Composition and characteristics of dill: a review

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Dill, *Anethum graveolens* L., has been used for its flavour and presumed medicinal properties for many thousands of years. It is still used extensively in Europe and North America. Dill is an annual plant of the Umbelliferae (parsley) family, growing to about one metre in height and bearing typical inflorescences of yellow flowers. Traditionally two species have been of commercial interest: "European" dill, or *Anethum graveolens* L., and "Indian" dill, or *Anethum sowa* Roxb. Each of these is available in a number of physical forms:

dill herb—the fresh aerial part of the plant
dried dill herb—the dried aerial part of the plant
dill seed—the dried fruits
dill herb oil (also known as dill weed oil)—obtained by steam distillation of stalks, leaves, and fruits of *Anethum graveolens*
dill seed oil—obtained by steam distillation of the crushed dried fruits of either *Anethum graveolens* or *Anethum sowa*
dill herb oleo-resin—obtained by solvent extraction of stalks, leaves, and fruits of *Anethum graveolens*
dill seed oleo-resin—obtained by solvent extraction of crushed fruits of either *Anethum graveolens* or *Anethum sowa*

Anethum sowa is primarily grown for its fruit, whereas *Anethum graveolens* is primarily grown as the herb, although its fruits are also commercially available. The fruit is usually classified as a spice along with other umbelliferous fruits such as caraway, cumin, and coriander. However, the whole plant is regarded as a herb and as such has uses similar to those of parsley herb.

Composition

When considering the chemical composition of dill and its oils the situation is complicated by the availability of the two distinct species, *Anethum graveolens* and *Anethum sowa*. This topic has been the subject of a number of publications but all identify two major components—carvone and limonene. These investigations have been well summarised by Scheffer and coworkers.[5]

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Table 1. Chemical composition of dill oils (5,8,9)

	A. graveolens		A. sowa
	Seed Oil Holland	Weed Oil U.S.A.	Seed Oil India
d-Carvone	55	30	20
d-Limonene	40	38	22
alpha-Phellandrene	0.2	18	12
M.W. 152	0.1	5.3	-
Dihydrocarvone	3.0	1.0	15
Dillapiole	-	-	14
alpha-Pinene	trace	1.2	5.0
Carveol	0.2	-	-

Only the most abundant compounds are listed above.

Dill seed oil from Anethum graveolens is characterised by a high carvone and high limonene content, carvone imparting a distinct caraway-like aroma (fig. 1).

Dill seed oil from Anethum sowa contains a much lower carvone content than the above, together with significant quantities of dillapiole. In fact Betts reported that the dillapiole content is usually twice that of carvone.[3]

Dill weed oil from Anethum graveolens contains carvone, limonene, and significant amounts of α-phellandrene and an as yet unidentified compound of molecular weight 152 (possibly a cumarane).[8] The flavour is quite distinctly "greener" than that from the seed, though the identity of those compounds responsible for this note have not been fully identified.

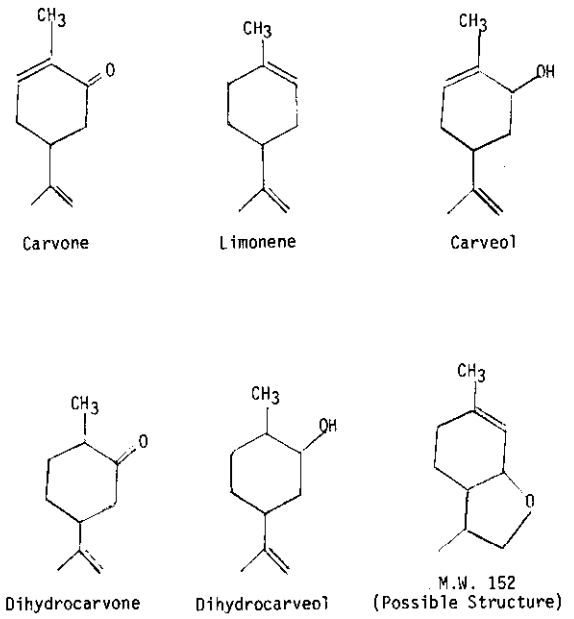

Figure 1. Structures of some dill oil components

Table I indicates typical figures obtained by GLC analysis of various dill oils. Over thirty separate compounds have been reported as being present, of which about twelve have been consistently reported as being present at levels of 0.1% and above.[5,8,9] It is generally agreed that the presence of dillapiole or apiole in the oils signifies that the oil originates from *Anethum sowa*. However, two factors may contradict this assumption.

- Lichtenstein and coworkers have identified the presence of these two compounds in the roots of *Anethum graveolens*.[12]
- The work of Baslas indicated that when *Anethum graveolens* seed from England was grown in India, dillapiole was found to be present and during successive years of sowing the oil composition gradually approached that of *Anethum sowa*.[9] This result, if it is reproducible, has important implications for the taxonomist, though it must be mentioned that the results of Betts do not agree with this finding.[3] This situation is further complicated by the observations of Shal and coworkers that there might be at least two separate varieties of *Anethum sowa* grown commercially in India.[4] These are:

  Variyali, characterised by a low dillapiole content (15%) and a high dihydrocarvone content.

