The Story of India's Mint Oils and Menthol

Cornmint, menthol, peppermint, *Mentha citrata*, Scotch spearmint and Native spearmint*

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All mints (known as *Pudina* in Hindi) are *Mentha* species that are members of the Labiatae or Lamiaceae family. There are 18 *Mentha* species and 11 hybrids (Tucker and Naczi, 2007) that are either cultivated or found in their natural habitat, which results in a wide compositional diversity found both within and among the species. Consequently, all commercial mint oils produced are from cultivated species or hybrids.

In recent years, 80% of the cornmint grown in India is the 'Kosi' cultivar pictured here.

All *Mentha* species are perennial, herbaceous plants with opposite leaves and quadrangular stems. They possess capitate, spicate or verticillate flowers that range in color from white to purple. The leaves contain both capitate and peltate glandular trichomes within which the essential oils can be found. All of the *Mentha* species cultivated for oil isolation are either sterile, or if they produce seeds, they are still clonally reproduced.

A survey of the *Mentha* species growing in India reveals that only two subspecies of *Mentha longifolia* L. [*M. longifolia* subsp. *hymalaiensis* Briq. and *M. longifolia* subsp. *royleana* (Benth.) Briq.] have been found to be endemic to the Himalaya region of India. Currently, India cultivates five commercially important mints (*Mentha* taxa) from which oils are produced. They are:

- ***Bergamot mint, or* Mentha citrata *oil:*** *M. aquatica* L.var. *citrata* (Ehrh.) Fresen [syn. *M. citrata* Ehrh.; *M.* x *piperita* L. subsp. *citrata* (Ehrh.) Briq., etc.].
- ***Cornmint oil, or Japanese mint:*** *Mentha canadensis* L. [syn. *M. arvensis* L. f. *piperascens* Malinv. ex Holmes; *M. arvensis* L. subsp. *haplocalyx* Briq. var. *piperascens* Holmes; *M. haplocalyx* Briq.; *M. sachalinensis* (Briq.) Kudo, etc.].
- ***Scotch spearmint oil:*** *Mentha x gracilis* Sole (syn. *M. cardiaca* Gerarde ex Baker, *M. gentilis* Auct. non L., etc.).
- ***Peppermint oil:*** *Mentha x piperita* L. var. *piperita*.
- ***Native spearmint oil:*** *Mentha spicata* L. subsp. *spicata* (syn. *M. spicata* var. *viridis* L. etc.).

Introduction to Cornmint

As cornmint is by far the most important mint grown, it is important to put its origin in perspective. Mint (cornmint) was introduced into Japan from China ca. 1,750 years ago; the oldest record of its use in traditional medicines was in 984 during the Song Dynasty (Liu and Lawrence, 2007). The first record that mint (cornmint) was being cultivated can be traced back to the Ming dynasty (1368–1644). During that time the plant was only used in traditional medicines. Menthol was first isolated by freeze crystallization from oil produced from the commercial cultivation of cornmint in Yamagata prefecture in the 1870s (Hiraizumi, 1959).

By the beginning of the 20th century, oil production in Japan had increased to more than 100 mt. A summary of the production of crude cornmint oil and menthol in Japan can be seen in **T-1**.

After the great earthquake in Tokyo in 1923, approximately 200,000 citizens emigrated to Brazil. Some of these Japanese expatriates were cornmint farmers, who brought with them planting stock and knowledge of oil and menthol production. By 1943, oil production in Brazil had grown to ca. 80 mt. However, because of the subsistence farming practices in Brazil, cornmint was farmed using the "slash and burn" system. As a result, cornmint cultivation, oil and menthol isolation quickly expanded to virgin land across the Paraguayan border. A summary of the production of crude cornmint oil and menthol in Brazil and Paraguay can be seen in **T-2** (Hopp and Lawrence, 2007).

T-1 Production of crude cornmint oil and menthol in Japan (metric tons)

Year	Crude oil	Menthol
1935	500	309
1938	887	233
1946	30	-
1956	330	40
1962	100	40
1968	180	50
1974	40	160*
1976	30	500*
1977	30	770*
1978	30	900*

*mostly synthetic menthol

* A version of this paper was presented at the 2012 Fall Seminar of the Women in Flavor & Fragrance Commerce in Saddle Brook, NJ.

