R60-1136-6m

TEXAS AGRICULTURAL EXPERIMENT STATION

A. B. CONNER, DIRECTOR

COLLEGE STATION, BRAZOS COUNTY, TEXAS

BULLETIN NO. 534 NOVEMBER, 1936

DIVISION OF CHEMISTRY

FACTORS WHICH MAY AFFECT THE HARDNESS OF COTTONSEED CAKE

AGRICULTURAL AND MECHANICAL COLLEGE OF TEXAS
T. O. WALTON, President

[Page Blank in Bulletin]

Specimens of the same slab of cottonseed cake varied from 2600 to 3500 pounds in crushing strength. No constant regions of hardness or softness were found.

No definite relations were found between the chemical composition and the hardness of the cake. A rapid change in moisture content of the cake resulted in a lowering of the crushing strength, contrary to expectations.

Meats with high moisture content produced a soft cake.

Storage for approximately two years had no appreciable effect upon the hardness of the cake.

The direction of the testing load and the degree of smoothness of the test specimen had a considerable effect upon the apparent hardness of the cake.

Modified Brinell, schleroscope, abrasion, and impact tests were found unsuitable for testing the hardness of the cake. The crushing test, as already stated in a previous publication, was found to be satisfactory.

The rate of application of the crushing load had no apparent effect upon the results of the crushing tests.

CONTENTS

FACTORS WHICH MAY AFFECT THE HARDNESS OF COTTONSEED CAKE

By G. S. Fraps, Chief, and C. D. Marrs, Assistant Chemist,
Division of Chemistry.

The hardness of cottonseed cake as related to its suitability for feeding has been discussed in a previous publication (Bulletin No. 523). As there pointed out, some lots of cracked cottonseed cake are so hard that animals do not eat them readily, and it is desirable to have a method of testing cake to ascertain the hardness in this respect. The force required to crush cottonseed cake between flat surfaces was adopted as the best method for securing the desired information regarding hardness. Tentatively, cracked cake with a crushing strength of less than 400 pounds was classed as soft for cows; cake with a crushing strength of 400 to 1500 pounds was classed as medium hard; cake with a crushing strength of 1501 to 2500 pounds was classed as hard, and that with a crushing strength of over 2500 pounds was classed as very hard. This classification refers to the cracked or cut cake as sold for feeding purposes.

In connection with the work referred to above, a study was made of some of the various factors which might affect the hardness of cottonseed cake. Other methods besides the crushing test referred to were also studied. It is the object of the present bulletin to present the results secured in this study.

SOME FACTORS AFFECTING HARDNESS

Some of the factors relating to the location of the sample taken from the slab, storage, etc., were studied as described below.

Relation of Position in Slab of Cake to Hardness

It is generally believed by oil mill men that the outside ends of a slab of cottonseed cake are softer than the inside portions. Since it seemed possible that the hardness varies in different portions of the same slab of cake, tests were made to ascertain the variation in the crushing strength of different portions of the same slab of cake.

The slabs of cottonseed cake were mapped, so that the position of the specimen tested could be recorded, and samples from regularly spaced positions in the cake were tested. Two of the slabs were tested by crushing specimens one inch square, and the third was tested by crushing and ball tests on alternate one-inch cores. The methods used have already been described.

There was a wide variation in the hardness of the samples taken from different parts of the same slab of cake. The crushing strength of the one inch squares varied from 2600 lbs. to 3800 lbs. in one slab and from 2700 lbs. to 3700 lbs. in the other. The crushing strength of the cores varied from 1140 lbs. to 2630 lbs., and the ball test required from 245 lbs. to 455 lbs. to break the core.

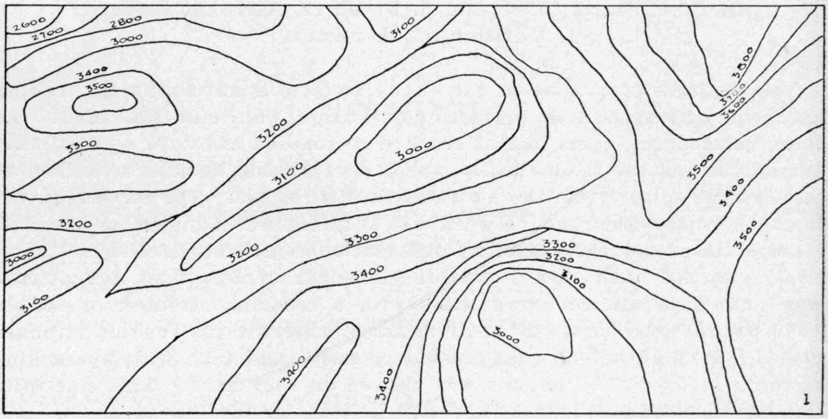

Fig. 1. Lines of equal crushing strength of one-inch squares cut from slab of cottonseed cake No. 1.

The results of the tests were plotted upon a map of the slab, and lines, similar to contour lines, were drawn through points of equal average crushing strength. These lines are shown for two slabs in Figures 1 and 2. It is clear from these that there is no definite relation between

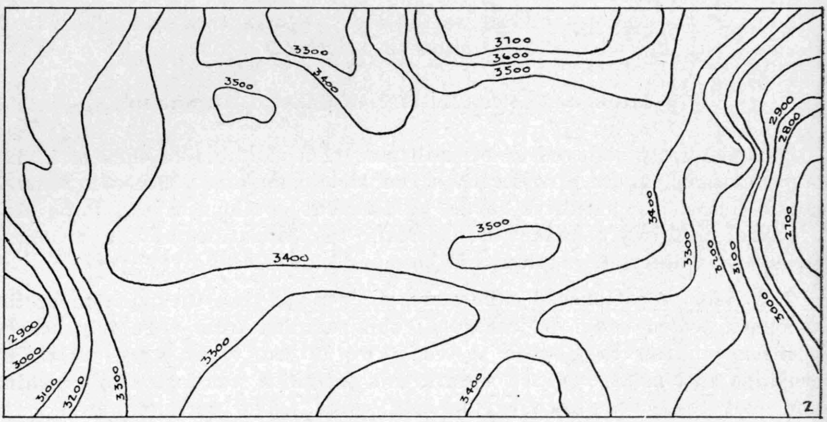

Fig. 2. Lines of equal crushing strength of one-inch squares cut from slab of cottonseed cake No. 2.

the regions of average strength in the two slabs. It is also evident that there are no special regions of hardness or softness.

The Relation of Chemical Composition to the Hardness

Many oil mill operators think that the oil content of cottonseed cake is related to the hardness of the cake. Two theories have been advanced as to the cause of this effect: first, the oil acts as a lubricant and as an inhibitor of excessive cementing of the particles of meal in the cake; and second, the oil content of the cake is a measure of the pressure attained in the presses used for extracting the oil, so that the cake is harder when the pressure is greater.

