# Essential Oils

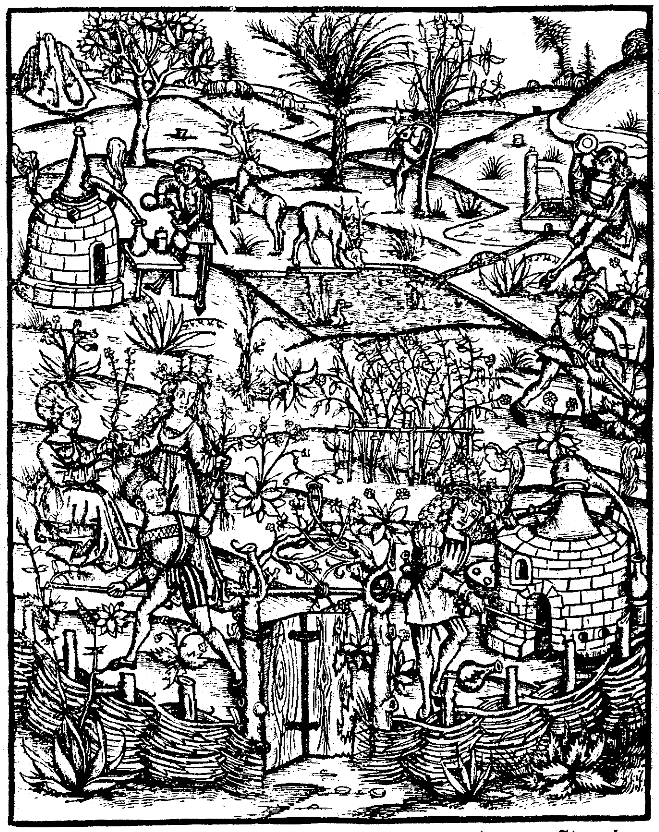
By A. J. HAAGEN-SMIT

ONE of the attractions of the subject of essential oils appears in its manifold aspects, its interest to the chemist, the plant physiologist, the pharmacologist, the historian, and, last but not least, the psychologist. When the historian and the psychologist are discussing this subject, they may well argue about the question of why Ulysses, the Greek traveler, was detained by Circe. The answer is that she used an odoriferous principle, which many present-day oil firms would like to lay their hands on. A similar secret was possessed by Helen of Troy, to whom Venus revealed a secret perfume, which was responsible for her fabulous beauty. While the secret of such magic perfumes was lost, later generations tried to make up for this in quantity, and even wise men, such as Diogenes, could not escape paying attention to the subject of perfumes. He is reported to have remarked that it was most wasteful to pour the oil on the head, whence the scent rose in the air and benefited only the birds, whereas by using it upon the feet one bathed the whole body in the delightful odors.

The important place these substances took can be gauged from the opposition they created. Solon, among the Greeks, and Julius Caesar, among the Romans, forbade the sale of perfumes, which sometimes were showered over the guests from the ceiling of the building. During the reign of King George III, in 1774, the British Parliament passed the following law: "All women of whatever age, rank, profession or degree whatever, virgins, maids or widows, that shall from and after this act impose upon, seduce and betray into matrimony any of His Majesty's subjects by the use of scents, paints, cosmetics, washes, artificial teeth, false hair, spanish wool (a kind of rouge), iron stays, hoops, high-heeled shoes or bolstered hips shall incur the penalty of the law now in force against witchcraft and like misdemeanors and the marriage upon conviction shall stand null and void."

It has been suggested that if fines should take the place of imprisonment, our problems of taxation would be solved.* In any case, legislation in such matters is not confined to the past. A similar unimaginative and unemotional law agency is the Federal Food and Drugs Administration, which refuses to believe in the scents which clear befuddled minds, help in all illnesses, and at the same time lead to thrilling adventures and romance. From the reactions of such governing bodies, we may conclude that the interest of the people in these oils has been great and the urge must have been strong to increase the number of perfumes. The discovery and conquest of countries and the waging of wars were chiefly caused by the desire to increase the wealth of the conqueror, and down the course of history perfumes and spices have been of prime consideration in this respect.

Liber de arte distillandi. de Simplicibus.
Das buch der rechten kunst zü distilieren die eintzigē ding
von Hieronymo Brunschwygk/bürtig vn̄ wund artzot der keiserlichē frye statt Straßburg.



un getruckt durch den wohlgeachte Johannem grueninger zu Strassburg in den achte tag des meyen als man zelt von der geburt Christi funfzehnhundert. Lob sy got. Anno 1500.

