TECHNICAL REVIEW

Optimising flavour in mint

Figure 1. For optimal flavour, harvest mint when plants are fully mature, but before flower initiation

Action points

- **Where possible, maintain a consistent daytime temperature of, or around, 23°C to promote production of aromatic compounds**
- **Use supplementary lighting where possible to artificially increase day length, as mint flavour is improved in long day conditions**
- **Harvest when plants are fully mature for a strong flavour, but before flower initiation as this affects the quality (Figure 1)**
- **Maintain temperatures of 0–2°C throughout postharvest storage, to reduce respiration and and the development of off-flavours**
- **Avoid stress conditions, such as high UV exposure or water deficit**

This technical review focuses on the chemical basis of flavour in fresh cut and potted mint grown in the UK. It provides information explaining factors which can influence flavour, both positively and negatively, and also gives advice on growing practice and available technologies to maximise flavour while maintaining yield and other quality attributes. Plant health and nutrition, available light and temperature during growth, harvest time and temperature during the supply chain all affect flavour in mints.

Introduction

Mint grown in the UK is primarily one of two species. *Mentha* x *piperita* is peppermint, while *Mentha spicata* is spearmint. Peppermint is a sterile hybrid of *M. spicata* and *M. aquatica* (water mint) and has a different profile of volatiles to either parent. This guide relates only to fresh cut and potted mint and focuses on spearmint and peppermint.

New varieties are slow to develop due to the complexity of the mint genome and the sterility of some varieties. The taste of mints is comparatively simple, as it is predominantly governed by a few compounds produced mostly by specialised glands in the leaves, but also elsewhere in the plant. Leaves are the greatest source of volatile flavour compounds in mints.

Flavour components

The characteristic flavour compounds of peppermint are menthol and its derivatives, which give a cooling sensation, and the typical mint aroma. In spearmint, the main flavour compounds are carvone and eucalyptol (1,8-cineole) which also combine to give a cooling sensation and the fresh minty flavour associated with spearmint, although in each case there are hundreds of minor flavour components which can alter perception of flavour. Table 1 shows a brief list of the main compounds in mint species, each of which contribute to the flavour of mints according to their relative concentration and their sensory detection threshold.

The most relevant flavour compounds found in mint volatile oils are of the monoterpene class, and are structurally similar. This is because they are derived from the same metabolic pathways, with strong genetic regulation. In peppermint, menthone is the precursor to menthol, the main component characterising its taste, although menthone also often accounts for a large proportion of the essential oil. Pulegone is considered an off taste, and is often only present at high levels in stressed plants. Menthyl-acetate has been implicated as being essential to a superior-tasting mint variety, but only up to concentrations of around 8–10%.

In spearmint, carvone is the main flavour component and often accounts for 75% or more of the total essential oil content. Other precursors are not thought to harm the flavour to a great degree, although carvyl acetate can impart a garlicy off-flavour (Figure 2).

Table 1. The most abundant constituents of mint oils, the species in which they are found, and the aromas for which they are responsible

Name	Chemical class	Aroma	Species dominant in
Menthol	Monoterpene	Fresh, minty (camphorous and musty in rare D-menthol form)	*M. piperita, M. spicata, M. aquatica, M. arvensis*
Menthone	Monoterpene	Bitter, woody, minty	*M. piperita, M. spicata, M. arvensis, M. pulegium*
Pulegone	Monoterpene	Sweet, camphor, undesirable	*M. piperita, M. spicata, M. pulegium, M. aquatica*
Menthyl acetate	Monoterpene	Fruity, tea-like minty	*M. piperita, M. arvensis*
1,8-cineole (eucalyptol)	Monoterpene	Spicy, herbaceous, camphor	*M. piperita, M. spicata*
Menthofuran	Monoterpene	Musty, nutty, earthy	*M. piperita, M. spicata*
Carvone	Monoterpene	Herbal, *M. spicata*, fresh	*M. spicata*
Piperitone	Monoterpene	Minty, bitter	*M. piperita*
Limonene	Monoterpene	Citrus, terpenic, fresh	*M. spicata, M. arvensis*