TABLE 1. Comparison of crushing test with chemical composition

Laboratory Number	Average Crushing Test (lbs.)	Protein %	Fats %	Crude Fiber %	Nitrogen Free Extract %	Water %	Ash %	Number of Cores Averaged	Range of Crushing Test (lbs.)
41038	710.0	41.56	6.14	11.55	28.64	6.60	5.51	7	180
41042	851.5	45.62	6.34	10.61	25.64	6.50	5.29	..	...
41049	928.8	45.28	6.45	9.67	25.73	7.28	5.59	8	90
41026	972.2	42.40	6.33	12.46	26.11	7.56	5.14	13	200
41349	1020.0	43.13	5.77	11.32	28.08	6.58	5.12	8	200
41353	1114.5	42.44	5.64	12.20	27.94	6.70	5.08	11	200
40998	1126.0	44.36	7.30	10.65	24.96	7.44	5.29	15	280
41043	1128.3	45.38	5.94	10.36	26.55	6.47	5.30	..	...
41053	1162.3	45.71	6.86	9.91	24.78	7.09	5.65	11	200
41050	1166.5	45.50	6.02	9.68	25.56	7.81	5.43	10	200
41035	1210.7	43.58	6.40	9.62	27.34	7.15	5.91	15	200
41039	1225.0	41.14	6.00	11.76	27.87	7.66	5.57	10	200
41022	1241.4	41.52	5.87	12.65	27.11	7.16	5.69	11	200
41020	1292.5	41.33	5.73	12.37	27.76	7.03	5.78	12	195
40996	1294.0	44.13	6.04	10.03	27.15	7.24	5.41	..	...
41054	1323.3	46.22	6.93	9.82	24.44	6.83	5.76	9	100
41033	1325.5	43.79	6.80	9.52	27.18	6.63	6.08	11	200
41352	1335.0	42.45	5.63	12.00	28.39	6.55	4.98	10	200
40994	1343.8	43.69	6.03	11.72	25.86	7.24	5.46	12	125
41346	1356.7	42.45	5.96	11.57	28.42	6.47	5.13	9	190
41000	1404.0	43.92	6.85	10.01	26.73	7.31	5.18	21	370
41009	1423.0	44.98	7.49	10.02	25.23	6.83	5.45	10	200
41024	1424.6	44.00	6.23	11.82	25.00	7.73	5.22	14	140
41029	1472.8	44.35	6.51	9.86	26.50	6.73	6.05	9	200
41017	1511.1	45.15	6.52	10.27	24.89	7.81	5.36	9	160
41005	1543.3	45.03	6.52	10.65	25.34	7.07	5.39	9	230
41002	1557.5	44.86	6.78	11.15	25.23	6.82	5.16	10	300
41057	1562.7	40.72	5.73	13.07	27.74	7.08	5.66	11	200
40992	1618.3	44.87	6.24	9.97	26.92	6.59	5.41	9	180
41010	1638.8	44.63	6.71	9.74	26.44	7.15	5.33	12	175
41030	1667.8	44.43	6.05	9.64	26.57	7.22	6.09	9	150
41013	1751.1	44.28	6.01	10.89	25.81	7.84	5.17	9	210
41018	1795.0	45.16	6.58	9.85	25.29	7.78	5.34	9	145
41006	1798.7	44.41	6.45	10.50	26.22	6.98	5.44	8	200
41058	1808.0	40.65	5.50	13.19	28.03	6.89	5.74	10	200
40990	1838.6	44.73	6.17	8.95	27.77	6.68	5.70	11	535
41014	1966.6	44.88	6.02	11.04	25.13	7.76	5.17	9	200
41046	2746.6	45.18	5.21	11.98	25.77	6.87	4.99	9	580

Other oil mill operators have held that the protein content, the crude fiber content, and the moisture content of the cake are related to hardness of the cake. Experiments were made to ascertain these relations.

Twenty-five cores were cut in a line from each slab of cottonseed cake to be tested. These cores were crushed in the Southwark-Emery testing machine and the crushing strength of each core was recorded. The cores were arranged in the order of the magnitude of their crushing strength,

TABLE 2. Crushing strength and chemical composition averaged in groups of 5 samples

Average Crushing Test (lbs.)	Protein %	Ether Extract %	Crude Fiber %	Nitrogen Free Extract %	Water %	Ash %
856.6	43.71	6.31	11.07	26.53	6.99	5.38
1105.5	44.01	6.20	10.69	27.06	6.77	5.29
1201.2	43.45	6.23	10.72	26.53	7.37	5.65
1314.1	43.58	6.23	10.73	26.98	6.85	5.60
1392.8	43.81	6.51	11.03	26.25	7.11	5.29
1529.5	44.02	6.41	11.00	25.94	7.10	5.52
1694.2	44.67	6.32	10.02	26.21	7.31	5.47
2079.9	43.78	5.79	10.68	26.29	7.12	5.33

TABLE 3. Comparison of ball test with chemical composition

Laboratory Number	Average Ball Test (lbs.)	Protein %	Fat %	Crude Fiber %	Nitrogen Free Extract %	Water %	Ash %	Number of Cores Averaged	Range of Ball Test (lbs.)
41040	220.0	45.58	6.55	10.59	25.32	6.65	5.31	9	50
41051	225.6	45.43	6.66	9.84	25.49	7.07	5.51	9	45
41047	228.5	45.30	6.88	10.05	24.94	7.51	5.32	10	35
41034	233.6	44.13	6.52	10.00	26.35	7.09	5.91	11	60
41007	245.0	44.49	6.73	9.52	27.17	6.76	5.33	9	55
41048	263.5	45.10	6.93	9.53	25.08	7.26	5.38	10	30
41052	276.5	45.36	6.91	9.95	25.27	6.98	5.53	10	40
40997	288.4	43.75	5.05	10.92	21.67	13.17	5.44	18	60
40999	291.4	44.38	6.59	8.77	27.54	7.43	5.29	16	65
41041	306.5	45.48	5.96	10.57	26.24	6.48	5.27	11	60
41015	306.6	45.49	6.70	10.17	24.57	7.76	5.31	9	60
41008	315.4	44.37	7.06	9.90	26.14	6.87	5.66	15	60
41025	322.0	43.20	6.53	11.71	25.50	7.81	5.25	12	45
41016	346.6	44.45	6.56	9.99	25.76	7.87	5.37	9	20
41031	347.7	43.75	6.17	9.95	27.51	6.59	6.03	9	60
41003	349.6	44.66	6.86	11.46	24.62	7.29	5.11	12	60
41348	356.5	43.04	5.74	11.80	27.98	6.38	5.06	10	60
41036	358.8	41.48	6.70	11.03	28.42	6.82	5.55	9	60
41351	360.0	42.57	5.87	11.99	27.91	6.68	4.98	11	60
41011	361.1	44.52	6.19	11.14	25.94	6.83	5.38	9	60
40995	363.0	44.49	6.41	10.69	25.62	7.40	5.39	14	85
41027	370.0	44.62	6.12	10.21	25.96	7.01	6.08	11	60
41019	382.7	41.29	5.81	12.26	28.20	6.84	5.60	13	45
41023	388.9	43.70	6.68	11.51	25.19	7.75	5.17	14	90
41350	406.0	42.65	6.00	11.76	27.96	6.62	5.01	10	40
41021	414.5	41.34	5.68	12.36	27.82	7.17	5.63	13	40
41012	415.8	45.51	6.07	10.96	25.48	6.80	5.18	12	40
41004	418.0	45.19	6.59	10.62	25.02	7.12	5.46	10	60
41032	418.7	44.29	6.25	10.20	26.62	6.55	6.09	11	60
41001	421.2	45.38	6.32	11.22	24.89	7.04	5.15	13	65
41055	428.9	41.27	5.65	13.06	27.70	6.71	5.61	14	65
41347	430.5	42.21	5.66	11.69	28.64	6.56	5.24	10	90
40993	432.3	44.08	5.77	11.68	24.21	8.72	5.54	13	60
41037	439.2	41.45	5.78	11.81	28.60	6.81	5.55	12	50
40989	449.0	45.26	5.98	9.02	27.30	6.63	5.81	14	110
40991	463.8	45.45	6.75	9.69	26.09	6.60	5.42	12	30
41028	467.5	44.53	5.79	9.61	27.07	6.88	6.12	8	80
41056	482.5	41.24	5.54	12.57	28.46	6.53	5.66	8	60
41044	489.0	45.03	4.83	11.83	26.27	7.07	4.97	11	60
41045	582.0	44.59	4.84	11.75	26.73	7.09	5.00	10	100

