Chemical Composition of Dusts from Cottonseed Oil Mills

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ABSTRACT AND SUMMARY

The proximate chemical composition of total dust samples from five Texas cottonseed oil mills was determined. Dust compositions were highly variable and were affected more by the processing step than by differences among mills. Composition of cleaning room dusts reflected differences in soil minerals. Typical inorganic values were: silicon (12%), aluminum (0.5%), and iron (0.7%). Delintering dust was highest in cellulosic materials (40%), whereas the 23% protein composition of the hulling dust showed the influence of kernel fragments. Baling dust contained large amounts of cellulose (38%) and noncellulosic organic constituents (36%).

INTRODUCTION

Very little information has been published about the composition, physical properties, and physiological activity of oil mill dusts. Data on the total and fine dust levels in cottonseed oil mills have been published (1-4). Data on organic and ash contents of dusts from two Egyptian oil mills have been published by Noweir et al. (2), who also found that dust generated in cottonseed handling (loading and unloading) operations in oil mills led to respiratory complaints, but dust from the grinding and oil extraction operations was inert. Decreased FEV_1 (maximum forced expiratory volume in first second of exhalation) values among workers in several American and Australian oil and delintering mills (3-5) have been observed, and Jones et al. (5) reported a low prevalence of chronic airways diseases among employees in five American oil mills. The high proportion of smokers included in the Australian surveys (3,4) and high dust levels (2-4) make interpretation of the health effects difficult. A comprehensive survey covering the total and respirable dust levels and the particle size distributions found in the cleaning, delintering, hulling, and baling areas in five Texas cottonseed oil mills was published recently by Matlock et al. (1).

The general layout and procedures utilized in a cottonseed oil mill have been described in detail by Norris (6). In the cleaning room, the majority of trash, such as weedseed, non-cottonseed plant parts, sand, soil, etc., is separated from cottonseed. Dust concentrations and compositions depend upon the cleanliness of the cottonseed being processed. In the delintering room, the linters remaining on the cottonseed after ginning are recovered with two or three successive cuttings by delintering saws. Appreciable quantities of hull material are included in second and third cuttings. Linters are transported pneumatically from the delintering area to the baling room, where they are removed from the air stream with a fine screen and baled. Baled first-cut linters superficially resemble ginned cotton, whereas the second-cut and third-cut linters can contain up to 10% hull fragments (hull pepper) but frequently less. In the dehulling room, the seeds are decorticated to liberate the kernels (meats), and the hulls are passed through a hull beater to detach the small meat particles adhering to the hulls. In the remainder of the process, the oil is recovered by screw pressing, prepress-solvent, or direct solvent extraction usually after the meats have been flaked and cooked. Relatively little dust is produced in the oil and meal preparation steps.

We have determined the proximate composition and the inorganic elemental composition of the dusts collected by Matlock et al. (1) in the four processing areas of the five Texas mills. In this paper, the results of the chemical analyses are reported and dust compositions are compared.

MATERIALS AND METHODS

Dust Samples

The dusts were collected in five Texas commercial oil mills in 1975, using high-volume samplers in draft-free sites located within the actual working areas of the employees. Samplers utilized flow rates of 40-60 ft^3/min and, to prevent biasing of the data, were protected from materials which could fall or be ejected directly from the machinery. Dusts were collected in the cleaning, delintering, hulling, and baling rooms. Samples were recovered from the high-volume filters using forceps and a camel's hair brush.

Chemical Analyses

Ash was determined gravimetrically after ashing for 2 hr at 750 C. Protein values were obtained by multiplying Kjeldahl nitrogen percentages by 6.25. Quantitative elemental analyses were performed by X-ray fluorescence, as described by Piccolo et al. (7). Silicon values were obtained using disks composed of a 9:1 mixture of microcrystalline cellulose and dust. All other elements were determined without dilution.

Moisture, water- and ethanol solubles, noncellulosic organics, cellulose, and inorganic residue were determined gravimetrically. Samples (100 mg) were weighed in 15 ml coarse fritted glass crucibles, and moisture was calculated from the loss at 110 C. Water solubles were calculated from the loss in weight after fourfold extraction with 5 ml portions of boiling water. Ethanol solubles were determined by fourfold leaching with boiling 95% ethanol. Noncellulosic organic constituents were removed by refluxing the extracted dust with 5 ml of 2-aminoethanol and filtering the resulting suspension in the respective crucibles (8). Cellulose was extracted by treatment with 10 ml of 0.5 M cupriethylenediamine hydroxide (cuene) for 1 hr with stirring (9). The remaining material was designated as inorganic residue.

