

THE CHEMICAL COMPOSITION OF KAFIR CORN.

(FIRST PAPER.)

By R. O. BAIRD AND C. K. FRANCIS.

Kafir corn, *Andropogon sorghum vulgaris*, comes under the general classification of sorghums, and is supposed to have originated from a single species native to tropical Africa. It takes its name from the well-known Kafir tribe.

The value of Kafir corn as a drought-resistant crop has been clearly proved.¹ It can be depended upon for good yields under conditions distinctly unfavorable to Indian corn. Its value in the semi-arid regions of the United States cannot be overestimated as it is better able to withstand the drought and hot winds than any other crop. The hot winds may cause this species of plant to wither, but if favorable conditions follow a period of drought it resumes growth, and produces good yields. During the past few years a large acreage has been devoted to this



Well developed Kafir corn.

crop and almost entirely for the purpose of producing roughage for live stock. The value of the grain as a food for stock and man is not fully appreciated,

¹ Oklahoma Agricultural Experiment Station, *Bulletin* 87, 1910.

though its milling qualities are given more consideration to-day than ever before.

Scope of the Investigation.—In order to determine the value of the Kafir corn kernel as a food and as a raw product in manufacture the experiments herein reported were planned as outlined below:

1. A study of the chemical compounds which make up the proximate constituents of the Kafir kernel for a comparison with Indian corn.
2. The relation between the inorganic plant constituents of Kafir corn and Indian corn, and the approximate amount of plant foods removed from the soil by each.
3. A study of the Kafir corn fat and methods of extracting it from the seed.

ANALYTICAL METHODS.

The samples of Kafir corn kernels were obtained from local dealers and from the Oklahoma Experiment Station fields. Sample No. 4764 was taken from a "no treatment" field while sample No. 4765 was taken from a plat which had been well manured. About one bushel of each sample was freed from hulls, thoroughly mixed and ground to a fine meal. The meal was quartered down to about 1 kilo and then placed in air-tight jars until analyzed.

Moisture.—The moisture was determined by drying five grams of the sample for 12 hours at 100°.

Ash.—The ash was determined by incinerating five grams of the sample until no loss of weight was noticed on further heating. The time required was about eight hours.

Crude Fiber.—This determination was made by the official method.¹

Ether Extract.—The indirect method was used.

Nitrogen.—The Gunning method was used in this determination.

Nitrogen-free Extract.—Was determined by subtracting from 100 the sum of the percentages of moisture, ash, crude fiber, ether extract, and protein.

Starch.—This determination was accomplished by the direct acid-hydrolysis (modified Sachsse method). The diastase method for the determination of starch was tried several times, but the results did not agree, and were never high enough in starch.

Reducing sugars, sucrose, galactans, and pentosans were determined by the official methods.

Specific Gravity.—A 25 cc. gravity bottle was used in this determination. The weighings were made at 15.5°.

Melting Point of the Fat.—This determination was carried out according to the method proposed by Wiley. A flat disc, made by dropping the melted fat on ice, was heated in a mixture of alcohol and water. The temperature at which the disc rolled into a sphere was considered the melting point.

¹ U. S. Department Bureau of Chemistry, *Bulletin* 107 (Revised), was used as a guide in all determinations unless stated otherwise.

Solidifying Point—Titer Test.—The method of Dali-can was used for this determination.¹

Iodin Absorption Value.—Hübl's method for the absorption of iodine was used according to the official methods.

Saponification Number.—The method used in this determination was that of Koettstorfer.

Acetyl Value.—This determination was made according to Lewkowitsch.²

Soluble and insoluble acids, Reichert-Meissl number, free fatty acids, Maumené number and inorganic plant constituents were determined according to the well-known standard methods.

1. **Proximate Constituents of the Kafir Kernel.**—In order to show the relative value of the proximate constituents of the Kafir corn kernel, some standard must be chosen for comparison. As Indian corn, in conditions of growth and nature of environment, is somewhat similar to Kafir corn, it will be used for comparison.

TABLE I.³—COMPOSITION OF KAFIR CORN.