and cores of each test which did not vary too widely from the average were selected for chemical analysis.

Table 1 contains the results of the crushing tests and the chemical analysis. Table 2 gives the averages by groups of five samples. There appears to be no consistent relation between the crushing tests of the cores and their chemical composition. The samples with the highest crushing strengths contain the lowest fat, but the samples with the next to the highest crushing strength have the same fat content as those with the lowest.

TABLE 4. Ball test and chemical composition averaged in groups of 5 samples

Average of Ball Test (lbs.)	Protein %	Fat %	Crude Fiber %	Nitrogen Free Extract %	Water %	Ash %
230.5	44.99	6.67	10.00	24.85	7.01	5.48
286.1	44.81	6.39	9.95	25.16	8.26	5.38
327.7	44.25	6.60	10.34	25.89	7.38	5.52
357.2	43.25	6.27	11.48	26.97	6.80	5.21
382.1	43.35	6.21	11.28	26.59	7.12	5.45
417.6	44.35	6.18	11.07	25.97	6.94	5.50
436.0	42.85	5.77	11.45	27.29	7.09	5.55
490.9	45.17	5.55	11.09	26.92	6.83	5.43

A similar comparison was made between the ball test and the chemical composition. Table 3 contains the results, and Table 4 the average in groups. There seems to be a distinct relation between the fat content and the ball strength of the core, but this relation is not consistent. In most cases, the harder samples seem to have the lower fat content.

It is seen in Table 4 that the fat content of the cores is lowest when the ball test is highest.

The Moisture Content of the Cake

The theory of some of the mill operators that cottonseed cake becomes harder after storage for a considerable time suggested that experiments be run to determine if this change in hardness is caused by a change in the moisture content of the cake.

Series of 24 one-inch cores were prepared in the usual manner. The even-numbered cores of three series cut from the same sample of cake were placed in a vacuum oven for varying lengths of time in order to remove varying amounts of moisture. The odd-numbered cores of these series were tested for hardness in the usual manner. The even-numbered cores of three series of cores cut from another slab of cake were placed in a closed container over water for varying lengths of time in order to add varying amounts of moisture to the cores.

Moisture determinations were made on the corings of each 12 cores cut, and the value found was taken to be the average original moisture content of the cores used. The final moisture content was calculated from the original moisture content and the difference in weight before and after treatment. After weighing, the even-numbered cores were crushed in the usual manner. Similar determinations were made with the ball test.

In another experiment, three series of 15 cores each were cut from each of three cakes of cottonseed. The first of these series was dried in a vacuum oven at 100° C for 5 hours before testing, the second series was tested in the same condition as the original cake, and the third series was placed over water in a closed vessel for 5 hours before testing. After each core was crushed, it was placed in a numbered tin box, Gill style, with a tight cover so that the moisture content of the core at the time of crushing could be determined. This moisture was calculated from the loss in weight of the crushed core which was dried for 5 hours in a vacuum oven.

TABLE 5. Effect of change in moisture upon crushing strength

Number of cores tested	Untreated Cores		Treated Cores		Percentage change in moisture	Percentage change in crushing strength
	Moisture per cent	Crushing strength pounds	Moisture per cent	Crushing strength pounds		
12	8.66	2492	2.84	2049	—5.99	—17.78
12	8.68	2055	4.68	1587	—4.27	—22.77
12	9.11	1843	8.67	1830	—0.54	—0.71
12	8.53	2393	9.33	2166	0.89	—9.49
12	8.57	2465	10.95	1528	2.54	—38.01
12	8.58	2149	11.25	1274	2.98	—40.71

The results of the crushing tests are shown in Table 5, and those of the ball test in Table 6.

TABLE 6. Effect of change in moisture upon ball test

Number of cores tested each determination	Untreated Cores		Treated Cores		Percentage change in moisture	Percentage change in ball test
	Moisture in corings per cent	Ball test (lbs.)	Moisture in cores per cent	Ball test (lbs.)		
12	9.70	266	2.20	243	—7.67	—8.65
12	9.34	265	4.14	255	—5.43	—3.77
12	9.19	272	7.09	228	—2.57	—16.18
12	10.12	263	12.54	253	2.78	—3.80
12	9.64	263	13.15	242	4.02	—7.97
12	9.50	289	16.38	161	7.67	—44.35

In each of the above cases, it will be noted that the cake was hardest under the original conditions. A rapid change of the moisture content seems to soften the cake. The crushing strength and the ball test were lower when the cake was dried, or when it took up water. Taking up moisture had a greater effect than drying.

Table 7 shows the result of the second series of tests. The results are the same as those previously found except in the case of one of the three samples, No. 40633-B. With this sample the average hardness of the dried cores was greater than the hardness of the original cores.

