

BOTANY AND CHEMISTRY OF *FOENICULUM VULGARE* VAR. *DULCE* MILL. AND *FOENICULUM VULGARE* VAR. *VULGARE* MILL: A REVIEW

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Abstract

The *Apiaceae* family (*Umbelliferae*) comprises both vegetable and aromatic and medicinal species. Among the most used aromatic species from this family is *Foeniculum vulgare* Mill, which can be cultivated in various climatic conditions. *Foeniculum vulgare* ssp. *vulgare* Mill. can be cultivated using three varieties: *Foeniculum vulgare* var. *azoricum* Mill., also called bulbing fennel or Florence fennel, *Foeniculum vulgare* var. *dulce* Mill. with the common name of sweet fennel and *Foeniculum vulgare* var. *vulgare* Mill., this variety is known as bitter fennel due to the bitter aroma of the seeds. In this review were presented the results of various publications, reported between 1961 and 2019, on two varieties of fennel, var. *dulce* and var. *vulgare*. The publications were selected from the electronic library. Therefore in this article, various botany and chemistry differences between sweet fennel and bitter fennel have been presented.

Key words: *Foeniculum vulgare*, sweet fennel, bitter fennel, chemistry, botany

The *Apiaceae* family (*Umbelliferae*) comprises both vegetable and aromatic and medicinal species. Plants belonging to the *Apiaceae* family can be cultivated mainly in temperate regions, and less often in tropical countries. The main botanical characteristic of the species belonging to this plant family is the way the flowers are arranged, in inflorescences called umbels.

Among the most used aromatic species from this family is *Foeniculum vulgare* Mill, which can be cultivated in various climatic conditions. *Foeniculum vulgare* ssp. *vulgare* Mill. can be cultivated using three varieties: *Foeniculum vulgare* var. *azoricum* Mill., also called bulbing fennel or Florence fennel, *Foeniculum vulgare* var. *dulce* Mill. named sweet fennel and *Foeniculum vulgare* var. *vulgare* Mill., this variety is known as bitter fennel due to the bitter aroma of the seeds (Barros L. *et al*, 2010).

This plant can be grown in many parts of the world, in countries like Russia, Japan, India and China it is commercially cultivated (Damjanović B. *et al*, 2005; Coşge B. *et al*, 2008).

MATERIAL AND METHOD

Different publications presented in journals and books between 1961 and 2019 were summarized in this review. The literature was selected from electronic databases (Science Direct and Research Gate). In total were reviewed 50 scientific studies, which furnish knowledge about the botany and chemistry of 2 varieties of *Foeniculum vulgare* Mill: var. *vulgare* and var. *dulce*. It also showed that from all 50 scientific papers reviewed in this study (*figure 1*), only 20% were reported between 1961 and 2000, in 2000-2010 the literature had a share of 32%, while in the last 9 years (2010-2019) were published 48% from the studies.

RESULTS AND DISCUSSIONS

In this article, several botany and chemistry distinctions between sweet fennel and bitter fennel have been presented.

Botany

From a botanical point of view, *Foeniculum vulgare* Mill. is a perennial herbaceous plant.

The root is pivoting and can have between 20 and 30 cm length.

The stem is 1-2.5 m high, very branched, cylindrical, with fine streaks, hollow inside (*figure*

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2(b)). The leaves present very thin and filiform segments (figure 2(c)).

The flowers are small, grouped in large, yellow umbels. The calyx is narrow and the corolla contains 5 ovate petals, angled inwards. The 5

stamens are longer than the petals, and the gynoecium is inferior. The fruit is a greyish-green achene, with a planar convex shape, narrowed at the edge (Gildemeister E., Hoffman F.O.V., 1961).

