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THE CHEMICAL DETERMINATION OF SOUNDNESS IN CORN
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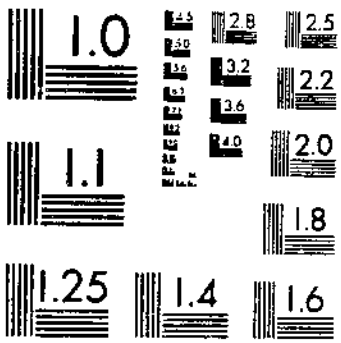

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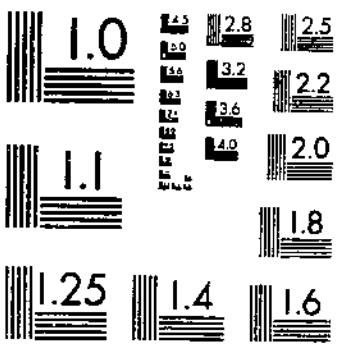

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NATIONAL BUREAU OF STANDARDS-1963-A

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THE CHEMICAL DETERMINATION OF SOUNDNESS IN CORN[1]

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IMPORTANCE OF SOUNDNESS AS A GRADING FACTOR

A primary objective in agricultural-standardization research is the development of devices and precise methods for measuring the quality of farm products. Under the official standards of the United States, the quality factors used in the grading of all cereal grains are test weight per bushel, moisture content, foreign material, condition, and damage. Of these factors, test weight per bushel, moisture content, and foreign material are readily determined with high accuracy by mechanical devices, for each determination has a fundamental physical basis. But condition and damage cannot be evaluated by precise physical measurements.

The factors of condition and damage are more closely related to the intrinsic quality of the grain than are the other grading factors. Most kinds of foreign material can be removed by appropriate cleaning machinery, test weight can be improved by drying and handling operations, and moisture content can be reduced by handling, mixing, and artificial drying. On the other hand, grain that has undergone severe heating or fermentation, or has been attacked by fungi or by certain types of bacteria, will have suffered in all cases a degree of irreparable damage. The outward evidence of such damage may be

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partially obscured in some instances by various kinds of grain-conditioning treatments, but the actual deterioration that has taken place will ultimately manifest itself in the inferior quality of products derived from the processing of the grain, in the inferior nutritive value of feed grains, or by an increased storage hazard.

The difficulty in determining degree of soundness lies chiefly in the fact that there exists no fundamental unit of soundness to be used as a basis of comparison. Soundness is necessarily a relative concept depending in its degree on numerous factors, the relative importance of which depends to a considerable extent on the ultimate use to be made of the grain.

In grain-grading practice, condition and damage are appraised by odor and by the percentage by weight of damaged kernels present in the grain. Heat-damaged kernels are considered separately, and their presence is interpreted as indicating a greater degree of deterioration than an equivalent percentage of kernels that have been damaged from other causes. Musty and sour odors are evidences of unsoundness, and their presence in grain eliminates it from the numerical grades. Such grain is graded Sample grade regardless of its damaged-kernel content. These methods of determining soundness have been valuable, and in the absence of more precise methods, have been used successfully in grain-inspection procedure under the United States Grain Standards Act since 1916.

The damaged-kernel index of unsoundness is subject to several important inherent weaknesses which limit its usefulness and justify an effort to devise a more desirable method In the first place, the damage-count method does not take into consideration the degree of damage in the damaged portion, nor the degree of soundness in the sound portion. Two samples containing the same percentage of damaged kernels may have undergone quite different degrees of deterioration.

In the second place, the method comprises only those forms of physical damage that are apparent by visual inspection. Certain forms of deterioration in their early stages do not affect the external appearance of the kernel, yet they undermine grain quality.

In the third place, in spite of the fact that surprisingly successful efforts have been made toward obtaining concordant results between inspectors, the damaged-kernel method is subject to errors arising from unavoidable differences in personal judgment as to what constitutes a damaged kernel. Many samples contain considerable quantities of kernels that are on the border line of damage and that may be judged sound by one inspector and damaged by another, thus affecting adversely the uniformity of inspection.

The Bureau of Agricultural Economics has undertaken a careful study of this problem in an effort to devise improved methods for determining the degree of soundness in the cereal grains, which may serve usefully as a commercial measure of grain quality.

This research has resulted in the development of a chemical method for determining the soundness of corn that is simple and rapid and which, it is believed, will meet the requirements of commercial practicability.

DETERIORATION OF VARIOUS COMPONENTS OF THE CORN KERNEL

The approximate chemical composition of domestic dent corn on a dry-matter basis is as follows:

	Percent
Ash	2
Protein	12
Crude fiber	2
Sugars	1
Pentosans	5
Other carbohydrates (principally starch)	73
Crude fat	5

Differences in variety and in the climatic and agronomic conditions under which the corn is grown may cause considerable variations in the percentages of the various components.

When corn deteriorates from any cause, measurable chemical changes occur in certain of its components. The extent of these chemical changes provides information concerning the nature and extent of the deterioration.

THE CARBOHYDRATES

Conditions that favor deterioration of corn are likely to result in hydrolytic changes in the starch and pentosans, chiefly through enzymatic action. In the case of starch, the principal carbohydrate of corn, soluble starches are first formed. They in turn are converted into dextrins, maltose, and finally glucose. Pentosans are hydrolyzed in an analogous way, resulting in the formation of pentose sugars. Theoretically such changes should result in a decrease in starch and pentosan content, an increase in water-soluble constituents, and an increase in the content of reducing sugars.

In order to determine whether or not the changes in the carbohydrates are of sufficient magnitude to serve as possible measures of soundness, determinations were made of cold-water extracts, total sugars, and reducing sugars. A series of eight samples of domestic commercial dent corn were used representing different degrees of soundness. The nitrogen contents (calculated as protein) of the extracts were also determined.

These data, shown in table 1, indicate that the total water-soluble carbohydrates do not vary appreciably with the degree of soundness of corn, except that there appears to be a slight decrease in this fraction in the case of badly damaged samples. The total sugar content is relatively constant for the entire series, while the reducing sugars are somewhat higher in the badly damaged samples, but show no significant differences between the sound and the moderately damaged samples.

It is probable that in the samples analyzed greater quantities of reducing sugars were formed than is indicated by the analyses, but as conditions favoring deterioration (high moisture, high temperature, molds, etc.) also favor a high rate of respiration, much of this sugar would be lost in the process of respiration. It appears, therefore, that the changes that occur in the carbohydrates of the corn kernel as it deteriorates are not reliable measures of the extent of deterioration.

TABLE 1.—*Water-soluble carbohydrate relationships between samples of corn representing different degrees of soundness*

Sample No.	Soundness score[1]	Cold-water extract	Protein of cold-water extract	Extract minus protein [2]	Total sugar [3]	Reducing sugar [4]
		Percent	*Percent*	*Percent*	*Percent*	*Percent*
7	99.2	5.1	1.1	4.0	1.4	0.21
17	98.5	5.1	1.1	4.0	1.0	.28
18	97.6	4.7	1.0	3.7	1.5	.25
16	95.7	5.2	1.1	4.1	1.5	.23
19	91.9	5.2	1.1	4.1	1.7	.32
9	89.8	5.2	1.1	4.1	1.5	.30
2	72.4	4.5	1.1	3.4	1.4	.43
242	67.1	4.2	1.2	3.0	1.4	.53

[1] For definition see p. 17.
[2] Consists essentially of water-soluble carbohydrates plus water-soluble ash.
[3] Calculated as maltose.
[4] Calculated as glucose.

THE PROTEINS

The proteins of the corn kernel consist chiefly of a prolamine (zein) and a glutelin (zeinin) along with lesser quantities of one or more globulins and traces of a proteose or peptone.

The mature, sound corn kernel also contains a small quantity of water-soluble nitrogenous compounds consisting chiefly of amino acids and polypeptides. It has been shown by Zeleny (*21*) [3] that the ratio of the quantity of these water-soluble nitrogenous compounds to the total nitrogen content decreases rapidly as the corn kernel approaches maturity, this decrease being accompanied by a corresponding increase in the zein. At any stage of maturity the sum of the zein nitrogen and the water-soluble nitrogen is an approximately constant fraction of the total nitrogen.