RESULTS AND DISCUSSION

The ash, moisture, organic, and cellulose contents of the dusts from the cleaning, delintering, hulling, and baling rooms of the five mills are reported in Table I. Mills A and B shared the same baling room. Only one set of samples was collected in the common baling room; the data are listed under mill A. The cleaning, delintering, and hulling areas of mill C were in one long room, with the delintering sample station being much closer to the huller sampler than to the cleaning area sampler. In mill D, the cleaning and the delintering areas were at the opposite ends of the same room, and the samplers were positioned correspondingly. Thus, dust generated in some areas of mills C and D could have affected the composition and dust levels in other areas, but the results reported in Table I do not suggest that the dust compositions in the adjacent areas were affected much.

The water-extractable fractions contain salts, carbo-

TABLE I

Proximate Composition of Dusts[a] from Texas Cotton Oilseed Mills

Mill	Area sampled and percentage composition			
	Cleaning	Delintering	Hulling	Baling
		Ash		
A	20.0	7.7	6.5	9.9
B	27.1	24.8	6.8	NA[b]
C	33.7	9.4	7.4	5.9
D	40.8	21.9	9.6	15.9
E	29.7	10.3	6.0	9.4
Avg.	30.3	14.8	7.3	10.3
		Protein		
A	12.1	9.8	23.3	13.0
B	8.9	14.1	21.1	NA
C	11.9	15.2	22.8	12.1
D	10.2	13.2	21.8	14.3
E	11.4	16.2	25.6	20.7
Avg.	10.9	13.7	22.9	15.0
		Moisture		
A	8.2	8.1	12.8	10.8
B	6.9	8.0	12.4	NA
C	5.4	8.6	10.4	9.8
D	5.1	6.8	8.6	8.4
E	5.5	9.9	9.2	10.6
Avg.	6.2	8.3	10.7	9.9
		Water solubles		
A	9.0	9.4	18.9	16.3
B	11.2	12.2	19.8	NA
C	12.4	13.9	15.1	8.4
D	7.3	8.9	11.7	11.0
E	11.0	13.4	18.4	12.6
Avg.	10.2	11.6	16.8	12.1
		Alcohol solubles		
A	0.6	1.1	2.4	0.8
B	1.4	2.5	2.0	NA
C	1.7	2.0	4.1	1.4
D	2.0	2.6	7.9	2.2
E	1.9	2.3	9.6	2.4
Avg.	1.5	1.6	5.2	1.7
		Noncellulosic organic		
A	28.3	22.2	48.3	36.1
B	23.9	30.4	48.8	NA
C	27.5	35.8	50.0	30.4
D	25.6	32.7	51.7	37.4
E	19.2	37.3	42.0	39.4
Avg.	24.9	31.7	48.2	35.8
		Cellulose		
A	42.2	57.6	15.4	33.5
B	44.6	37.7	17.0	NA
C	26.5	35.5	20.0	50.0
D	32.2	33.3	19.6	35.6
E	46.2	36.7	19.9	31.2
Avg.	38.3	40.2	18.4	37.6
		Residual inorganic		
A	11.7	1.6	2.2	2.5
B	12.0	9.2	0.0	NA
C	26.5	4.2	0.4	0.0
D	27.8	15.7	0.6	5.4
E	16.2	0.4	0.9	3.8
Avg.	18.8	6.2	0.8	2.9

[a]Dust collected by high volume sampler at flow rates of 40-60 ft^3/min.

[b]NA signifies independent sample not available; same baling area as Mill A.

hydrates, amino and organic acids, some proteins, phenolics, and other compounds of low molecular weight, plus a small fraction of the fine particulates which pass through the fritted glass crucibles. Waxes, as well as some plant pigments, lipids, and glucosides, are extracted by hot 95% ethanol. The noncellulose organic (2-aminoethanol soluble) fraction consists of lignin, water-insoluble proteins, simple carbohydrates, pentosans, and presumably simple acids and phenolics released by digestion of all but the highly resistant cell wall cellulose and inorganic minerals and salts (7). Cuene is a specific solvent for cellulose, and the residual material is believed to consist of inert inorganic substances (10).