TABLE 7. Effect of moisture content upon crushing strength

Laboratory Number	Cores dried		Cores not treated		Cores moistened	
	Moisture per cent	Crushing strength per cent	Moisture per cent	Crushing strength per cent	Moisture per cent	Crushing strength per cent
40640A	4.01	2338.0	6.31	2521.0	8.24	2134.6
40633B	2.09	2496.6	7.84	2116.6	11.34	1308.6
40634B	2.09	2368.0	7.13	2428.7	8.79	2102.7

The Effect of Moisture Content Before Pressing Upon the Hardness of Cottonseed Cake

Some mill operators think one of the causes of the production of hard cottonseed cake is the introduction of too much moisture during the cooking process. Tests were made of the effect of the quantity of moisture in the meal before the meal was pressed into cakes. Samples of the cooked meal were taken from the cake-former in the Bryan Cotton Oil Mill, and samples of the corresponding cake were tested. The moisture in the cooked meats was increased as much as possible, until the meats had a tendency to crawl in the press-cloths. The results are shown in Table 8. Within the limits of this experiment the cake becomes softer as the moisture in the unpressed meats increases. The specimens in which the moisture in the unpressed meats exceeded 6.00% were so soft and waxy that no point of failure could be noted on the testing machine. The specimens seemed to flow under pressure and to exhibit no typical failure cracks. Additional work is desirable.

TABLE 8. Effect of moisture in unpressed meats upon hardness of resulting cottonseed cake

Laboratory Number	Number of specimens	Moisture per cent in unpressed meats	Crushing strength (lbs.)	Average ball test (lbs.)
38943	8	4.71	2720	511
38942	8	4.83	2886	480
38941	8	5.80	2154	440
38944	8	5.93	1561	306
38946	8	6.74	low	298
38945	8	6.80	low	318

Effect of Press Box Temperature upon Hardness

Some mill operators think that hard cottonseed cake is produced if the temperature of the press boxes in the hydraulic presses has been permitted to go too high.

Experiments were made in the Bryan Cotton Oil Mill to determine the effect of press box temperatures upon the hardness of the cake. Ther-

TABLE 9. Effect of press box temperature upon hardness of resulting cottonseed cake

Laboratory Number	Number of specimens tested	Press box temperature °F	Average crushing test (lbs.)	Average ball test (lbs.)
38941	8	96°	2154	440
38942	8	106	2886	480
38943	8	114	2720	511
38944	8	124	1561	306
38945	8	136	low	318
38946	8	132	low	298

mometers were placed in the press boxes and were read when the cake was removed from the press. The cake from the press was saved for testing. The results are shown in Table 9. As the press box temperature increases above 114° F, the hardness of the cake decreases. The cake was soft and waxy at 136° and 132°. It was also harder at 106° F than at 114° F. This factor needs further study.

Effect of Storage on the Hardness

It has been suggested that cottonseed cake becomes harder after long storage than it was when first pressed. An experiment was designed to ascertain the effect of storage.

Samples of slab cottonseed cake which had been stored for twenty-three months in a covered wooden box in a dry basement were tested. In Table 10 the crushing tests are compared with the crushing tests which were made on these samples when received.

It is evident from the results that, in general, storage did not increase the hardness of the cake. Although some of the samples had a higher average crushing strength after storage, most of the samples had lower crushing strengths. In practically every case, however, the differences between the tests were within the differences which could have been caused by the location of the test specimen in the slab.

Relation of Specific Gravity of Cake to Hardness

It was noticed that some specimens of the cottonseed cake tested seemed to be more dense than others. The specimens seemed to vary from a fine grained, very tightly compacted mass to a coarse grained, very loosely compacted mass. This suggested that the density or specific gravity of the specimens might be related to the hardness of the cake. Two experiments were made to ascertain the relation of the specific gravity to the crushing strength. Cores were cut from a sample of cottonseed cake, and the end surfaces of the cores were sanded smooth and parallel.

TABLE 10. Effect of storage on crushing strength

Laboratory Number	Before storage pounds	After storage pounds
39679-B	835	1099
39680-A	948	1123
39680-B	963	1323
40703	1071	1296
40633-B	1143	1475
40634-A	1169	835
40640-B	1181	1192
40643-C	1199	1171
39680-C	1234	1092
40704	1234	1123
40643-B	1322	1419
40633-B	1405	1321
40633-A	1415	1404
40640-A	1416	1624
40633-E	1533	1450
40633-F	1557	1629
40718	1604	1429
40633-H	1655	1619
40643-A	1670	1057
40624-A	1679	1262
40633-O	1722	1702
40633-G	1796	1776
Average..............	1352	1337

In the first experiment the specific gravity was obtained for each core by first weighing the core in air, dipping it in hot paraffin, and then obtaining the loss of weight in water. Crushing tests were then run on each core.

In the second experiment, one-inch cores were cut from a cottonseed cake which had been found by previous tests to have below the average hardness. The flat ends of these cores were sanded smooth and parallel by a sanding wheel. The cores were brushed well with a brass wire brush to remove all loose particles and were then weighed and the weight of each was recorded.

The specific gravity was determined by the following method: A 50 cc lipless, tall-form beaker was placed in a 4″ evaporating dish. The beaker was filled to overflowing with mercury. Down on top of this beaker was forced a pyroxylin plate which had 3 tacks pushed through it to form a triangle of such size that all 3 tacks would rest on one of the cores. In this way the excess mercury was removed from the beaker. One of the cores was then placed on top of the mercury and was forced down by the three tacks in the pyroxylin plate until the plate again rested on top of the beaker. The overflowing mercury was caught in the evaporating dish, transferred to a tared 25 cc beaker, and weighed. The weight of this mercury divided by 13.595 was recorded as the volume of the core. The results of determinations of the specific gravity of three sets of six cores by the above method showed that the error in computing the specific gravity of the cores of cottonseed cake by this method is less than 0.5 per cent.

Forty-five cores were prepared from cake No. 40653 and their specific gravity was determined by the above method. The same cores were crushed, and the results of the tests were averaged in groups of 9. The same procedure was repeated for cakes No. 40633A and 40633G, except that twenty-five cores were used and the tables are, therefore, averaged into groups of five determinations each.

TABLE 11. Comparison of specific gravity and crushing strength of cottonseed cake

Group Number	40633A		40653		40633G	
	Average crushing strength (lbs.)	Average specific gravity	Average crushing strength (lbs.)	Average specific gravity	Average crushing strength (lbs.)	Average specific gravity
1	2020	1.2880	1976	1.3222	2198	1.2896
2	2128	1.2867	2243	1.3230	2438	1.2940
3	2240	1.2946	2412	1.3175	2593	1.3071
4	2340	1.2991	2534	1.3216	2693	1.3077
5	2562	1.3057	2709	1.3157	2838	1.3118
Average...	2255	1.2946	2375	1.3200	2551	1.3022

Table 11 shows the comparison of the averages of the separate groups from each of the samples tested. An inspection of this table shows that for two of the samples, Numbers 40633A and 40633G, the average crushing strength for each group increases regularly as the average specific gravity of the group increases, but that the reverse is true for Sample 40653, and also that these results are irregular. There seemed to be a relation with two of the slabs, but not with the other one.

SOME FACTORS WHICH AFFECT THE METHOD OF TESTING

Some of the factors which affect the method of testing were studied as described below.