Sample.	Mois- ture.	Ash.	Pro- tein.	Fiber.	Nitro- gen-free extract.	Fat.	Nitro- gen.
3302 Kafir meal...	12.43	1.13	11.25	1.89	71.09	2.21	1.800
3804 Kafir meal...	12.63	1.28	11.47	....	71.83	2.79	1.834
3308 Kafir meal...	13.50	1.25	11.47	1.79	69.47	2.52	1.834
3367 Kafir meal...	13.46	1.23	10.60	1.86	70.80	2.05	1.697
3383 Kafir meal...	13.31	1.27	10.95	1.85	71.31	1.32	1.751
4122 Kafir meal...	12.02	1.26	10.06	....	73.72	2.94	1.610
4123 Kafir meal...	12.06	1.23	9.89	....	73.87	2.95	1.582
4720 Kafir grain...	10.08	1.40	9.19	2.15	74.31	2.87	1.477

TABLE II.—COMPOSITION OF INDIAN CORN.

Sample.	Mois- ture.	Ash.	Pro- tein.	Fiber.	Nitro- gen-free extract.	Fat.	Nitro- gen.
3301 Cornmeal...	11.59	1.38	9.70	2.16	71.64	3.53	1.551
3803 Shelled corn...	12.56	1.23	9.63	....	72.96	3.62	1.540
3804 Cornmeal...	12.54	1.35	9.27	....	72.91	3.93	1.484
3307 Cornmeal...	14.58	1.28	9.71	2.03	71.40	1.00	1.553
3366 Cornmeal...	13.81	1.35	9.30	2.13	72.26	1.11	1.487
3382 Cornmeal...	13.03	1.47	9.74	2.13	72.30	1.33	1.558
4121 Cornmeal...	11.26	1.29	8.84	....	74.25	4.26	1.414
4706 Corn chops...	10.89	1.02	8.57	1.99	74.27	3.26	1.372
4716 Corn chops...	9.74	1.27	10.06	2.65	72.29	3.99	1.610
4717 Corn chops...	9.70	1.22	10.06	2.54	72.12	4.36	1.610

From the preceding analyses of Kafir corn and Indian corn obtained from different parts of Oklahoma, the conclusion can be reasonably drawn that Kafir corn is similar in composition to Indian corn and is therefore a valuable food. The analyses presented by Tables I and II show that the protein and carbohydrates in Kafir corn are slightly higher and the fat somewhat lower in per cent. than in Indian corn.

Samples Nos. 4764 and 4765 were taken from unmanured and manured fields, respectively. The effect of the fertilizer is apparent in every determination, and illustrates a remarkable response to the application of fertilizing material.

¹ Food Inspection. Leach, p. 403.

² Jour. Soc. Chem. Ind., 503, 1897. Chemical Technology, Lewkowitsch, 1, 268 (1904).

³ The results in all tables are expressed in per cent. unless otherwise indicated.

TABLE III.—ANALYSES OF KAFIR CORN.

Sample.	Moisture.	Ash.	Crude fiber.	Fat.	Protein.	Nitrogen- free extract.
4760.....	13.471	1.453	2.648	3.416	12.85	66.162
4762.....	12.250	1.196	2.470	3.541	12.97	67.573
4763.....	11.474	1.277	3.319	3.570	11.92	68.440
4764.....	12.805	1.599	2.957	3.517	11.06	68.061
4765.....	13.105	1.700	2.890	3.896	11.99	66.419
Maximum.....	13.448	1.668	2.900	3.800	12.85	70.826
Minimum.....	11.264	1.196	1.880	3.464	11.37	65.334
Mean.....	12.356	1.432	2.390	3.632	12.11	68.080

Table III shows that the proximate constituents of Kafir corn are fairly uniform, for the samples were obtained from various places.

In the following tables the results of a number of analyses have been averaged and calculated to moisture-free basis. The data for Indian corn is that reported by Dr. C. G. Hopkins.¹

TABLE IV.—COMPARISON OF INDIAN CORN AND KAFIR CORN. MOISTURE-FREE BASIS.

	Indian corn.		Kafir corn.	
	Maximum.	Minimum.	Maximum.	Minimum.
Ash.....	1.74	1.09	1.93	1.35
Protein.....	13.88	8.35	14.85	12.81
Fat.....	6.02	3.95	4.39	3.90
Carbohydrates.....	85.78	78.92	84.33	76.44

The following table will show more clearly the comparison of the food constituents of Indian corn and Kafir corn:

TABLE V.—FOOD VALUES COMPARED.