The first large scale production of cornmint oil and menthol in China commenced in 1923 in the Shanghai area (Hopp and Lawrence, 2007). Information on the production amounts were not readily available in the early years of production. Production of crude oil and menthol in China from 1977–1999 can be seen in **T-3**. Since 2000, it has again become increasingly difficult to determine the cornmint oil and menthol production levels of China. This is because a lot of menthol powder is being imported into China from India and then being further processed and sold as Chinese menthol. Current cornmint oil production in China is estimated to be less than 1,500 mt, with most of it originating from Anhui province, while the menthol production from Chinese-produced cornmint oil is probably less than 500 mt.

The 'Shivalik' cultivar of cornmint, which originated in China and was introduced in the 1990s, was at one time the commonly grown cultivar.

T-2. Production of cornmint oil and menthol in Brazil and Paraguay (metric tons)

Year	Brazil (oil)	Paraguay (oil)	Menthol (Brazil & Paraguay)
1955	300	-	170
1962	2,000	-	930
1967	2,900	50	1,280
1973	6,300	180	2,940
1976	1,860	1,000	1,300
1980	400	1,500	700
1986	50	1,100	500
1990	30	400	300*
1995	-	25	400*
1999	-	10	300*

*mostly Indian menthol

T-3. Production of crude cornmint oil and menthol in China (metric tons)

Year	Crude oil	Menthol
1977	1,000	540
1979	2,500	1,400
1982	6,000	3,300
1985	8,000	4,300
1989	4,500	2,400
1993	5,500	3,000
1998	4,000	2,000
2000	2,800	1,500
2002	2,600	1,450
2004	2,300	1,300

Cornmint in India

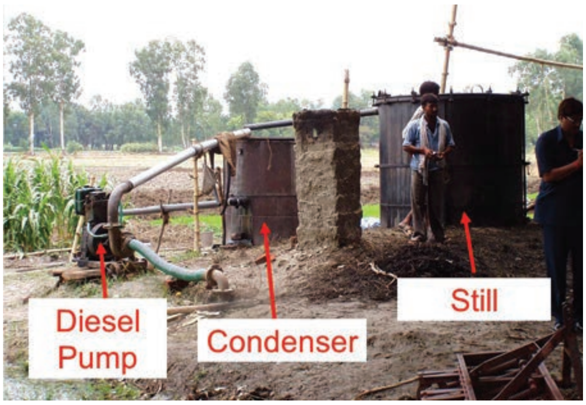
Prior to the 1960s, India was a net importer of L-menthol, dementholized cornmint oil (DMO) and the other mint oils. It is of interest to note that as early as the 1880s menthol was considered to be a valuable commodity that should be produced in India (Virmani and Datta, 1979). To this end, locally available mints of unknown origin were introduced into different regions of India including the Forest Research Institute (FRI) in Dehra Dun (then Uttar Pradesh [UP], now Uttarakhand) where they were grown for a season. At that time, it was learned from the Japanese that menthol could be isolated from cornmint oil by chilling it. Although the oil produced at FRI smelled strongly of menthol, it did not deposit any crystals on cooling, so the project was abandoned.

In 1953, as a gesture in response to a visit to the Regional Research Laboratories (RRL) of Jammu-Kashmir by a Japanese Professor of Botany (who was working on *Ephedra* species; Kapoor, 1974), five suckers (stolons) of cornmint were sent to his Indian host (R.N. Chopra) as a Christmas present. Fortunately, these stolons did not get sterilized through the normal plant quarantine channel. They were initially planted in pots as they were still alive. After a season of planting in an experimental garden, it was determined that the plants yielded an oil very rich in menthol that was similar to the commercially available Japanese mint oil. Although there were a number of successful field trials of this mint in the late 1950s in different regions in the Jammu-Kashmir area, little interest was shown in this new potential crop until it was exhibited at the World Agricultural Fair in New Delhi (Kapoor, 1974).

As a result of the formation of the Central Indian Medicinal Plants Organization (CIMPO) in 1959 by the Council of Scientific and Industrial Research Organization (CSIRO), cornmint cultivation, oil production and menthol isolation became a major project. This project was undertaken by CIMPO at Haldwani (then UP, now Uttarakhand) and Jammu. Initially, a polyploidal cornmint cultivar was developed at RRL which had a higher oil content than the original. This higher-oil-yielding cultivar became known as 'Jammu mint.' As a result, the first commercial

Most of the cornmint is grown by small holders on land of less than one hectare; after harvesting the herbage, which is done by hand, it is allowed to air-dry before transporting it to a distillery.