Ash contents averaged 8.5% higher than the residual inorganic values. The discrepancy between ash content and residue is probably due to a loss of soluble salts during water extraction and to release of bound elements during ethanolamine extraction. Results of the X-ray fluorescence analyses (Table II) also indicate that most of the inorganic elements that were detected are those commonly found in plants. Only the cleaning and delintering room dusts contained large quantities of the two elements not normally found in plants—silicon and aluminum.

In most cases, summation of the elemental percentages in Table II yields a value which is intermediate between the ash and residual inorganic values. If a ratio of two oxygens is assumed for each silicon atom, agreement between ash values and elemental compositions is generally quite good. A similar empirical relationship between ash and inorganic elemental composition was found in card room dusts, which contain relatively large quantities of sand and silicates (10).

Inspection of the data in Table I indicated that the dust from the cleaning rooms is characterized by the highest ash and the lowest protein content of any of the processing areas sampled, averaging 30.3 and 10.9%, respectively. Cleaning room dust also contains the least moisture and the lowest amounts of water-soluble, alcohol-soluble, and noncellulosic organic materials. The high ash content indicates very large quantities of minerals, sand, and other soil constituents. This conclusion is supported by the high percentages of silicon, 11.9%, and aluminum, 0.56%, found in the dust (Table II). From the high cellulose value, it appears that cotton lint and linters are the other main constituents of cleaning room dust.

The ash contents of cleaning room dust, 20-41%, were lower than the ash levels found in cotton gin dusts, 35-57%, (11) and were higher than card room dust ash levels, 16-28% (10). Noweir et al. (2) reported mineral contents averaging 44% in dusts from the seed-handling areas of Egyptian cottonseed oil mills as well as more protein, 18%, and less cellulose, 27%. The higher mineral and protein contents may indicate the utilization of different harvesting techniques as well as the roller-ginning process in Egypt. Part of the difference also may be due to that fact that most Egyptian cotton is long staple and has only a small apical tuft of linters (12).

Dust from the delintering area is characterized by the highest cellulose levels and intermediate quantities of the other components listed in Table I. Dust generated during the delintering step would be expected to be cellulosic and derived from fibers and linters. The probable source of the protein and noncellulosic materials is the hull and kernel, since cotton cellulose contains only 1-2% protein (13).

The hulling work area dusts were characterized by the lowest ash content, 7.3%, and the most protein, 22.9%. Dust from this area contained the largest quantities of water- and alcohol-soluble and noncellulosic organic constituents, 48.2%. Since "pure" kernels contain about 36% protein, the hulling area dust protein level of 23% indicates about 60% of the hulling area dust was derived from kernels. Hulls are composed primarily of crude fiber, 26%, and contain very low amounts of protein, 4% (13).

TABLE II

Inorganic Composition of Dusts[a,b]