Conditions that favor deterioration in the corn kernel in general also cause an increase in the amino acid content, the amino acid being produced by the action of proteolytic enzymes which are either present in the kernel or come from external sources such as molds or microorganisms, on the proteins of the corn. Preliminary studies have shown that the increase in amino acid content of corn as it deteriorates is readily demonstrable and may therefore be of value in the measurement of soundness.

THE OIL

The fatty oil of the corn kernel is a liquid of the semidrying class, having an iodine number (Hanus) of about 125. It usually comprises from 3 to 6.5 percent of the kernel. The oil is found chiefly in the germ, which consists of about 30 percent of oil. As the germ appears to be the vulnerable part of the kernel for most types of damage, it might be anticipated that incipient damage could be detected in chemical changes in the oil more readily than in other parts of the kernel.

Deterioration of fatty oils is manifested either as oxidative rancidity caused by the oxidation of the unsaturated constituents of the oil, or hydrolytic rancidity caused by the enzymatic hydrolysis of the oil with the production of free fatty acids. As the oil of the unbroken kernel is fairly well protected from the air, no appreciable oxidation of the oil is likely to occur unless the kernel is rather badly damaged. The free fatty-acid content of the oil, on the other hand, increases measurably with most types of damage.

[3] Italic numbers in parentheses refer to Literature Cited, p. 22.

ACIDITY AS A MEASURE OF DETERIORATION

As deterioration of cereals and cereal products appears to be associated with the formation of various types of acidic substances, numerous methods have been proposed to determine this acidity in order to measure the degree of deterioration which the cereal or cereal product has undergone.

HYDROGEN-ION CONCENTRATION

The hydrogen-ion concentration in terms of pH was determined on the water suspensions of a series of seven samples of freshly ground corn, ranging from very sound to badly damaged corn. These data are shown in table 2.

TABLE 2.— *pH values of water suspensions of freshly ground corn samples of different degrees of soundness*

Sample No.	Soundness score [1]	pH	Acid number of oil	Sample No.	Soundness score [1]	pH	Acid number of oil
284	98.7	6.25	2.2	26	70.2	6.24	14.7
285	98.7	6.29	2.4	141	66.2	6.17	26.0
203	97.6	6.22	5.4	138	55.8	6.03	33.6
129	74.4	6.20	22.4				

[1] For definition see p. 22.

Except in the case of the very badly damaged samples, the pH values in the series of samples are suprisingly constant in spite of the wide differences in titratable acidity as measured by the acid numbers of the oils. The high buffer values of the meal undoubtedly account for the relative constancy of the pH values.

TITRATABLE ACIDITY

The relationship between soundness of corn and titratable acidity was first studied in this country by Black and Alsberg (*6*) in 1910. They proposed a method for determining acidity consisting of the extraction of the meal with 85-percent alcohol, diluting the extract with water to a concentration of from 12- to 16-percent alcohol, and titrating with 0.05 N alkali, using phenolphthalein as an indicator. Acidity was expressed as the number of cubic centimeters of normal alkali required to neutralize the acids in 1 kg of corn. It was recommended that for food purposes any corn having an acidity greater than 30 should be rejected.

Besley and Baston (*4, 5*) proposed a somewhat similar method wherein 80-percent alcohol was used for extraction and the extract diluted to 20-percent alcohol before titrating. These workers studied extensively the relationship between acidity and general appearance, percent damage, commercial grade, and germination. They proved conclusively that acidity was a criterion of soundness and quality. Their method has been used to a considerable extent in commercial practice but has not been considered entirely satisfactory.

A great deal of work has been done on the determination of acidity in wheat and particularly in wheat flour. Ladd (*13, p. 54*) in 1909 recommended determining the acidity of flour by extracting with water for 2 hours at 35° to 40° C. and titrating the filtered extracts.

White (*20, pp. 198–199*), Barnard (*3, p. 87*), and LeClerc (*14, pp. 446–449*) have reported on various modifications of the water extract method. The present method (*2, p. 208*) of the Association of Official Agricultural Chemists is an outgrowth of these researches.

In contrast to this method, the Government of Greece has adopted as its official method for determining the acidity of flour, a procedure by which the flour is extracted with 85-percent alcohol, is filtered, and the filtrate is titrated with alcoholic potash, using curcuma as an indicator. This method was developed by the French chemist Balland, and is known as the Balland or Greek method. Since flours imported into Greece from the United States were frequently rejected on the basis of this acidity determination, the Balland method has been rather carefully investigated in this country. Fifield and Bailey (*8*) and Markley and Bailey (*15*) made an extensive comparison of the Balland method with the A. O. A. C. method and found a general, but no specific relationship between the results obtained by the two methods.

Johnson and Green (*10*) conclude from their studies that ether-extractable acids alone are responsible for the changes in titratable acidity that occur in flours during storage, regardless of the method used in determining acidity. They have shown that the increase in the acidity of a water extract of flour, with age of the flour, is rather small compared with the increase in acidity of an ether or alcoholic extract, and believe that the slight solubility of the fatty acids in water is sufficient to account for this increase.

The conclusions of Johnson and Green are supported by Kozmin (*11*) and Kozmin and Alakrinskaya (*12*), who recommend the determination of the acid number of the extracted oil as an index of the age of a flour.

Schulerud (*17, 18*) has made a study of the acidities of flour extracts made with different concentrations of alcohol. He states that water alone extracts not only the acid phosphates originally present in the flour but acid phosphates that are formed during the extraction. This view has come to be generally accepted, the phosphoric acid probably being formed by enzymatic hydrolysis of phytin. Water extracts, therefore, probably do not give a true picture of the actual acidity of the flour. Schulerud further shows that while the high concentrations of alcohol usually recommended for making acidity determinations will extract the fatty acids, they fail to extract the acid phosphates quantitatively. He recommends the use of 67-percent alcohol for extraction, showing that this concentration will extract the acid phosphates as well as the fatty acids, and that it contains sufficient alcohol to inhibit the formation of acid phosphates not originally present in the flour.

Panopoulos and Megalooikonomos (*16*) appear to be in essential agreement with Schulerud. They recommend 70-percent alcohol for the extraction of the acids from flour.

Coleman (*1, 7*) has used the acid number of the petroleum ether extracted oil as a measure of wheat soundness and indirectly as a means of predetermining flour soundness. The approximate upper acidity limits for sound wheats have been shown to differ considerably according to the class of wheat.

FURTHER STUDY OF ACIDITY PROBLEM

CLASSIFICATION OF ACIDIC SUBSTANCES OF THE CORN KERNEL

It has been frequently shown that the various proposed methods for determining the acidity of cereals or cereal products not only fail to give similar results, but in most cases the results obtained by one method are not proportional to those obtained by other methods. This fact is illustrated in table 3 by the acidity of two samples of corn as determined by six different methods, all results being expressed on a common basis.

TABLE 3.—*Acidity of two samples of yellow dent corn as determined by six different methods*

Method	Acidity [1]		Method	Acidity [1]	
	Sample 41	Sample 42		Sample 41	Sample 42
Black and Alsberg (85-percent alcohol)	8.5	14.0	Schulerud (67-percent alcohol)	18.0	27.7
Besley and Baston (80-percent alcohol)	10.7	16.6	Balland (85-percent alcohol)[2]	15.5	25.3
			A. O. A. C. (water extract)	16.7	17.3
			Petroleum ether extract	5.0	9.7

[1] Values expressed as milligrams of potassium hydroxide required to neutralize the acids extracted from 10-g of corn (dry-matter basis).
[2] For the sake of uniformity, phenolphthalein was used as the indicator in place of curcuma.

In the case of the A. O. A. C. water-extraction method, of the petroleum ether-extraction method, and of the alcohol-extraction methods as a group, the differences in results obtained may conceivably be due to differences in the solubilities of the various acidic substances in water, petroleum ether, and alcohol. Among the various alcoholic-extraction methods, however, the differences in acidity values appear to be much greater than could be explained by the relatively small differences in the concentrations of alcohol used for extraction. In the Balland method and the Black and Alsberg method identical concentrations of alcohol are used for extraction, yet the Balland method indicates acidities nearly double those of the Black and Alsberg method. Obviously these differences must be due to some factor other than solubility.