  Ghoda, characterised by relatively high d-carvone (35%) together with a dillapiole content of about 12%. These results however do not correspond with those of Betts.[3] There may also be another variety containing no d-carvone at all.[7]

It is thus very evident that further work is required to clarify the taxonomy of dill plants and to subsequently determine the composition of their seed oils. To maintain product quality it is essential that only organoleptic assessment backed up by GLC analysis serve as a reasonable guide to quality.

The composition and hence the flavour character of the various dill oils can also be influenced by a number of other factors, including distillation time, distillation conditions, and the plant's maturity.

Distillation time

The relationship between carvone and limonene content is to some extent determined by distillation time. When distilling dill seed oil, the d-carvone (B.P. 230°C) distills over before the limonene (B.P. 176°C) since carvone is much more water soluble than the hydrocarbon, limonene.[11] Thus the carvone content is to some extent determined by the distillation time; a fact described by Koedam and coworkers.[1] After two hours distillation the limonene:carvone ratio was found to be 20:80; after sixteen hours the ratio was 42:58. Solvent extraction of seed oil yielded a limonene:carvone ratio of 46:54, thus indicating that some limonene is still retained in the seed after prolonged steam distillation.

This fact may be a possible means of producing high carvone content seed oil from *Anethum sowa* by simply reducing the distillation time. Obviously, the particle size of the crushed seed will also influence distillation time; the finer the grind the more rapid the distillation, although fine grinding will lead to volatile oil loss due to the heat produced in the mill. This can, however, be obviated by the use of liquefied nitrogen or carbon dioxide.

Distillation conditions

Dihydrocarvone is present in both its cis and trans form and it is interesting to note that each has a characteristic aroma.[2] Trans-dihydrocarvone is caraway-like, whereas cis-dihydrocarvone is cineole/woody in character.

The ratio between the cis and trans form varies with the pH of the distillation water and length of distillation. It has been reported that solvent extracted oils have a cis:trans ratio of 84:16, whereas in steam distilled oils the ratio varies throughout the pH range being (for example) 70:30 at pH 7.[1] This then indicates that the conditions of distillation would contribute to a flavour change. It is also very likely, as reported by Koedam and coworkers, that this change from cis to trans is catalysed by metal ions either present in the seed or dissolved from the process apparatus.[1] It is interesting to note that a number of metal ions including copper, iron and manganese have been found to be present in dill seeds in sufficient levels to effect this change.

The as yet unidentified compounds of MW152 (either a cyclic ether or epoxide) have also been shown to be pH dependent.[1] The amount present increased with increasing pH to a maximum at pH 8.

Maturity of the Plant

Luyendijk found that the carvone content of the seeds gradually increases during their development. This is accompanied by a decrease in the limonene content whereas the α-phellandrene levels appear to remain fairly constant.[6] Thus the chemical composition and flavour of dill and its extract will depend on the maturity of the plant at the time of harvest.

Cultivation

Dill is cultivated over a wide geographical area. *Anethum graveolens* is grown commercially in Germany, Holland, Hungary, Russia, Sweden, the United States (mainly in Oregon, Washington, and Nevada) and Canada (Manitoba), while *Anethum sowa* is cultivated in India, Bangladesh, China, and Japan.

Anethum graveolens can be grown in most climates, although it requires light and warmth with a soil that is neither too sandy nor too stony. A medium to heavy well-drained humus-rich soil is preferred, where manure has been applied to a previous crop and a relatively high phosphate level is present. It is ideally grown in

rotation following a root crop. In Europe the seed is sown in spring at levels of between 20 and 30 kgs per hectare. This level of sowing aids the suppression of weeds (herbicides are not usually applied, weed control being carried out mechanically) and ensures growth of plants with tender stalks and a large number of leaves. In India, by comparison, sowing rates for *Anethum sowa* as low as 5 kgs per hectare are reported though soil conditions and the fact that the fruits are the major crop influence this level.[16] The European plant is harvested just before full bloom, when a height of 70-90 cm is attained. A reaper-binder is used to minimise plant damage. After full bloom the plants lose weight and become woody, thus detracting from the quality of the herb, especially if this is to be used either fresh or dried.

Uses

A number of historical references can be found to the use of dill; the following are two typical examples. Pliny states that inhalation of the vapour is recommended to cure hiccups and administration of the seed alleviates indigestion, though he warns that dill may also weaken the eyesight and the generative powers. In the middle ages in England, it was reportedly used by magicians in their spells against witchcraft.

Culinary

The fresh herb is widely used in Scandinavia, Germany, and Eastern European countries as a flavouring for many foods, including pickled cucumber, vinegar, salads, pickled and fermented cabbage, sauces and marinades particularly for fish (gravlax being a classic example), and as a garnish on vegetables.