	Kafir corn.	Indian corn.
Average yield per acre.....	30 bu.	35 bu.
Feeding value, considering corn 100.	90	100
Pounds of protein per acre, considering 11.3 per cent. of Kafir corn and 10.5 per cent. Indian corn...	219.84	205.80
Pounds of fat per acre, considering Kafir corn 3 per cent. and Indian corn 3.5 per cent.....	50.4	68.6
Pounds of nitrogen-free extract per acre, considering Kafir corn 70 per cent., Indian corn 72.5 per cent.....	1176.0	1421.0
Value per acre, considering corn worth 37.5 cents and Kafir corn worth 30 cents per bu.....	\$9.00	\$13.125

Nitrogen-free Extract.—Under this head is included the starch, glucose or dextrose, sucrose, galactans and pentosans. The determination of these compounds show more completely the value of the nitrogen-free extract.

The following table contains the results of the analysis of nitrogen-free extract:

TABLE VI.—COMPOSITION OF NITROGEN-FREE EXTRACT.

Sample.	Nitrogen- free extract.	Starch.	Pento- sans.	Galactans.	Glucose.	Sucrose.
4760.....	66.162	59.484	3.92	0.240	1.375	0.275
4762.....	67.573	60.713	3.79	0.150	1.362	0.406
4763.....	68.440	59.031	4.41	0.136	1.360	0.493
4764.....	68.061	57.125	4.53	0.119	1.440	0.659
4765.....	66.419	57.956	5.04	0.104	1.345	0.795

From the preceding table the following conclusions can be reasonably drawn:

That Kafir corn kernel has as much sucrose, reducing sugars and pentose bodies as Indian corn. The analyses also show that 90 per cent. or more of the nitrogen-free extract can be utilized as a food.

The following table has been computed from Table VI, and shows the value of Kafir corn for the production of alcohol as compared with Indian corn:

TABLE VII.—PRODUCTION OF ALCOHOL.

	Kafir corn.	Indian corn.
Pounds of fermentable material (starch and sugars) in one bushel.....	38.0	39.2
Approximate pounds of alcohol per bushel.....	18.0	19.0
Gallons of alcohol in one bushel.....	2.56	2.7
Cost of grain ¹ to produce one gallon of alcohol.....	12 c.	14 c.

2. Determination of the Inorganic Plant Constituents.

—The ground meal was ignited in a muffle furnace and the charred material extracted with a 10 per cent. solution of acetic acid. The acid was washed out with hot water and the combined filtrates evaporated and burned to a white ash. The residue was also burned to a white ash, and the two thoroughly mixed and placed in ground-glass stoppered bottles until used for analysis.

In Table VIII complete analyses of the ash of Kafir corn are reported. The composition of the ash of Indian corn is shown in Table IX.:

TABLE VIII.—ASH OF KAFIR CORN.

Sample number.	3898.	3958.	3230.	3231.	Average.
Sand.....	4.30	3.33	5.73	2.88	4.06
Soluble silica.....	0.96	1.28	2.25	4.15	2.16
Carbon.....	0.24	0.31	0.28	0.17	0.25
Sulphur trioxid.....	0.19	0.17	1.22	0.51	0.52
Chlorin.....	0.45	0.48	0.58	0.44	0.49
Sodium oxid.....	0.94	0.96	2.42	2.39	1.18
Phosphorus pentoxid.....	43.76	44.21	37.47	46.72	43.04
Iron and aluminum oxids.....	1.19	1.18	2.08	1.84	1.57
Calcium oxid.....	1.95	2.15	1.64	1.46	1.80
Magnesium oxid.....	18.86	18.56	16.67	15.25	17.34
Potassium oxid.....	27.11	26.99	29.78	24.82	27.17

TABLE IX.—ASH OF INDIAN CORN.

	By Wolff. ²	By Ford. ³
Potassium oxid.....	29.80	29.15
Sodium oxid.....	1.10	1.76
Calcium oxid.....	2.20	1.60
Iron and aluminum oxids.....	0.80 ⁴	1.64
Phosphorus pentoxid.....	45.60	49.58
Magnesium oxid.....	15.50	13.29
Sulfur trioxid.....	0.80	0.54
Silica.....	2.10	2.45
Chlorin.....	0.90	0.66

From the above analyses it will be seen that 87.55 per cent. of the Kafir ash and 92.29 per cent. of the corn ash is in the form of potassium and magnesium phosphates. The average per cent. of ash in Kafir corn kernel is 1.433 while that of corn is 1.372.

The following table shows the approximate amount of potassium oxid, phosphorus pentoxid, and nitrogen, which is removed from the soil by an average crop of Kafir corn and Indian corn:

¹ Corn, 37.5 c.; Kafir, 30 c. per bushel.