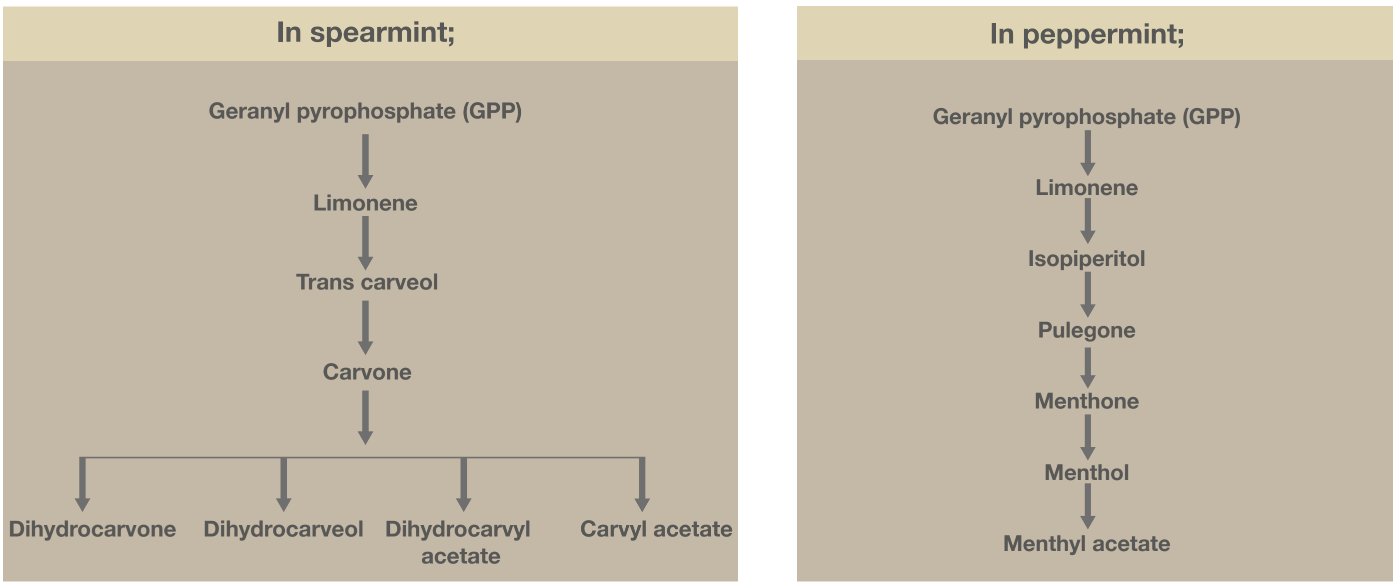

Figure 2. Metabolic pathways giving rise to flavour profiles in spearmint and peppermint

Tables 2 and 3 rank the major chemicals in a typical peppermint and spearmint sample by their overall influence on flavour in the herb. This is based on the total abundance of a chemical, as well as its detection threshold. Mint may contain other minor components which influence the flavour, for example 0.01% thymol is said to impart a phenolic or medicinal off-taste in peppermint. Its detection threshold is 450 times lower than that of menthol. Intensity of flavour is seen as an important quality aspect, but as most varieties are dominant in one or two chemicals, research is focused on these. Less is understood about the overall effect of minor constituents on consumer preference.

Table 2. Compounds found in peppermint, [1] and a typical concentration (percentage of essential oil), the minimum threshold at which they can be detected, and their relative contribution to flavour based on these two factors. Menthol and menthone are the most critical compounds to the flavour of peppermint

Peppermint				
Compound	Flavours associated	Concentration (% of essential oil)	Taste threshold (ppb)	Relative intensity (% contribution)
L-(-)-Menthol	Cool, balsamic,	25.3	3.9	46.0
Trans-p-Menthone	Minty, balsamic, medicinal	26.5	3.3	35.3
Cis-p-Menthone	Minty	5.17	4.2	7.6
Neomenthol	Minty, sweet	3.64	4.7	3.1
α-Pinene	Pine, resin	0.88	2.5	2.1
Piperitone	Cumin, anise	1.22	2.9	1.9
Cis-Menthylacetate	Infusion, dry herb	0.28	2	1.7
Linalool	Floral	0.82	2.8	1.5
Trans-Ocimene	Medicinal	0.03	1.7	0.4
α-Terpinene	Floral	0.23	5	0.3
2,5-Diethyltetrahydrofuran	Toasty, roasted nuts	0.05	4.7	0.1
Hexanal	Herbaceous, green	0.02	3.3	0.1

