TECHNICAL REVIEW

Optimising flavour in coriander

Figure 1. Vegetative growth leads to desirable intense flavour in coriander

Action points

- **Flavour in coriander is dominated by primary metabolites which are not greatly affected by the environment; however, stress conditions affect growth**
- **Avoid or limit environmental stresses, including stress from lighting conditions, as this elicits a defence response in coriander that changes a proportion of the metabolites to undesirable flavour compounds**
- **Promote vegetative growth and avoid conditions which lead to floral transition, such as long days, stress and varieties not adapted to long days, as increased vegetative growth correlates to strong flavour (Figure 1)**
- **Maintain a daytime temperature of less than 24°C to avoid a stress response**
- **Minimise post-harvest chain, maintaining a constant temperature of between 0°C and 2°C**

This guide is focused on coriander/cilantro (*Coriandrum sativum*) which is grown for the fresh cut and potted markets in the UK. Coriander is used for its leaves and the seeds are used for spice. There is also a market for oil production. The UK market is primarily driven by fresh herb sales, either cut pre-packaged herbs or whole live potted plants.

Information on flavour of coriander leaf is limited, with many studies focused only on seed production and flavour. The chemical basis for flavour in seed is very different to that of herbage. Other work looks at the human detection of flavour, as consumers differ in their detection of key components. More work is needed to fully understand the chemical basis of flavour and how it may be maximised.

Introduction

Coriander plants have been extensively bred and can be categorised in two broad types. One type is used for seed production, bolts rapidly and has a high yield of seed with relatively low vegetative material (typically these are used in India and South East Asia). The other type, which prevails in Europe, North America and Latin America is produced for its leaves and has a much longer vegetative period and is insensitive to day length. Breeding between these varietal groups may lead to different oil composition, but this carries the risk of reducing time to flowering in varieties grown for leaf, and therefore reduces yield.

In coriander, it is the primary metabolites, sugars, which are responsible for sweetness and aliphatic aldehydes, fatty acid derivatives, which are mostly responsible for the characteristic aroma, although some secondary metabolites are also relevant. As most flavour compounds are primary metabolites, coriander's response to environmental conditions is less flexible than for herbs which produce secondary metabolite flavour compounds which have a more flexible response to changes in the environment.

An off taste described as 'bug-like' is described by some consumers. Soapiness is also an undesirable taste detected by consumers. There is a genetic component in detection of soapiness with twin studies [1] showing that woman are more likely to detect soapiness in coriander than men. In the studies there was a difference between different ethnicities, mirroring cultural use. Nine per cent of Latin Americans and four per cent of South Asians who consume greater quantities of coriander are less likely to detect soapiness than Europeans or North Americans (13 per cent). Differences in a taste receptor 'OR6A2' is thought to account for the detection of this soap taste [2].

A typical coriander oil extract from leaves may contain around 50 individual components, which affect flavour to differing extents depending on their concentration and sensory threshold (Table 1).

The aliphatics (fatty acid derivatives) Z-2-decanal and dodecanols are the main contributors to coriander flavour. Their impact contrasts with their absolute concentrations with 1-decanol comprising almost 20 per cent of the oil content, but less than 0.2 per cent of the overall flavour due to different detection thresholds. Z-2-Decanal has a low detection threshold and contribute more to the flavour. Secondary metabolites eugenol and camphor also contribute around 8 per cent and 3 per cent of the flavour in coriander. β-ionone, with an aroma typical of violets contribute 12 per cent of the overall aroma of the variety studied by Eyres [3].

E-2-decanal is a fatty acid derivative which is structurally very similar to Z-2-decanal. It is associated with stress and poor flavour, and is largely associated with a strong 'bed-bug' aroma; reducing plant stress is important to preventing production of this off-flavour.