The Direction of the Testing Load

The process of manufacturing cottonseed cake is such that the cake tends to have well defined bedding planes which are analogous to the bedding planes of sedimentary rocks. It was decided, therefore, to ascertain the differences in crushing and ball strength when the testing forces acted in a line parallel to the bedding plane and when they acted in a line perpendicular to the bedding plane.

A jig for cutting 1″ squares from cottonseed cake was arranged so that all specimens tested would be of the same size and shape. This jig was made similar to the box used by a carpenter for fitting moulding. Fifty specimens were cut from each sample in four adjacent rows. The tests were arranged so that the two adjacent specimens were given different tests.

TABLE 12. Relation of Ball and Crushing Tests of 1″ squares tested flat and edgeways

Laboratory Number	Crushing strength		Percentage strength on edge is of strength flat
	Flat	On edge	
40654	3371.2	2652.0	78.7
40629	3070.4	2019.6	65.8
40718	3373.8	2166.2	64.2
	Ball strength		
40956A	580.8	310.2	53.4
40650	493.4	269.0	54.5

Table 12 shows the results of the work. The crushing strength was much lower when the sample was tested on edge than when it was tested flat—that is, along the bedding plane. The crushing strength of the sample on edge was about two-thirds that of the sample placed flat in the machine. The force required of an animal to break the cake would seem, therefore, to depend upon how the crushed cake is presented to the teeth, but it is likely the piece would be rolled around in chewing so that all sides would be presented.

Effect of Smoothness or Roughness of Ends of Specimens

In some of the experimental work, the samples of cottonseed cake were sanded smooth. The following experiments were made to ascertain the effect of this procedure.

A series of forty-five cores was cut from three cakes of widely different crushing strength as determined by previous tests. The cores were cut in three adjacent lines of fifteen cores each and were numbered in the order of their removal from the sample. The odd-numbered cores were tested with their plane surfaces rough; the even-numbered cores were sanded on a sand wheel until their plane surfaces were smooth and parallel. This arrangement was made so that average results of the crushing tests on the cores could be compared. The results of these tests are shown in Table 13.

The experiment was repeated on two rows of 10 cores each from three cakes. One row of cores from each cake was tested in the condition in which they were taken from the cake, and the other row of cores from each cake was tested after the ends of the cores had been sanded smooth and parallel. The results of these tests are also included in Table 13.

The crushing strength of the smooth cores is much greater than that of the rough cores. The crushing strength of the rough cores varied from 40.2 per cent to 70.5 per cent of the crushing strength of the sanded cores.

It is seen that the standard deviations for the rough cores in four cases are extremely high, and that the standard deviations for the sanded

TABLE 13. Comparison of crushing strength of cores with rough ends and with smooth ends

Rough ends				Smooth ends				Percentage crushing strength for rough ends is of crushing strength for smooth ends
Number of specimens tested	Average crushing strength (lbs.)	Standard deviation	Per-centage deviation is of average	Number of specimens tested	Average crushing strength (lbs.)	Standard deviation	Per-centage deviation is of average	
23	1027	166	16.18	22	2360	258	10.92	43.50
10	1126	139	12.38	10	2085	185	8.89	53.95
10	1129	208	18.39	10	2110	187	8.85	53.50
23	1145	147	12.85	22	2187	281	12.81	52.35
23	1349	247	18.34	22	3352	391	11.65	40.20
23	1415	338	23.85	22	2255	202	8.96	62.75
10	1436	260	18.23	10	2908	183	6.31	49.40
23	1573	286	18.11	22	2602	334	12.82	60.40
23	1796	223	12.40	22	2552	225	8.04	70.38

cores vary from 6.31% to 12.82% of the mean. The data also suggest that, although the testing of the rough cores gives a more accurate indication of the hardness of the cake as fed to the cows, smooth cores may be better for the purpose of experiments on the factors affecting the hardness of the cake.

This suggestion is also given because the theory of testing materials indicates that, for comparative results, the testing load must be applied uniformly over the surface of the test specimen. This is obviously impossible with the rough cores of cottonseed cake. The theory of loads concentrated at a point on a surface (1) is that maximum stresses are set up along the approximate surface of a cone with the apex of the cone at the point of application of the load and with the angle at the apex of the cone of approximately 110°. The rough projections of the unsanded cores tend to concentrate the testing loads at these projections and the forces within the core tend to split it rather than to cause it to fail by straight compression.

The Effect of the Rate of Application of Load of Cottonseed Cake Upon Its Crushing Strength

It has long been known that the rate of application of a load in testing material by compression materially affects the yield point and ultimate strength of the material (2). It was decided, therefore, to make tests to determine the effect of this factor upon the ultimate strength of specimens of cottonseed cake.

Since there is a probability of a great difference in the ultimate compression strength of two cores of cottonseed cake taken from adjacent positions in the slab, and since compression tests with two different speeds cannot be run on the same specimen, it was necessary to devise some means of approximating the ultimate compression strength of a specimen in terms of other neighboring specimens.

Series of 24 cores were cut in a line lengthwise of the cake and as close together as the thickness of the metal in the core drill would permit. A complete series of cores was tested at a constant rate of deformation of .4 inch per minute, and another series was tested at a rate of .2 inch per minute.

TABLE 14. Effect of rate of application of load upon crushing strength and ball test

Speed of Crushing Table (In. per Min.)	.4	.2	.2	.1	.1	.05
Number of Specimens Tested:						
Crushing Test pounds..	12	12	12	12	12	12
Ball Test pounds.......	21	24	....	12	....	12
Average load at Failure:						
Crushing Test pounds..	1540	1432	1368	1340	1331	1420
Ball Test pounds.......	404	392	....	369	....	339
Standard Deviation of Load at Failure:						
Crushing Test pounds..	157	210	212	266	186	195
Ball Test pounds.......	68	48	....	33	....	40
Percentage standard deviation is of average:						
Crushing Test pounds..	10.02	14.63	15.50	19.82	13.95	13.71
Ball Test pounds.......	16.83	12.24	....	8.95	....	11.80
Average total deformation (inches):						
Crushing Test.........	.1521	.1412	.1089	.1225	.1270	.1510
Ball Test.............	.074	.080	....	.073	....	.082
Average load applied per second (lbs.):						
Crushing Test.........	67.5	33.8	41.7	19.8	17.5	7.84
Ball Test.............	36.7	16.3	....	8.42	....	3.46
Average time required to apply failing load (sec.):						
Crushing Test.........	22.8	42.4	32.7	67.5	76.0	181.1
Ball Test.............	11.0	24.1	....	43.8	....	98.0

The crushing strengths of each two consecutive odd-numbered cores were averaged and the average strength was compared with the strength of the intermediate even-numbered core. A comparison of the average strength of two consecutively even-numbered cores with the intermediate odd-numbered core was made. The results are shown in Table 14. As the tabulation shows in each case that the error caused by the assumption that the ultimate compressive strength of any one specimen in the series is equivalent to the average of its proximate neighbors in the series is considerably less than the standard deviation, it is assumed that this method of computing the ultimate compression strength of a specimen of cottonseed cake in terms of specimens from adjacent positions is sufficiently correct for the purpose of this study.