With the Balland method the acids are titrated directly in the 85-percent alcoholic solution used for extraction, whereas in the Black and Alsberg method the alcoholic solution is diluted with water to a concentration of about 14-percent alcohol before being titrated.

To determine the effect of concentration of alcohol in the solution being titrated on the titration value of alcoholic extracts of corn, aliquots of a 50-percent alcoholic extract of a sample of badly damaged corn were diluted with varying quantities of alcohol and water and the resulting solutions were titrated with standard alkali. The results are shown in the following tabulation and graphically in figure 1.

Concentration of alcohol at end-point of titration	Acidity[1]	Concentration of alcohol at end-point of titration	Acidity[1]
Percent		Percent	
86	39.3	33	23.3
79	39.1	19	18.7
75	37.6	10	15.9
65	34.0	5	14.6
56	29.8	2.5	14.3
47	27.9		

[1] Acidity is expressed in terms of milligrams of potassium hydroxide required to neutralize the acids extracted from 10-g of corn (dry-matter basis).

Foreman (*9*) has shown that in 85-percent alcohol the amino groups of amino acids do not have a basic reaction and that the carboxyl groups may therefore be titrated quantitatively with standard alkali. In water solution the monoamino monocarboxylic acids are essentially neutral in reaction. This principle has been used ex-

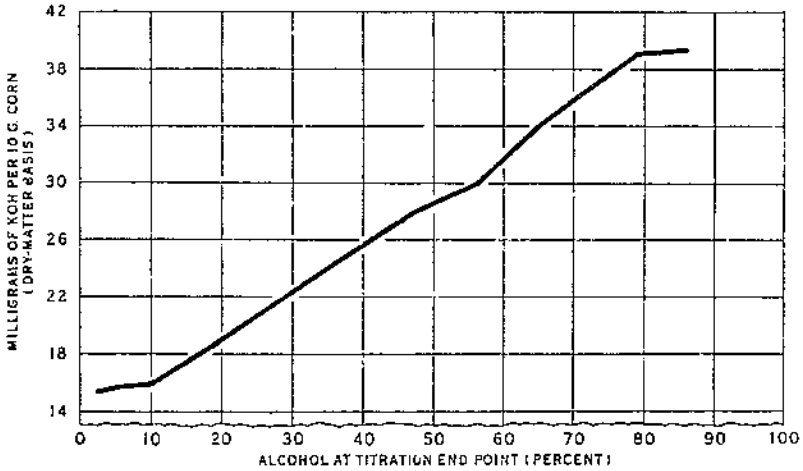

FIGURE 1.—Effect of concentration of alcohol in the solution being titrated on titration value of a 50-percent alcoholic extract of a sample of damaged corn.

tensively as a convenient method for estimating amino acids and explains the differences in apparent acidity of corn extracts when adjusted to different concentrations of alcohol before titration. This fact appears to have been entirely overlooked in the comparative studies that have been made on various methods for determining acidity in cereals and cereal products. In general it may be stated that the concentration of alcohol in the solution titrated is of greater significance than the concentration of alcohol in the solution used for extraction.

To determine the relative quantities of the various types of acidic substances extracted by different concentrations of alcohol the following experiment was performed.

Eleven replicate 10-g samples of freshly ground corn were extracted for 16 hours with petroleum ether and the free fatty acid contents of the ether extracts were determined. The extracted residues were shaken with 100-ml portions of neutral alcohol-water mixtures of varying concentrations for 1 hour and then filtered. Twenty-five-milliliter aliquots of the filtrates were diluted with neutral 95-percent

alcohol to a final concentration of 85-percent alcohol, and were titrated with standard alkali, using phenolphthalein as an indicator. Another series of 25-ml aliquots of the filtrates were diluted with carbon dioxide-free water to a concentration of 5-percent alcohol and were titrated in a similar manner. A second series of 10-g samples of the same corn were extracted with various concentrations of alcohol without the preliminary extraction with petroleum ether. Aliquots of these extracts were titrated in 85-percent alcoholic solution.

From the data obtained three classes of acidic substances extracted by different concentrations of alcohol were determined as follows:

(1) Free fatty acids were determined by the differences in titration values of the alcoholic extracts of the ether-extracted and unextracted samples in 85-percent alcohol.

(2) Amino acid acidities (exclusive of the acidity of the second carboxyl group of dicarboxylic amino acids) were determined by the

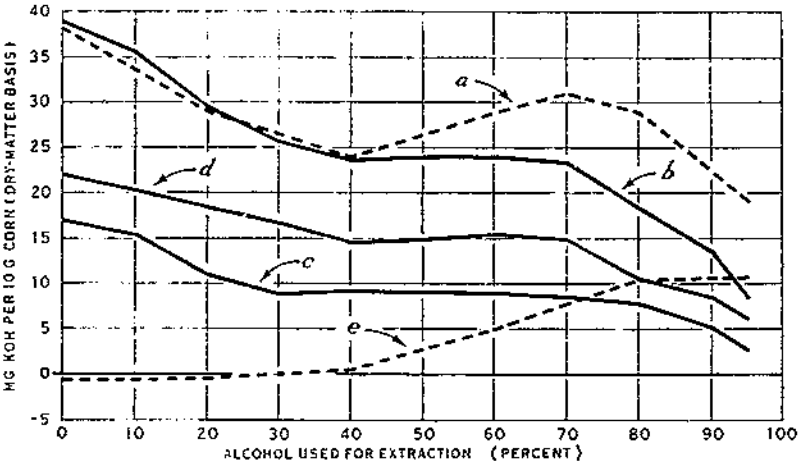

FIGURE 2.— Different types of acidity as determined by extraction of a freshly ground sample of damaged corn with various concentrations of alcohol both before and after extraction with petroleum ether. Letters refer to columns in table 4.

differences in titration values of the alcoholic extracts of the ether-extracted samples in 85-percent alcohol and in 5-percent alcohol.

(3) Acidities due to substances other than petroleum ether-soluble acids and the carboxyl groups of monocarboxylic amino acids were determined by the titration values of the alcoholic extracts of the petroleum ether-extracted samples when titrated in 5-percent alcohol. For convenience the acidities of this group of substances will be referred to as "phosphate acidities" since acid phosphates are the principal acid-reacting substances present. Actually, however, the acidity of this fraction is due to the following classes of compounds:

(1) Inorganic acid phosphates.

(2) Dicarboxylic amino acids. One of the two carboxyl groups of these amino acids is determined in this fraction.

(3) Proteins. A certain quantity of zein is extracted by the alcohol and precipitated as a fine suspension on dilution with water. This zein, along with lesser quantities of other proteins present in the extract acts as an acid toward bases because of its amphoteric properties.

From the data listed in table 4 and shown graphically in figure 2 it appears that the free fatty acids are extracted quantitatively with alcohol of concentrations of 80 percent or over. The amino acids and acid phosphates in the extracts are essentially constant over the ranges of 40- to 70-percent and 30- to 70-percent alcohol, respectively. Below these concentrations of alcohol both the amino acids and acid phosphates increase significantly. These increases appear to be due to the formation of additional amino acids and acid phosphates during the extraction process rather than to the solution of an increasing quantity of these substances originally present in the corn, for in the latter case the flat areas of the extraction curves (fig. 2) would be difficult to explain. This assumption is confirmed by the observation that, with low concentrations of alcohol, the quantity of acid extracted depends to a considerable extent on the temperature and time of extraction, whereas with concentrations of alcohol greater than 40 percent the quantity of acids extracted is relatively independent of these two factors.

It appears, then, that all concentrations of alcohol between 40 and 70 percent contain sufficient water to extract quantitatively the free amino acids and acid phosphates from corn when 100 ml of solvent are used to each 10 g of ground corn, and that such solutions contain sufficient alcohol to inhibit the formation of additional quantities of acidic substances by enzymatic action. These conclusions are substantiated by similar studies on other samples of corn of various degrees of soundness.

