A Fundamental and a Rapid Empirical Test for Dust in Corn[1]

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ABSTRACT

The fundamental procedure employs suction and manual shaking to evacuate nearly all dust from corn and to trap it in distilled water. The dust is filtered into a Gooch crucible, dried, and weighed to determine percent dust. Four determinations require approximately 60 min. Results are exact except for dissolved minerals. The loss is 1% of the weighed dust. The fundamental method becomes the empirical procedure with only slight loss of accuracy by: 1) extracting only part of the dust; 2) measuring conductivity due to minerals dissolved from the dust with an electrode rather than weighing the dust itself; and 3) reading dust content from a conversion table which relates a dust index, based on conductivity, to percent of dust in corn. Time per test is approximately 3 min.

Excessive dust arising from the transport of corn is known by grain handlers to constitute a health hazard because of its abrasive effect on eyes, nose, throat, and lungs. Grain dust, including that from corn, is recognized also as a fire hazard in elevators and cargo ships.

Methods are available for the determination of dust in air (1), but no procedure is known to have been published for determining dust in grain prior to its escape into the air. In grain inspection, a test for broken kernels and foreign material includes dust as a component but does not measure the amount.

In this report dust is defined as particles of grain less than 420 μ in diameter which are evacuated while shaking through a U.S. No. 40 woven-wire sieve. The dust is drawn into distilled water, where it is trapped. The amount of dust, which can be estimated by the cloudiness of the resulting suspension, may be determined accurately by filtering through a Gooch crucible and drying the dust to constant weight. A more rapid method is to determine the electrical conductance of the suspension. Corn dust contains various minerals, a proportion of which is soluble in distilled water, causing an increase in conductivity. This increase is easily measured by means of a conductivity bridge.

MATERIALS

1. Conductivity bridge (Barnstead Model PM 70CB or equivalent).
2. Air pump (pressure vacuum) supplied with 1/3-h.p. motor, vacuum and pressure gauges, hose nipples, and intake filter.
3. Water bath (constant temperature of 78° ±0.5°F.).
4. Thermometer with a range of 0° to 100°F.
5. U.S. No. 40 and No. 50 woven-wire cloth sieves.
6. Boerner Divider or equivalent.
7. Twelve 500-ml. dust-trap bottles, each approximately 2.5 in. in diameter and 7 in. in height, requiring a No. 6 rubber stopper. (Pyrex, Corning No. 1260.)

[1]Use of a company or product name does not imply approval or recommendation of the product by the U.S. Department of Agriculture to the exclusion of others which may also be suitable.

8. Two 2.5-ft. lengths rubber pressure hose, 1/8-in. wall thickness and 3/16-in. I.D.
9. One two-holed No. 6 rubber stopper containing a 3/8-in. O.D. glass tube 12 in. in length bent L-shaped approximately 3 X 9 in., and another tube 6 in. in length bent at 90°, approximately 3 X 3 in.
10. A heavy-walled glass suction funnel of approximately 250-ml. capacity, short-stemmed, and approximately 115 mm. in O.D. (a Ribbed Mooney Airvent funnel or equivalent).

    Note 1: Notches (approximately 1/16-in.) are carefully filed on the rim of the funnel as needed to maintain a vacuum of 20 in. that allows easy 6-in. movements of the funnel for dust release.

    Note 2: A 2.5-in. diameter woven-wire screen with 420 μ openings (equivalent to a U.S. No. 40 sieve) is inserted into the cone of the funnel and secured with epoxy cement.
11. A dust platform approximately 9 X 15 X 0.5 in. (a masonite clipboard is excellent).
12. A supply of distilled water.
13. A timer.
14. A centrifuge. (I.E.C. International centrifuge, model U.V., or equivalent.)
15. Twelve Gooch crucibles and filter disks.

PROCEDURE AND RESULTS

Five-pound samples of commercial corn with a wide range in dockage content were obtained from a District Office of the Grain Division, Consumer and Marketing Service, U.S. Department of Agriculture. Sampling error for duplicate determinations was minimized by reducing a sample to 200 g. with a Boerner Divider. Divider pans were blown free of dust between samples.

Determination of Percent Dust by the Fundamental Method

One hundred milliliters (±0.2) of distilled water with known conductivity was poured into a dust trap (item 7). One hundred grams of corn was placed into the extraction funnel, which was connected by rubber tubing with the dust trap. The trap was, in turn, connected to the vacuum pump (see Fig. 1).