Series of 24 cores were prepared from a slab of cottonseed cake in the manner already described. The odd-numbered specimens were tested at one rate of deformation and the even-numbered specimens of the same series were tested at another rate.

An inspection of Table 14 shows that in general the ultimate crushing strength of the cores of cottonseed cake increases as the rate of application of the load increases. This fact suggests that there may be a certain amount of plastic flow of the material under the slow application of the load.

TABLE 15. Effect of rate of application of load upon crushing strength and ball tests

Speed of crushing table (in. per min.)	Crushing strength				Ball test			
	Number of samples tested	Average crushing strength (lbs.)	Standard deviation of crushing test	Per cent deviation is of average	Number of samples tested	Average ball test (lbs.)	Standard deviation of ball test	Per cent deviation is of average
.4	23	1413	319	22.57	24	404	68	16.83
.4	12	1540	157	10.02	12	419	53	12.65
.2	24	1386	285	20.55	24	392	48	12.24
.2	12	1432	210	14.63	24	348	76	21.81
.2	12	1368	212	15.50	12	346	44	12.71
.2	...	....	...	.....	12	430	56	13.10
.2	...	....	...	.....	12	392	34	8.67
.1	24	1338	196	14.65	24	350	46	13.12
.1	12	1340	266	19.82	12	342	36	10.51
.1	12	1331	186	13.95	12	333	34	10.20
.1	...	....	...	.....	12	402	37	9.20
.1	...	....	...	.....	12	369	33	8.95
.05	24	1343	260	19.31	24	310	42	13.54
.05	12	1420	195	13.71	12	376	40	10.63
.05	...	....	...	.....	12	339	40	11.80

Table 15, however, shows that on specimens tested from the same slab of cottonseed cake the ultimate crushing strength of the cores under different rates of application of load does not vary more than the variation shown for the ultimate strengths of the cores from different positions in the slab tested at the same rate of application of load.

It may be assumed, therefore, that for all practical purposes the rate of application of load to the cores of cottonseed cake has no effect, within the limits of these experiments, upon the ultimate crushing strength of the cake.

The Relation of the Unit Deformation of 1″ Cores under a Load of 1000 lbs. to Their Crushing Strength

Elastic materials under compressive or tensile loads are deformed in proportion to the load until the elastic limit of the material is reached (1). The deformation per unit of load then increases rapidly until the specimen under test fails. Because of the varying dimensions of test specimens of cottonseed cake, the deformation per unit of length was used as a measure of comparison of two specimens.

Cores on which the original surfaces were left intact were crushed in the testing machine with the crushing head of the machine moving at a known constant speed. The time required for the applied load to change from nothing to 1000 pounds was checked by a stop watch, and the deformation of the specimen was computed by multiplying this elapsed

TABLE 16. Comparison of unit deformation under a load of 1000 lbs. to crushing strength

Number	Unit deformation at 1000 lbs. (in./in.)	Crushing strength (lbs.)	Unit deformation at 1000 lbs. (in./in.)	Crushing strength (lbs.)	Unit deformation at 1000 lbs. (in./in.)	Crushing strength (lbs.)	Unit deformation at 1000 lbs. (in./in.)	Crushing strength (lbs.)
1	.129	1000	.089	1380	.064	1570	.115	1630
2	.105	1120	.098	1420	.096	1570	.080	1640
3	.121	1140	.091	1440	.062	1580	.062	1670
4	.108	1220	.113	1440	.076	1580	.114	1700
5	.093	1240	.056	1490	.066	1590	.070	1740
6	.125	1250	.077	1490	.095	1590	.076	1760
7	.101	1260	.115	1510	.115	1590	.092	1760
8	.114	1320	.043	1530	.069	1600	.068	1790
9	.092	1340	.063	1540	.072	1610	.075	1790
10	.090	1360	.081	1540	.079	1620	.069	1810
11	.113	1370	.061	1570	.065	1630	.047	1820
Mean......	.108	1238	.081	1480	.078	1594	.079	1737
1	.087	1820	.059	2010	.049	2110	.053	2410
2	.051	1850	.063	2010	.065	2170	.052	2470
3	.080	1880	.054	2030	.071	2180	.056	2490
4	.049	1890	.088	2030	.069	2210	.059	2490
5	.074	1910	.058	2040	.059	2220	.064	2490
6	.061	1930	.054	2050	.058	2250	.047	2510
7	.094	1940	.074	2060	.065	2260	.079	2550
8	.065	1950	.075	2060	.071	2290	.078	2610
9	.091	1970	.045	2070	.088	2290	....	....
10	.050	2010	.065	2070	.059	2300	....	....
11	.053	2010	.056	2100	.067	2310	....	....
Mean......	.069	1924	.063	2048	.066	2235	.061	2503

time by the velocity of the crushing table. The unit deformation was obtained by dividing the total deformation in inches by the original thickness of the specimen in inches.

Table 16 shows the results of the comparison of the unit deformation under a load of 1000 pounds with the ultimate crushing strength of 1″ cores of cottonseed cake. The determinations were arranged in the table in the order of the magnitude of the crushing strength of the cores. The determinations were then averaged in groups of eleven determinations and these averages were examined for possible relationship between the factors. An inspection of the table seems to indicate that the hard specimens are deformed less than the soft specimens under the load of 1000 pounds.

OTHER POSSIBLE METHODS FOR TESTING HARDNESS

As explained in Bulletin 523, the crushing test was considered to have the best relation to the hardness of cottonseed cake.

Other methods for testing the hardness of cottonseed cake were tried. They include the so-called "bootheel" test, the abrasion test, the Brinell test, the schleroscope test, the impact test, the "tooth" test, and the ball test. The bootheel test, the tooth test, and the ball test were described in Bulletin 523.

The Modified Brinell Test

The definition of hardness includes the physical properties of resistance to penetration and to permanent deformations. One of the accepted tests for penetration which is used in the metal industries is the Brinell test (3). This test is made by forcing a 10 mm steel ball into the surface of a material to be tested by a standard load. The depth of penetration is computed from the diameter of the indentation and the diameter of the ball. The ratio of the load to the depth of indentation is the measure of the hardness of the material.

An attempt was made to determine the hardness of cottonseed cake by means of a modified Brinell test. A steel ball 15/32 inch in diameter was mounted in a section of steel shafting in such a manner that it could be forced into the specimens of the cake by means of the Olsen machine. The specimens for use in this experiment were pieces of cake cut in squares with dimensions 2″ x 2″. The surfaces of the squares were sanded to a smooth finish before the test was made. The preliminary tests of the Brinell hardness of cottonseed cake were unsatisfactory because of the lack of accurate means of measuring the diameter of the indentation caused by the steel ball. A Beggs Deformeter Microscope was later available, and was used for further tests of the method.

