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The Extraction and Use of Kukui Oil.

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COMMERCIAL IMPORTANCE OF KUKUI OIL.

BY E. V. WILCOX.

Kukui, (Aleurites triloba,① or A. moluccana), is generally distributed throughout Polynesia, Malaysia, Philippines, Society Islands, India, Java, Australia, Ceylon, Bengal, Assam, China, Tahiti and Hawaii. It has been introduced into the West Indies, Brazil, Florida and elsewhere. The tree has wide-spreading branches, attains a height of 40 to 60 feet, and is characterized by large, irregularly lobed leaves of a pale green color, and nuts about two inches in diameter containing one or two seeds. In Hawaii kukui is common on all the islands, being the dominant native tree of the lower mountain zone and easily recognizable at a distance by the pale color of its leaves.

The oil expressed from the kernel of the nut is known in different countries as kukui oil, country walnut oil, kekune oil, artists' oil, Bankul oil, Eboc oil, candle nut oil, Spanish walnut oil, Belgaum oil, etc. The oil has found use for a variety of purposes. The Hawaiians strung the nuts together on sticks and used them for lighting their houses. The natural candles thus produced gave rise to the name candle-nut. In an examination by the Imperial Institute it was found that "the oil belongs to the class of drying oils typified by linseed oil, and would be

① A. triloba is a different tree. It is not found in Hawaii. T

suitable for the manufacture of soft soap and in the preparation of oil-varnishes, paints, linoleum and other similar purposes".[1]

Guthrie and Ramsay state: "It is a drying oil and is used in the arts for the same purposes as linseed oil, and for burning. Its drying power is quite as high as that of linseed oil, and it may be used for all purposes for which the latter is used, namely in the manufacture of oil-colors, lacquers, and varnishes, and for soap making. It is used medicinally as a plaster, and as an article of diet—as olive oil is used."[2] Both the oil and the cake are cathartic and have been used for the purpose in medicine. The cathartic effect is reduced by subjecting the nuts to heat. Kukui oil has been used in China for oiling paper, as China wood oil is used. As a wood-preservative kukui oil has given good results in China and in Hawaii both on the hulls of sailing vessels and on buildings. Thrum, referring to kukui oil in Hawaii says: "The last use, to our knowledge, made of it in house painting here was at the construction of the Judd building, about 1855, by R. Gilliland, who is said to have made the statement that it was good for fifteen or twenty years".[3]

As is well known to the old residents of Hawaii, there was once an industry of quite respectable proportions in kukui oil, exported from Hawaii. The exportation amounted to as much as 8,000 to 10,000 gallons of oil per year, the greatest production of kukui oil having occurred from 1840 to 1850. The oil even at that date was valued at 50 cents per gallon. It is reported that in 1857 a native woman in Palolo valley expressed kukui oil at the rate of 140 gallons per month with a crude hand-made lever press, the nuts having been previously roasted or boiled in oil to facilitate extraction.

It is quite impossible to estimate even approximately the quantity of kukui nuts which could be collected annually in Hawaii. Every one knows that the ground under kukui trees is literally covered with nuts of which few are used for any purpose at present, except in very small quantities in the preparation of a native relish and occasionally for fuel. According to our experiments in the laboratory it would require 210 tons of nuts to produce 10,000 gallons of oil weighing 7.36 pounds per gallon or 73,600 pounds in all.

With regard to the total area of kukui in Hawaii we have obtained the estimates of various individuals who are personally familiar with forest conditions in Hawaii. Their estimates range from 10,000 to 40,000 acres. We may probably assume 15,000 acres as a safe estimate. At the rate of 80 trees per acre and

1. Bull. Imp. Inst. 5 (1907) P. 136.
2. Agric. Gaz. N. S. Wales 17 (1906) P. 859.
3. Hawaiian Annual 1893 P. 107.

200 pounds of nuts per tree, there would be a yield of eight tons of nuts per acre. It has been found that algaroba yields from two to fourteen tons of beans per acre. A good stand of kukui will give a larger product per acre, and a conservative estimate would be five tons of nuts. On 15,000 acres the annual crop of nuts would thus be 75,000 tons. If we assume that not more than 10,000 acres of this area are readily accessible the yield would be 50,000 tons, which would produce 2,375,000 gallons of oil. In 1911 the importation of Chinese wood oil into the United States amounted to 5,800,000 gallons, and a buyer in New York stated that his firm alone could have used an additional 500,000 gallons.