SCHEMATIC DIAGRAM OF APPARATUS TO DETERMINE DUST IN CORN

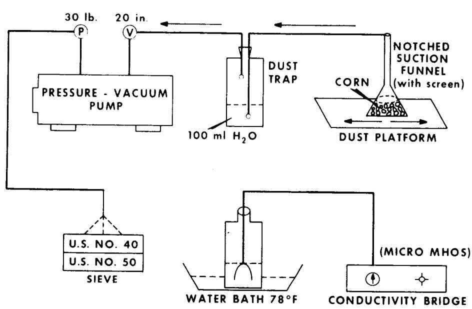


Fig. 1. Schematic diagram of apparatus to determine dust in corn.

The timer and vacuum pump were started, and the funnel was moved by hand back and forth 6 in. across the dust platform at the rate of two round trips per sec. for 30 sec. The conductivity was measured, and then the evacuation continued for 30-sec. intervals until the meter reading failed to rise by more than 10 micromhos.

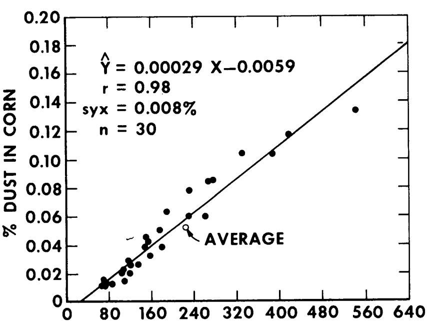
The dust trap was centrifuged when dust settled slowly. Twenty milliliters of the clear supernatant liquid was poured into a graduate and reserved for washing the dust from the dust trap into a Gooch crucible. (Distilled water may not be used to wash dust because it lowers conductivity.) The clear filtrate, measuring nearly 100 ml., was drawn into a clean suction flask previously rinsed with distilled water.

The crucible was dried for approximately 20 min. at 104°C., then cooled and weighed to determine the percent of dust. The filtrate was returned to the original dust trap and placed in a water bath. The conductivity was measured at 78° ±0.5°F. This value was corrected by subtracting the conductivity of a blank determination made as follows: A sample weight of corn was placed between a U.S. No. 40 and a No. 50 sieve and freed of all dust with a strong blast of air for approximately 1 min. The dust-free corn was then handled like the sample, drawing any dust generated by the shaking process into a fresh 100 ml. of distilled water. Conductivity of the blank, expressed in micromhos, was due mainly to a trace of minerals in the distilled water. The actual weight of dust in the blank was not significant.

A correlation coefficient was determined between percent dust and conductivity for 30 samples. The result, 0.98, is shown with the regression equation and standard error of estimate in Fig. 2. The results shown in Table I were obtained with 200-g. samples; however, results of 100-g. samples (not shown) were equally accurate and required less work.

Determination of Percent Dust by the Rapid Empirical Method

The samples used were the same set as in the fundamental method. The dust from 100 g. of corn was evacuated for exactly 30 sec. and trapped in distilled water, as described previously. The corn was removed from the funnel and set aside. A second 100 g. of corn was placed in the funnel and the dust evacuated by another 30-sec. extraction. The dust trap containing both extractions was placed in a water bath and the conductivity determined at 78° ±0.5°F. This value became the dust index after subtraction of the conductivity of a blank, which was determined as



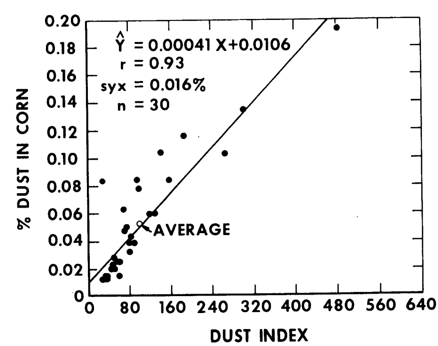


Fig. 2 (left). Dust in corn vs. mineral conductivity.
Fig. 3 (right). Dust in corn vs. dust index.