A still being loaded with air-dried cornmint.



Many small holders either have their own locally made steam and water field distillation system (cost ca. $500–600) or are close to a distillery so that their herbage can be custom-distilled.

T-4. Production of crude cornmint oil and menthol in India

Year	Crude oil	Menthol
1970	40	25
1974	190	105
1983	400	200
1988	2,500	1,400
1990	2,800	1,500
1993	3,800	2,100
1996	6,200	3,400
2000	11,000	6,500
2003	15,000	9,000
2005	15,000	7,800

planting of this cornmint clone commenced in Bilaspur (Rampur district, UP) in 1964 (Kapoor, 1974).

During the period from 1960 to the mid-1970s, 'Jammu mint' was the only cultivar used to produce cornmint oil and menthol. This menthol production allowed India to start to become self-sufficient in the commodity as can be seen from their production statistics shown in **T-4**.

Once cornmint had become established as a viable new crop that would allow India to produce its own menthol, Richardson Hindustan Aromatics Ltd. (now P&G) and M/S Bhavana Chemicals Ltd., set up their own small scale cultivation, oil distillation and menthol isolation processes in the Tarai region of UP (Kapoor, 1974). From that time onward, cornmint cultivation continued to expand into the areas around Bareilly, Rampur and Moradabad (UP). However, oil and menthol production stagnated in the 1970s because of the low oil yield and high cost incurred during menthol isolation. As no formal selection or breeding program had been established for the cornmint, there was some genetic deterioration in the cultivar resulting in lower oil yields (<0.4%) than originally experienced, and a reduced menthol content (ca. 60%) in the oil (Hussain, 1993).

To address the problems facing the farmers that were cultivating cornmint, a genetic improvement program was initiated by Central Institute of Medicinal and Aromatic Plants (CIMAP, formerly CIMPO) in 1978, the objective of which was to improve the oil yield and increase its menthol content. Initially a collection of germplasm from throughout Asia was made, from which a variant of the Thai strain ('MA-3') was selected to be a promising candidate for breeding and selection. One such selection known as 'MAS-1', which possessed a much higher oil content (>0.5%) and was richer in menthol (>70%), was released to the cornmint farmers in 1983 (Husain, 1989). Unfortunately, although 'MAS-1' was resistant to leaf rust, it was susceptible to two other damaging fungal diseases (leaf spot and powdery mildew) and produced narrow, less robust stolons (Kumar et al., 2007).

As a result of cross pollination studies and selections, new cornmint cultivars have been introduced over the years to address plant morphology, herbage yield, leaf to stem ratio, disease resistance, resistance to insect attack, ease of reproducibility, robustness, susceptibility to water-logging, drought resistance, crop season length, oil yield, and menthol content of the oil requirements.

The cultivars that have been introduced over the years are:

- 'Kalka' (also known as HYB-77) isolated from 'MAS-3' (Anon., 1985), introduced in 1990.
- 'Shivalik' originated from China (Kumar et al., 1997), introduced in the 1990s.
- 'Gomti,' an offspring of 'Shivalik' (Kumar et al. 1999a), introduced in 1994.
- 'Himalaya,' a hybrid of 'Gomti' and 'Kalka' (Kumar et al., 1997), introduced in 1997.
- 'Kosi,' an offspring of 'Kalka' (Kumar, 1999b), introduced in 1999.
- 'Sambhav,' a somaclone of 'Himalaya' (Khanuja et al., 2001a), introduced in 2000.
- 'Saksham,' a somaclone of 'Himalaya' (Khanuja et al., 2001b), introduced in 2001.
- 'Kushal' (Vaze, 2003), introduced in 2002.
- 'Damroo,' a progeny of 'Shivalik' (Patra et al., 2000a), introduced in 2009.
- 'Saryu' (Sundaresan, 2011), introduced in 2010.

It is important to note that CIMAP has developed cultivar-specific DNA-fingerprints for these and all mint cultivars to ensure that they can measure and maintain the purity of the cultivars being grown commercially (Kumar et al., 2007).

