halick, Richardson and Cline (1957). Heating in a few mixtures was described in the same reports. The mixtures investigated contained ground corn and molasses and ground corn and fat. Heating in mixtures containing ground corn and molasses depended on the moisture content of both the ground corn and the molasses, but mixtures containing molasses high in moisture always heated more readily than those containing molasses low in moisture. When the moisture content of ground corn was high, the mixture heated regardless of the moisture content of the molasses. The addition of fat had no significant effect on heating in the mixtures, but a mixture containing a large amount of fat heated at a lower total moisture level than one containing no fat or only a small amount of fat.

After the critical moisture level of most of the individual ingredients had been determined, further studies were initiated to determine the nature of spontaneous heating in various mixtures of feed ingredients. The following studies are described in this report: (1) heating in mixtures containing two ingredients; (2) heating in mixtures containing five or more ingredients; (3) heating in pelleted feeds; (4) sodium propionate as a heat inhibitor in mixtures containing ingredients high in moisture; and (5) screening of various materials as possible heat inhibitors.

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EXPERIMENTAL PROCEDURE

The procedure and apparatus used were the same as that described by Halick and Richardson (1953). Generally, the following procedure was used in preparing the various mixtures. Each individual ingredient was adjusted to the desired moisture content by direct addition of a calculated amount of water. The water was allowed to equilibrate with the ingredient overnight in a room maintained at 40° F. After equilibration, weighed amounts of each individual ingredient were mixed thoroughly so that the resultant mixture contained the desired concentration of each ingredient. Two kilos of the final mixture were placed in a 4-liter Dewar flask in the heating apparatus. Moisture contents of the individual ingredients and of the final mixtures were determined by drying in a vacuum oven according to the AOAC procedure.

RESULTS AND DISCUSSION

Heating in Mixtures Containing Two Ingredients

The combinations used to determine the effect of each ingredient on heating in mixtures of two ingredients were: ground corn and bonemeal, ground corn and cottonseed meal, ground corn and fish meal, cottonseed meal and bonemeal, sorghum gluten meal and bonemeal, and distillers dried grain solubles and fish meal. It is recognized that these mixtures are not representative of practical feed mixtures, but they were used to demonstrate the complex nature of heating in mixed feeds.

One Ingredient Above the Critical Moisture Level. The results when the moisture content of one ingredient was above the critical level are summarized in Table 1, series A. In this case, the moisture content of the other ingredient was adjusted to a value slightly below the critical level so that no heating would occur before it was mixed with another ingredient that was above the critical level. Three experiments were carried out with mixtures containing ground corn and steamed bonemeal. In these tests, the moisture content of the bonemeal was above the critical level.

When the moisture content of bonemeal was 10.6 and 12.1 percent (groups 4 and 9), it took 200 gms/kg or 20 percent bonemeal for the mixture to heat. However, the mixture heated in 25 days with bonemeal containing 12.1 percent moisture (group 9), but it required 32 days when the bonemeal contained 10.6 percent moisture (group 4). When the moisture content of the bonemeal was increased to 13.6 percent (groups 10-13), it took only 100 gm/kg or 10 percent of bonemeal to start to heat in 12 days. Similarily, if the moisture content of the ground corn had been increased, heating probably would have occurred with a smaller amount of the bonemeal. But if the moisture content of the corn had been lower, a larger quantity of bonemeal could have been added before heating would have occurred.

These tests also illustrate that the moisture value of the final mixture is not a reliable indication of when a mixture will heat. For example, (groups 1-5), the mixture with a moisture content of 12.1 percent heated in 15 days while the mixture with 13.2 percent did not heat. The reason for this difference is due to the proportion of the bonemeal present which had a lower critical moisture level than the ground corn.

A more practical situation with respect to the effect of the concentration of each ingredient on heating in mixtures is illustrated by the combination of ground corn and cottonseed meal (groups 14-17). The moisture content of the ground corn was below the critical level and it did not heat during storage, while cottonseed meal containing 13.7 percent moisture heated in 21 days. When 20 percent or 200 gms/kg of this meal was mixed with the corn containing 13.0 percent moisture, no heating occurred, but when 30 percent or 300 gms/kg of the cottonseed meal was mixed with the same corn, heating occurred in 43 days. Similar tests with ground corn and fish meal (groups 18-21), cottonseed meal and bonemeal (groups 22-25), sorghum gluten meal and bonemeal (groups 26-29), and dried distillers grain solubles and fish meal (groups 30-33) illustrate the same principles as those demonstrated by the tests with mixtures of ground corn and bonemeal.