FIG. 1. Title page of a book on distillation, by Brunschwig (printed in 1500).

In the early periods the resins and oils obtained from plants were burned on altars, and extensive recipes are found in Egyptian manuscripts. The Israelites, during their exile in Egypt, became acquainted with the use of these perfumes and salves, and some of their recipes are recorded in the Old Testament, where it is stated that the Lord ordered Moses: "Take unto thee three principal spices: pure myrrh, 500 shekels, and sweet cinnamon half so much and of sweet calamus, 250 shekels, and of cassia, 500 shekels, and of olive oil a hin."

While only crude resins and oils were used chiefly in ointments and in certain combinations, as incense to be burned, progress in scientific research made it possible to separate the volatile and odoriferous principles from the plant material. This was a great step forward, since it made it possible to preserve the smell and flavor of a much larger number of plants. It had been observed that boiling water carries with it the volatile material and that after condensation strongly smelling oil droplets appear on the surface of the water. These oil droplets soon form a liquid, to which is given the name of essential oils, because they are easily volatile and are thus distinguished from the fatty oils. The volatility and the derivation from plants are the characteristic properties of these oils, and it is for this reason customary to include volatile plant oils obtained by other means than direct steam distillation. Bitter almond, mustard,

*A. Hyatt Verrill, *Perfumes and Spices*, L. C. Page & Co., Boston (1940).

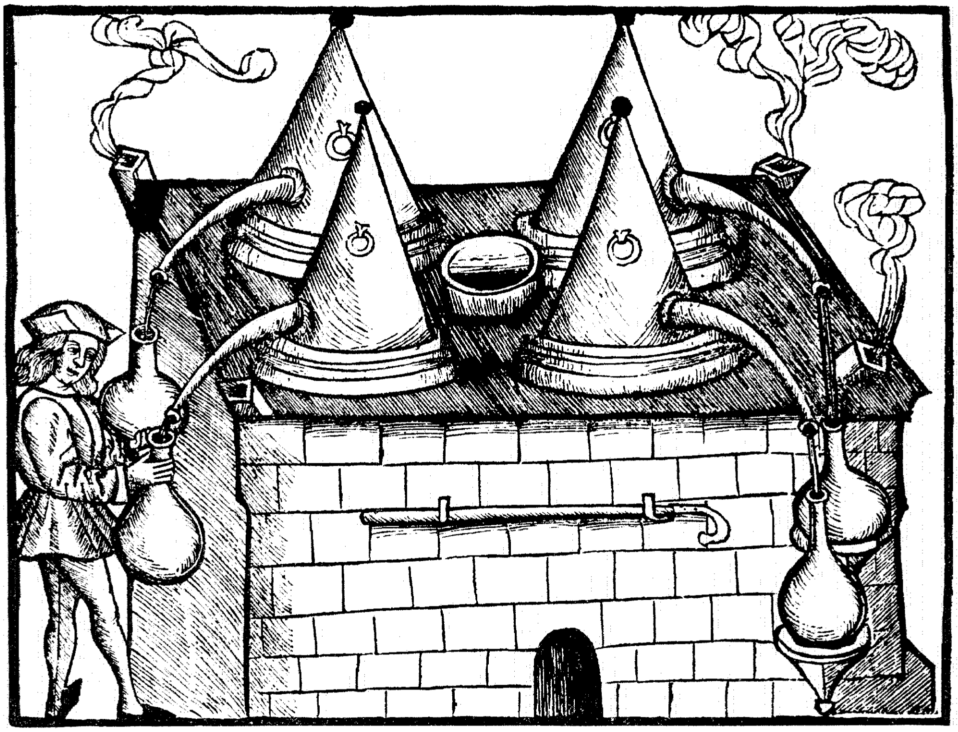


FIG. 2. "Rosenhut," distillation apparatus of 1500. Reproduced from Gildemeister and Hoffmann, Die Atherischen Ole, p. 224 (1910).