Table 3. Compounds found in spearmint, [2] and a typical concentration (percentage of essential oil), the minimum threshold at which they can be detected, and their relative contribution to flavour based on these two factors. Carvone content is the single most important factor in defining the aroma of spearmint

Spearmint				
Compound	Flavours associated	Concentration (ppm)	Taste threshold (ppb)	Relative intensity (% contribution)
R-(-)-carvone	Spearmint	752,000	6.7	65.3
1,8-cineole	Eucalyptus	19,100	1.3	8.6
(E,Z)-2,6-nonadienal	Cucumber	332	0.03	6.5
Limonene	Citrus	97,100	10	5.7
β-damascenone	Apple sauce	14.7	0.002	4.3
(3E,5Z)-1,3,5-undecatriene	Tape	122	0.02	3.6
3-methylbutanal	Malty	921	0.2	2.7
Myrcene	Grassy, pine	21,300	13	1.0
Ethyl-2-methylbutyrate	Fruity	216	0.15	0.8
β-ionone	Floral, sweet	10	0.007	0.8
Methyl-2-methylbutyrate	Fruity	356	0.25	0.8
Hexanal	Herbaceous, green	0.02	3.3	0.1

Environmental effects and agronomic impacts

Mints typically respond with an ideal flavour profile under optimum growth conditions, and respond poorly to stress.

Maintaining consistent growing conditions throughout production, avoiding stress from sources such as water deficit, intense lighting or UV exposure is recommended. Good practice for plant growth will result in robust plants with a typical flavour profile. Micronutrients should be monitored to maintain high quality, while techniques such as supplementing light are a viable consideration to growers with the capacity to do so.

Cultivar

Peppermint cultivar has a significant effect on the total abundance of menthol with reported oil content of between 0.3% and 1.5% reported [3] and a variable response to environment [4]. Similar variation can be observed in spearmint, with total essential oil content recorded between 1 and 2% dry weight, as well as carvone content varying by up to 50% [5]. Growers must research the ideal variety for their production method and customer.

Fertiliser and nutrition

Nitrogen application in peppermint can have a significant positive effect on oil composition. Low nitrogen can lead to less menthol and menthyl acetate, and more menthone and eucalyptol. Ensuring adequate nitrogen fertilisation is essential to quality crop production as menthol and menthyl acetate are the most important chemicals in terms of flavour and will also help to maintain yield. High nitrogen fertilisation in spearmint increases total essential oil yield, but reduces the proportion of the desirable carvone, to the detriment of overall flavour quality.

Manganese is the micronutrient most positively correlated to production of terpenes, while cobalt and heavy metal ions have been found to reduce the levels of menthol [6]. Reduced levels of phosphorous are associated with higher levels of menthol in mature leaves, but also higher levels of the deleterious pulegone in young leaves.

An optimal fertilisation regime is needed for growth, as this also aids flavour in mint, however excess nitrogen in spearmint may adversely affect carvone content.

Biostimulants and growth regulators

Inoculation by the arbuscular mycorrhizae *Glomus etunicatum* may lead to higher levels of menthol, and improves the essential oil quality in both peppermint and spearmint [7]. It causes higher water retention by the plant, and increases total nitrogen, boron, zinc, copper and manganese. This leads to better growth, more leaf mass and higher photosynthetic rate. Mycorrhizae generally have the greatest effect in poor quality soils, but are also employed to lower fertilisation requirements.

Further research on using mycorrhiza is needed before any recommendations can be made as current understanding is limited, with no results directly related to flavour in crops grown in ideal growing conditions.

No specific information is available on use of growth regulators in terms of flavour.

Irrigation

Mints do not respond well to water deficit, with significant reduction of biomass and oil content. The highest level of menthol may be present under a slightly lowered water availability, at the expense of menthone and menthofuran but this does not appear to be consistent. It is not recommended to take action which significantly affects yield, for marginal gain in flavour.