Both Ingredients Above the Critical Moisture Level. When both ingredients were above the critical level, every combination heated regardless of the proportion of each ingredient in the mixture. The data for combinations of ground corn and cottonseed meal which are summarized in groups 34-36 (Table 1) illustrate this condition. In general, the data in Table 1 show that spontaneous heating and the accompanying deterioration in mixed feeds depends on the moisture content and the concentration of each individual ingredient in the mixture, rather than on the particular kind of ingredient or ingredients present. The addition of one ingredient with a moisture content above the critical level may increase the amount of available moisture within the mixture to a point where mold growth and the accompanying heating will occur.

TABLE 1. HEATING IN MIXTURES CONTAINING TWO INGREDIENTS WHEN STORED AT 90°F AND 70 PERCENT RELATIVE HUMIDITY

Group no.	Ingredients[1] gm/kg	Moisture, %			gm/kg	Moisture, %	Moisture mixture, %	Heated, days
SERIES A—Moisture content of one ingredient above the critical level								
1. Corn	1000	13.2	+	BM[2]	0		13.2	
2. Corn	0		+	BM[2]	1000	10.6	10.6	5
3. Corn	900	13.2	+	BM[2]	100	10.6	13.2	
4. Corn	800	13.2	+	BM[2]	200	10.6	12.8	32
5. Corn	600	13.2	+	BM[2]	400	10.6	12.1	15
6. Corn	1000	13.2	+	BM	0		13.5	
7. Corn	0		+	BM	1000	12.1	12.1	5
8. Corn	900	13.2	+	BM	100	12.1	13.2	
9. Corn	800	13.2	+	BM	200	12.1	13.1	25
10. Corn	1000	13.2	+	BM	0		13.2	
11. Corn	0		+	BM	1000	13.6	13.6	2
12. Corn	950	13.2	+	BM	50	13.6	13.2	
13. Corn	900	13.2	+	BM	100	13.6	13.2	12
15. Corn	0		+	CSM	0		13.0	
14. Corn	1000	13.0	+	CSM	1000	13.7	13.7	21
16. Corn	800	13.0	+	CSM	200	13.7	13.0	
17. Corn	700	13.0	+	CSM	300	13.7	13.1	43
18. Corn	1000	13.1	+	FM	0		13.1	
19. Corn	0		+	FM	1000	13.6	13.6	58
20. Corn	900	13.0	+	FM	100	13.6	13.2	
21. Corn	800	13.0	+	FM	200	13.6	13.2	64
22. CSM	1000	12.2	+	BM	0		12.2	
23. CSM	0		+	BM	1000	11.5	11.5	3
24. CSM	900	12.2	+	BM	100	11.5	12.2	
25. CSM	800	12.2	+	BM	200	11.5	12.1	22
26. MGM	1000	10.7	+	BM	0		10.7	
27. MGM	0		+	BM	1000	9.9	9.9	6
28. MGM	900	10.7	+	BM	100	9.9	10.6	
29. MGM	800	10.7	+	BM	200	9.9	10.4	38
30. DGS	1000	13.2	+	FM	0		13.2	
31. DGS	0		+	FM	1000	13.5	13.5	34
32. DGS	950	13.2	+	FM	50	13.5	13.2	66
33. DGS	900	13.2	+	FM	100	13.5	13.2	55
SERIES B—Moisture content of both ingredients above the critical level								
34. Corn	1000	14.3	+	CSM	0		14.3	41
35. Corn	0		+	CSM	1000	13.9	13.9	19
36. Corn	900	14.3	+	CSM	100	13.9	14.1	29

[1]Determined
[2] Corn = Ground corn
BM = Steamed bonemeal
CSM = Cottonseed meal
FM = Fish meal
MGM = Sorghum gluten meal
DGS = Dried distilled grain solubles

Heating in Complex Mixtures Containing Five or More Ingredients

Mixtures containing five or more ingredients were then investigated to determine the effect of varying the moisture content of the major ingredients on heating in complex mixtures. Another condition superimposed on the variation of the moisture content of the major ingredient was the addition of 2.5 and 5.0 percent corn fermentation solubles and fish solubles which contained 45 to 53 percent moisture, respectively. The basal mixture used in these tests contained, in percentage: corn meal or ground sorghum grain 69, soybean oil meal 25, steamed

TABLE 2. HEATING IN COMPLEX MIXTURES CONTAINING INGREDIENTS WITH VARIOUS AMOUNTS OF MOISTURE

Group no.	Moisture content: Corn meal, %	Moisture content: Soybean meal, %	Amount of supplement added, gm/kg		Equivalent amount of water added as supplement, gm/kg	Moisture content of mixture, %	Heated, days
SERIES A—Moisture content of corn and soybean meal varied							
1	12.5	12.5	None			12.6	
2	12.5	16.0	None			13.8	27
3	12.5	15.0	None			13.0	
4	15.0	12.5	None			13.9	24
SERIES B—Ingredient high in moisture added							
7	12.5	12.5	CS[1]	25	11	13.2	31
8	12.5	12.5	FS	25	13	13.2	38
9	12.5	12.5	Water	10	10	13.2	33
SERIES C—100 gm animal fat added							
10	12.5	12.5	None		0	11.0	
11	12.5	16.0	None		0	11.5	29
12	12.5	12.5	CS	25	11	11.8	33

