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TUNG OIL

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Production

Domestic commercial production of tung oil started in 1932, when two full cars of tung oil (150,000 pounds) were shipped from the first tung oil mill located near Gainesville, Florida. Frost damaged the crops of tung nuts in 1933 and 1935, but in 1934, approximately 400,000 pounds of tung oil were produced in tung oil mills in Florida and Louisiana from tung nuts grown in the Gulf States. In 1936, about 2,000,000 pounds of oil were produced and processed in the South. The 1937 crop was only 500,000 pounds of tung oil due to frost damage, but the 1938 crop yielded 3,000,000 pounds of oil. In the following years, the production of tung oil was as follows: 1939.....62,000 pounds; 1940.....3,533,000 pounds; 1941.....2,290,000 pounds; 1942.....5,310,000 pounds; 1943.....2,558,000 pounds; 1944.....10,000,000 pounds; 1945(estimated).....13,600,000 pounds. The chief production centers are northern Florida, the southern parts of Mississippi, Georgia, Alabama and Louisiana. Some tung oil is also produced in the Buna, Silsbee, Jasper and Woodville area of Texas.

American tung oil is generally superior to that produced in China and has commanded a premium of several cents a pound over the Chinese product in some instances. A prominent varnish expert has stated, " the high gravity, high refractive index, low acidity, short time of polymerization with heat test and excellent color of American tung oil are noteworthy". After varnish-making tests by eighty varnish manufacturers, they reported to him almost without exception that they found the American oil generally superior to the imported oil for varnish making. They obtained a varnish which was paler and clearer, which dried quicker, and which gave a harder, tougher, more elastic, and more water resistant film.

The time when the ripe tung fruit containing about 65 percent of moisture drops to the ground in the fall varies from September through November depending upon the variety of the tree, the location and the seasonal conditions. It is the present practice to allow the fruits to lie upon the ground until they have dried out sufficiently to permit storage without danger of heating, sprouting, or moulding. They are then collected and stored in especially constructed ventilated drying barns wherein the tung fruit slowly dries from a moisture content of about 30 percent to about 13 percent. The air dried tung fruit are then hauled from the storage to the tung oil mill to be processed. At the tung mill the dried tung fruit are passed through a decorticator, which removes the hulls and a portion of the shells from the kernels, and they then go over shaker screens where, by mechanical and pneumatic action, the hulls and broken shells are separated from the kernels and seeds. It appears that the loss of oil in the hulling operation will be at a minimum if the tung fruit are hulled while the kernels are moist and pliable and if most of the shell is allowed to remain on the tung seed.

Commercial tung oil mills have given the following yields on the component parts of the fruits:

Hulls & Shells ...	55 to 60 percent of the fruit
Meal..............	40 to 45 percent of the fruit
Oil	14.7 to 19.5 percent of the fruit
Oil	42.1 to 53.2 percent of the meal
Oil	310 to 390 pounds per ton air-dried fruits
Oil in cake	3.1 to 6.6 percent

Tung nuts are not processed on the farm. They are shipped to oil mills which are provided with the special equipment necessary for expressing the oil from the fruits. The cost of such a plant ranges from $25,000 to $75,000 or more, depending on the size of the oil mill and its location.

Drying of Tung Fruit

The dehydration of tung fruit is a subject of much interest to the tung oil industry because processing is delayed and hindered by the presence of excessive moisture in both the tung fruit and tung meal. Many have felt it would be a great help to the industry if it were possible to dry and process the fruit as soon as it is ripe. Exhaustive tests have indicated, however, that the artificial drying of the whole tung fruit shortly after it falls to the ground is hardly feasible because of the higher cost of such drying in comparison with that of natural drying. It has been found that under favorable weather conditions the fallen tung fruit containing originally about 65 percent of moisture will dry in the fields to about 30 percent moisture content in a few weeks. The tung oil industry has favored the completion of the drying of the tung fruit containing about 30 percent moisture to air dryness in ventilated barns and bins. If the partially dry fruit containing about 30 percent moisture is gathered and placed in the drying barns it will take about two months for this material to dry to about 13 percent moisture content. Tung fruit of this moisture content will yield a tung meal containing about 7 percent of moisture which can be reduced to about 4 percent in passing through the tempering bin at the tung mill. Such dried meal can be processed efficiently in the expeller press yielding a press cake containing 4 to 5 percent oil which is considered good extraction.