TABLE I. RELATIONSHIP BETWEEN CONDUCTIVITY OF TOTAL DUST EXTRACTED AND PERCENT DUST BY THE FUNDAMENTAL METHOD

Conductivity Micromhos	Blank Micromhos	Corrected Conductivity Micromhos	Dust %
402	24	378	.104
301	26	275	.084
175	22	153	.043
170	22	148	.039
92	23	69	.016
255	24	231	.078
257	26	231	.060
140	22	118	.029
126	17	109	.015
181	22	159	.033
155	20	135	.027
143	22	121	.027
105	20	85	.013
125	18	107	.023
90	17	73	.015
90	15	75	.014
722	26	696	.193
215	26	189	.063
183	25	158	.047
197	22	175	.052
365	36	329	.105
578	36	542	.135
458	40	418	.117
302	35	267	.085
132	28	104	.021
143	23	120	.021
93	20	73	.013
91	21	70	.013
204	24	180	.039
240	31	209	.060
Average 224.3	24.4	199.9	.053

follows: The corn in the funnel was combined with the portion set aside from the first extraction and placed between a U.S. No. 40 and a No. 50 woven-wire cloth sieve. All remaining dust was blown out with a strong blast of air for approximately 1 min. The dust-free corn was treated exactly as the original sample; that is, by returning approximately 100-g. portions to the funnel and extracting each for 30 sec. The conductivity was then determined at 78° ±0.5°F. Dust index, therefore, may be defined as a difference in conductivity obtained by subtracting the conductivity of a dust-free sample from the conductivity of the original identical sample. The results for all samples are shown in Table II.

A correlation coefficient was determined between dust index and percent dust obtained by the fundamental method. The result, 0.93, is shown with the regression equation and standard error of estimate in Fig. 3. The chart for converting dust index to percent dust (Table IV) was prepared from the regression equation.

TABLE II. RELATIONSHIP BETWEEN CONDUCTIVITY OF DUST EXTRACTED BY THE EMPIRICAL METHOD AND DUST INDEX

Dust Index Conductivity Micromhos	Blank Micromhos	Dust Index
288	22	266
179	21	158
101	19	82
102	22	80
53	24	29
122	24	98
144	25	119
69	20	49
73	15	58
102	22	80
79	20	59
76	21	55
53	20	33
67	20	47
46	18	28
45	16	29
506	22	484
93	24	69
95	25	70
88	17	71
168	28	140
327	26	301
217	29	188
118	24	94
66	21	45
67	21	46
50	18	32
49	21	28
109	21	88
151	23	128
Average 123.4	21.6	101.8

In a different experiment, the percent broken kernels and foreign material and the percent combined chaff and dust were determined on 25 samples with the Carter dockage tester, an instrument well known in grain inspection. A dust index was determined on the samples before and after passage through the dockage tester. The results in Table III show that, on the average, approximately 67% of dust still remained in the corn after passage through the Carter dockage tester. The coefficient of correlation between dust index (before passage) and combined broken kernels, foreign material, chaff, and dust was -0.001. This indicates that dust is unrelated (statistically) to "dockage" (broken kernels, foreign material, dust, and chaff), even though samples with high "dockage" content are usually quite dusty.

DISCUSSION AND CONCLUSION

Those who test corn for dust by these methods should establish statistical relationships between percent dust (extracted by the fundamental method) and conductivity, and also between the percent dust and dust index (as determined by the rapid method). In most instances the blank for dust index may be used as the blank for conductivity.

The nearly perfect correlation between conductivity and percent dust by the fundamental method is explained by the fact that corn dust consisted of 99% starch cells in all samples examined microscopically. Apparently, mineral content of starch cells does not vary greatly among samples. If dust consisted of other parts of the kernel—such as germ, which is high in mineral content—the correlation might be lower. Conductivity data for correlation must be obtained from or determined on the same filtrate from which the dust was removed for weighing. This eliminates sampling error which would occur if a separate sample were used for each of the two operations.

An advantage of this technique for dust is that the rapid test can be standardized against the fundamental procedure within the same laboratory. Therefore, lengthy interlaboratory collaboration usually needed to standardize an

TABLE III. COMPARISON OF DUST INDEX IN CORN BEFORE AND AFTER REMOVAL OF BROKEN KERNELS, FOREIGN MATERIAL, CHAFF, AND DUST BY THE CARTER DOCKAGE TESTER[a]

Dust Index		Broken Kernels and Foreign Material	Dust and Chaff
Before	After	%	%
39	29	3.5	0.8
62	25	3.3	1.2
82	41	4.5	1.3
100	55	3.4	1.0
32	9	2.5	0.6
47	18	2.6	0.7
34	30	3.0	0.7
44	36	2.9	0.7
83	54	2.4	0.8
68	60	3.1	0.7
45	45	4.1	1.0
41	27	4.4	1.3
71	44	4.6	1.2
108	40	2.5	0.7
41	41	4.2	1.0
14	14	2.9	1.0
15	15	2.3	0.4
58	44	5.3	1.5
25	25	4.7	1.3
25	19	3.8	1.6
18	18	2.7	0.6
63	52	5.0	1.9
22	14	3.6	1.2
24	22	3.5	1.1
15	15	2.9	0.9
Average			
47.0	31.68	3.5	1.0

[a]Dust remaining in corn: 67%.