Light quality

Light quality is important to plant growth, and different light wavelengths, which are interpreted by the plant as factors of shade, climate and altitude, can alter plant physiology. Light levels are known to influence volatiles produced by herbs within the Lamiaceae plant family.

UV light is known to affect the shikimate pathway involved in producing phenylpropanoids, flavonoids and amino acids, and the IPP (isopentenyl pyrophosphate) pathway involved in the production of terpenes, and therefore all the main flavour compounds. Glasshouse production cuts out large quantities of UV-B (wavelengths of 280 to 315nm), while natural shade and changes in sunlight throughout the year affect naturally available UV, although modern diffuse glass allows more UV light to pass through. Field grown plants, typically for cut production are exposed to higher UV-B than would be experienced under glasshouse conditions.

A high UV-A:UV-B ratio elicits a shade response, ideal to mints. Higher UV-B light decreases the total menthol content in peppermint and increases menthofuran and menthone, and so is disadvantageous. A higher proportion of UV-A typical of glasshouse growing leads to higher content of menthol, higher levels of phenolics, though smaller leaves. Complete absence of UV-B however is associated with lack of terpene production by halting the normal filling of glandular trichomes/oil sacs where essential oils are stored [8].

Blue and white light when applied together appears to have a similar effect on plant physiology as increase in UV-B, resulting in larger leaves, though lower terpene content and an undesirable ratio of menthol to menthofuran [6].

As mint is often field grown, environmental conditions such as weather and aspect will affect the light quality, as will the season. Where possible, shade conditions are ideal, as this results in a better chemical profile in both peppermint and spearmint.

Supplementary lighting, either by increasing the light intensity or by supplementary LED lighting to add to optimal light wavelengths where possible in glasshouses, is recommended. Ideal light conditions for peppermint are low blue light, or higher UV-A. Some UV-B is necessary to development of trichomes; a short period of supplementary lighting may be beneficial to glasshouse growers. Field grown mints typically prefer cool shaded conditions.

Day length

Time of harvest affects flavour, with crop grown early or late in the season being less favourable. This is likely a factor of light levels rather than quality, with long days significantly improving the ability of the plant to accumulate photosynthate.

As seen in Figure 3 the field grown mint season in the UK generally extends from March through to the end of October, months when at least 12 hours of daylight are available [9].

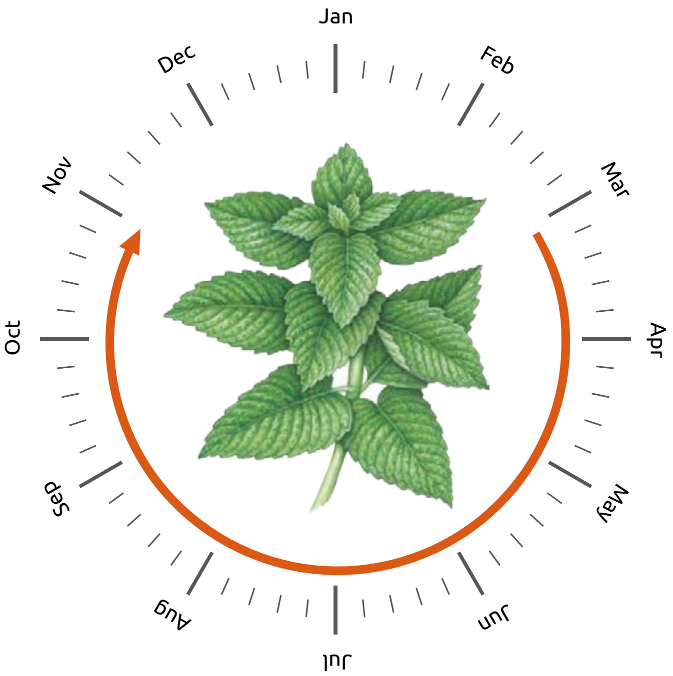

Figure 3. UK cut mint season shown in red. Mints are typically field grown, from early spring through to November

Plants grown in long day conditions (up to 21 hour days) appear to have the highest oil content and biomass yield [10]. Short days and cool nights limit growth and causes menthol to convert to menthone more rapidly, lowering the content of desirable menthol. Very short days result in physiologically young leaves, and can cut out menthol production almost entirely [11]. In the UK production is limited by day length, though glasshouse growers can extend the day by use of supplementary lights. Across mint species long days also lead to more rapid growth, though quicker flowering also occurs. Little is known on whether night break lighting is effective with regards to changing day length response.