TABLE 4.—*Different types of acidity as determined by extractions of a freshly ground sample of damaged corn with various concentrations of ethyl alcohol both before and after extraction with petroleum ether* [1]

Concentration of alcohol by volume for extraction (percent)	Original corn	Fat-free corn			
	Acidity in 85-percent alcohol, total acidity	Acidity in 85-percent alcohol	Acidity in 5-percent alcohol, phosphate acidity	Amino acid acidity	Fat acidity [2]
	a	*b*	*c*	*d=b−c*	*e=a−b*
95	10.19	8.55	2.51	6.04	10.84
90		13.47	5.11	8.36	
80	28.82	18.39	7.72	10.67	10.43
70	30.92	23.29	8.50	14.79	7.63
60	28.91	24.08	8.75	15.33	4.83
50		23.84	8.99	14.85	
40	23.98	23.84	9.04	14.80	.31
30		25.50	8.79	16.71	
20	28.86	29.31	10.86	18.45	−.48
10		35.45	16.23	20.15	
0	38.10	38.87	16.81	22.06	−.77

[1] See footnote 1, table 3.
[2] Fat acidity as determined by petroleum ether extraction: 10.38 mg KOH.

Since alcohol in concentrations greater than 70 percent fails to extract all the amino acids and acid phosphates, and in concentrations less than 80 percent fails to extract all the fatty acids, it is evident that no single concentration of alcohol will extract all the acids of all three types. A concentration of about 70-percent alcohol extracts the

greatest quantity of total acid. This is in approximate agreement with Schulerud's observations on the determination of acidity in wheat flour in which he recommends the use of 67-percent alcohol for extracting the maximum quantity of acid.

METHODS FOR SEPARATE DETERMINATION OF THE THREE PRINCIPAL CLASSES OF ACIDIC COMPOUNDS IN CORN

For the purposes of the present research the following method based on the foregoing investigations has been adopted for determining the fatty acids, the amino acids, and the acid phosphates in corn.

A 50-g representative sample of the corn is ground with a suitable mill to such a degree of fineness that at least 90 percent of the ground material will pass through a 40-mesh gauze sieve. A 10-g sample of the ground corn is extracted for approximately 16 hours in a Soxhlet extractor with petroleum ether. For this purpose a petroleum ether conforming to the specifications adopted as official for the analysis of cottonseed (*19*) is used.

The solvent is completely removed from the extract by evaporation on the steam bath. The weight of the extract is determined, after which the extract is dissolved in 50 ml of a 1:1 solution of benzene and ethanol containing 0.02 percent of phenolphthalein. The dissolved extract is titrated with 0.02 N potassium hydroxide to a definite pink color. From the data obtained, fat acidity may be calculated either in terms of the acid value of the extract or in terms of free fatty acids per given weight of corn. In case the latter value only is desired, the weight of the extract need not be determined.

The petroleum-ether extracted residue is mixed with 100 ml of neutral 60-percent ethyl alcohol containing 0.01 percent of phenolphthalein in a glass-stoppered flask and is shaken at frequent intervals for 30 minutes. The mixture is then filtered rapidly through a folded filter paper.

Two 25-ml aliquots of the filtrate are taken for titration. To one aliquot is added 279 ml of carbon dioxide-free water, and to the other aliquot is added 69 ml of neutral 95-percent ethyl alcohol. The solutions are titrated to a definite pink with 0.02 N potassium hydroxide. The titration value of the aliquot to which the water has been added is a measure of the phosphate acidity, whereas the difference in titration values between the two solutions is a measure of the amino acid acidity of the sample.

ACIDITY OF CORN OF DIFFERENT DEGREES OF SOUNDNESS

The fat acidities, amino acidities, phosphate acidities, and with a few exceptions germinability [4] of 246 samples of corn were determined (table 5). This series consisted of 58 samples of seed corn of various varieties, 175 commercial samples, and 9 special damaged samples consisting of damaged-kernel separations and experimentally damaged corn. Average acidity and germination values classified according to the grade of the samples are shown in table 6.

[4] Most of the germination determinations were made by the Division of Seed Investigations, Bureau of Plant Industry. Germination figures herein reported include both normal and abnormal germination.

TABLE 5.—*Damaged kernels, germination, fat acidity, amino acid acidity, phosphate acidity, total acidity, and soundness score, of 246 samples of corn classified as to grade according to the factor, damaged kernels*

GRADE NO. 1, SEED CORN

Sample No.	Damaged kernels	Germination	Fat acidity [1]	Amino acid acidity [1]	Phosphate acidity [1]	Total acidity [1]	Soundness score
	Percent	*Percent*					
45	1.6		1.7	11.0	5.5	18.2	
46	1.0		1.9	11.3	7.3	20.5	
47	Tr.	100	0.9	10.0	7.4	19.2	100.0
48	2.0		1.1	12.3	8.4	21.8	
49	1.7	84	1.4	8.6	6.3	16.3	98.9
62	Tr.	64	1.7	9.5	9.0	20.2	98.1
63	Tr.	68	1.4	9.2	7.2	17.8	98.3
64	Tr.	85	1.6	9.8	8.1	19.5	99.3
73	0.0	84	.9	11.1	8.2	20.2	99.2
74	.8	70	1.4	10.1	8.9	20.4	98.3
75	.0	88	1.0	12.8	8.6	22.4	99.4
76	.0		1.4	11.3	8.2	20.9	
91	Tr.	36	1.5	12.0	7.3	21.7	99.3
92	Tr.	97	1.2	10.5	9.2	20.9	99.7
93	Tr.	100	1.1	12.3	9.3	22.7	99.8
94	Tr.	96	1.8	11.4	8.7	21.9	99.8
144	.8		1.3	13.1	5.4	19.8	
145	1.3		1.3	12.4	5.5	19.2	
146	1.1		1.0	12.0	5.1	18.1	
147	2.2		1.6	12.8	6.4	20.8	
148	2.4		1.4	12.2	5.8	19.4	
149	.4		1.3	11.0	6.9	19.2	
151	.9		1.3	10.0	7.9	19.2	
152	2.2		1.3	12.4	6.7	20.4	
153	2.6		1.2	11.1	7.3	19.6	
239	1.9		1.3	11.1	7.2	19.6	
240	Tr.	88	1.6	12.9	7.1	21.6	98.3
252	Tr.	88	1.4	11.2	5.2	17.8	99.4
251	Tr.	94	1.4	12.2	5.7	19.3	99.5
256	Tr.	88	1.5	12.3	6.4	20.2	99.4
258	1.0	94	1.3	11.1	6.3	18.7	99.5
260	1.2	70	1.8	10.7	9.0	21.5	98.2
261	.0	100	1.0	11.8	6.9	19.7	100.0
262	.6	98	1.3	13.2	8.8	23.3	99.8
263	1.5	92	1.2	11.3	6.8	19.3	99.3
264	1.0	85	1.5	11.3	8.3	21.1	99.1
265	2.4	86	1.5	10.2	5.6	17.3	98.9
208	.1	100	1.5	14.3	8.3	24.1	99.6
267	.1	96	1.1	12.2	7.7	21.0	99.8
268	2.2	100	1.4	12.6	7.5	21.5	99.6
269	.2	100	1.2	11.0	7.1	19.3	100.0
270	1.0	96	1.3	12.3	7.4	21.0	99.6
271	.6	98	1.6	14.0	7.5	23.1	99.8
272	2.1	94	1.2	9.4	7.3	17.9	99.3
273	.6	90	1.2	10.2	7.5	18.9	99.4
274	.8	100	1.3	12.2	7.2	20.7	99.9
275	.6	96	1.4	11.7	6.8	19.9	99.7
276	1.7	98	1.4	11.1	6.7	19.2	99.0
277	.2	98	1.1	12.9	8.4	22.4	99.9
278	1.0	96	1.2	11.3	5.9	18.4	99.6
279	.1	88	.9	12.0	6.7	19.6	99.4
280	1.1	84	1.2	11.4	6.4	19.0	99.0
281	1.9	86	1.8	11.8	5.6	19.2	99.0
282	.1	92	1.0	13.1	6.2	20.3	99.6
283	.2	84	1.0	13.2	8.4	22.6	99.2
284	1.5	80	.9	10.2	6.8	17.9	98.7
285	.4	76	1.1	11.5	8.3	20.9	98.7
286	1.2	82	1.3	12.6	6.8	20.7	98.0

GRADE NO. 1, COMMERCIAL

1	1.1		2.4	11.8	6.8	21.0	
4	Tr.	86	2.8	10.8	5.8	19.4	98.6
7	Tr.	83	1.5	10.8	6.8	18.1	99.2
11	Tr.		2.5	12.0	6.5	21.0	
67	1.0	93	1.1	8.3	5.8	15.2	99.5
77	1.6	82	1.2	10.7	7.3	19.2	98.8
78	2.0	85	1.2	11.2	6.6	19.0	98.9
81	2.6	85	1.6	11.1	7.9	20.5	98.5
97	2.7	91	2.5	11.2	5.6	19.3	98.6
118	2.6	58	4.2	12.1	5.8	22.1	96.2

[1] See footnote 1, table 3.