Mill	Percentage of element in dust													Total (%)
	Ti	Fe	Zn	Cu	Mn	Al	Si	S	Cl	K	Ca	Mg	P	
A	0.10	0.40	0.01	0.01	0.003	0.25	7.62	0.22	0.15	1.07	1.19	0.78	0.69	12.49
B	0.15	0.64	Tr[c]	ND[d]	0.004	0.43	10.3	0.13	0.11	0.94	1.46	0.87	0.65	15.70
C	0.18	0.77	ND	ND	0.006	0.48	13.1	0.17	0.09	1.05	1.19	0.85	0.68	18.57
D	0.18	0.72	ND	ND	0.006	0.64	16.6	0.16	0.06	0.89	2.16	1.28	0.91	23.61
E	0.14	0.82	ND	ND	0.004	0.49	11.7	0.16	0.14	1.01	1.65	1.09	0.68	17.88
Avg.	0.15	0.67	Tr	Tr	0.005	0.46	11.9	0.17	0.11	0.99	1.53	0.97	0.72	17.65
							Delintering area							
A	0.04	0.30	Tr	0.01	0.003	ND	2.38	0.13	0.12	1.11	1.00	0.63	0.55	6.27
B	0.10	0.83	Tr	0.01	0.004	0.24	8.86	0.18	0.14	1.08	1.72	1.02	0.87	15.05
C	0.05	0.15	Tr	0.01	0.002	ND	2.32	0.15	0.06	1.30	0.63	0.61	0.63	5.91
D	0.10	0.46	ND	ND	0.004	0.20	8.66	0.14	0.04	1.02	1.80	1.07	0.79	14.29
E	0.04	0.25	ND	0.01	0.001	ND	2.72	0.19	0.16	1.53	1.19	0.91	0.73	7.73
Avg.	0.07	0.40	Tr	0.01	0.003	0.09	4.99	0.16	0.10	1.21	1.27	0.85	0.71	9.85
							Hulling area							
A	0.01	0.12	0.01	0.02	0.002	0.19	0.92	0.22	0.14	1.57	0.72	0.71	0.83	5.57
B	0.02	0.09	0.01	0.02	0.001	0.21	0.82	0.22	0.14	1.55	0.72	0.70	0.83	5.32
C	0.03	0.10	0.01	0.02	0.003	0.28	1.54	0.22	0.09	1.59	0.61	0.72	0.92	6.15
D	0.04	0.13	0.01	0.01	0.004	0.26	2.66	0.22	0.06	1.52	1.09	0.86	0.90	7.77
E	0.01	0.05	0.01	0.02	0.001	0.19	0.90	0.25	0.15	1.53	0.62	0.74	1.04	5.51
Avg.	0.02	0.10	0.01	0.02	0.002	0.23	1.37	0.23	0.12	1.55	0.75	0.75	0.93	6.06
							Baling area							
A	0.04	0.15	Tr	0.01	0.001	0.07	2.22	0.16	0.14	1.49	1.04	0.81	0.59	6.73
B	(Dust from Baling Area of Mill B not available for analysis)													
C	0.02	0.07	0.01	0.03	0.001	ND	1.08	0.12	0.06	1.25	0.47	0.55	0.45	4.21
D	0.09	0.27	Tr	0.01	0.003	0.24	6.36	0.17	0.05	1.31	1.57	1.06	0.78	11.92
E	0.04	0.15	0.01	0.03	0.001	0.03	2.20	0.17	0.14	1.48	0.98	0.83	0.65	6.72
Avg.	0.05	0.16	0.01	0.02	0.002	0.09	2.96	0.16	0.10	1.38	1.02	0.81	0.62	7.40

[a]By X-ray fluorescence.

[b]Dust collected by high volume sampler at flow rates of 40-60 ft^3/min.

[c]Tr = Trace.

[d]ND = Not detectable.

In comparison to the dusts collected in the seed grinding and oil extraction areas of the Egyptian oil mills, the dust from the hulling areas contained about two-thirds as much protein, a little less ash, and one-fifth more cellulose (2). The reason for the differences between the data from the present study and the Egyptian work probably lies in the fact that dust generated in the oil extraction process of American oil mills comes from the essentially hull-free kernels, which contain little fiber and most of the protein.

In general, the composition of baling dust was similar to delintering dust (Table I). Baling room dust contained a relatively small amount of ash (10.3%) and large amounts of cellulose (37.6%) and noncellulosic organic components (35.8%). These data suggest that large quantities of seed fragments, as well as linters, were contained in the air stream being drawn from the delintering saws. The presence of hull fragments in first-cut linters is easily detected in the baled product (14), and the high incidence of hull pepper is obvious in second- and third-cut linters.

Results of the analyses for inorganic elements furnish additional evidence concerning the genesis of dusts collected in the cleaning, delintering, hulling, and baling areas. Elements normally associated with soil minerals, i.e., titanium, aluminum, and silicon, were found in much higher concentrations in the cleaning and delintering dusts than in the hulling and baling dusts. Detection of silicon and aluminum suggests the presence of silica and silicates in the dusts. Calcium, magnesium, and iron, which are commonly found in both plant and soil matter, also were found in greater abundancce in the cleaning and delintering dusts. Part of the elevated iron content in the delintering dust probably was due to the wearing action of the delintering saws and machinery. Potassium, which is accumulated in large quantities in vegetable matter, occurred at the lowest concentrations in the cleaning and delintering areas and in the greatest concentrations in the hulling area. The average phosphorus content of the cottonseed kernels, 1.1%, is considerably higher than in hulls and linters (13,15). The elevated phosphorus content of the hulling dusts also suggests that large amounts of cottonseed meats remain attached to the hull.