Of the more recently introduced cultivars, 'Saksham' was characterized by possessing an increased herbage yield/ha, faster regeneration after harvest and an increased oil yield. 'Kushal,' another important cultivar, has been found to be very adaptable to changing conditions and is particularly tolerant of water-logging. It is richer in oil than all of the other cultivars, with an approximate yield of 177–198 kg/ha (Vaze, 2003). Prior to 2000, 'Shivalik' was the major cultivar of cornmint grown. More recently it can be seen that more than 80% of the cornmint grown in India is the 'Kosi' cultivar. It takes time for the wider acceptance of these more recently introduced cultivars.

In the early 1960s it was estimated that India imported ca. 200 mt of menthol (main product) and dementholized cornmint oil (DMO). By the 1965–1966 season the importation had dwindled to ca. 50 mt. Between the mid-1960s and mid-1980s, cornmint cultivation and the opening of numerous small and medium-sized distilleries spread throughout UP to Bareilly, Chandusi, Moradabad, Rampur and Sambhal (Gupta, 1993). From 1985–1995, the area devoted to cornmint expanded to the UP districts of Barabanki, Fatepur, Gorakhpur, Lucknow and Sitapur (Vaze, 2003).The production statistics for cornmint oil between 2004 and 2012 can be seen in **T-5**.

Initially, the Indian production satisfied the internal Indian requirements for menthol; however, it soon picked up the additional menthol market requirements because production in Brazil and Paraguay could not compete with the Indian prices, so production there almost ceased. Since then, India has displaced China as the major menthol manufacturer because China's production has declined in favor of importing Indian powder menthol to be processed into "Chinese menthol." Production of menthol between 2004 and 2012 can be seen in **T-5**.

It is estimated that in India there are ca. 85,000 ha devoted to cornmint cultivation with ca. 1,300,000 people involved with cultivation, oil and menthol isolation in the following five areas in the Indo-Gangetic plains:

- Hoshiarpur, Amritsar, Jalandhar and Ludhiana districts of the Punjab
- Ambala and Yamunanagar districts of Haryana
- Nainital and Udam Singh Nagar districts of Uttarakhand
- Moradabad, Rampur, Bareilly, Badaun and Basti districts of northern UP
- Barabanki, Sitapur and Lucknow districts of central UP

Over the past five years, cornmint cultivation has spread to the eastern districts of UP and into Bihar and Himachal Pradesh (Kumar et al., 2007).

Introduction to Peppermint

Peppermint, or *Mentha piperita* (2n=72), is a sterile hybrid of the cross between a high menthone clone of *Mentha spicata* (2n=48) and a high menthofuran clone of *Mentha aquatica* L. (2n=96) (Udo et al., 1962). This origin was proved by Murray (1972), who performed the natural hybridization using the two parents to produce progeny whose oils possessed the typical peppermint oil composition and profile.

There are three recognized varieties of peppermint.

- Black peppermint, (Mitcham mint or selections of the same such as Italo-Mitcham mint, etc.): *Mentha piperita* L. var. *piperita*
- White peppermint: *Mentha piperita* L. var. *officinalis* Sole
- Crispy-leafed peppermint: *Mentha piperita* L. var. *crispa* (Benth.) W. Koch

Only Black, or more commonly Mitcham, peppermint has ever achieved any value as a source of peppermint oil because it has a much higher oil content than the other varieties and a more refined peppermint aroma.

Peppermint in India

Peppermint was first introduced into India during the British period, where it was treated as a garden crop until the commercial production of peppermint oil was developed in the late 1950s by RRL in Jammu. The director of RRL obtained stolons of Black Mitcham peppermint from Kew Gardens in England (Atal, 1979), and after some pot experiments, it was field planted to yield an oil from fresh herbage (0.2% yield) in the Haldwani area (Gulati et al., 1973).

In the late 1980s, CIMAP launched a selection and breeding program for peppermint, resulting in the introduction of the cultivar 'Kukrail' in 1994, which was a mutant of the local strain (Anon., 1994). In the early 2000s, the 'Pranjal' cultivar (Dwivedi et al., 2001a), the 'Tushar' cultivar and the 'Madhuras' cultivar were introduced (Khanuja et al., 2004). This latter cultivar is an oil-rich selection of 'Kukrail.' The following year, a menthofuran-rich cultivar known as 'Indus' (Khanuja et al., 2005) was introduced; however, this latter cultivar has not attained any sizable production level as yet.