TABLE 5.—*Damaged kernels, germination, fat acidity, amino acid acidity, phosphate acidity, total acidity, and soundness score, of 246 samples of corn classified as to grade according to the factor, damaged kernels*—Continued

GRADE NO. 1, COMMERCIAL—Continued

Sample No.	Damaged kernels	Germination	Fat acidity	Amino acid acidity	Phosphate acidity	Total acidity	Soundness score
	Percent	*Percent*					
119	2.7	77	3.5	11.6	4.9	20.0	97.0
122	2.3	88	1.4	10.5	6.9	18.8	99.0
201	2.7	81	2.2	13.1	6.9	22.2	98.4
210	3.0	77	1.9	13.9	7.6	23.4	98.3
213	2.8	80	1.6	12.3	6.0	19.9	98.9
214	2.8	79	1.7	11.5	6.6	19.8	98.4
216	3.0	80	1.7	12.0	8.6	22.3	98.0
220	1.1	90	2.0	10.9	6.8	18.8	99.3
250	3.0	82	2.4	10.8	6.6	19.9	98.2
201	2.2	72	2.2	12.4	8.4	23.0	98.0
202	1.8	64	2.3	12.7	8.0	23.0	97.4
203	2.8	72	1.6	13.3	8.2	23.4	98.6
204	2.6	80	3.4	12.4	9.3	25.1	97.6
205	3.0	80	3.1	12.5	10.5	26.1	96.2
206	2.5	48	2.6	16.2	10.9	29.7	92.0
303	3.0	54	3.0	16.6	8.9	28.5	93.0
304	3.0	50	3.0	16.9	9.0	28.9	92.6
305	2.8	42	3.9	16.0	9.7	29.6	91.2
306	3.0	90	1.9	12.1	6.3	20.3	98.9
311	3.0	.....	1.9	8.3	8.0	18.2	.....
312	2.6	.....	2.7	8.4	7.9	19.0	.....

GRADE NO. 2

15	5.0	48	2.9	14.6	7.6	25.0	94.5
17	4.5	80	2.1	10.9	6.0	19.0	98.5
18	4.0	74	2.4	10.5	5.8	18.7	97.6
20	3.7	83	2.4	10.1	5.3	17.8	98.1
68	3.1	90	1.7	10.2	7.9	19.8	98.9
69	4.8	.....	1.9	12.2	7.3	21.4	.....
70	3.5	83	1.3	10.7	7.6	19.6	98.5
71	3.2	86	1.4	11.7	7.1	20.2	98.7
72[1]	3.6	82	1.3	11.8	9.1	22.2	98.4
79	3.2	85	2.3	12.2	6.1	20.6	98.4
80	5.0	70	2.6	11.5	6.0	21.0	97.5
82	4.5	85	2.3	11.3	5.6	19.2	98.8
90	3.2	15	3.3	12.8	8.6	24.7	90.0
95	4.3	85	3.1	10.1	6.2	19.4	97.5
96	3.5	69	2.3	10.2	5.8	18.3	97.4
98	5.0	79	2.7	11.5	5.5	19.7	97.4
112	4.2	80	2.1	10.7	5.5	18.3	98.1
116	4.0	74	2.0	11.2	5.8	19.0	97.1
120	3.8	83	2.6	11.9	6.2	20.7	97.9
121	4.0	58	1.4	11.6	6.5	19.5	98.8
123	3.8	83	2.0	10.4	7.6	20.0	98.4
124	4.3	.....	1.9	10.2	7.2	19.3	.....
125	3.8	84	1.9	9.4	7.2	18.5	98.5
126	4.5	77	2.7	10.0	8.0	20.7	97.4
139	3.4	93	2.8	9.0	8.3	21.0	98.3
143[1]	3.4	.....	1.6	13.0	6.8	21.4	.....
150[1]	3.2	.....	1.3	11.2	7.1	19.6	.....
151[1]	3.2	.....	1.8	11.0	7.2	20.0	.....
178	5.0	88	2.0	11.0	6.7	19.7	98.4
196	5.0	73	3.2	12.4	7.6	24.2	96.6
197	5.0	75	2.2	13.6	7.4	23.2	97.6
206	5.0	76	2.5	13.4	9.5	25.4	96.7
207	5.0	90	2.3	12.0	8.6	20.9	98.3
212	4.2	81	2.7	12.5	7.7	22.9	97.8
215	3.2	90	1.7	13.1	9.7	24.5	98.3
230	4.5	63	5.0	9.3	7.6	21.9	94.5
207	4.2	38	3.4	15.1	9.6	28.1	92.0
208	4.4	54	3.4	11.3	8.3	26.0	94.5
299	4.8	48	2.5	13.8	9.4	24.7	95.4
300	4.3	58	2.6	13.5	7.6	23.0	98.1
301	4.0	2	5.0	13.4	10.2	28.6	78.6
307	4.0	54	3.0	13.8	7.9	24.7	95.7
308	5.0	30	4.2	15.6	11.3	31.1	88.2

[1] Seed corn.

TABLE 5.—*Damaged kernels, germination, fat acidity, amino acid acidity, phosphate acidity, total acidity, and soundness score, of 246 samples of corn classified as to grade according to the factor, damaged kernels*—Continued

GRADE NO. 3

Sample No.	Damaged kernels	Germination	Fat acidity	Amino acid acidity	Phosphate acidity	Total acidity	Soundness score
	Percent	*Percent*					
8	7.0	33	6.1	12.7	10.5	29.3	89.0
11	7.0		6.3	14.2	14.1	34.6	
13	0.2		3.6	13.9	8.7	26.2	
16	5.4	76	3.2	10.3	5.6	19.1	96.7
19	5.5	28	3.7	13.8	8.9	26.4	91.9
28	6.0	42	2.9	12.2	7.0	22.1	94.3
38	7.0	16	4.1	16.5	9.6	29.2	87.7
113	5.4	50	2.8	9.1	6.9	18.8	95.9
114	6.5	60	4.5	11.8	6.0	22.3	94.3
115	6.6	52	4.3	10.5	7.0	21.8	93.9
117	5.1	82	2.8	11.1	4.9	18.8	97.4
199	6.8	86	2.3	11.4	5.2	18.9	97.7
200	6.3	83	2.4	12.0	5.7	20.1	97.6
202	5.5	85	2.4	10.0	7.4	20.4	97.9
204	6.8	69	3.2	12.7	11.6	27.5	93.8
205	6.6	81	2.3	13.3	9.5	25.1	97.1
209	6.3	81	2.2	12.6	6.3	21.1	97.6
211	5.9	80	3.5	11.3	6.4	21.2	96.6
217	6.3	85	2.8	11.2	7.0	21.0	97.3
227	6.7	60	5.2	11.6	8.2	25.0	93.7
228	6.1	58	3.1	11.6	7.1	21.8	95.5
231	6.2	57	3.5	8.3	8.3	20.1	95.0
232	6.4	64	5.8	8.9	8.0	22.7	93.5
233	6.0	67	3.2	8.6	7.5	19.3	96.0
234	6.3	67	3.0	9.4	7.5	19.9	96.1
235	6.0	55	5.0	10.1	7.2	22.3	93.6
237	6.4	41	3.5	10.9	6.5	20.9	93.5
246	7.0	69	3.3	9.9	6.5	19.7	95.8