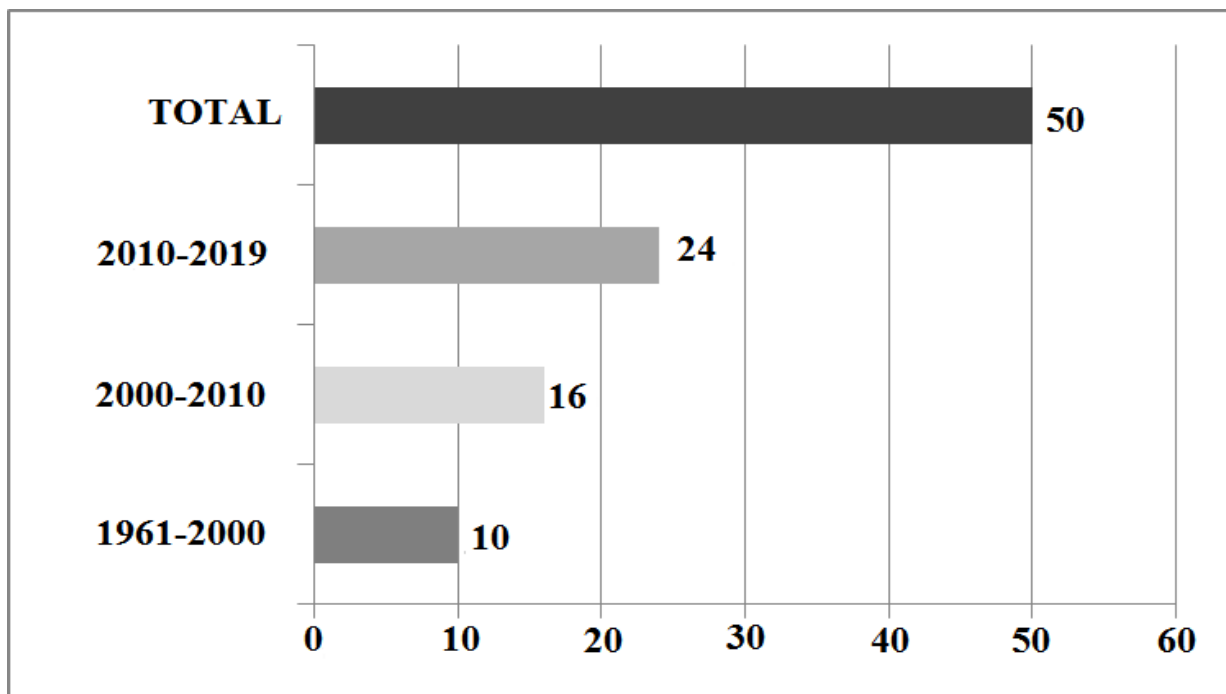


Figure 1 Publications (1961- 2019) collected from electronic library

The two varieties of *Foeniculum vulgare* Mill. var. *vulgare* and var. *dulce* can be botanically distinguished due to some differences. The bitter fennel present a stronger root than sweet fennel, so it can resist better during the winter temperatures. The stem height can reach 2 m at var. *vulgare* and at var. *dulce* only 1.3 m. The number of stems for the bitter fennel is 6-7 while the sweet fennel present an individual stem.

The number of umbels also vary, the sweet fennel has less umbels, but their weight is greater than the bitter one.

The vegetation period of sweet fennel is 150-160 days, and of the bitter fennel of 190-200 days, or more depending on the climatic conditions, so that in some years it may not reach maturity (Tchingova B., 1967).

Phytochemistry

Many researches have been accomplished on the chemical composition of fennel oil from various origins (Krishnamurthy K.H., 2011; Grover S. *et al*, 2013). The essential oil content varies depending on the variety and origins.

In some studies published in the literature, the volatile oil content extracted from fennel seeds was between 2 and 6% (Stănescu U. *et al*, 2004), and in other experiments the essential oil content reached up to 8,5% (Istudor V., 2001).

For the bitter variety (var. *vulgare*), the plants from Central and Eastern Europe had 3.44-7.2% volatile oil, some from India, reached 8.5%, and those of Romanian origin 4.3-5.41% volatile oil. Fruits from the sweet variety (var. *dulce*) contained less volatile oil, 1.7-3.5% (Cucu V. *et al*, 1982).

Phytochemical researches carried out on this plant resulted in the isolation of several secondary metabolites: volatile components (volatile oil), fatty acids, phenolic compounds (Gildemeister E., Hoffman F.O.V., 1961; Bodea C., 1982; Rasul A. *et al*, 2012; Bukhari H. *et al*, 2014).

The relative content of essential oil in sweet fennel fruits was about 2.05% by weight, while in case of the bitter fennel the essential oil content was 3.37% (Tchingova-Boiajjeva B., 1970).



Figure 2 *Foeniculum vulgare* Mill: (a) in its natural habitat, (b) stem, (c) leaves

The main component in fennel oil is trans-anethole, which was found between 50 and 75% in var. *vulgare* and about 85% in var. *dulce* (Cucu V. *et al*, 1982).

In addition to trans-anethole, significant amounts of cis-anethole, estragole and methylcavicol were also detected in the essential oil (Shah C., 1970).

The chemical composition of the essential oil obtained by hydrodistillation from fennel seeds was analyzed in various studies (*table 1*) (Akgül A., Bayrak A., 1988; Damjanović *et al*, 2005; Fang L. *et al*, 2006; Singh G. *et al*, 2006; Telci I. *et al*, 2009; Zoubiri, S. *et al*, 2014).

Özcan M.M. *et al* (2006) investigated the main chemical compounds of volatile oil extracted from fennel seeds originated from Turkey: estragole (61% - 41%), fenchone (23% - 17%) and limonene (9% - 18%).

The volatile oil obtained by hydrodistillation from fennel originated from Pakistan presented in considerable amounts of trans-anethole (68%) fenchone (9.5%), estragole (4.9%) and limonene (4.5%) (Anwar F. *et al*, 2009).