Processing of Tung Fruit

In studies of the processing of tung fruit at the mill it has been found that the oil yields were invariably lower than those calculated from analyses of samples even when an allowance is made for the oil remaining in the tung press cake. Some of this difference undoubtedly is due to poor sampling methods, but in the past a considerable amount of oil has also been lost due to pieces and whole kernels in the separated hulls and probably some oil is lost due to its oxidation and the retention of this oxidized oil in the press cake during the expression process. In a study of the hulling of tung fruit at the tung mills, it has been found that the higher loss of oil occurred when the mills were processing very dry tung fruit whereas the loss of oil was lower when the tung mill was processing tung fruit containing between 15 and 20 percent moisture. From the results of this study it appeared that appreciable loss of oil in the hulling process can be prevented by processing the tung fruit while the kernels are moist and pliable. If this is done it is necessary for the tung mill to have adequate tung meal drying equipment so that the tung meal can be dried to between 4 and 5 percent moisture before it enters the expeller.

Hulling of Tung Fruit

The hulling of the undried tung fruit on the farm has appeared to have some important advantages. The hull which constitutes about 50 percent of the tung fruit has no value for oil production, as the oil comes only from the kernel. Hulling the tung fruit on the farm would not only decrease by 50 percent the weight of material hauled to the mill but would leave the hulls on the farm where they could be used for mulch. The hulls could also be used as a fertilizer since they contain from 0.40 to 0.81 percent nitrogen, 0.14 to 0.25 percent phosphoric acid and 2.1 to 3.1 percent potash. Because of the wide variation in size and in the hardness of air-dried tung fruit, it has been impossible to remove the hulls with the type of huller used at the tung mill without damaging a considerable proportion of the seeds and kernels. It was believed from experience with other oil bearing seeds that unless the damaged abraded kernels are pressed almost immediately there would be a marked rise in the free fatty acid content of the expressed oil, as well as a marked oxidation in the damaged kernels. However, contrary to expectation it has been found that the damaged kernel from the thoroughly dried tung fruit can be kept for several weeks with only a slight increase in fatty acid content and with no appreciable oxidation of oil. However this is not the case with damaged kernels from moist tung fruit.

Efforts have been made to develop a portable tung fruit huller whereby the moist tung fruit can be hulled in the grove shortly after they fall to the ground. Two experimental tung hullers have been developed, one a modified walnut huller wherein the hull is removed from the tung fruits by passing them over hulling knives and under a rotating wire brush and then removing the hulls, which do not pass through the hulling knives, by means of aspiration before the hulled tung fruit leaves the huller. The second tung fruit huller operates on a principle similar to that used in a commercial peanut sheller. In this huller the moist tung fruits are fed from above into a compartment in which a cylinder, studded with either wooden or iron cleats, rotates at about 200 RPM, the cylinder being surrounded by a perforated screen having 7/8" holes at a distance of about 1 5/8" from the top of the cleats. The holes in the screen are large enough to allow the hulled seed to fall through upon a wire-mesh conveyor; the broken pieces of hull pass through the conveyor, while the seeds and large pieces of hull move forward under an aspirator which removes most of the hull fragments, after which the conveyor carries the clean seed out of the huller. Tests with these hullers indicate that the modified walnut huller would damage about 7 percent of the seeds and would leave about 14 percent of hull material with the dehulled fruit. This huller appeared to have a rather limited capacity. The huller operated on a principle similar to a peanut sheller was found to leave about 12 percent of hull material with the dehulled tung fruit and to damage about 15 percent of the seed with tung fruit containing about 29 percent moisture and to damage a much larger amount of the seed if the tung fruit were much drier. It is necessary to dry the moist dehulled tung fruit without undue delay to prevent deterioration as it was found that dehulled tung fruit containing 19 percent moisture, stored in bags on a concrete floor for about six weeks, developed a considerable quantity of free fatty acids in the cracked and shelled tung seeds.