In 1973, the average annual Indian importation of peppermint oil was ca. 30 mt. By 1992, India had become self-sufficient in peppermint oil as production had increased to 100 mt. This production has further increased over the years as can be seen in **T-5**. It is estimated that more than 15,000 ha in India are devoted to peppermint with the main areas being around Bareilly, Pilibhit and Shahjahanpur districts (UP) where some 210,000 people are involved with all facets of the crop and its oil production.

T-5. The production figures for Indian mint oils and menthol (metric tons)

Year	Cornmint	Menthol	Peppermint	*Mentha citrata*	Scotch spearmint	Native spearmint
2012	34,500	23,500	650	35	16	180
2011	32,000	22,400	570	35	10	210
2010	24,000	16,800	590	30	8	160
2009	30,000	21,000	500	30	10	160
2008	23,000	16,100	450	30	10	150
2007	28,000	19,600	450	30	15	150
2006	24,000	16,800	400	30	15	120
2005	18,000	12,600	350	30	10	100
2004	14,000	9,800	300	20	10	70

Introduction to *Mentha citrata*, or Bergamot Mint

Bergamot mint oil, which is obtained from a variety of *M. aquatica,* was once thought to be a hybrid between *M. aquatica* and *M. spicata.* It is native to Europe where it is known as bergamot mint, lavender mint or even sometimes as lemon mint. Unlike the other mint oils, bergamot mint oil is primarily used in the perfumery and cosmetic industries rather than the flavor industry.

Mentha citrata, or Bergamot Mint, in India

The bergamot mint plant was introduced in 1959 into the Jammu-Kashmir region of India. Before 1970 it was only grown in the experimental gardens of the various RRLs. Bergamot oil was first produced in the 1970s from several clones imported from both the United Kingdom and United States (Atal, 1979); however, the oil yield and quality did not meet the requirements of commerce. As a result of selection, induced mutations and agronomic studies at CIMAP, a sterile mutant clone called 'Kiran' was selected for commercial introduction as a source of an oil that was rich in linalool (48%) and linalyl acetate (38%) (Anon., 1988).

Commercial production of bergamot mint oil began toward the end of the 1980s. It was reported that oil production at that time was 20–30 mt (Krishnamoorthy, 1989). Over the years data on the production of bergamot mint oil has varied from a low of 10 mt to a high of 60 mt, depending on who was reporting the data. Gupta (1993) noted that in the early 1990s the area under bergamot mint cultivation had expanded to 500 ha. It is surmised that the prices and market requirements for bergamot mint oil along with the competition of market and financial returns on the other mint oils are the real determining factors for the amount of oil to be produced. A summary of the production levels of bergamot mint oil over the past few years can be seen in **T-5**.

Introduction to Native Spearmint

Mentha spicata is cultivated throughout the world as an herbal crop. Although Native spearmint originated in England, only a limited cultivation still exists there. It was initially introduced into the United States in the mid-15th century. By the early 17th century it had become an important crop in Massachusetts. Over the next 200 years, Native spearmint cultivation spread West first to the Midwest and then to the Pacific Northwestern states (Landing, 1969).

Mentha spicata is sterile (2n = 36), so it can only be reproduced by vegetative methods.

Native Spearmint in India

The British introduced Native spearmint into India, where it is grown as a garden crop, the leaves of which are used as a condiment. It was initially introduced into India in the early 1950s (Hussain, 1993). Although spearmint farming and oil production had commenced, there was not enough grown commercially for oil production to supply the flavor needs of the Indian confectionery and oral-care industries. Unfortunately, there was no support to expand spearmint growing and oil production because of the poor oil quality and low oil yield. According to Atal (1979), numerous genotypes of garden spearmint were collected at RRL from across India. This screening of genotypes did not reveal any high-oil-yielding

On cooling cornmint oil, the temperature at which the menthol congeals is measured; the farmer receives payment for the oil based on the menthol content determined from the congealing point.

Blocks of menthol from the second stage of crystal isolation standing on a drip table to release the remaining DMO.

strains rich in carvone that were fit for introduction on the commercial scale.