Chinese wood oil obtained from the nuts of *Aleurites cordata* and *A. fordii* has been imported into Europe for the last twenty-five years and into the United States for fifteen years. It finds its chief use in the manufacture of varnish, for which it is more and more in demand. The oil has a specific gravity of .94 and dries more quickly than any other known oil. In this regard kukui oil stands between Chinese wood oil and linseed oil. Chinese wood oil is sold by the pound and the price during the past fifteen years has ranged between 6½ and 12½ cents, being 9 cents in December, 1912. In experiments at this Station the kernels of fresh nuts contained 27.1 per cent of oil, the whole nut being 14.1 per cent oil. The tree has been introduced into Hawaii and the southern states of the mainland, but no estimates can be made at present on the possible yield of oil.

Kukui oil has been shipped from various islands of the Pacific to the United States for the past 75 years for use in making soap, paint, varnish and artists oil. The market price is the same or slightly higher than that of linseed oil and varies with the price of the latter. Kukui oil can replace linseed oil for all purposes, but dries more quickly. According to Andés it dries four hours sooner than linseed oil.[1]

The kukui is a tree which is practically free from serious insect pests or fungous diseases, and bears an annual crop of nuts without fail. The nuts mature in summer during school vacation, when children as well as men and women can engage in collecting them. The difficulties in collecting the crop are no greater than those which have been met and overcome in the algaroba meal industry. To secure a large part of the crop at a central oil mill it is merely necessary to offer a reasonable price per hundred pounds for the nuts.

It will probably require one season of practical experience to arrive at a working basis for collecting the nuts. We have attempted to gather data which would give a hint of the price

1. **Vegetable fats and oils 1902 pp. 174-176.**

which can be paid for the nuts, a price which will give an attractive wage to the collector and leave a reasonable profit to the oil mill. From our experiments it appears easy for a man, woman or child to pick up 500 pounds of nuts per day. The nuts are of course to be gathered free from the soft outside husk. Only an extremely small percentage of the nuts spoil or turn rancid even after lying two years on the ground. The spoiled nuts float in water and may thus be easily separated from the sound ones. At 30 cents per 100 pounds the laborer would receive $1.50 for 500 pounds, a day's work. The average oil content of the meat or kernel is 65 per cent. The kernel equals 30 per cent of the weight of the nut. About 19.5 per cent of the nut is therefore oil. In the Sunda Isles, where kukui oil is an important article of export, experiments have shown that 90 per cent of the oil is obtained by commercial methods through the use of presses.[1] The oil recoverable by commercial methods would thus amount to 17.5 per cent of the weight of the nuts. From 100 pounds of nuts 17.5 pounds of oil would be obtained, or a value of $1.75 at 10 cents per pound. During the fiscal year ending June 30, 1911, nearly 50,000 gallons of linseed oil was imported into Hawaii, valued at $49,127. Kukui oil would make this importation unnecessary.

Langeron found that 100 Kg. of kukui nuts contained 33 Kg. of knernels; that 100 Kg. of kernels yielded 66 liters of oil; and that 100 liters of oil weighed 91 Kg. In another test 224 pounds of kernels yielded 50 quarts of oil. Frick[2] at a meeting of the Royal Hawaiian Agricultural Society exhibited six vials of kukui oil prepared in different ways and possessing different colors and properties. He stated that the oil could be sold with profit at 50 cents per gallon.

Kukui oil may be obtained by grinding the kernels and applying pressure with or without previous roasting of the nuts. The color of the oil is lighter if no heat is used, but the oil is more easily expressed after heating. Mr. W. A. Anderson of Hana, Maui, ran a quantity of nuts through the steel rollers of a rubber mangler. The resulting oil has a wine color, derived from the husk of the nut. The oil is naturally of a light straw color. The most economic and efficient method of grinding the nuts and the most suitable kind of press to be used, will naturally, have to be determined by the manager or engineer of the company that may engage in manufacturing kukui oil. Apparently the oil can not be obtained by boiling the ground nuts in water, for the oil is thereby completely emulsified and can not

1. Semler, Die tropische Agrikultur, Vol. 2, P. 517.
2. Trans. Roy. Haw. Agric. Soc. 2 (1856) pp. 101-103.

be set free by the use of a centrifuge. The oil has been successfully extracted, however, by boiling the nuts in oil.