The second principal method consists in extraction with fats and vaseline. This process is especially used to concentrate flower oils, which would be easily decomposed at the higher temperature during water distillation. In the extraction with fats, we can distinguish two methods:

1. Use of liquid fat under heating, called maceration: and

2. Enfleurage, whereby the volatile material is absorbed in substances such as vaseline and paraffin, at room temperature. This last method is especially used on flowers which have a low content of oil but are continuously producing and evaporating their fragrant substances. In this way it is possible with jasmine, for example, to obtain by enfleurage five times more essential oil than by extraction with some solvent. The enfleurage is carried out by putting the flowers on wooden frames about two inches high and two or three feet square, in which a glass plate is placed. On both sides of the glass plate is applied a fatty layer on which the flowers are spread. On top of this frame a new one is placed, filled in the same way, until large stacks of these frames are piled one upon another. The essential oils given off by the flowers are taken up by fat, and the same fatty layer can take up the essence of many layers of new flowers.

The absorbent material, the fat or vaseline, is then removed by treatment with alcohol or other solvents, and the resulting concentrated flower extract is ready to be sold.

and wintergreen oil obtained by enzymatic action, or lemon and orange oil obtained by simple pressing, can be distilled with steam and are therefore included among the essential oils. Also included are oils obtained by extraction.

## MANUFACTURE OF THE OILS

The distillation of steam is the most frequently applied separation method for these oils. The amount of compounds which we find in the essential oils boiling between 150-300° C., their vapor pressure at 100° C., the boiling point of water, is considerable—for camphor 20.4 mm., for pinene, the chief component of oil of turpentine, 147 mm. In a mixture of oil and water the oil contributes, therefore, materially towards reaching the atmospheric pressure at which distillation occurs and will boil at a temperature somewhat lower than 100°, *i.e.*, 96°, whereas without the help of water the pinene would boil at 155-156° C. The components of the essential oil are, therefore, in a steam distillation less exposed to higher temperatures: less decomposition takes place, and a better-smelling product is obtained.

The essential oils in plants are contained in cells, mostly with reinforced walls. It is necessary before distillation to open up these oil containers by grinding or cutting the seeds or other parts of the plant. In its simplest form, this material is poured into a still; the outside is heated and the vapor condensed. This procedure was described by Herodotus and Pliny, but the method is still used in the country by farmers, whose stills do not differ greatly from those shown in *Figs. 1, 2 and 3.* By the more modern methods, the water vapor necessary for carrying over the oil is produced in a separate still or apparatus and the steam is blown through the plant material. The production of this type of oil is limited in the United States to oil of turpentine, peppermint, eucalyptus, erigeron, witch-hazel, wormwood, and lemon-grass.

## CHEMISTRY OF THE OILS

The oils and extracts obtained in these ways consist of

FIG. 3. Distillation apparatus with condenser tubes. Reproduced from Gildemeister and Hoffmann, Die Atherischen Ole, p. 226 (1910).

a great variety of substances. Some of these may constitute an odoriferous principle; others will be odorless impurities, or may even detract from the value of the oil by their smell or, for example, their solubility properties. In the search for pure principles and possible means of preparing these synthetically, considerable efforts have been made in the analysis of the oil. It has been found that the oil consists of compounds belonging to many groups of organic compounds, consisting of carbon, hydrogen, and oxygen and in some cases containing in addition sulphur and nitrogen.

It is possible to arrange these compounds in groups, which, because of their structure, suggest similarity in their formations. One group of substances consists of molecules of straight-chain hydrocarbons, such as we find in *Pinus sabinus*, which gives us an oil consisting of 70 per cent n-heptane, resembling normal gasoline. Other representatives of this group are found in the stearoptenes present in precipitates formed in many oils. Another group consists of substitution products of benzene, chiefly n-propylbenzene derivatives; examples of these substances are to be found in eugenol, from clove oil.

A third group contains a number of compounds which show connections with nitrogen metabolism, such as indole in orange flowers and allyl isocyanates in mustard oils. A fourth group that we may distinguish consists mostly of hydroaromatic hydrocarbons and their oxygen derivatives. These compounds show a remarkable similarity in their structure, since they can be divided into a number of branched $C_5$ chains, as shown in *Fig. 4*. This building principle links the components of essential oils called terpenes ($C_{10}$), sesquiterpenes ($C_{15}$) with the diterpenes ($C_{20}$) present in resins, vitamin A, and the chlorophyll alcohol, phytol. Triterpenes with 30 carbon atoms are built along the same lines; we find saponins present in the roots of some plants. Many of the yellow or orange plant pigments belong to the tetraterpenes with 40 carbon atoms. In natural Hevea, as well as guayule, the same principle unites 1000-2000 of these $C_5$ units.