To address the lack of a commercially viable Native spearmint cultivar, CIMAP introduced a strain of Native spearmint from the United States in 1978 that possessed an oil yield double that of the existing strains and a high carvone content (Hussain, 1993). A selection of this strain, which was known as 'MSS-1,' was released by CIMAP to farmers in 1984 (Husain, 1989). Since then other cultivars have been introduced. The first being 'MSS-5' whose oil content and carvone content were 0.55% and 65%, respectively (Anon.,1994). A cultivar, 'Arka,' whose oil and carvone contents were 0.6%, and 68%, respectively, has also been introduced (Anon, 1993).

The other cultivars that have been introduced over the past years were 'Supriya' (Anon, 1987), 'Neera' (Patra et al., 2000b) and 'Neerkalka,' the latter of which possesses an oil content of 0.8% and a carvone content of 72% (Bahl et al., 2000). 'Neerkalka' is a selection of the progeny of the hybrid between the 'Neera' cultivar of *M. spicata* and the 'Kalka' cultivar of *M. canadensis* (Kumar et al., 2001). A cultivar known as 'Punjab spearmint-1' is also under limited cultivation. Finally, there is also a strain of *M. spicata* known as 'Ganga,'which is been widely grown in India; however, it is not used as a source of Native spearmint oil (Khanuja et al., 2001c).

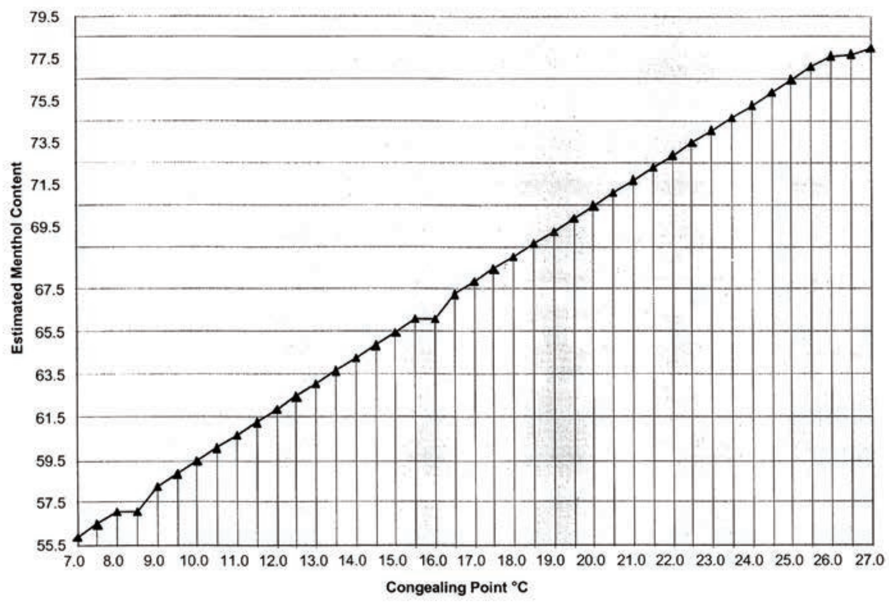
In 1982, only 2 mt of Native spearmint oil were produced; however, by 1992 this had grown to 150 mt (Husain, 1993). The current level of production of oil can be seen in **T-5**. It is estimated that in India there are ca. 8,000 ha devoted to the cultivation and production of Native spearmint oil in the Bareilly and Badaun districts (UP). It is estimated that the number of people supporting the cultivation and production of Native spearmint mint oil is around 112,000.

Introduction to Scotch Spearmint

The name Scotch spearmint was given to a mint that was being grown in a Wisconsin garden. As this spearmint originated from Scotland this became locally known as Scotch spearmint, a name that has become synonymous with this very pleasant smelling, important commercial oil.

Like Native spearmint, Scotch spearmint is cultivated for oil production in both the Midwestern and far Western states. More recently, southern Alberta (Canada) has become a sizable producer of Scotch spearmint oil. Also, it has been determined that the main spearmint being grown for oil production in China is the sterile hybrid *Mentha gracilis,* which originated from the United States (Morris, 2007). The Chinese oil is offered at a variety of carvone contents because it is fractionally distilled to increase its carvone content. Also, as China has become a leading supplier of synthetic L-carvone, Chinese spearmint oils must be examined for adulteration.