GRADE NO. 4

9	8.8	55	6.1	10.5	11.7	28.3	89.8
12	9.4	38	6.5	14.6	11.2	32.3	87.5
22	10.0	10	6.0	14.8	10.5	31.3	85.2
23	9.5	1	7.0	14.5	11.6	33.1	71.1
25	8.5	19	4.3	12.7	10.1	27.1	88.2
27	8.5	5	5.1	16.7	10.5	32.3	78.4
30	9.7	18	4.8	11.9	13.3	30.0	84.6
31	9.3	4	5.0	13.3	12.6	31.8	77.8
32	7.8		4.4	12.6	12.9	29.9	
33	9.6	28	3.6	11.4	11.6	26.6	89.0
34	9.0	30	3.5	10.8	12.2	26.5	89.0
35	10.0	17	3.7	14.3	9.6	27.6	87.8
39	9.6	31	3.2	11.6	9.8	24.6	91.3
40	8.8	3	5.0	12.5	8.8	26.3	80.6
130	10.0		6.5	16.6	9.4	32.5	
142	7.1	71	4.3	12.9	8.5	25.7	95.1
160	9.9	29	4.4	12.6	7.3	24.3	90.6
170	10.0	24	6.5	10.3	8.8	25.6	87.9
171	8.8	39	5.4	11.1	9.0	25.5	91.2
172	7.8	30	4.6	10.7	7.8	23.1	91.0
173	8.0	42	5.0	11.6	7.8	24.4	92.1
174	7.6	25	4.5	9.2	7.4	21.1	90.3
198	8.6	80	3.3	12.2	5.9	21.4	96.2
203	8.0	84	2.1	11.6	6.9	20.6	97.6
208	7.2	85	3.0	11.2	5.8	20.0	97.0
223	8.4	52	3.9	10.2	7.2	21.3	93.8
224	9.0	46	4.2	9.6	7.1	20.9	92.9
225	10.0	65	4.5	11.2	7.6	23.3	93.9
226	10.0	46	4.5	11.0	8.4	23.9	92.4
229	8.4	41	3.0	9.5	7.7	20.2	93.6
236	9.8	73	3.9	9.4	7.4	20.7	95.0

TABLE 5.—*Damaged kernels, germination, fat acidity, amino acid acidity, phosphate acidity, total acidity, and soundness score, of 246 samples of corn classified as to grade according to the factor, damaged kernels*—Continued

GRADE NO. 5

Sample No.	Damaged kernels	Germination	Fat acidity	Amino acid acidity	Phosphate acidity	Total acidity	Soundness score
	Percent	*Percent*					
3	11.5	13	5.9	14.2	11.2	31.3	83.4
5	12.0	13	5.9	14.1	10.7	30.7	83.8
6	12.0	15	5.3	11.6	13.6	30.5	82.7
21	11.4	14	6.4	15.5	11.7	33.6	81.4
24	13.0	.....	6.6	15.9	11.3	33.8	.....
26	13.0	2	8.0	16.2	12.1	36.3	70.2
29	12.0	14	4.8	11.8	13.6	30.0	82.8
127	11.0	0	8.1	15.1	11.9	35.1	68.7
132	11.0	2	8.1	17.8	13.6	40.5	66.6
133	11.8	13	6.3	17.2	12.1	35.6	78.9
156	11.4	36	5.3	10.6	7.7	23.6	90.4
157	11.5	46	3.5	13.6	8.0	25.1	93.1
158	12.1	31	4.0	11.3	8.5	21.8	90.8
159	11.0	.....	5.2	11.3	7.1	23.6	.....
161	11.0	.....	4.0	11.0	7.1	22.1	.....
162	11.8	47	3.8	10.9	7.9	22.6	92.8
163	11.1	55	3.8	11.5	7.2	22.5	93.0
164	13.5	11	4.9	11.4	8.4	24.7	85.2
165	11.4	.....	3.5	9.4	9.0	21.9	.....
166	14.3	11	5.4	10.4	9.6	25.4	84.1
167	13.0	20	5.4	10.0	9.1	24.5	87.4
168	14.6	.....	5.6	10.1	8.7	25.4	.....
169	14.4	31	6.7	10.8	9.6	27.1	87.5
218	13.9	73	3.1	15.5	13.2	31.9	89.6
219	14.0	77	2.7	15.2	11.8	29.7	91.8
221	15.0	45	3.6	9.8	8.5	21.9	92.1
245	11.1	49	6.0	9.4	7.2	22.6	91.2
247	13.3	.....	3.8	13.0	8.8	25.4	.....

SAMPLE GRADE

2	25.5	4	7.3	15.5	11.7	34.5	72.4
128	19.0	5	8.3	14.2	11.0	34.0	75.3
129	18.7	7	9.9	15.2	11.5	36.6	74.4
131	19.5	0	10.0	16.4	10.9	37.3	64.9
134	34.0	0	8.3	16.5	13.1	37.9	61.5
135	28.0	0	10.4	16.9	15.2	42.5	58.7
136	50.0	0	8.1	18.2	15.1	41.4	55.0
137	26.0	3	12.7	18.2	12.3	43.2	62.9
138	32.0	0	15.6	16.8	12.4	44.8	55.8
140	21.0	6	14.0	15.0	11.7	40.7	69.8
141	24.0	2	10.5	15.4	12.6	38.5	66.2
222	15.8	47	4.1	9.8	8.5	22.4	91.7
238	40.0	21	7.5	14.1	13.7	35.3	76.4
240	100.0	0	18.7	32.0	27.7	78.4	9.9
241	100.0	0	9.8	12.0	10.3	36.7	47.1
242	35.0	7	9.2	17.8	13.6	40.6	67.1
243	19.0	68	3.2	16.8	12.0	32.0	87.9
248 [3]	97.0	0	19.2	12.4	14.7	46.3	40.9
250 [3]	95.0	0	21.4	12.8	15.6	49.8	38.6
251 [4]	53.0	.....	9.2	19.5	12.1	40.8	.....
253 [3]	96.0	0	24.3	13.0	11.7	49.0	39.1
256 [3]	94.0	0	22.5	12.3	10.8	45.6	41.9
257 [3]	98.0	0	21.0	13.8	12.5	47.3	41.0
302	25.0	52	5.4	14.2	9.1	28.7	88.9
302b [6]	100.0	0	19.2	14.5	23.5	57.2	32.4
302c [6]	100.0	0	24.7	19.9	20.7	74.3	16.5
302d [7]	100.0	0	13.4	16.5	13.5	43.4	43.5

[3] Diplodia rotted.
[4] Gibberella rotted.
[5] Slightly heat damaged fraction.
[6] Badly heat damaged fraction.
[7] Fraction consisting of damage other than heat damage.

TABLE 6.—*Acidity and germination data on 252 samples of corn classified by grade according to the factor, damaged kernels*

Grade	Damaged kernels, percentage range	Samples	Average fat acidity [1]	Average amino acid acidity [1]	Average phosphate acidity [1]	Average total acidity [1]	Average germination
	Percent	*Number*	*Milligrams*	*Milligrams*	*Milligrams*	*Milligrams*	*Percent*
1	0- 3.0	55	1.7	11.7	7.3	20.7	84.3
2	3.1- 5.0	46	2.6	11.8	7.5	21.9	72.5
3	5.1- 7.0	28	3.6	11.4	7.7	22.7	62.9
4	7.1-10.0	31	4.6	12.0	9.2	25.8	37.9
5	10.1-15.0	28	5.3	12.7	9.9	27.9	28.1
Sample grade	Over 15.0	31	12.5	17.0	15.8	45.3	7.4

[1] See footnote 1, table 3.

The grade classifications used in tables 5 and 6 are based on the percentage of damaged kernels as defined and determined by the official standards of the United States for shelled corn.