TABLE IV. CONVERSION OF DUST INDEX TO PERCENT DUST IN CORN[a]

Dust Index	Percent Dust	Dust Index	Percent Dust
10	.015	210	.098
20	.020	220	.102
30	.024	230	.106
40	.028	240	.110
50	.032	250	.114
60	.036	260	.118
70	.040	270	.122
80	.044	280	.126
90	.048	290	.130
100	.052	300	.134
110	.056	310	.138
120	.061	320	.143
130	.065	330	.147
140	.069	340	.151
150	.073	350	.155
160	.077	360	.159
170	.081	370	.163
180	.085	380	.167
190	.089	390	.171
200	.093	400	.175

[a]Dust = (0.00041 X Dust Index) + 0.0106.

empirical test is not necessary. Although the dust index is expected to vary between laboratories owing to differences in equipment and technique, the percent dust reported by different laboratories should agree.

However, substantial differences in results may occur within the same laboratory, due mainly to the problem of obtaining a representative sample. In preparing a sample for the dust test, a sample divider should be used.

A controlled vacuum of 20 in. allows the funnel to be moved smoothly against the pull of suction and at the same time permits an even flow of air under the notched funnel. Optimum operation is dependent on the number and depth of notches made on the funnel. These should be filed on the rim as needed when testing the vacuum. It is helpful to draw the funnel back and forth several times across emery paper placed on the dust platform, to obtain perfect contact between funnel and board. A masonite platform makes better contact with the funnel than one made of wood. It also generates a minimum of wood dust.

The Carter dockage tester seems unsuitable for dust determination in corn for the following reasons: 1) Most (67%) of the dust remains in the corn even after separation of broken kernels, foreign material, dust, and chaff; 2) no provision is made in the machine to separate a defined dust fraction; and 3) the fraction of dust lost or gained through contamination during passage through the sieves would probably cause too great a percent of error.

Since the Carter instrument is widely known and used in grain inspection, efforts are still being made to relate the results by this instrument to percent dust.

Microscopic examination shows that corn dust consists mostly of starch cells and small particles of bran. This suggests that the dust problem could be solved through better methods of harvesting and shelling to minimize rupture of kernels.

The starchy endosperm probably spills from the torn and broken seed coat of the kernels when the corn is put in motion, thus creating greater dust with each relocation.

Percent dust should be reported on an "as-received basis", noting the moisture content. It is doubtful that the accuracy of the rapid method would justify adjusting the result to a 14% moisture basis.

Importers often complain about excessive dust, broken kernels, foreign material, and chaff in U.S. corn cargoes. Although these factors are linked together, probably because of the Carter dockage test, they are distinctly different and create different problems.

For instance, corn containing more than normal amounts of small pieces, chaff, and dust might be objectionable for poultry feed. Similar corn might be objectionable to the milling industry because it produced lower yields of grits.

Dust is a different problem and relates to the health of workmen who unload the corn cargo. This health hazard may be compounded by the possibility of fire and explosion in holds of ships if atmospheric dust is at high levels. The first step suggested to eliminate such dangers is to determine the amount of dust in corn by one of the proposed methods and then relate it to atmospheric dust arising when loading and unloading.

When the relationship is established, a second step suggested is to load future cargo with only that corn which has a safe or nonobjectionable amount of dust. An eventual third step suggested is to relate dust in corn with the percentage of kernels damaged at harvest. Efforts might then be made to improve present methods of picking and shelling in order to prevent corn kernel damage, and thus eliminate the basic cause of dust in corn.

If percent dust were to be used as a criterion for corn quality, a range such as the following could be used:

% Dust	*Condition of Corn*
Below 0.05	Normal
0.06 – 0.12	Dusty
Above 0.12	Very Dusty

Work is underway to apply this method to wheat, oats, barley, sorghum, rye, soybeans, and flaxseed.

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Literature Cited

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