F-1. Estimated menthol content with respect to congealing point



Scotch Spearmint in India

A strain of Scotch spearmint was introduced into India from the United States in 1985, from which, in 1988, an improved clone was selected and introduced into cultivation by CIMAP as 'MCAS-2' (Sundaresan, 2011), and a second cultivar 'Pratik' (Dwivedi et al., 2001b). As these cultivars are not a high oil yielding plants (<0.5%) the production of Scotch spearmint oil in India has never achieved any true commercial position in the international marketplace. A summary of the production levels of Scotch spearmint oil over the past few years are seen in **T-5**.

From Cornmint Oil to Menthol

Cornmint is being grown in a wide number of soil types, particularly soils from a sandy-loam to heavy clay whose pH is between 6.5–9.0 (Kumar et al., 2007). As cornmint is vegetatively propagated, stolons are typically planted either from the last week of December to the last week of February (early planting) or from the first week of January to the first week of March (late planting). Late planting tends to result in reduced herbage and oil yields. Although cornmint is a perennial, it is treated as an annual because it is a 90–115 day crop. As a result, it becomes part of a crop rotation scheme with other crops such as sugar cane, wheat, rice, maize, sorghum, *Brassica*, lentils, peas, chick pea, potato, onions, etc.

Most of the cornmint is grown by small holders on land of less than 1 ha. After harvesting the herbage, which is done by hand, it is allowed to air-dry before transporting it to a distillery. Many small holders either have their own locally made steam and water field distillation system (cost ca. $500–600) or are close to a distillery so that their herbage can be custom-distilled. Most of the farmers have stills capable of distilling 500–700 kg in 5–8 hr (Kumar et al., 2007). A limited number of farmers who have tracts of cornmint of 10 ha or more have invested in a steam distillation system (cost ca. $10,000–12,000). These systems generally are constructed to distill up to 3,000 kg/batch.

Once the oil is produced, the farmer can either sell it directly at a collection center for one of the large menthol processors, or hold on to the oil and speculate on the future oil price. Oil delivered to a collection or receiving center is first of all filtered into a clean 200 kg mild steel drum and tested for its water content, vegetable oil contamination and menthol content. The menthol content is measured by placing a sample in a test tube which is inserted with a thermometer. On cooling the oil, the temperature at which the menthol congeals is measured. This temperature is then compared to a chart from which the menthol content can be determined (**F-1**). More recently, Singh and Sharma (1994) developed a more detailed congealing reference in which not only the amount of menthol could be determined, but also the levels of menthone and menthyl acetate. Once the menthol content of the oil is determined the farmer is then paid immediately in rupees.

Purchased oil at the collection center is transferred to the menthol isolation facility where it is subjected to the following process steps:

1. At the factory, the oil is initially bulked. Most companies subject the oil to vacuum distillation to remove any unpleasant distillation odors, *cis*-3-hexenol, the low molecular weight aldehydes and dimethyl sulfide.

2. The oil, whose menthol content is ca. 68–78%, is transferred to slightly tapered galvanized steel containers that are placed upright in a deep freezer whose temperature can be as low as -40°C. This process is known as fast crystallization which causes the menthol to form a block of very small crystals known as powder menthol.

3. Once the block of powder menthol is formed the container is removed from the deep freeze and inverted onto a drip tray where any oil clinging to the block of crystals is allowed to drip away.

4. After all of the occluded oil has been removed the block of powder is broken up and centrifuged to further remove residual oil (DMO).

5. The powder menthol is then melted and transferred to a heated container where it is mixed with a small amount of oil to form a an enriched menthol solution with a menthol content of 88–94%; the level depends on the companies' processes.

6. The hot enriched menthol solution is then transferred into a second set of upright tapered stainless steel containers that

are arranged in large horizontal well-insulated freezers within which the cold contact to the containers is from the bottom.

7. A temperature differential is maintained within the container by a light bulb above the top of each container so that crystal formation will be from the bottom to the top.

8. A seed crystal is added to each container to speed up the crystallization process.

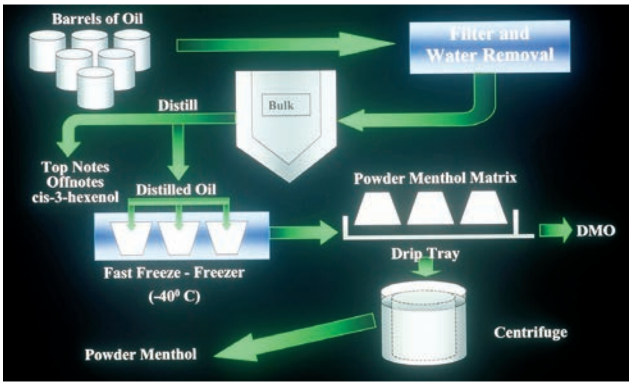
9. The temperature of the bottom and top of the containers is carefully controlled with a regimen that allows the production of large crystals of menthol that grow up from the bottom of the container. Typically the temperature is decreased to -10°C over a period of 15–35 days, the timetable being equipment- and company-specific.