Solvent Extraction of Tung Oil

For several years the Tung Oil Laboratories at Gainesville, Florida, and Bogalusa, Louisiana, have been studying the recovery of oil from tung press cake and from tung fruit by means of solvents. The increased quantities of oil and the higher fertilizer value of the residue left after oil extraction were advantages clearly recognized some years before these studies were undertaken. Former investigators found that solvent-extracted tung oil solidified as a result of isomerization of the alpha-eleostearic glyceride to the solid beta-glyceride form, and this solidified tung oil was not readily accepted by the trade. It was found, however, that solvent-extracted tung oil becomes permanently liquid at room temperature if it is heated to 200° C. for 30 minutes.

In both laboratory and pilot-plant experiments it was found that the oil could be extracted from tung press cake without difficulty in batch-type extraction equipment. However, when tung kernels were ground commercially in attrition-type grinding mills so that 98 to 99½ percent of the oil in the ground material was extractable it was found that complete extraction was not obtained as a result of channeling. This channeling effect in the extraction of ground tung kernels was prevented when alternate layers of porous material, such as tung hulls, tung press cake or gravel and ground tung kernels, were placed in the extraction tower and 93.3 percent of the available oil was extracted.

In a later study employing a continuous countercurrent solvent extraction pilot plant, using normal hexane as solvent, it was found that the best preparation of tung kernels and seed for extraction was obtained with roller mills, but that no special preparation was needed for tung press cake. Extraction efficiencies of 99 percent or better were obtained with ground tung kernels, ground tung seeds, commercial press cake, and experimentally prepared tung press cake containing 20 percent oil. Solvent-extracted tung oils from the first experiments contained excess acidity and tended to solidify but were rendered permanently liquid by a mild heat treatment.

It was found that the excessive acidity in the solvent-extracted tung oils was due to enzyme action in the moist tung meal before extraction and also possibly in the miscella during the time it was awaiting distillation. Therefore, in later pilot-plant studies, the tung meals and press cakes were processed soon after they were prepared, and the miscella was filtered without delay. This was responsible to a great extent for the production in the subsequent runs of extracted oils which were liquid at icebox temperature and had low acidity and satisfactory quality. These oils were formulated into varnishes and tested for durability. The tests indicated that these oils can be used by the paint and varnish industry although the oil from tung press cake is somewhat lower in quality than that of expressed tung oil, and the varnish prepared from it appears to be inferior to the standard spar varnish in durability. Further tests have indicated that dehulled tung fruit should contain about 7 percent moisture for the best preparation of this material for solvent extraction and for its most efficient extraction.

Filtration of Crude Tung Oil

The crude tung oil produced at the mill contains considerable amounts of foots which are derived principally from the ground tung kernels and shell present in a tung meal; it is necessary, therefore, to filter the crude tung oil to remove these foots. This is usually accomplished at the tung oil mill by passing the oil from the expeller to a steam-jacketed tank, where it is heated to about 180° F., agitated with about 1 percent diatomaceous filter-aid and then filtered, under about 40 pounds per square inch of pressure, through a filter press having plates precoated with a thin layer of filter-aid. Filtration is continued until an excessive amount of pressure is required to maintain the flow of filtered oil. The flow of crude oil to the filter press is then shut off and air is blown through the press to remove as much oil as possible from the cake, which is then removed from the press. This filter cake usually contains about 50 percent of tung oil and amounts to 20 percent of the weight of the crude tung oil filtered; therefore, it is necessary to recover as much oil as possible from this material. This is accomplished either by adding the filter cake a little at a time to the tung meal while it is on its way to the expeller or by allowing the filter cake to accumulate, and at about weekly intervals make a separate expression of this material after it has been thoroughly mixed with considerable quantities of tung oil press cake and tung hulls. Neither process appears to be very satisfactory.