Table 1. Data from [3]. The main constituents of coriander aroma profile: Z-2-Decanal contributes the most to flavour, despite its low concentration. Conversely, 1-Decanol and E-2-Decen-1-ol contribute little to the flavour despite their much higher concentrations

Name	Aroma descriptors				% contribution to aroma	% proportion of volume	Intensity factor
Z-2-Decenal	Coriander	Aldehydic	Pungent	Spicy	18.25	0.16	114.06
E-2-Dodecenal, E-2-Dodecen-1-ol,1-Dodecanol	Coriander	Floral	Pungent	Soapy	14.04	10.16	
b-Ionone	Floral	Rrose	Violet		12	0.02	600.00
Eugenol	Medicinal	Eugenol			7.95	<0.01	>795
E-2-Decenal	Aldehydic	Fatty	Pungent		7.02	9.12	0.77
E-2-Tridecenal E-2-Tridecen-1-ol	Coriander	Pungent	Spicy	Soapy	5.4	0.55	
E-2-Tetradecenal, Tetradecen-1-ol	Pungent	Spicy	Aldehydic	Floral	4.55	7.92	
Decanal	Floral	Citronellol	Fruity	Green	4.08	6.56	0.62
Camphor	Aldehydic	Green			2.69	0.02	134.50
Octanal, Z-3-Hexen-1-ol acetate	Watermelon	Fruity			2.46	0.95	
E-2-Nonen-1-ol	Aldehydic	Floral			2.12	0.04	53.00
a-Terpinolene	Mushroom	Truffle	Mouldy	Earthy	1.81	0.02	90.50
Dodecanal	Pungent	Spicy	Floral	Citronellol	1.66	2.99	0.56
Pentadecanal	Pungent	Spicy	Woody		1.33	0.09	14.78
1-Decanol	Floral	Spicy			0.17	19.64	0.01
E-2-Decen-1-ol	Aldehydic	Wet Dog			0.39	26	0.02

Z-3-hexenal is also thought to be a major contributor to flavour [4, 5]. However due to the extraction method, this is not always detected and reported. This compound gives a typical green or grassy aroma, which is typical of most leaves.

The compounds most commonly associated with soapiness are E-2-tridecanal; this is also associated with the bug-like aroma, and tetradecanal, although the latter is not detected by all consumers as being soapy. Consumers fall into distinct groups according to their detection thresholds of soapy aromas and the putrid 'bed bug' like aroma but, beyond these broad groups, it is not understood what contributes to preference in coriander.

The metabolic pathways involved in the production of the flavour compounds is not well understood, although the underlying process is through oxidation of fatty acids. In terms of flavour modification, an important distinction is that the majority of flavour compounds in coriander are primary metabolites which are not typically changeable. Only a minority of the important flavour compounds are the much more adaptable phenylpropanoid and terpenoid pathways (Table 1); these are influenced by environmental conditions to a great extent. The impact of these on flavour have been reported as up to 26 per cent of the overall flavour, despite low absolute content in the leaves [3], but the factors affecting the concentration of these compounds in coriander are not well understood. Broadly speaking, they allow the plants to adapt to their environment and are altered by growing conditions such as light, temperature, and stress.

The overall content of the fatty oils can directly affect flavour with low oil leaves being seen as watery and insipid although, due to the low detection threshold of these, the overall content required for a quality herb is lower than in other species. The total content of the fatty oils is typically 0.2–0.5 per cent, compared to 2–3 per cent oil content seen in other herbs.

Available leaf sugars influence flavour, counteracting bitterness from polyphenols and adding a sweet taste. Young leaves or leaves of infected plants have substantially reduced free sugars. In coriander, the sugar content by Brix is high at around 7 per cent in healthy leaves [6].

Environmental effects and agronomic impacts

Data on flavour is limited, especially from the UK. Most research is conducted for the essential oil industry and focuses on seed oil, or otherwise is data from other leaf producing countries. More research is required, especially in understanding what consumers want from the herb with regards to flavour. In general, consumers prefer flavours that they describe as 'strong' and 'typical'.

Cultivar

Choice of cultivar is the best and most reliable means of maintaining a high quality product. The plant must have the inherent characteristics to make an economically viable crop, as well as the metabolic pathways to create the desirable flavour compounds in the ideal ratios. The composition of the essential oil, and therefore the flavour quality varies greatly between cultivar, with 2-3x variation in content of flavour compounds often reported. Cultivar response to the environment is also highly variable.