[1]CS = Condensed corn fermentation solubles
FS = Fish solubles

bonemeal 3, dehydrated alfalfa leaf meal 2.5 and salt 0.5. The moisture content of the steamed bonemeal and of dehydrated alfalfa leaf meal was constant in all tests at 7.0 and 13.5 percent, respectively. These moisture values are below the critical levels for both ingredients and, because of the relatively small amounts present, would have little effect on heating in the mixture.

Moisture Content of Corn Meal and Soybean Meal Varied. Heating in mixtures when the moisture contents of the two major ingredients varied (corn meal and soybean meal) is summarized in Table 2, series A. When the moisture content of corn meal was 12.5 percent, mixtures containing soybean meal with 12.5 (group 1) and 15.0 (group 3) percent moisture did not heat; but when the soybean meal contained 16 percent moisture, the mixture (group 2) heated in 27 days. However, when the moisture content of the corn meal was 15.0 percent and that of the soybean meal 12.5 percent, the mixture heated in 24 days, even though the critical moisture levels of these two ingredients were approximately the same. These data show that the moisture content of the ingredient which is present in the largest amounts, has a greater influence on heating than another ingredient which is present in relatively smaller amounts. This condition would be true regardless of whether the feed was a concentrate to be supplemented with grains produced on the farm or a complete feed to be fed without any supplementation.

In general, when a complex mixture does not contain an ingredient excessively high in moisture, such as those containing 40 to 55 percent moisture, heating is influenced most by the moisture content of the ingredient which is present in largest amounts. Since animal and poultry feeds usually contain large amounts of cereal grains, it is essential that the moisture content of these materials be decidedly below the critical level. With present federal standards for the moisture content of grain, these components of a feed are likely to be responsible for a large percentage of the spontaneous heating in mixed feeds.

Heating in Mixtures Containing Ingredients High in Moisture. The data in Table 2 series B, show the effect of adding ingredients high in moisture on heating in a basal mixture which did not heat before the supplements were added. The addition of 2.5 percent of corn fermentation solubles (group 7) or fish solubles (group 8) to the basal mixture (group 1), caused the mixture to heat during a storage period of less than 6 weeks. When ordinary tap water was added (group 9) to the basal mixture in an amount equivalent to the amount of water in the supplement, heating occurred in essentially the same time as when the supplement was added. These data show that heating in mixtures containing the high moisture ingredients is due to the amount of water added by that present in the ingredient, rather than to any other property.

When corn fermentation solubles and fish solubles were

TABLE 3. EFFECT OF PELLETING AND TREATMENT AFTER PELLETING ON SPONTANEOUS HEATING IN MIXTURES CONTAINING CORN FERMENTATION SOLUBLES

Corn solubles added, gms/kg	Moisture content: Mixture before pelleting, %	Moisture content: Mixture after pelleting and cooling, %	Heated, days
Pellets cooled in shallow trays exposed to air			
0	15.1	11.1	
25	15.9	11.8	
50	16.4	11.6	
Pellets cooled in closed containers			
0	15.0	15.0	11
25	15.9	15.9	10
50	16.4	17.0	9

TABLE 4. HEATING-INHIBITING ACTIVITY OF SODIUM PROPIONATE IN COMPLEX MIXTURES

Mixture no.	Moisture content: Corn meal, %	Moisture content: Soybean meal, %	Ingredient & amount added, gm/kg		Moisture content of mixture, %	Heated, days
1	12.5	12.5	CS[1]	25.0	13.2	32
2	12.5	12.5	CS +	25.0	13.2	
			P	3.0		
3	12.5	12.5	CS	50.0	14.1	16
4	12.5	12.5	CS +	50.0	14.1	
			P	3.0		
5	14.5	15.0	CS	50.0	16.0	8
6	14.5	15.0	CS +	50.0	16.0	
			P	3.0		

[1]CS = Condensed corn fermentation solubles
P = Sodium propionate

added to the mixtures at a level of 5.0 percent, heating occurred sooner than with 2.5 percent. Tests were carried out to determine the lowest moisture content of ground corn or ground sorghum grain in order for mixtures containing corn fermentation or fish solubles to remain safe from heating. When the moisture content of ground corn or ground sorghum grain was above 10.5 percent, the mixture with 5.0 percent of either ingredient heated, but when it was 10.5 percent or less, the mixture did not heat.