Chemical and Physical Properties

American tung oil is composed chiefly of alpha eleostearic acid, with about 4 percent of saturated acids, 8 percent of oleic acid, and 4 percent of linoleic acid, in the form of glycerides. It solidifies below -17° C. The specific gravity at 15.5° C. of 0.9390 to 0.9490 and refractive index at 25° C. of 1.5099 to 1.5200 are relatively high in comparison with most fatty oils. The iodine number of this oil with the Wijs reagent is usually 163.0 to 167.4, although the value obtained varies with the temperature, time of reaction, and excess of reagent. When heated to a temperature slightly under 300° C. (Browne test), it sets to a solid mass in 9 to 12 minutes.

The imported Chinese oil, due to crude methods of expression, is colored and may contain considerable free fatty acid. However, the oil as found in the cells of the tung seed is practically colorless and neutral in reaction. When produced by modern American machinery, a very pale, practically neutral oil is obtained which is superior to the Chinese oil.

Tung oil of good quality can be stored in full containers in the dark for a considerable period without deterioration. Upon exposure to light in the absence of air, the alpha eleostearin of the oil gradually changes to the beta glyceride which separates as a white precipitate. This change takes place much more rapidly in the presence of traces of sulphur or iodine dissolved in the oil.

It has been shown that satisfactory varnishes can be prepared from these solidified oils. Tung oil of a good quality can be bleached by heating it for a short time at 200° C., or by heating it to 120° C. for 30 minutes and agitating it with 5 percent of fuller's earth or with 2½ percent each of fuller's earth and bone char. Raw tung oil dries to give a film which is opaque (frosted), wrinkled and dull, with poor elasticity and adherence. The addition of metallic driers, resinates, rosin, ester gum, and linseed oil to tung oil greatly reduces or eliminates the surface defects of the dried film. When tung oil is heated to a high temperature with rosin or other ingredients to produce a stand oil suitable for use in the manufacture of varnish, this bodied or polymerized oil gives a smooth, clear film.

Films prepared from tung oil, and especially those from tung stand oil, have been found to be tougher and more water-resistant than linseed oil films. The addition of linseed stand oil to a tung oil varnish is said to improve the elasticity and durability of the film without affecting very much its water resistance or drying time.

Uses of Tung Oil

Tung oil has been produced and used in China for centuries but it has been only during the past 40 years that it has been used in large quantities in America and Europe.

In China, tung oil has been used for waterproofing woods and other materials to protect them from the weather. It is the principal paint oil of the Chinese. They use it in waterproofing masonry, in oiling and calking their junks, as an ingredient for dressing leather, in floor varnishes, and, when burned to a fine carbon, in making India ink. During the war tung oil has been used extensively in China for making motor fuels.

More than 80 percent of the tung oil consumed in American industries has been utilized by paint and varnish manufacturers. The linoleum industry was the second largest user. Considerable quantities of tung oil was used in the manufacture of certain insulating compounds for the electrical industry. Tung oil was an important ingredient in the manufacture of some automobile brake linings, and also in some gaskets on steam pipes, pumps and engines, on the undercoating of most automobile finishing jobs, in certain compounds used for the production of wallboard, and in the table oilcloth industry. It has been widely used in waterproofing various types of fabric, both cloth and paper, for raincoats, bags, balloon outer covers, etc. It has also been used for waterproofing cartridges and many other products requiring a waterproof coating. During the last few years the tung oil produced in this country has been purchased by Commodity Credit Corporation and has been used only for essential purposes which contribute to the war effort. Wartime censorship has kept secret the uses to which tung oil has been put during this period.

The use of tung oil in the manufacture of varnishes and other important products in the varnish and paint industry completely revolutionized the processes used. The manufacturers of these products had been using imported fossil gums, together with treated linseed oil, in the manufacture of the better grades of varnish. It was found that tung oil, together with American rosin, produced varnishes which were equal in all respects, and superior in many respects, to the old types of varnishes.