Studies of a broad range of coriander types in Iran has shown large differences in content of 2-decanoic acid, E-11-tetradecanoic acid, E-2-decanal, decanal, E-2-decanol and n-decanol [7]. The main differences between varieties are the content of compounds classed as alcohols or as aldehydes, which have an influence on the flavour intensity. There is however less difference between varieties in terms of the length of the fatty acid chain (which ultimately determines soapiness or bug-like flavour). As the metabolism of fatty acids is less influenced by environment than the production of other flavour compounds, changing variety is one of the most reliable ways of ensuring good flavour.

Fertiliser and nutrition

Little information on the impact of crop nutrition on flavour is available. Nutrient requirements of coriander are similar to other leafy herbs. Iron and zinc can increase oil content of coriander, but information on how this affects the overall flavour composition is limited. Optimum growing conditions are suggested to prevent proportional increases in E-2-decanal which may occur in stressed plants.

Biostimulants and growth regulators

Salicylic acid and ascorbate have been shown to increase the total oil content in trials in Egypt [8]. Spraying the plants with either increased their oil content, but applying both together produced a larger effect than either alone. It is not known how this impacts the composition of the oil or the overall flavour.

Such treatments are cultivar-dependent; further research is needed.

Irrigation

Mild water stress may increase pentadecanone, which is said to aid quality [7]. Water stress is however harmful to the vegetative growth and it is unknown to what extent the overall flavour profile is affected.

A Tunisian study [9] found that a salt level of up to 50mM (or 3g/L) increased content of E-2-Decanal significantly, but the total content of flavour compounds fell to very low levels at higher salt concentrations, suggesting that salt stress leads to deterioration in flavour. Dodecanals also rose by up to 50 per cent under mild salt stress and E-2-tridecanal concentration fell by 80 per cent with all levels of salt stress. These proportions may change under different conditions, but generally it appears that mild salt stress harms the flavour, while extreme salt stress causes loss of flavour and yield.

Coriander should be irrigated according to crop needs, to reduce the risk of a stress response.

Light quality

Use of netting cuts light intensity and can be used to manipulate the wavelengths to which the crop is exposed. Red netting increased the proportion of red light available, causing an increase in decanal, but at the expense of the healthful antioxidants; polyphenols and ascorbate. Purple and red-coloured netting resulted in better flavour, possibly because this allowed more light through than the black. Black netting resulted in herbs being rated as having the least typical aroma [10].

A higher level of both aldehydes and alcohols was seen in leaves, and particularly young leaves, when grown in intense light conditions in Turkey [11]. These conditions may not be applicable to UK growers due to the large difference in growing conditions, however it suggests that there is a benefit to growing in conditions with higher light, such as avoiding shade and using supplementary lighting for glasshouse-grown crops.

Day length

Time of harvest is a factor in maintaining flavour, with crop grown early or late in the season being less favourable. The typical UK coriander season is shown in Figure 2 [12], although modern glasshouse production extends this significantly with potted herb grown all year round.

Summer-grown coriander produces a higher yield and has a higher oil content than spring-grown herbs [13]. Longer days improve yield and oil content, but must be short enough to prohibit bolting. Most coriander varieties are day length sensitive, meaning they will flower only when the days are suitably long. This is a cultivar-dependent response. Conversely, shorter days delay the onset of flowering, which is undesirable to flavour, and allow for multiple cuts, increasing yield.

Growers should choose varieties which do not bolt under UK summer day length conditions however, until the point at which bolting is initiated, longer days are beneficial to the overall yield and content of flavour compounds. Glasshouse growers may benefit from supplementary lighting in winter months when days are short.