In Balkan and Middle Eastern countries yoghurt, sour cream, chicken, stuffed vine leaves, and soups may be flavoured with dill. Generally the uses of dill are similar to those of parsley and mint in the United Kingdom, and it is quite common for all three herbs to be included in the same recipe, as for example lamb casserole or savoury yoghurt soups. When used in this way dill tends to be the predominant flavour in Scandinavian dishes, whereas in the Middle East it is often the mint which is the more important herb. It is thus somewhat surprising that in the United Kingdom the use of dill is very limited. Perhaps there exists an opportunity for the development of new retail products incorporating dill as part of a mixed herb seasoning. Dill fruits (seeds) are often used as an alternative to caraway seeds in breads and flour confectionery.

Commercial

The seed and herb oils and, to a more limited extent, the oleo-resins find many applications as a part of compounded seasonings and flavouring for use in food products such as meat products, desserts, pickles, alcoholic beverages, and in the perfumery and soap industries. The primary use of the herb oil, especially in Germany and the United States, is in the production of pickled cucumber. In addition to those applications listed above, the fresh or dried herb has uses in cheese.

Medicinal

The seed oil, particularly that of *Anethum graveolens*, possesses carminative, stomachic, and stimulant properties and is excellent for digestive problems in children. Two preparations in the British Pharmaceutical Codex include dill oil:

1. Dill Water Concentrated B.P.C., which contains 2% v/v of "European" dill seed oil (minimum 43% carvone).
2. Sodium Bicarbonate Mixture, Paediatric B.P.C., which again contains 2% v/v of the same seed oil. Both are primarily recommended as a remedy for flatulence in children.

Toxicity

There is little information available on the toxicity of dill or of its extracts. The National Academy of Science reported in 1967 that the safety margin between organoleptically acceptable levels and toxic levels is small.[13] The presence of myristicin, which has been implicated in liver damage and which is a psychoactive agent, appears to have influenced this statement. Also influential is the fact that the apioles are, structurally, closely related to myristicin and saf-

role (fig. 2) and that they are biologically active. Marczal's suggestion that the diuretic effect of parsley was due to apiole must also be taken into consideration.[17] However, since the per capita consumption of dill is relatively low the FAO/WHO established an A.D.I. of 1.25 mg/kg body weight as carvone.[15] This still allows room for expansion of the use of dill in the food industry when one bears in mind that, in the United States, it is estimated that the consumption of dill oil is about 0.56 mg/capita/day.[14]

Some toxicity data are available for the principal constitutents of dill oil. Carvone has an LD_{50} level of 1640 mg/kg in the rat.[18] Dillapiole has an LD_{50} level of 1000-1500 mg/kg in mice.[19] However, since about one half of the dill consumed is from Indian seed the toxicity of dillapiole needs to be more fully investigated, although the FDA has reported that there is no evidence that dill or dill oils demonstrate a hazard to the public when used at current levels.[14]

Insecticidal properties

Since a number of the constituents of dill have been shown to be biologically active it is particularly interesting to note the results of the work of Lichtenstein and coworkers, which demonstrated that myristicin, apiole, dillapiole, and carvone were all effective insecticides.[12] The insecticidal activity of "European" dill herb extracts was primarily due to carvone whereas in the roots the apioles were the active compounds.

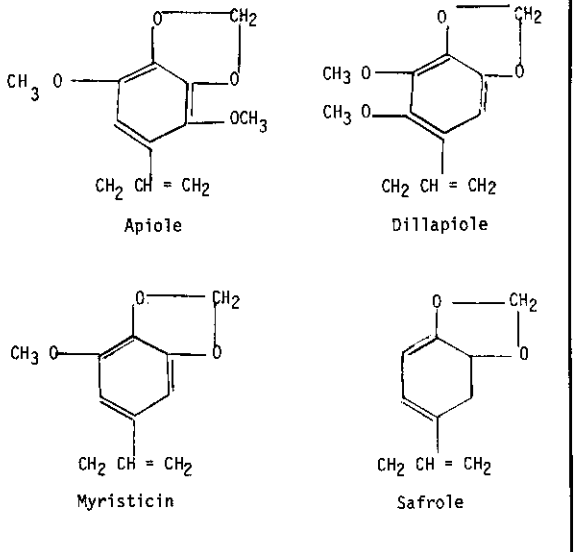

Figure 2. Structures of dillapiole and related compounds

These were found to have lower LD_{50} values than myristicin.

Furthermore, it was shown that these constituents act synergistically with commercial insecticides such as carbamate and organophosphorus compounds, although additional trials are required to determine whether these results have any commercial significance. They could possibly be integrated with the work of Sethi and coworkers, who put forward the idea of fractionating *Anethum sowa* seed oil with a view to removing the dillapiole, thus yielding an oil of high carvone content of similar character to *Anethum graveolens* seed oil.[10] The dillapiole could then be used as a synergist in insecticides. In any event, it is apparent that dill and its extracts are a potential source of biologically active compounds, some of which could be extracted from the plant material without detriment to its flavour quality.

Acknowledgement

This paper was originally presented at the Phytochemical Society of Europe's International Symposium on Spices, held in London January 3, 1980.

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