Consumption, imports and prices of tung oil in the United States in stated years.

Year	Total Consumption	Paint and Varnish	Linoleum and Oilcloth	Printing Inks	Miscellaneous Products	Imports	Average Price per lb.
	1,000 lbs.	1,000 lbs.	1,000 lbs.	1,000 lbs.	1,000 lbs.	1,000 lbs.	Cents
1931	82,314	72,853	7,303	965	1,193	79,311	7.4
1932	67,948	59,158	7,299	713	778	75,922	6.3
1933	91,549	76,714	11,746	1,523	1,566	119,760	6.8
1934	105,978	88,184	12,854	1,660	3,280	110,007	8.9
1935	114,287	98,435	10,391	2,013	3,448	120,059	17.0
1936	107,875	94,642	7,131	2,331	3,771	134,830	16.1
1937	120,378	105,731	7,198	2,762	4,687	174,885	15.7
1938	87,415	78,310	4,131	2,084	2,890	107,456	13.5
1939	90,720	82,307	3,763	2,105	2,545	78,718	21.0
1940	59,057	54,611	2,064	1,728	654	97,049	26.3
1941	54,008	48,825	1,896	2,960	327	43,800	32.2
1942	11,830	10,896	82	255	597	8,269	39.6
1943	12,047	9,667	...	17	2,363	68	39.0
1944 1/	10,109	8,084	...	27	1,998	1,771	39.0

Compiled from Publications of the Bureau of the Census, Bureau of Foreign and Domestic Commerce, United States Department of Commerce, and Bureau of Agricultural Economics, United States Department of Agriculture.

1/ Preliminary

The total acreage of tung trees in 1940 according to 16th census reports* was as follows:

Alabama..........	1,600
Florida.........	18,600
Georgia..........	1,200
Louisiana.......	27,000
Mississippi....	146,000
Texas	570
	194,970

* Obtained by dividing number of trees per state by 65.

Tung Nuts (unhusked, air-dried): Production in commercial states, 1940-45.

STATE	1940	1941	1942	1943	1944	1945 1/
			TONS			
Alabama	200	350	500	100	500	800
Florida	4,700	2,250	3,700	700	7,000	8,400
Georgia	1,200	650	950	200	1,000	1,100
Louisiana 2/	1,200	1,800	4,000	3,260	7,550	9,800
Mississippi	3,700	3,700	7,200	1,940	10,630	13,000
UNITED STATES	11,000	8,750	16,350	6,200	26,680	33,100

1/ Preliminary .. 2/ Includes small quantities of tung nuts produced in Texas.

Average price of Tung Nuts per ton received by growers for crop marketing seasons, 1940-45.

STATE	1940	1941	1942	1943	1944	1945 1/
			DOLLARS			
Alabama	64.30*	93.00*	93.90*	93.30*	100.00	101.00
Florida	60.00	90.00	90.00	93.00	100.00	100.00
Georgia	64.30*	93.00*	93.90*	93.30*	95.00	93.00
Louisiana 2/	55.00	91.00	87.00	95.00	103.00	103.00
Mississippi	60.00	85.00	95.00	100.00	104.00	104.00
UNITED STATES	60.00	88.30	91.80	96.40	102.00	102.00

1/ The 1945 price and value figures are preliminary.
2/ Includes small quantities of tung nuts produced in Texas.
* Price and value for two states combined.

Tung Nuts: Value of Production, Commercial States, 1940-45 2/

STATE	1940	1941	1942	1943	1944	1945 1/
		THOUSAND DOLLARS				
Alabama	13	33	47	10	50	81
Florida	282	202	333	65	700	840
Georgia	77	60	89	19	95	102
Louisiana	66	164	348	326	778	1,009
Mississippi	222	314	684	194	1,106	1,352
UNITED STATES	660	773	1,501	614	2,729	3,384

1/ Preliminary
2/ Production multiplied by season average prices received by growers

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