10. Once the container has become filled with large crystals, it is inverted on a second drip tray where any occluded residual oil is removed by gravity. Some companies use mild centrifugation of the block once it is carefully broken up to further remove any residual oil.

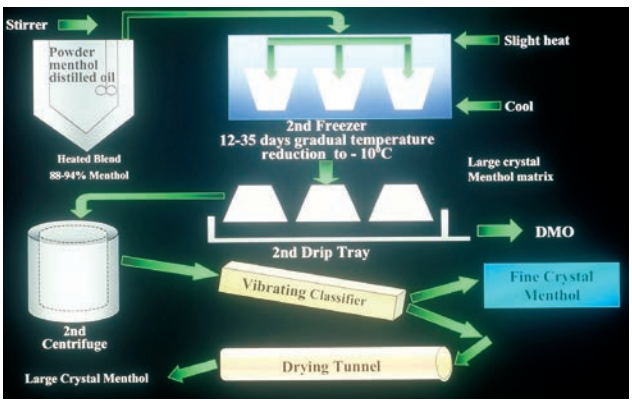
11. The menthol crystals are then carefully sieved or graded into various sizes (large, medium, small or powder). At this stage any malformed crystals are carefully removed and set aside to be used as seed crystals.

12. The large, medium and small crystals are further dried using a variety of processes to further remove the miniscule amount of oil held by surface tension on the crystals.

F-2. Schematic representation of the menthol production process, part 1 of 2



F-3. Schematic representation of the menthol production process, part 2 of 2



13. The pure menthol of various size crystals is packaged either into poly-lined 25–50 kg fiber drums or corrugated boxes for sale.

A diagrammatic representation of the two stages of menthol isolation can be seen in **F-2** and **F-3**.

Market Conditions

As a result of the liberalization of India's National Agricultural Policy, the government has lifted all restrictions and permitted futures trading on all commodity agricultural products including menthol and the mint oils in 2003 (Sahadevan, 2008).

As production of menthol and the mint oils are basically seasonal, prices tend to fluctuate depending on the crop season and off-season. Unfortunately, because of this seasonal effect prices are susceptible to speculation, Sahadevan (2008) believes that this makes menthol and mint oils ideal candidates for futures trading.

In India there are three national commodity exchanges that offer futures:

- Multi Commodity Exchange (MCX)
- National Commodity and Derivatives Exchange (NDEX)
- National Multi Commodity Exchange of India (NMCEIL)

The standard trading and delivery unit for menthol and mint oils is 350 kg and 720 kg, respectively.

The benefits of futures trading for mint oils and menthol include:

- Future prices for menthol and oils are known.
- Future contracts are used for price-risk-management.
- National online markets offer continuous auction of contracts which theoretically automatically stabilizes any supply and demand imbalances.
- Futures trading becomes an excellent source of price statistics and the dissemination of market information.

Disadvantages of futures trading for mint oils and menthol include:

- The general awareness of futures trading in mint oils and menthol by farmers is low.
- Many farmers are not able to access the futures market because they lack the critical minimum size of units for lots of oil.
- Many farmers do not want to offer their oil for sale during the May–July season when the prices of oils are generally at their lowest.
- Many farmers do not trust the futures market because of hedging by speculators.
- The futures market that was set up for use by producers and consumers has been taken over by traders who are nothing more than gamblers.

In 2012, a tobacco chewing product known as *gutka*, which is a large consuming category of menthol, was banned for sale in India. As the gutka industry uses up to 20% of India's annual menthol production, it could have an effect on the prices and availability of menthol.

Finally, natural menthol completes with the chirally pure synthetic menthol, which is produced in quantities by Symrise and Takasago (Hopp and Lawrence, 2007). More recently, BASF has announced that it is entering the synthetic menthol market (Bergner et al., 2010).

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