² Wolff's Aschen Analysen, 1880. See also Thorp's Dictionary of Applied Chemistry, Vol. I, page 497, 1890.

³ Oklahoma Experiment Station.

⁴ Wolff reported iron oxid only.

TABLE X.—PLANT FOOD REMOVED FROM SOIL.

	Kafir corn.	Indian corn.
Average yield in bushels per acre.....	30.000	35.000
Pounds per bushel of potassium oxid....	0.218	0.227
Pounds per acre of potassium oxid.....	6.540	7.945
Pounds per bushel of phosphorus pentoxid.....	0.345	0.366
Pounds per acre of phosphorus pentoxid....	10.362	12.810
Pounds per bushel of nitrogen.....	1.089	1.023
Pounds per acre of nitrogen.....	32.940	35.798

As shown by the above table, corn takes up from the soil a larger quantity of the three important plant foods than Kafir. This knowledge is of special value when allowance is made for the fact that corn has been shown by analysis, to be very little, if any, better than Kafir corn as a feed for stock and poultry.

3. *Kafir Corn Fat*.—Equal quantities of five samples of Kafir corn kernel were well mixed, ground to a very fine meal and the fat extracted with gasoline. Large bottles were used in the extraction, and the mixture of meal and gasoline was shaken thoroughly every few hours. After standing for 24 hours the gasoline and the extracted fat were put into another bottle with a new charge of meal, and this process continued for five days, each charge of meal being extracted five times. The liquid was then filtered, evaporated, and purified.

In the evaporation of the mixture most of the gasoline was removed by the aid of heat and a suction, pump. The liquid was placed in 500 cc. Jena flasks attached to a suction pump, and the flasks placed in a bucket of water. The water was heated from 55° to 60° C., the suction started, and the process continued for 36 hours.

The golden liquid obtained from the gasoline extraction was poured into a flask (1000 cc.) and heated in a water oven kept at 100°. While the liquid was being heated carbon dioxid, which had previously been dried by means of calcium chlorid and sulphuric acid, was drawn through it. After 40–50 hours this treatment usually removed all of the water and any traces of gasoline.

The fat on cooling, became solid, not unlike vaseline, though somewhat harder. It had a yellow color with a greenish hue, a pleasant though not marked odor, and a pleasant vegetable oily taste.

TABLE XI.—CONSTANTS OF KAFIR CORN FAT AND CORN OIL.

	Kafir fat.		Corn oil. ¹	
	1.	2.	1.	2.
Specific gravity.....	0.9398	0.9397	0.9274	0.9213
Melting point.....	44.4°	44.0°	18.0°	20.0°
Titer test.....	34.1°	33.8°	14.0°	16.0°
Iodin value.....	109.98	109.43	111.0	180.0
Soluble acids.....	0.64	0.68	...	...
Insoluble acids.....	93.04	93.41	82.2	95.7
Saponification value.....	249.7	248.5	188.0	193.0
Richert-Meissl No.....	6.14	6.07	4.2	9.9
Liquid acids.....	86.44	85.52	...	...
Solid acids.....	7.40	7.55	...	...
Free fatty acids.....	26.93	27.10	...	...
Acetyl value.....	42.22	42.24	7.8	8.75
Maumené number.....	68.2°	68.0°	5.6°	8.6°
Unsaponifiable res.....	1.72	1.71	...	...

¹ Chemical Technology, Lewkowitsch, II, 515, 1904.

In Table XI the chemical and physical constants of two samples of Kafir fat are compared with those of two samples of corn oil.

The melting point of Kafir corn fat is 44.2, and that of corn oil is 18° to 20° C. This and the higher Titer test of the Kafir fat shows that the latter contains more of the solid fatty acids than corn oil. The indications are that Kafir fat could be utilized much more satisfactorily than corn oil for soap-making. An experiment demonstrated that the fat could not be used as a lubricant owing to the high percentage of acids. The fat might, however, be used with other oils especially the edible fats and oils, as it has an agreeable taste and odor. Owing to its high melting point it might be used with such fats as lard, oleomargarine and butterine. The fat was found to be practically non-drying.

The fat is soluble in gasoline, ether, chloroform, carbon bisulphide, and to some extent in absolute alcohol. This property is receiving attention with more detailed consideration of the investigation.

SUMMARY AND CONCLUSIONS.

The proximate analysis shows the Kafir kernel to compare favorably with corn.

a. Kafir corn is more uniform than corn in composition.

b. It is a cheap food.