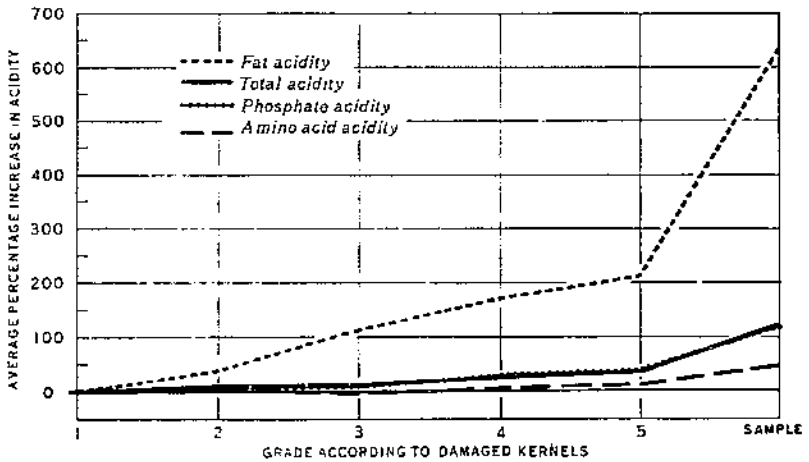

FIGURE 3.—Average percentage increase in acidity of various types in corn of each of the grades below No. 1 (grades determined according to damaged kernels).

Figure 3 shows graphically the average percentage increase in acidity of various types in corn samples of each of the grades below No. 1 (grades determined according to damaged kernels). The phosphate acidity does not increase significantly in corn of the grades above No. 4, and the amino acid acidity shows a significant increase only in the Sample grade samples (damaged-kernel content greater than 15 percent). The fat acidity values, on the other hand, increase very rapidly in corn of the grades below No. 1, the average value for the No. 2 grade samples being 53 percent greater than for the No. 1 grade samples. The data therefore indicate that whereas deterioration of corn is accompanied by an increase in all three types of acidity, the fat acidity alone is influenced sufficiently to show significant differences in corn of the top grades. The average percentage increase in fat acidity between grades No. 1 and No. 2 is 18 times as great as the average increase in phosphate acidity and 59 times as great as that in amino acid acidity.

The various alcoholic extracts that have been suggested for the determination of acidity in grains and cereal products contain a mixture of varying proportions of the three types of acids, depending on the concentration of alcohol used and the composition of the sample analyzed. As previously shown, the amino acids in such a mixture are determined together with the fatty acids and acid phosphates if the extract is titrated in strong alcoholic solution, as in the case of the Balland method and Schulerud's method; whereas the fatty acids and acid phosphates alone are determined together if the titration is made in dilute alcohol, as in the case of the Besley and Baston method. Referring again to figure 3, it is obvious that in neither case is the acidity value nearly as indicative of the damaged-kernel content of the sample as is the fat acidity alone.

SOUNDNESS SCORE: A MATHEMATICAL EXPRESSION OF RELATIVE SOUNDNESS

Efforts to develop commercially applicable methods for determining the degree of soundness of corn are complicated by the fact that no definite measure of soundness is available with which to correlate the data obtained by any tentative procedure. An exact mathematical definition of soundness is hardly possible as corn that would have one degree of soundness when considered for one specific use might have a considerably different degree of soundness for some other use.

For the present study, however, it has been found necessary to establish some standard measure of soundness to permit a comparison between the relative merits of different procedures designed to estimate the degree of soundness. This soundness score is based on the following five criteria of soundness for which data have been accumulated on the series of samples under investigation.

(1) *Damaged kernels.*—The percentage by weight of physically damaged kernels as determined by visual inspection in the official grading procedure is a generally accepted criterion of soundness. As a sample that is free from damaged kernels is 100-percent sound when judged by this criterion alone, the partial soundness score based on damaged kernels may be expressed by the equation:

$$S_{DK} = 100 - \text{percent of damaged kernels}$$

(2) *Germination.*—Although germinability is not a direct measure of commercial soundness, kernels which will germinate are essentially free from deterioration, and badly deteriorated kernels will usually fail to germinate. Percentage germination appears to be essentially a logarithmic function of damaged-kernel content and fat acidity, hence the partial-soundness score based on this criterion may be expressed:

$$S_G = 100^{\frac{(\log \text{ percent germination})}{2}}$$

(3) *Fat acidity.* - In the series of 55 variety samples of seed corn, the fat-acidity values ranged from 0.9 to 1.9. Since samples of this type are probably of the highest degree of soundness obtainable, any sample having a fat-acidity value less than 2 may be considered 100-percent sound from the standpoint of this criterion. The highest fat-acidity value obtained for any sample was 25. Considering this value as an indication of complete unsoundness (zero soundness from a standpoint

of fat acidity), the partial soundness score based on fat acidity is expressed by the equation:

$$S_{FA}=100-\frac{100\ (FA-2)}{23}$$

(4) *Amino acid acidity.*—The amino acid-acidity values for the seed-corn series ranged from 8 to 14, and the highest value for any sample analyzed was 32. The following equation therefore expresses the partial soundness score based on this criterion of soundness:

$$S_{AA}=100-\frac{100\ (AA-14)}{18}$$

(5) *Phosphate acidity.*—Values for phosphate acidity support the following equation for partial-soundness score by the same reasoning used above:

$$S_{PA}=100-\frac{100\ (PA-9)}{24}$$

The soundness score used in the present study, then, is the average of the five partial-soundness scores[5] described, and may be expressed by the equation:

$$S=\frac{S_{DK}+S_G+S_{FA}+S_{AA}+S_{PA}}{5}$$

This equation is not expected to express the ultimate degree of soundness of a sample of corn, since other criteria of soundness than those herein considered might change the relative ratings of any series of samples. In the absence of other suitable standards, however, the equation probably comes closer to expressing the relative soundness of different lots of corn than does any other available mathematical expression, and it is therefore of distinct value as a tentative standard with which to compare data obtained by any suggested procedure for determining the degree of soundness. Soundness scores for the series of samples under investigation are given in table 5.

FAT ACIDITY AS A MEASURE OF SOUNDNESS

Fat acidity values correlate well with damaged-kernel determinations as previously shown. Samples of seed corn of unquestionable soundness had fat acidity values of less than 2 in all cases, whereas samples of badly damaged corn showed values as high as 25.

To find the relative merits of the damaged-kernel value and the various acidity values as measures of the degree of soundness, coefficients of correlation were determined and found to be as follows:

Percent damaged kernels and soundness score	$r=-0.75$
Fat acidity and soundness score	$r=-.87$
Phosphate acidity and soundness score	$r=-.71$
Amino acid acidity and soundness score	$r=-.39$

These statistical data indicate that the fat acidity value is a significantly more reliable index of soundness in corn than are either the amino acid acidity, the phosphate acidity, or the percentage of damaged kernels as determined by visual inspection.

[5] Samples having fat-acidity values less than 2, amino-acid acidity values less than 14, or phosphate-acidity values less than 9, are considered to have respective partial-soundness scores of 100.

The acidity arising from the presence of free fatty acids may be expressed either as: (1) The acid value of the fat, defined as the number of milligrams of potassium hydroxide required to neutralize the acids present in 1 g of fat or, (2) the fat acidity, herein defined as the number of milligrams of potassium hydroxide required to neutralize the free fatty acids present in 10 g of dry corn. The question as to which of these two values is the more reliable index of soundness is rather difficult to answer since within the relatively narrow range in the fat content of most commercial corn the two values are nearly proportional.

Two samples of sound seed corn having abnormally high and low fat contents were obtained from the Illinois Agricultural Experiment Station, where the particular strains represented by these two samples are the result of many years of selective breeding. The oil content, acid value of the oil, and fat acidity of these samples compared with the maximum and minimum values in the series of 55 seed corn samples are shown in table 7.

TABLE 7.—*Oil content, acid value of oil, and fat acidity of high-oil and low-oil corn compared with those of normal corn*

Item	Percentage oil (dry basis)	Acid value of oil	Fat acidity [1]
Seed corn (maximum)	5.6	4.3	1.9
Seed corn (minimum)	3.5	2.6	.9
High-oil sample	12.0	1.3	1.5
Low-oil sample	1.4	8.4	1.2

[1] See footnote 1, table 3.