The Beggs Deformeter microscope is a 10-power microscope fitted with a micrometer eyepiece. This eyepiece contains a set of crosshairs which may be moved across the field by means of a micrometer screw. The head of this screw is divided into 100 parts. The crosshairs are fitted with an index which moves along a divided scale in the field of the eyepiece. This arrangement permits the measurement of two diameters of a circle at one setting of the specimen provided the specimen is placed so that the circle is tangent to both crosshairs when the movable scale is at the zero index. The crosshairs are moved so that the horizontal and vertical crosshairs traverse the indentation to be measured. The scale and micrometer head are read when each crosshair has traversed the circle. The mean of these readings is recorded as the diameter of the circle.

The perimeter of the indentation caused by the ball is not a true circle, because the hard particles in the cake are forced down into the soft parts of the cake. The difficulty in reading the true diameter of the indentation was overcome in part by marking with chalk the surface to be tested. This procedure gave a clearly defined indentation because the oil in part of the specimen under the ball was pressed out and obliterated the chalk in that area. The indentation had a perimeter closely approximating a true circle. The reading of the two diameters and the estimation by eye of the position of the true circumference of the indentation reduced the error in reading the diameter.

The indentations were made in the smoothed surfaces of 12 one-inch cores cut from each sample. They were made by means of a steel ball 15/32 inch in diameter and under a load of 50 kg. After the Brinell tests were made, six specimens from each sample were tested by crushing and the remaining six specimens from each sample were tested by means of the ball test. A comparison of results is shown in Table 17.

TABLE 17. Comparison of modified Brinell tests with ball and crushing tests

Laboratory Number	Number of cores tested	Average diameter of indentation (mm)	Average ball test on cores (lbs.)	Average crushing test on cores (lbs.)
39679-A	12	2.863	527	3078
38570	12	3.168	493	3427
38564-C	12	3.218	343	2131
39680-C	12	3.295	415	2020
38592	12	3.401	360	1733
39680-B	12	3.592	373	1505

The results of the Brinell test seem to correlate with those of the crushing test. One set of the five sets of results, that of Sample No. 38570, is not in accord with this conclusion.

The Brinell test, however, does not seem to correlate as closely with the ball test as it does with the crushing test, for two of the sets in this comparison are not in accord. The Brinell test did not seem to offer a practical method of testing cottonseed cake.

The Modified Schleroscope Test

The schleroscope (4) test consists of the dropping of a steel ball upon the test specimen and the measuring of the height of the rebound of the ball. This has been used by the ball-bearing industry for the testing of the hardness of ball-bearings and for the automatic classification of the balls into three classes: balls that are too soft, balls that have the right hardness, and balls that are too hard. The classification is obtained by arranging for the balls to roll down a chute, strike a hard steel plate, and bound to three slots arranged at different distances from the point of rebound of the balls from the steel plate. The hard balls bounce to the most distant slot, the balls which have the right degree of hardness bounce to the middle slot, and the balls which are too soft bounce to the slot which is nearest to the point of rebound of the ball from the steel plate. The schleroscope test and many modifications of the test are used in the metal industries to test the hardness of finished products that may not be destroyed through testing. Steels and other alloys are tested by this method.

This test was modified for use with cottonseed cake so that the steel balls rolled down a tube of a certain length, struck the specimen, and bounced to a piece of paper covered by a sheet of carbon paper. In this way, the point at which the ball struck was recorded and the distance the ball bounced could be measured. The length of tube used in this experiment was 40 cm. and the angle of incidence of the ball on the specimen was 60° from the vertical.

TABLE 18. Comparison of average modified Schleroscope test with ball and crushing test 40 cm tube and 60° angle of incidence

Laboratory Number	Average Schleroscope test (cm)	Average Ball test (lbs.)	Average Crushing test (lbs.)
39680-B	31.6	373	1505
38570	31.6	493	3427
38592	35.3	360	1733
38564-C	36.5	343	2131
39679-A	36.9	527	3078
39680-C	37.5	415	2020

The results are shown in Table 18. It is seen that there is no relation indicated between the schleroscope test and the ball or crushing test. It was decided, however, to make further tests of this method before discarding it as impractical.

A series of 10 cores was cut from each of three cakes and plane surfaces of these cores were sanded smooth and parallel to each other. The

TABLE 19. Comparison of Schleroscope tests to crushing strength of cottonseed cake 20 cm tube and 45° angle of incidence

Specimen Number	Trial Number	Laboratory Number					
		40634-B		40633-B		40643-A	
		Average Schleroscope test (cm)	Crushing strength (lbs.)	Average Schleroscope test (cm)	Crushing strength (lbs.)	Average Schleroscope test (cm)	Crushing strength (lbs.)
	1	18.9	2400	18.5	2300	18.9	2680
	2	19.7	2400	19.0	2490	18.7	2880
	3	18.2	2610	17.8	2540	19.1	2960
	4	19.0	2660	17.6	2600	18.1	3040
	5	18.3	2680	19.4	2660	18.4	3060
	6	19.3	2690	17.7	2690	18.8	3180
	7	18.5	2900	18.5	2700	19.1	3340
	8	19.3	2930	18.4	2740	18.5	3360
	9	19.1	2990	18.8	2820	19.0	3390
	10	18.2	3020	18.1	2990	18.6	3440
Mean.............		18.85	2728	18.38	2653	18.72	3133

schleroscope tests were similar to those previously described, except that the tube was 20 cm long and inclined at an angle of 45°. Four tests were made on each core and the core was then crushed in the usual manner. The results of the tests are shown in Table 19. These results confirm the conclusion that there is no relation between the schleroscope hardness and the crushing strength of the cake.

The Impact Test

The impact test (5) is made by dropping a standard weight upon the specimen either from a fixed height or from varying heights. The number of strokes of the weight required to shatter the specimen is recorded as the hardness of the specimen. The impact test is primarily intended for the testing of highway materials, such as crushed stone and gravel, which are required to bear the continued impact of passing vehicles.

A series of tests was made on cores from the same sample of cake in order to compare the hardness of 1″ cores of cottonseed cake as measured by a Page Impact Machine with the hardness as measured by the ball and crushing tests. The Page Impact Machine is designed to measure the toughness of rock and gravel used for paving roads. The machine is so constructed that a 2 kg. weight is raised and dropped vertically at regular intervals upon a 1 kg. striker which rests upon the specimen to be tested. The specimen rests on a fixed anvil which has a plane surface. The Page Impact Machine is so arranged that the hammer may be raised to heights which increase by one cm. for each blow, or that it may be raised the same height for each blow. Both methods were used in the tests of cottonseed cake.

In these tests, the energy required to fracture the specimen is reported as the impact test of the specimen. This energy is computed by multiplying by the weight of the hammer the total distance through which the hammer falls in order to fracture the specimen.