Alcohol and glucose can be produced cheaper from Kafir corn than from corn if the cost of the raw material is alone considered.

Kafir corn removes a smaller quantity of the important plant foods from the soil than corn. This fact has been shown by analyses of the ash of both grains which were grown under similar conditions.

The fat from the Kafir kernel is a solid which melts at 44.2°.

c. It should be valuable in the manufacture of soaps and fatty acid products.

OKLAHOMA A. & M. COLLEGE
AND EXPERIMENT STATION,
STILLWATER, OKLAHOMA.

ADDRESSES.

PRESENT STATUS OF OZONE, WITH REFERENCE TO AIR PURIFICATION.¹

By RALPH D. SMALL.

The development of ozone for industrial uses, water purification and ventilation, has progressed rapidly since 1903, which seems to be the median line between inaccuracy and accuracy so far as determination, concentration, economical operation, properties and uses of ozone are concerned. In 1890, the French Academy appointed a commission to report on the status of ozone in Europe. After a lengthy investigation their report submitted proved absolutely inconclusive. The members were almost divided as to what they recognized had been scientifically proven. From 1895 to the present date the whole subject has

¹ Read before the 18th general meeting of the American Electrochemical Society, October 14, 1910, at Chicago, Ill.

been largely taken out of the laboratory and put on a commercial plane, and this has been chiefly dependent upon the progress and developments that have taken place in the electrical industry.

As this paper is to be largely devoted to the uses of ozonized air as an adjunct or supplement to ventilation, very little reference will be made to the largest commercial use to which ozone has at present been put, namely—that of water purification, except to state that water purification by ozone has in many places in Europe supplanted every other method of filtration and sterilization that is known. In the United States, owing probably to imperfectly developed methods, a like success cannot be claimed. Schneller, De Fries, W. Siemens, Vosmaer, Becquerel, Otto, Ehrhwein, Gerard, Berthelot, Koch, Ohlmüller have all been largely responsible for the progress that has been made along this line. To-day there are over 40 cities and towns in France that are purifying all or part of their water supply with ozone apparatus. In Germany also this method is being rapidly adopted. Some idea may be gained of the efficiency of this method when, as is stated,¹ "ozone treatment reduced the bacterial count in water from 12 million to 40 with a total consumption of 18 grams of ozone per cubic meter." To-day there are over 150 patents in the United States Patent Office, and this department is rapidly becoming one of the "busy" departments, thus indicating the amount of interest that is now being taken in the latest development of the electro-chemical field. One of the former heads of the Westinghouse interest has been credited with the remark that "not only was ozone the coming thing in electricity, but was destined to be in the course of time one of the largest fields with which electricity would be identified, barring the use of light and power."

There are various ways of producing ozone, such as the oxidation of phosphorus, or the action of ultraviolet rays upon air, these rays being produced by a mercury vapor lamp in a quartz receptacle, or by heat, according to Nernst and Clement, by which they produce 3 grams per kilowatt hour. It should be stated here that concentration is the percentage of ozone usually measured in grams contained in a cubic meter (about 35 cubic feet) of air. All these processes, however, are not economical for commercial purposes. Ozone is produced in nature by evaporating water, when acted upon by the ultraviolet rays of either sunlight or electrical discharge. It is also produced from green plant life in what is known as the process of photo synthesis. In this process carbon dioxide is absorbed and unites with water to form carbohydrates. In this chemical reaction the atoms of oxygen are liberated and appear in a nascent state. This affords a logical origin for the presence of ozone in the vicinity of forests or where much plant life is found. Its presence in mountainous regions and higher air strata is largely accounted for, first—by the lack of organic impurities to use it up, and, second, because the sun's ultraviolet rays having less atmosphere to pass through are more slowly absorbed. This is investigated quite extensively by Ladenburg and Lehmann, as was noticed in the *Scientific American* of August 6th, and their works are now the basis of a series of investigations on the part of the United States Weather Bureau. The spectroscope is used to determine the presence of ozone in such investigations.

It is generally conceded now since the research of Henriot and Bouysey, and also Steinmetz, that ozone is created by the action of ultraviolet rays upon oxygen; that it is an endothermic process; heat is absorbed. In nature this usually takes place and is more observable when there is much electricity in the air, or when water evaporates quickly as on the beach of the seashore, where it is in a finely divided state, and on account of which these rays have a better opportunity for their peculiar action.

¹ *Engineering News*, April 28, p. 497.