Heating in Mixtures Containing Feed Grade Animal Fat

The data in Table 2, series C, illustrate that moisture contents of complex mixtures often may be misleading with regard to the susceptibility of a mixture to heat. For example, when 10 percent of feed grade animal fat (group 11) was substituted for an equal amount of ground corn in the mixture used in group 2, heating occurred in essentially the same time as it occurred without the fat, even though the final moisture content was reduced from 13.8 to 11.5 percent. When 2.5 percent of corn fermentation solubles was added to the mixture used in group 10, heating occurred even though the final moisture content was only 11.8 percent, as compared with 13.2 percent when the mixture contained no fat. Halick, *et al* (1957) reported that heating in mixtures containing fat is due to the moisture content of the hygroscopic ingredients, rather than to the final moisture of the mixture. When fat is added, the moisture content of the mixture is reduced because no moisture is added by the fat.

Effect of Pelleting on Spontaneous Heating in Mixed Feeds

A large portion of commercial feeds are pelleted. The effect of pelleting and the treatment immediately after pelleting on heating in feeds that were relatively high in moisture were determined. The results with feeds containing 2.5 and 5.0 percent of corn fermentation solubles are summarized in Table 3. When the pellets were allowed to cool in shallow trays exposed to normal air currents in the laboratory, the moisture content of the pellets was decreased from approximately 16.0 percent to below 12.0 percent, and the pellets were safe from heating regardless of the amount of corn fermentation solubles present. However, when the pellets were allowed to cool in closed containers with essentially no loss in moisture, all mixtures heated within 9 to 11 days.

In general, feeds coming from the pelleting machine are hot enough to evaporate off the excess moisture when the pellets are allowed to cool and aerate in thin layers. If conditions are such that the excess moisture is not removed, the pellets will heat as readily as the non-pelleted feed with the same moisture content. These data indicate that pelleting and proper treatment after pelleting may be a safe way to use ingredients that contain excessive amounts of moisture.

Heat-inhibiting Activity of Sodium Propionate

Sodium propionate is used to prevent the growth of molds in many human foods, and it has been shown that calcium or sodium propionate prevents heating in ground corn high in moisture. In view of these earlier reports, tests were carried out to determine whether sodium propionate would prevent heating in mixtures containig 2.5 and 5.0 percent of corn fermentation solubles. These results, which are summarized in Table 4, show that the addition of sodium propionate at a level of 0.3 percent inhibited heating in mixtures containing 13.2 to 16.0 percent moisture.

TABLE 5. COMPOUNDS TESTED AS HEAT INHIBITOR

Compound	Amount, %	Heated, days
Cetyltrimethyl ammonium bromide	1.1	
Methyl p-hydroxybenzoate	0.7	
Propyl p-hydroxybenzoate	0.5	
Sodium dehydroacetic monohydrate	0.2	
Dehydroacetic acid	0.1	
Dichlorophene	0.2	8
Tetraalkyl ammonium stearate	2.0	6
Bentonite	10.0	5

[1]Did not heat in 6 weeks

Recent studies indicate that sodium propionate added to corn fermentation solubles at a pH below 4.5 will prevent heating in feed mixtures that contain as little as 0.1 percent propionate.

Products Tested for Possible Heat-inhibiting Activity

Richardson and Halick (1957) reviewed the literature on the use of various substances that have been used to prevent the growth of molds and reported the results of tests with several products that were tested for their inhibiting activity in ground corn. Several additional products have been tested and these results are given in Table 5. Both sodum dehydroacetic monohydrate and dehydroacetic acid at relatively low dose levels prevented heating for the entire 6 weeks storage period. Products screened that did not delay or prevent heating at the highest levels tested were: dichlorophene, tetralkyl ammonium stearate and bentonite.

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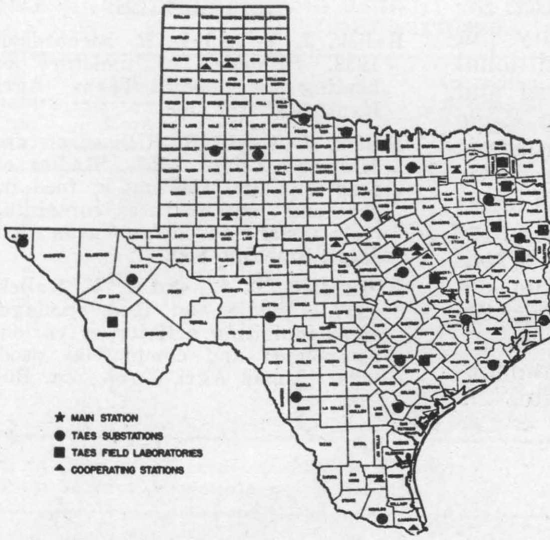

Location of field research units of the Texas Agricultural Experiment Station and cooperating agencies

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