TABLE III[a]

Average Total Dust Levels Measured by High-Volume Sampler Method in Cotton Oilseed Mills

Mill	Area and dust level (mg/m^3)			
	Cleaning	Delintering	Hulling	Baling
A	11.6	8.5	12.2	27.0
B	26.7	4.3	11.9	NA[b]
C	12.9	17.5	17.7	4.9
D	14.1	10.4	17.3	12.4
E	86.8	11.8	6.9	3.7
Avg.	30.4	10.5	13.2	12.0

[a]Source: Matlock et al., reference (1).

[b]NA signifies independent sample not available, same baling area as Mill A.

Average total dust concentrations in the cleaning, delintering, hulling, and baling areas of the mills, recorded by Matlock et al. (1) during collection of the samples, are summarized in Table III. As noted by Matlock et al. (1) total dust levels in at least one area of each mill exceeded 15 mg/m^3, which is the limit for inert or nuisance dust allowed under the OSHA General Industrial Standards (16). Cleaning areas had the highest average dust concentrations (30.4 mg/m^3), and the lowest average dust concentrations were recorded in the delintering rooms (10.5 mg/m^3).

Even though the dust levels in all of the cleaning rooms were relatively high, each mill appears to have a unique dust problem. In Mills B and E, the primary problem was in the cleaning area, but dust levels in the hulling room of Mill B and the delintering room of Mill E also were high. The very high dust levels in the two cleaning areas probably are due to unusually high levels of foreign matter in the seed being processed. Both the respective ash contents (27% and 29%) and the cellulose contents (42% and 46%) of the cleaning dusts were high. In Mill A, the main problem was in the common baling room shared with Mill B. The dust concentration was twice the area average, with no particular component being unusually high.

The high dust concentrations found in the delintering areas of Mills C and D probably reflect the use of an abrasive delintering process in the two mills. The high protein (16%) and noncellulosic organic (37%) values, along with the high dust level found in the delintering area of Mill E, also indicates removal of an excessive amount of the seed during delintering. An abrasive process, which produced the major portion of the delintering dust, was being used to obtain third-cut linters in Mill E. The relatively high dust concentrations found in the hulling areas of Mills C and D may also reflect the use of the abrasive delintering process in the two mills.

The space allotted to a particular operation in a cottonseed oil mill seemed to affect the apparent dust levels. Relatively high dust levels were often found in work areas in which the volume of air available for diluting the dust concentration was low. This effect can be seen in the data in Table III. The delintering rooms in Mills A and B were huge in comparison to Mills C, D, and E, and the corresponding dust levels were low. Likewise in baling rooms, the smaller areas associated with Mills A, B, and D were also the sites with the high dust levels (27, 27, and 12 mg/m^3, respectively).

The suggestion (3-5) that byssinosis and chronic bronchitis may be a problem in oil mills is difficult to evaluate. The observation by Noweir et al. (12) that dust from seed handling operations in Egypt (73-590 mg/m^3) led to chest tightness and subjective symptoms in up to 30% of the workers in these areas also suggests potential respiratory problems. However, the observed aggravation of symptoms on exposure over successive days of the week (2) is not typical of byssinosis or chronic bronchitis. Whether or not cottonseed oil mill dusts can stimulate histamine release, which is a commonly used indicator for establishing physiological activity in cotton dusts, is uncertain. Results of preliminary tests of the histamine release capacity of dusts collected in Mill B (C.B. Parnell, Jr., unpublished data) suggest that oil mill dusts do not stimulate histamine release from pig lung tissue. The results of our chemical analyses shed little, if any, light on the question of physiological activity. Much more research on the biological effects of cottonseed mill dusts and epidemiological data are required to draw valid conclusions about the possibility that byssinosis and other occupational respiratory problems occur among oil mill workers.

In conclusion, dust generated during cottonseed oil milling is a very heterogeneous substance, whose composition depends upon the source, agronomic history, ginning procedures, and the milling process. Dust compositions are affected more by the location and processing procedures within a mill than by differences among mills. The major inorganic contaminants found in cottonseed oil mill dusts are silicon, aluminum, and iron. Present epidemiological evidence indicates that chronic airways diseases are not major problems in American cottonseed mills, but a definitive answer requires concerted medical and physiological evaluation.

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