Cores were cut from various samples of cottonseed cake and were tested in the rough condition in which they were when cut. An equal number of cores was tested by ball, crushing, and impact tests. Impact tests were run by permitting the hammer to drop from varying heights for each blow, from a constant height of 6 cm. for each blow, and for some of the tests from a constant height of 4 cm. for each blow.

Table 20 shows the comparison of the ball tests with the impact tests, and Table 21 shows the comparison of the crushing test with the impact tests. There appears to be no relation between either the ball or crushing tests and the two kinds of impact tests.

The Abrasion Test

The abrasion test (5) is made by determining the weight lost by specimens of the cake when ground in a ball mill under special standard conditions. This loss in weight indicates to a certain degree the amount

TABLE 20. Comparison of impact tests with ball test on 1" cores of cottonseed cake

Number of cores tested	Average ball test (lbs.)	Average Impact tests (Kg. cm)		
		Varying drop of hammer	Constant drop of hammer (6 cm)	Constant drop of hammer (4 cm)
12	186	92.3	94.8	....
12	221	119.7	113.0	....
12	245	45.3	54.0	....
25	267	117.6	51.8	236.5
25	291	94.6	42.7	151.4
12	323	102.6	122.3	....
25	364	154.6	142.7	290.2
12	370	145.8	147.0	....
25	383	113.1	136.3	284.8
12	390	187.5	246.0	....
12	425	120.8	42.0	....
25	445	128.0	56.2	293.6
12	460	92.5	86.0	....
12	488	35.7	57.0	....
25	524	72.5	42.7	113.3
12	531	87.2	105.0	....

of cohesion between the particles of the tested specimen. This test is used for the determination of the ability of certain highway materials, such as stone and gravel, to stand up under the continued abrasion of the wheels of passing vehicles.

TABLE 21. Comparison of impact tests with crushing tests on 1" cores of cottonseed cake

Number of cores tested	Average crushing test (lbs.)	Average Impact tests (Kg. cm)		
		Varying drop of hammer	Constant drop of hammer (6 cm)	Constant drop of hammer (4 cm)
12	710	92.3	94.8	....
12	835	92.5	86.0	....
12	937	119.7	113.0	....
12	948	120.8	42.0	....
12	963	45.3	54.0	....
25	1094	113.1	136.3	284.8
12	1216	102.6	122.3	....
25	1234	117.6	51.8	236.5
12	1234	145.8	147.0	....
25	1405	94.6	42.7	151.4
25	1415	154.6	142.7	290.2
25	1604	128.0	56.2	293.6
12	1876	187.5	246.0	....
12	2068	87.2	105.0	....
25	2326	72.5	42.7	113.3
12	2768	35.7	57.0	....

Six series of one-inch cores were prepared from one slab of cottonseed cake. These cores were cut and sanded smooth and true to size. Each of the twelve cores in a series was tested by means of the ball test, and the average ultimate load of the twelve was taken as the ultimate load of the series. The ball test was carried just to failure so that the cores still appeared intact.

Each series of cores was then weighed as a whole and was placed in a ball mill with 10 one and one-half inch iron balls. The mill was run at

TABLE 22. Comparison of ball test with loss of weight of cores under abrasion test

Number of specimens	Average ball test (lbs.)	Loss in weight of cores per cent
12	350	5.80
12	375	8.96
12	386	5.88
12	390	5.36
12	393	6.95

a speed of 25 revolutions per minute for one hour, after which the cores were taken from the mill and reweighed.

Table 22 shows the results of the test. It is evident that there is no relation between the ball test and the abrasion test described.

The abrasive hardness of cottonseed cake was also compared with the crushing strength of the cake for 6 one-inch cores placed in a ball mill with five 1½″ iron balls. The mill was run at a speed of 25 R.P.M. for one hour and the loss of weight of the cores was determined. The cores

TABLE 23. Comparison of crushing test with loss of weight of cores under abrasion test

Number of cores tested	Average crushing test (lbs.)	Loss in weight of cores per cent
6	1956	1.92
6	2017	2.60
6	2333	1.37

were then crushed in the usual manner and the average crushing strength of the cores was recorded. The results of the test are shown in Table 23. It is evident that there is no relation between this abrasion test and the crushing test.

ACKNOWLEDGMENT

The authors wish to acknowledge the cooperation of Mr. F. D. Fuller of the Division of Feed Control Service, Profs. J. J. Richey, J. T. L. McNew, and C. E. Sandstedt of the Civil Engineering Department, and Mr. J. Webb Howell and Mr. Jack Howell of the Bryan Cotton Oil Mill, as well as of a number of cottonseed oil millers who furnished samples and information.

SUMMARY

Various factors in the composition and the manufacturing of cottonseed cake were investigated to ascertain their relation to the hardness of the cake.

No definite regions of hardness or softness were found in slabs of the cake. Hard spots and soft spots were found both in the central portions and in the end portions of the cake.

There seemed to be a slight relation between the fat content of the cake and the hardness, but not sufficient to be definite. There seemed to be no relation between the protein, crude fiber, or ash and the hardness of the cake.

A rapid and radical change in the moisture content of the cake resulted in a lowering of the crushing strength.

In experiments made to determine the effect of the moisture content of the unpressed cottonseed meal upon the hardness of the cake, it was found that, within the limits of this experiment, the meats with a comparatively high moisture content gave a soft and waxy cake. Hard or very hard cake was not obtained in this experiment.

The temperature of the press box during the pressing of the cake affected the hardness of the cake to some degree. Soft and waxy cake was made with the press boxes at high temperatures while hard cake was made with press boxes at lower temperatures. This factor requires further study.

Storage for approximately two years in a dry place apparently has no effect upon the hardness of the cake.

There seems to be only a slight relation between the specific gravity of the cake and the hardness.

The cake gave a lower crushing test if the crushing force was applied parallel to the bedding plane of the cake than if the crushing force was applied across the bedding plane.

Those specimens which were sanded smooth before testing had a higher crushing strength than those specimens which were not smoothed.

The rate of application of load within the limits of the experiment did not affect the apparent hardness of the cake.

Harder specimens were deformed less at the crushing load than were the softer secimens.

The modified Brinell method and the schleroscope method of testing the hardness of the cake were found unsuitable for the testing of the cake.

There was no relation between the crushing strength and the force required for the failure of the test specimens under impact and under steadily applied loads. There was also no relation between the loss of weight of the test specimens under abrasive tests and the crushing strength of the specimens.

REFERENCES

1. Batson, R. G., and Hyde, J. H. Mechanical Testing. E. P. Dutton and Co. 1922.

2. Abrams, D. A. Effect of rate of application of load upon compressive strength of concrete. American Society for Testing Materials. 17:364. 1917.

3. Brinell Hardness Testing of Metallic Materials. American Society for Testing Materials Standards. 1933.

4. Shore, A. F. The Schleroscope. American Society for Testing Materials Proceedings. 10:490. 1910.

5. Test for the Toughness of Rock. American Society for Testing Materials Standards. 1933.