Where possible, growers could control lighting as far as is practical under their growing system, for example by using supplementary lights. Approximately 12 hours lighting period is the minimum required for healthy crop development.

Temperature

Temperature ranges best suited to terpene production in mint are around 20 to 23°C. Summer months, especially in glasshouse production can be in excess of this, leading to release of volatile flavour compounds, while potted glasshouse production in winter will benefit from heating to promote growth and oil production.

Harvest time

Time of harvest across the day is little understood though common practice is to maximise shelf life by harvesting early while there is less field heat. In spite of higher field heat, sugar content will be higher at the end of the day, to the benefit of flavour, and if properly cooled, may also help shelf life as sugar content correlates to shelf life. Crops at the end of the season have lower essential oil content and a weaker flavour, especially if the crop has had repeated cuttings through the season.

Plant physiology

Terpenes in mint are held in glands on the leaf called trichomes, (shown in Figure 4) these take two main forms, peltate and capitate glandular trichomes. Most terpenes are primarily produced in capitate trichomes, though in peppermint most of these glands are of the peltate type, found on the upper side of the leaf. Levels of photosynthate correlate strongly to total volatiles, with conditions favoring photosynthesis being related to higher contents of menthol and eucalyptol and lower levels of pulegone – a healthy plant will have high levels of desirable flavour compounds.

Figure 4. [12] Scanning electron micrograph showing capitate glands on a peppermint leaf

The physiological age of leaves (size and maturity) affects the oil composition. Menthol in peppermint is primarily produced in leaves 12 to 20 days after emergence [13]. In peppermint, younger leaves at the top of the plant have a lower content of menthol and menthone than the older leaves lower down, but have a higher content of its precursors. Limonene levels are higher in younger leaves while eucalyptol appears not to be linked to leaf age. Spearmint has more glands in younger leaves, leading to a more intense flavour, though quality is less good in younger leaves due to lower levels of carvone.

Harvesting should be prior to flower initiation as the flavour composition and yield are ideal. In peppermint, the majority of leaves should ideally be at least 12 days old due to the initiation of menthol production at this time. Spearmint leaves also have higher content of the most relevant flavour components as the plant matures, though mature leaves of both species have lower oil content overall.

Post-harvest

Postharvest respiration is limited by consistent temperatures of about 0-2°C for cut mints and around 4°C for potted plant throughout the supply chain. Harvesting when temperatures are low, and careful handling of the herb reduces stress and susceptibility to infection. This will in turn reduce the presence of breakdown products such as aldehydes, which may impact on flavour even before physical degradation can be seen. Mint is climacteric and responsive to ethylene, the plant growth regulator associated with ripening and senescence, but does not respond well to application of 1-MCP (an ethylene blocker used to reduce ethylene based changes).

Careful handling should be employed and an appropriate post-harvest cold chain should be maintained. Removing field heat and maintaining temperatures of 0–2°C after harvest is ideal for cut herbs, as is use of polyethylene covering to reduce water loss. Modifying the atmosphere to increase carbon dioxide and reduce oxygen levels is recommended.

Low temperatures, and lack of physical damage will limit the risk of oxidation of fats leading to off flavours.

Conclusion

- Use appropriate varieties to suit your growing conditions and market. Varietal differences are likely to result in the greatest differences in flavour due to the specific variation in the metabolic pathways of terpenes
- Minimise biotic and abiotic stress to maximise the essential oil content and quality
- Where possible maintain long periods of high quality light
- Harvest when conditions are cool and minimise heat shock post-harvest. Handle with care throughout the supply chain to minimise degradation
- Harvest when plants are fully mature. Plants grown to greater maturity with fewer cuts throughout the season will lead to a more intense flavour and higher concentration in preferable oil constituents

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