The acid values of the oils from the samples with abnormal oil content both fell far outside the range observed for normal oil-content seed corn, whereas the fat acidities for the abnormal samples were well within the normal range for seed corn. These observations indicate rather definitely that fat acidity as herein defined is a more reliable index of soundness than is the acid value of the oil.

COMMERCIAL USEFULNESS OF THE FAT ACIDITY FACTOR

Although there is a need for further research to compare fat acidity values with the processing and feeding values of corn, especially to check the effect of relatively high fat acidity values on the quality of processed corn products and on the nutritive value and palatability of corn for feed, the studies herein reported appear to indicate that fat acidity is a more reliable index of the soundness of corn than the factor of damaged kernels determined by visual inspection.

The determination of fat acidity values in corn may be accomplished for practical purposes by using the rapid method described on page 20. With this method the analyst, aided by one nontechnical assistant, should be able to analyze from 75 to 100 samples for fat acidity in a 7-hour day. The method is thus usually more rapid than the damaged-kernel method specified under the official grain standards. Furthermore, fat acidity determinations should yield more concordant results between laboratories than damaged-kernel determinations, since the chemical method eliminates in a large degree, the element of per-

sonal judgment necessarily present in the damaged-kernel determination.

These studies of soundness in corn and methods for its determination indicate the desirability of pursuing additional research in the field of commercial application and usefulness, as well as the desirability of conducting comparable research with wheat, rye, barley, oats, grain sorghums, and other grains.

RAPID METHOD FOR DETERMINING THE FAT ACIDITY OF CORN

In order that the fat acidity determination be made practicable as a method for determining the degree of soundness or condition of corn in commercial inspection procedures, a rapid method for determining this value has been developed.

EQUIPMENT AND REAGENTS REQUIRED

The following equipment and reagents are required for this rapid method:

One suitable type mill capable of grinding corn without undue heating to such a degree of fineness that at least 90 percent of the meal will pass through a 40-mesh gauze sieve.

One torsion balance or other balance suitable for weighing 20 g samples of corn meal to an accuracy of ± 0.01 g.

One mechanical shaking device capable of accommodating a dozen or more 100-ml bottles or flasks.

One 25-cc burette (glass stopcock) with stand.

One 50-cc pipette.

One funnel rack.

Supply of 100-ml glass-stoppered bottles or flasks.

Supply of 25-ml volumetric flasks or 25-ml graduated cylinders with a tolerance of ± 0.05 ml, such as are used with the Brown-Duvel moisture-testing apparatus.

Supply of 200-cc Erlenmeyer flasks, 8-cm glass funnels, 15-cm folded filter papers and glass disks or Petri dishes of a size to cover the tops of the funnels.

Benzene, c. p.

Ethyl alcohol, 95 percent.

Phenolphthalein.

Accurately standardized 0.0178 N solution of potassium hydroxide free of carbonate.

PROCEDURE

(1) Grind about 50 g of a representative portion of each sample to such a degree of fineness that at least 90 percent of the meal will pass through a 40-mesh gauze sieve. (If the moisture contents of the samples are not known they may be determined with the Tag-Heppenstall moisture meter on the samples before grinding.)

(2) Weigh out 20-g portions of the well-mixed meals to an accuracy of ± 0.01 g and transfer to 100-ml glass-stoppered flasks or bottles.

(3) Add exactly 50 ml of benzene to each flask, insert the stoppers, shake a few seconds to saturate the air in the flasks with benzene vapor, momentarily loosen the stoppers to release pressure, and replace stoppers.

(4) Shake flasks for 30 minutes using the mechanical shaking device.

(5) Tilt flasks at such an angle that settling will take place in such a way that decantation will be made easy. Allow flasks to rest in this position at least 3 minutes.

(6) Carefully decant as much of the liquid as possible into 15-cm folded filter papers inserted in 8-cm glass funnels. Cover the funnels

with glass disks or Petri dishes to minimize evaporation. Collect the filtrate in 25-ml volumetric flasks or accurately calibrated 25-ml graduated cylinders.

(7) When exactly 25 ml of the filtrates have been collected, transfer the filtrates to 200-ml Erlenmeyer flasks.

(8) Refill each volumetric flask or cylinder to the 25-ml mark with 95-percent ethyl alcohol containing 0.04 percent of phenolphthalein and transfer to the respective flasks containing the benzene extracts.

(9) Titrate the extracts with carbonate-free 0.0178 N potassium hydroxide solution to a distinct pink color. In the case of the yellow extracts from yellow corn the final color should be a little more pink than orange.

(10) Run a blank titration on a mixture of 25 ml of the benzene and 25 ml of the alcohol.

(11) Calculate fat acidity by the formula:

$$\text{Fat acidity}^{6} = \frac{100\ (T-B)}{100-M}$$

Where T = titration value of extract in milliliters.
B = titration value of blank in milliliters.
M = percent of moisture in sample.

NOTE.—Benzene is poisonous and is readily absorbed through the skin. Care must therefore be taken to avoid contact with the liquid or inhalation of its vapor. Benzene should be handled only in a well-ventilated room, preferably under a hood. As benzene is also inflammable it must be protected from any possible source of ignition.

SUMMARY

The determination of the degree of soundness is of major importance in the grading of corn and other cereal grains. The present methods of determining soundness principally by odor and by the percentage of damaged kernels have proved to be useful, but because of their shortcomings efforts are being made to find more accurate methods that will be equally—or even more—practicable from a commercial standpoint.

As deterioration of the corn kernel is necessarily associated with chemical changes in several of its components, the more important of these chemical changes have been studied in an effort to discover some easily measurable change that will serve as a reasonably accurate index of the degree of deterioration. It has been shown that the quantity of free fatty acids, amino acids, and acid phosphates in the kernel, tend to increase as deterioration progresses.

Of these three types of acidity only the fat acidity increases significantly with incipient deterioration and is therefore the only type of acidity which appears to be useful in differentiating degrees of soundness in corn. For the samples included in this study the average increase in fat acidity between grades No. 1 and No. 2 is 20 times as great as the average increase in phosphate acidity and 59 times as great as the increase in amino acid acidity. Most of the previously suggested methods for determining acidity as a measure of soundness in corn or other cereal products have taken into account combinations of various fractions of two or all of the three types of

[6] In terms of milligrams of potassium hydroxide required to neutralize the free fatty acids from 10 g of corn (dry-matter basis). This result should be multiplied by 10 in case it is desired to express fat acidity on the basis of 100 g of corn (dry-matter basis). For routine use it is suggested that the 100-g basis be adopted.

acidity. Such methods are therefore likely to be less reliable as indexes of soundness, particularly in the case of very slightly damaged samples, than is the fat acidity method. Fat acidity based on the sample as a whole appears to be a more reliable index of soundness than fat acidity based on the extracted fat.

In an effort to obtain an equitable basis of comparison for various possible methods of estimating the degree of soundness, a soundness score has been devised as a mathematical expression based on percentage of damaged kernels, germinability, fat acidity, amino acid acidity, and phosphate acidity, as criteria of soundness. In a series of 244 samples of corn, fat acidity values correlated more closely with the soundness score than did the percentages of damaged kernels.

A rapid method for determining fat acidity has been devised by which 75 to 100 determinations may be made in a 7-hour day by an analyst with the aid of one nontechnical assistant, the method thus being usually more rapid than the damaged-kernel method.

It is suggested that fat acidity values have commercial usefulness as a measure of the relative soundness or unsoundness of corn for the following reasons:

(1) Fat acidity is a more reliable index of soundness in corn than is the percentage of damaged kernels. The damaged-kernel method of estimating soundness fails to take into account the degree of damage in the damaged portion and the degree of soundness in the sound portion. Furthermore, hidden damage not discernible by visual inspection remains undetected. All of these factors influence the fat acidity value.

(2) Prompt determination of fat-acidity values for commercial usage is possible.

(3) The use of the fat acidity value as a measure of soundness for corn would assure accurate and uniform determinations and would avoid errors arising from unavoidable differences in personal judgment.

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