## FORMATION IN THE PLANT

On the basis of the structural peculiarities of the components, we can draw the conclusion that the complexity of the oil composition is caused by the excretion or secretion of products formed in many metabolic processes taking place in the plant. Microscopic examination of the plant shows that only distinct cells or spaces in the plant tissue are filled with oily droplets, which are difficult to distinguish from fatty oils. In many cases these glands are epidermal cells or modifications of these, such as the excretion hairs. The secretion product is usually accumulated outside the cell between cuticula and the rest of the cell wall. A slight touch is sufficient to break this thin outer membrane and to cause the release of the oil with its typical smell. The internal glands are spread throughout the plant and these intracellular glands have often grown to form long canals, coated on the inside with a layer of thin-walled cells. The oil is deposited in these canals, but the exact place of their formation is not known. Also the circumstances under which the oils are secreted are far from known. It is suspected that for many of the oil components a relation exists with photosynthetic activity, whereby carbon dioxide is reduced and synthesized to carbohydrate. A support is given to these ideas by studies on the effect of climatic and soil conditions, whereby it has been shown that generally light favors formation of the oils and that the optimum coincides with the most active growth period in plant life.

It would seem as if many of the secreted compounds were by-products in a number of syntheses important

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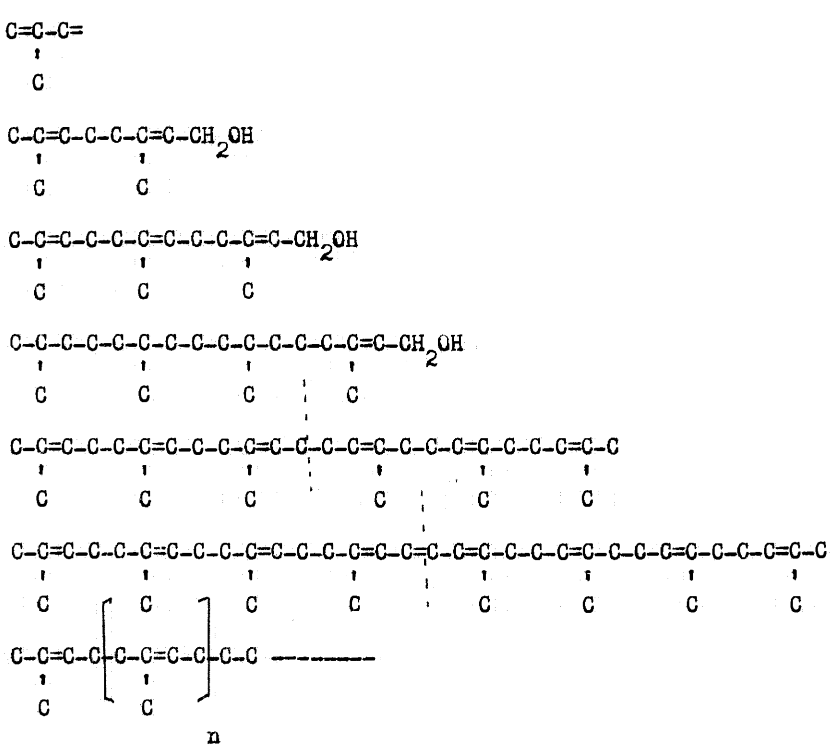

(isoprene) 5
Hemiterpenes

(geraniol in rose oil) 10
Terpenes

(farnesol in rose oil) 15
Sesquiterpenes

(phytol in chlorophyll) 20
Diterpenes

(squalene in shark oil) 30
Triterpenes

(lycopene in tomatoes) 40
Tetraterpenes

(caoutchouk in hevea rubber) n
Polyterpenes

FIG. 4.

strain is greatest at stalled speeds, but is substantial up to a speed equal to the reverse speed of the craft. The hydraulic torque converter insures maximum pull on the anchor line at all times and also sufficient speed on the spooling drum to make sure that all slack is taken up as the boat is floated by the combination of the anchor line pull and action of the waves.

Many of the army tractors used in transporting moderate field pieces included torque converters in their drive. The latest of these units are powered by two 215-horsepower engines, each equipped with its own torque converter. It has been proved that the smooth flow of power to the tractor treads has allowed the converter-equipped tractors to move equipment in areas where other units cannot travel. The army tractors are an outgrowth of early developments of Allis-Chalmers with converter-equipped industrial tractors, and Allis-Chalmers is again in production of these units in limited numbers.