A miscroscopic examination of the kernel of a kukui nut shows the usual structure of oil seeds, such as the castor bean. The cells contain no free water or cell sap, but are filled with free oil and typical aleurone grains. The latter account for the high percentage of protein in the press cake. Occasionally clusters of crystals of calcium oxalate are observed in the cell structure of the kernels. No trace of starch could be found even in immature nuts. Iodine also failed to give the starch reaction in the press-cake.

When we consider the constantly increasing demand for oils suitable for use in making paints, varnish and soap, as well as for other purposes, it seems high time that a company were organized to utilize the large quantity of kukui nuts which annually go to waste in Hawaii. Not only is the oil a valuable product, demanded by the paint and varnish trade, but the press-cake is unusually rich in nitrogen, phosphoric acid and potash. It, therefore, has high value as a fertilizer. The chemical investigations reported in this bulletin were undertaken to furnish a basis upon which an industry in producing kukui oil could be established. Among firms which are interested as possible buyers of kukui oil we may mention Edward Hill's Son & Co., 64 Wall St., New York City. The Glidden Varnish Co., Cleveland, Ohio, and A. M. Parks Co., Bourse Building, Philadelphia.

CHEMISTRY OF KUKUI OIL

BY ALICE R. THOMPSON.

Kukui oil, commonly known as candle nut oil, belongs to the class of drying oils, valuable therefore as a paint and varnish oil. It is also used for soap making and is a good illuminating oil. It is produced in large quantities in Australia, China, New Zealand and the Fiji Islands[1] and is exported to America and Europe in ever increasing shipments.

When extracted from the crushed kernel by ether or petroleum, the oil is light yellow in color, with a specific gravity of 0.92. When expressed, the oil may be dark colored due to impurities. It dries in thin films on standing several days.

At this Station, a sample of oil was extracted by gasoline from the crushed kernels; the gasoline removed by evaporation and an analysis made on the oil to determine its chemical and physical properties. The values are as follows:

1. Bull. Imp. Inst. 1907, 5, P. 135, 136.

Specific Gravity..... .92 at 15.5° C.
Saponification Value 179.1
Iodin Number 155.5
Hehner Value 89.9
Soluble Acids 1.71
Reichert Meissl Number . 2.82

The fatty acids congealed to a pasty mass between 18° and 20° C. The oil itself was still fluid at—3° C. Fendler[2] found the congealing point of candle nut oil to be —15° C. The oil was soluble in ether, petroleum ether and slightly soluble in alcohol. Concentrated sulphuric acid colored it dark brown.

The drying property of the oil is indicated by the high Iodin Value. Linseed oil which is a fine drying oil has an Iodin Value of 170-181[3].

A sample of oil expressed from kukui nut was sent by Mr. Anderson to this laboratory. The oil was in a crude state, containing suspended matter, and had a dark red color. This oil had the following values:

Specific Gravity ..... .92 at 15.5° C.
Saponification Value 190.2
Iodin Number..... 164.2

In the following table are given the values found by chemists in the oil of Aleurites moluccana obtained in other parts of the world.

	1	2	3	4	5
Specific Gravity at 15° C.	.925.	920- .926	.925	.925	.924
Acid Value	1.72			.97	0.5
Saponification Value...	204.2	184 - 187.4	192.6	194.8	189.5
Iodin Value	139.7	136.3-139.3	163.7	114.2	152.8
Hehner Value	96.4		95.5		95.2
Volatile Acids	1.98			1.2	
Titer	17.8				
Butyro-refractometer		76-75.5(15° C)	76(25° C		

1. Imperial Institute, Bull. of the Imperial Inst. Vol. V (1907) p 135-136.
2. De Negri, Jour. Soc. Chem. Ind. 20 (1901) p 909.
3. Lewkowitsch, Jour. Soc. Chem. Ind. 20 (1901) p. 909.
4. G. Fendler, Jour. Soc. Chem. Ind. 23 (1904) p. 613.
5. Kassler, Jour. Soc. Chem. Ind. 22 (1903) p 639.

The values vary to some extent in these analyses; nevertheless, the general characteristic of high Iodin Value and Saponification extends throughout.

CONSTITUENTS OF THE KUKUI KERNEL.