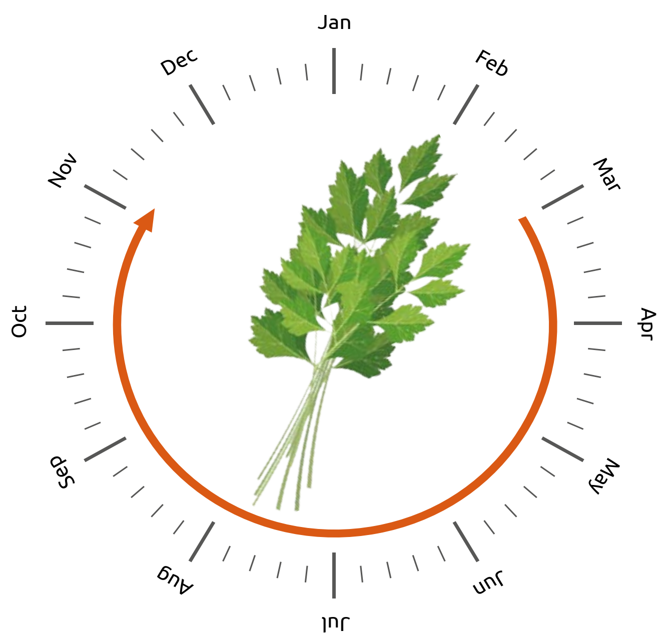

Figure 2. UK main cut coriander season shown in red. Coriander is mostly grown from May up till October although, with supplementary lighting, it can be grown under glass for an extended season

Temperature

Temperature affects volatile production. The maximum temperature for ideal growing is around 24°C, although there is no clear evidence to show its effect on flavour.

Plant physiology

The essential oils of coriander are produced within the cells, in all tissues of the plant, but primarily the leaves and stems. The composition of seed oils is very different, with few aliphatic compounds and more secondary metabolites, terpenes and phenylpropanoids.

Flower initiation (bolting) has a profound effect on the flavour of coriander. E-2-decanal in leaves has been reported to increase in content by 4000 per cent, resulting in a very strong undesirable aroma [14]. This change starts before the crop visibly bolts and so care must be taken to avoid flower initiation. Other components which change in concentration are borneol, dodecanal, linalool and E-2-tridecanal which all increase, while decanal content is reduced, although the effect of this on flavour is overwhelmed by the E-2-decanal.

Coriander is cut multiple times which can cause a stress response leading to an increased content of off-flavours from E-2-decanal, as well as E-2-decanol and nonane. Content of 1-decanol, oleic acid and phytol all fall after the second cut. The first cut will therefore have the lowest levels of E-2-decanal and the best composition of flavour chemicals. Subsequent cuts should be limited, as far as possible, from a flavour perspective.

Young leaves have fewer aldehydes and alcohols than older leaves when grown in Turkey in summer [9]. More research is needed to determine if young leaves grown under UK climate also have this difference. There is a greater variation in terpenoids such as camphor than in aliphatics, as terpenoids are produced by the more adaptable secondary metabolism.

Minimising repeat cuts where possible and disposing of plants approaching bolting would help ensure a more desirable flavour. Short days discourage bolting in varieties grown in Europe for the leaf material. Young unstressed plants are seen as having a better overall flavour, so replacing plants regularly can help to maintain the highest quality.

Harvest time

There is no known effect of harvest time on the aroma of coriander.

Post-harvest

Cut herbs are best stored at 0°C to minimise respiration and associated senescence. This is the most important step in maintaining volatiles and overall quality. Coriander is especially susceptible to temperature abuse and should be closely monitored.

Coriander aroma is very temperature dependant; off-flavours develop within six days of storage at non-ideal temperatures (up to 15°C). These changes occur before physical appearance changes and so cannot be easily detected. The compounds involved are unknown, but likely to be fatty acid derivatives, and may be the result of oxidation of the existing fatty acids responsible for the aroma of coriander. As coriander leaf has a high content of fatty acid derivatives, there are post-harvest impacts as beneficial flavours are lost and off-flavours are generated.

Coriander is ethylene-sensitive. Ethylene-blocking chemicals such as 1-MCP extend shelf life. The effects are minimal when temperatures are low but could help if there is a breakdown in the cool chain post-harvest. 5–10 per cent carbon dioxide in modified atmosphere helps to prolong the shelf life of coriander, however the most significant factor is maintaining a low temperature from 0°C to 2°C from harvest to consumption.

Field heat should be removed rapidly from the harvested crop and the post-harvest cool chain should be maintained to preserve flavour in coriander.

Conclusion

- More research is urgently needed to improve flavour in coriander. UK-based studies on herb flavour are undergoing in AHDB Horticulture project FV/PE 455
- Growers should use coriander varieties that are suited to their growing conditions, and which have an underlying good flavour profile
- Avoid stresses, such as water stress, as this generally causes a reduction in the flavour quality of the herb due to increases in the concentration of E-2-decanal
- While long day conditions can increase the flavour intensity and yield, they can also promote bolting, as can stress and repeat cuttings, which impairs the flavour

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