City buses, heavy-duty short-haul trucks, and rail cars show other interesting applications of torque converters to mobile equipment. Many of the newer buses in Los Angeles are now equipped with torque converter drives. They can be identified by their rapid acceleration and even engine speed. No change in exhaust sound can be detected as the buses pick up speed, since they do not shift gears and the engines maintain maximum speed at all times. The loss of efficiency at high road speeds limits the use of torque converters, but this is not a problem on city buses in view of the number of stops and starts they make and the short distances they travel at high speeds. Rail cars present a different problem. They require high starting torque and smooth application of power to the wheels in starting the trains, but they also require full power and speed between stops. Special direct-drive converters are used for drives on buses and rail cars so the operator can shift from converter drive to direct drive when the high starting torque is not required.

Many other suitable applications will no doubt be developed for torque converters. At the present time plans are being made for off-the-highway trucks with a gross load of 300,000 pounds, powered by two 200-horsepower engines driving through torque converters. Fishing boats are also using converters to provide a constant strain on the lines used in recovering their heavy nets. The Navy uses torque converters on submarine net hoists guarding one southern California harbor.

### LIMITATIONS OF TORQUE CONVERTERS

Care must be used in selecting the ratio of all drives in connection with torque converters in order that they may do most of the work in the efficient range of the converter. The high torque developed in the output shaft also places added loads on all conventional gear trains installed in many pieces of machinery. The loss of an average of 25 per cent of power through the converter makes this type of drive undesirable in those units operating at their maximum horsepower capacity and relative uniform loads for long periods of time.

### SUMMARY OF HYDRO-KINETIC DRIVES

Both hydraulic couplings and hydraulic torque converters require relative high input speeds in order to operate to their best advantage. Industrial internal combustion engines operating at 1400 *rpm* and greater rates are very suitable for use with the present hydraulic drives. Both drives provide smooth starting of loads, prevent overloading and stalling the prime mover, and absorb much of the torsional vibration of the engines. Couplings are suitable on constant-speed, constant-torque drives where efficiency in excess of 95 per cent is desired. Torque converters are adaptable to those operations in which the prime mover will be operated at various speeds and loads, and where the output speed and torque varies with successive operations.

There are many applications in which couplings and converters are not suitable, and many more suitable applications will be developed as more experience is gained with these drives. Each new development will require careful study of the operations to be performed and careful engineering to select proper speed and torque requirements.

### POSITIVE HYDRAULIC DRIVES

In addition to the hydro-kinetic units which have been described, there are several fine positive hydraulic drive units in widespread use in industry. These units are often built into various machine tools and generally develop but a low horsepower. In this type of drive a hydraulic pump provides a flow of fluid at the required pressure and volume for the drive. The fluid is carried through suitable lines to the positive-driven hydraulic motor. In most types of positive-drive units either the pump or the motor has a variable volume control to regulate the speed of the driven unit. One of the manufacturers of positive hydraulic drives very aptly compares his unit with an electric generator and an electric motor. The hydraulic pump generates hydraulic power which can be transported reasonable distances and around obstructions to the hydraulic motor, just as electricity can be carried over wires. The power developed depends upon the volume and pressure of the fluid, just as electric power depends upon the voltage and current.

Positive hydraulic drives have three outstanding characteristics. The hydraulic motors can be reversed very easily, a wide range of motor speeds can be obtained, and the hydraulic power can easily be transported reasonable distances through suitable pipes. The hydraulic fluid is in a closed circuit so that it is used repeatedly.

The positive hydraulic drive units do not have the ability to absorb shock loads which is so characteristic of the hydro-kinetic drives.

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## ESSENTIAL OILS

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for plant life and as if, because of the nature of the oils, the plant reacted by walling them off, as is also the case when intradermal oil injections are made in animals.

The question has repeatedly come up as to what function the oils could have in plants, and many guesses have been made, such as the attraction of insects for pollination, protection against snails or other enemies, sealing of wounds, varnish against excessive evaporation, etc. The experimental evidence for these opinions is not very strong: it rests on a few individual experiments which do not allow generalization.

The interesting field of the biochemistry of the oils, which also includes our perception of these as odors and flavors, is still practically a closed book. Our chief interest up to the present has been to enrich our statistical knowledge, mostly in view of commercial advantages. A diversion of this interest to the underlying biochemical principles will undoubtedly be of benefit to all concerned.