Several samples of nuts were obtained and the fat especially determined in the kernels. The fat content appears to vary but a few per cent in the kernels of nuts a year old or fresh. The fresh nuts naturally contain more moisture.

2. Jour. Soc. Chem. Ind. 23 (1907) P 613.
3. Commercial Org. Analysis—Allen, Vol. II, Pt. 1, p. 97.

	1 year old nuts. per cent.	Fresh nuts. per cent.	Immature nuts p. c.
Moisture	3.55	7.14	13.39
Fat	65.00	66.25	56.7
Ash	3.56	3.05	
Protein	18.75	19.88	
Fiber	2.14	1.39	
Nitrogen free extract by difference	7.00	2.29	
	100.00	100.00	

The fiber and the ash are very low, the principal constituents being fat and protein. It is of interest to note in this oil seed the small percentage of hydrolyzable carbohydrates (only 1.40 per cent by analysis). A qualitative test showed the absence of starch in the kernel. The quantity of fat, if calculated to the water free basis is quite constant in the three samples.

Analyses made of the kernels of this same nut, Aleurites moluccana, by various chemists are given in the table below.

	1 Per Cent	2 Per Cent.
Water	5.00	8.23
Oil	62.175	59.93
Protein	22.653	8.04
Nitrogen free extract	6.827	17.62
Ash	3.345	3.56
Fiber	....	2.62
	100.00	100.00

1. H. Semler—Die Tropische Agrikultur Vol. 2, p 515.
2. N. S. Wales—Agri. Gazette 17 (1906) p 859.

G. de Negri[1] extracted 62.25 per cent fat by ether extraction. At the Imperial Institute, 60.8 per cent oil was extracted from the kernels by means of light petroleum. In all the analyses, the fat and protein content are high. The mineral constituents of the kernel were also determined as shown in the following table:

$Mn_3 O_4$	.03	per cent
Ca O	.17	" "
Mg O	.60	" "
$P_2 O_5$	1.59	" "
$K_2 O$	.75	" "

On extraction of the oil these constituents[2] increase in proportion to the dry matter. The residue contains, therefore, large

1. Jour. Soc. Chem. Ind. 17 (1898) p 931.
2. Bull. Imp. Inst. Local Cit.

amounts of phosphoric acid potash and nitrogen, all valuable as fertilizing ingredients. Analysis of the residue of ground up kernels extracted with ether for two days is as follows:

Moisture	2.42	per cent
$P_2 O_5$	2.79	" "
$K_2 O$	2.77	" "
Protein	53.75	" "

Press cake obtained commercially by expressing the oil from kukui nuts would compare favorably with the residue, as most of the oil can be expressed. According to an article in the Agricultural Gazette[1] 55 per cent oil can be obtained from kernels containing 60 per cent. Analyses of press cake made elsewhere shows it to be valuable as a fertilizer.

ANALYSES OF PRESS CAKE.

	1 Per Cent	2 Per cent.
Oil	8.8	5.5
Moisture	10.00	10.25
Ash	8.28	
Protein	46.16	47.81
Fiber	1.47	
$P_2 O_5$	4.39	3.68
$K_2 O$	1.95	1.53
Mg & Ca		7.19

1. Lewkowitsch Jour. Soc. Chem. Ind. 20 (1901) p 909.
2. H. Semler—Die Tropische Agrik. Vol. 2 p 515.

Press cake cannot be used as a fodder in spite of its apparent food value as it has a poisonous effect upon stock.[1]

The proportions of fat to kernel and whole nut were determined in several samples. In a sample one year old in which the fleshy husk that covers the shell when the nut is green, had decayed away, the kernel weighed 31.5 per cent of the hard nut. As the fat content of the kernel was 65 per cent, the fat content of the nut minus the husk, averaged about 20 per cent.

In a sample of fresh nuts, the kernel was 29.3 per cent of the nut minus the husk and 12.1 per cent of the nut with the husk on. The fat content of the kernel was about 66 per cent. It was therefore about 8 per cent of the nut with the husk on and about 19.4 per cent of the hard nut minus the husk.

In another sample of fresh nuts, the kernel was 12 per cent of the nut with the husk on and 30.4 per cent of the hard nut minus the husk. The kernel contained about 57 per cent fat. The fat content of the whole was therefore about 7 per cent and of the nut minus the husk, about 17 per cent.

1. Agric. Gaz. N. S. W.—17 (1906) p 859.