The essential oil originated from Montenegro contained 62% trans-anethole, 20% fenchone, 4.9% estragole and 3% limonene (Damjanovic A.M. *et al*, 2005).

In the essential oil were found some phenylpropanoic compounds: p-methoxy phenylacetone, anisic acid, anisic ketone, dihydroxyanethol, anisic aldehyde and p-methoxy-1-phenil-1-propanol (Parejo I. *et al*, 2004; He W., Huang B., 2011; Anka Z. M. *et al*, 2019).

The fennel oil contains also some terpenic compounds: α -pinene, β -pinene, camphene, myrcene, limonene, α -phellandrene, β -phellandrene, p-cimene, linalool, terpineol and bornyl acetate (Kraus A., Hammerschmidt F.J., 1980; Shahat A.A. *et al*, 2011; Diao W.R. *et al*, 2014). The fennel fruits contain 20% fatty acids, and the specific fatty acid of the fennel fruits is petroselinic acid. The level at which this kind of acid can be found is up to 70-80% (Charvet A. S. *et al*, 1991; Reiter B. *et al*, 1998). The two varieties of *Foeniculum vulgare* Mill. var. *dulce* and var. *vulgare*, did not show differences in fatty acid composition (Coşge B. *et al*, 2008).

Table 1

Main *F. vulgare* seed essential oil components (in %) as reported in the literature

| Compound | Zoubiri S. et al, 2014 | Akgül A., Bayrak A., 1988 | Telci I. et al, 2009 | Damjanović et al, 2005 | Singh G. et al, 2006 | Fang L. et al, 2006 |
|--|------------------------|---------------------------|----------------------|------------------------|----------------------|---------------------|
| α -thujene | - | - | - | 0.05 | tr | - |
| α -pinene | 1.22 | 3.18 | 0.12 | 2.81 | 0.2 | 0.42 |
| camphene | 0.19 | 0.93 | - | 0.34 | tr | - |
| sabinene | - | - | - | 0.56 | tr | - |
| β -pinene | - | 1.17 | 0.05 | - | 0.2 | 0.08 |
| β -phellandrene | 0.28 | - | 0.01 | - | - | 0.26 |
| <i>p</i> -cymene | - | 1.78 | - | 0.28 | 3.1 | - |
| limonene | 6.37 | 2.87 | 2.96 | 3.15 | 3.1 | 6.29 |
| 1,8 -cineol | - | - | - | 1.20 | 0.1 | 0.53 |
| 1,3,6 – octatriene, 3,7 –dimethyl, (E) | 0.54 | - | - | - | - | - |
| 3-carene | 0.17 | - | - | - | - | 0.11 |
| β -ocimene | - | - | 0.83 | 0.22 | - | - |
| γ -terpinene | - | 0.83 | - | 1.05 | 2.1 | 2.35 |
| fenchone | 12.93 | 13.85 | 1.19 | 20.30 | 8.6 | 3.28 |
| linalool | - | - | - | - | 1.2 | - |
| camphor | 0.21 | - | tr | - | 0.3 | 0.09 |
| estragol | 3.41 | 4.96 | 5.16 | 4.90 | 4.7 | 5.95 |
| fenchyl acetate | 0.14 | - | 0.13 | - | 0.2 | 0.11 |
| <i>trans</i> -anethol | 72.86 | 64.71 | 87.85 | 62.00 | 70.1 | 73.2 |
| germacrene D | - | - | - | 0.18 | - | - |
| anisketone | - | 1.12 | - | - | - | - |
| 4- methoxy-benzaldehyde | - | - | - | - | - | 1.99 |

tr: Traces (<0.05%); -: not detected

CONCLUSIONS

The available scientific research showed that the relative content of essential oil in sweet fennel fruits is about 2.05% by weight, while in case of the bitter fennel the essential oil content is 3.37%. The oil extracted from the bitter fennel fruits is characterized by high concentrations of α -pentene and fenchone, and relatively low concentrations of *trans*-anethole (50%), in comparison with sweet fennel oil which contains almost 85% *trans*-anethole.

Regarding the botanical aspect, bitter fennel presents a stronger root in comparison with the sweet fennel, and the number of stems for the bitter fennel is 6-7 while the sweet fennel presents an individual stem.

In conclusion, this review highlights the major differences between the two fennel varieties, and as well the scientific interest on the botany and chemistry of *Foeniculum vulgare* Mill. which was internationally increased in the last decade.

ACKNOWLEDGMENTS

The authors are grateful to all the researchers of the available literature sources consulted and to all the informants who freely shared their knowledge. This work was supported by a grant of the Romanian Ministry of Research and Innovation, CCCDI - UEFISCDI, project number PN-III-P1-1.2-PCCDI-2017- 0850/ contract 14 PCCDI /2018, within PNCDI III.

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