TECHNICAL REVIEW

AHDB

Optimising flavour in herbs

Figure 1. Herbs are used primarily as culinary flavours; growing to maximise this attribute may help to drive sales

These technical reviews explain the chemical basis of flavour in herbs grown in the UK. They provide information explaining factors which can influence flavour, both positively and negatively, and give advice on growing practice and available technologies that growers could employ to maximise flavour while maintaining crop yields and quality. Plant health and nutrition, available light and temperature during growth, harvest time and maintenance of cool chain temperatures are all to be considered, to maximise the flavour quality of herbs.

Flavour components

Flavour development and retention is the result of both pre-harvest conditions and post-harvest management. In general, a plant's response to environmental conditions is very specific and can vary depending on the species, cultivar, and the class of chemical involved.

Plants contain a wide range of molecules; primary metabolites such as amino acids and sugars which are essential to the growth and development of the plant and secondary metabolites which adapt the plant to its environment (Table 1). The primary metabolites are often tightly regulated within the plant and do not alter with environmental changes as much as secondary metabolites. Some conditions, especially stresses which affect the healthy normal growth of the plant, will affect the production of primary metabolites.

Herb flavour in general is largely a factor of the specific combination of secondary metabolites, but also sugar and other primary metabolites, as is the case in chives and coriander. Some secondary metabolites affect taste such as bitterness, but the majority will affect the aroma. The essential oil of herbs is characteristic of the crop and oils contain most of the flavour compounds, especially volatile secondary metabolites which affect the aroma. Essential oils are often referred to in literature when reviewing the flavour of herbs. Plant stress can modify the flavour profile of herbs by causing production of secondary metabolites, many of which are produced in response to stress. Some are used by the plant to reduce oxidative damage from sunlight, or as antimicrobials which are used to defend plants against infection.

Other secondary metabolites are produced as signalling molecules to alert other plants in the area to infection, a defence system called allelopathy. These compounds are the flavours we exploit, so inducing or limiting stress to a plant can greatly alter its flavour profile. Other changes to the environment, such as shade, can also affect the secondary metabolites that a plant produces, without causing a stress response. More extreme stress can reduce plant yield and primary metabolite content, but the secondary metabolites respond differently to biological stress affecting the flavour in ways specific to the type of stress, the crop species and the specific molecules involved.

Detection of flavour

There are two main factors which affect how much of a contribution a chemical makes to flavour. First is the chemical's absolute concentration, where more of a substance will have a stronger taste; the second is related to the chemical's detection threshold. This is how easily a consumer can detect the compound. The detection threshold varies enormously between compounds. For example, for a solution of menthol it is quoted as 0.26ppm (parts per million), but for thymol it is 0.001ppm. The threshold can also be influenced by other compounds in the crop or the structure of the leaf. For this reason, it can be difficult to stipulate chemicals in the herb which have the greatest influence on flavour.

Another consideration is how much the flavour affects liking, which can be difficult to determine because of differences in how a herb is used, cultural differences of the consumer and because consumers are not a single homogenous group, with age, gender, and often specific genetic differences changing how the consumer perceives the product. A strong flavour is generally preferable to a weak flavour and 'typical' flavours of the herb or flavours which fit the consumer expectations are ideal. It can often be hard to determine what the biological basis of these 'typical' flavours is, given that different aromas interact.

Main classes of flavour compound

Sugars are considered primary metabolites which means they are essential to the growth of the plant. There is potential to improve the sugar content through varietal selection. Available leaf sugars also influence flavour as consumers typically prefer sweet-tasting foods. This does apply to herbs in the cases that have been researched. Aside from imparting sweetness, sugar content affects perception of other tastes, reducing the perception of bitterness and increasing perception of some aromas. The balance of sugars and acid rather than sugar alone is often cited as an important factor in flavour perception. Young leaves or leaves of stressed or infected plants often have substantially reduced free sugars. Sugar content also positively correlates with shelf life.

Terpenes are one of the main groups of secondary metabolites related to flavour, especially in the Lamiaceae plant family which contains mint, lavender, basil and rosemary. Terpenes are volatile, they generally dictate the aroma of the herb and they are present to some extent in nearly all plants. Iron is essential for the synthesis of terpenes; deficiency in iron is a limiting factor in nutrient-poor soils. Terpene production is also closely regulated by light.

Table 1. Metabolites contributing to flavour in herbs, the location of glands producing flavour compounds and conditions triggering off-flavours

Herb	Chemical basis of flavour	Location of flavour chemicals	Off flavour risk
Basil	Secondary metabolites	Specific glands	Flower initiation, stress, old leaves
Chives	Primary metabolites	All cells throughout the plant	Stress, infection, poor nutrition
Coriander	Primary metabolites	All cells throughout the plant	Stress, flower initiation
Mint	Secondary metabolites	Specific glands	Old leaves, stress, flower initiation
Parsley	Combination of metabolites	All cells throughout the plant	Stress, flower initiation
Rosemary	Secondary metabolites	Specific glands	Loss of volatiles, poor storage

Phenylpropanoids and polyphenols are a main group of secondary metabolites related to flavour. They have varied effects on flavour. Some chemicals are volatile, affecting the aroma, while larger polyphenols are generally bitter or have other effects on taste. However they are beneficial in the plant and the human diet as antioxidants.

Fatty acids and their derivatives such as aldehydes and ketones include hexanal which is responsible for the typical green or grassy smell of leaves, but also include a wide range of off-flavours which develop as the leaves degrade. They are also typical flavour compounds in the Apiaceae family containing parsley and coriander.

Sulphur-containing compounds are sometimes perceived as spicy or hot and are typical of the Alliaceae (onion) family, as well as many of the typical aromas from the Brassica family. The typical 'cabbage-like' off flavour in some decomposing plants is the result of sulphur-containing compounds.

Cultivar

Choice of cultivar is one of main means of ensuring a high quality product. Production of metabolites is highly controlled genetically; it can be highly variable, even with closely related cultivars. The most important difference between cultivars is the overall composition of flavour compounds or the essential oil, but the absolute concentration may also change significantly. The response to the environment also varies between cultivars, so it is crucial to ensure that plants are adapted to growing conditions. One of the simplest factors to change when aiming to improve flavour quality is to alter the variety used.

Growers should choose varieties suited to their production method and consumer preference. It is easier to grow a better tasting variety, and focus on its agronomic needs to maximise its potential for yield and quality, than it is to improve the flavour of a variety which does not have the genetic pre-requisite to a high quality flavour.

Biostimulants and growth regulators

Biostimulants are agents which can be applied to a crop to modify how it grows and are typically available in the form of seaweed extracts and other commercial products.

Application of a biostimulant can cause a change in volatile oils similar to when the crop is experiencing a biological stress, but without exposing the crop to damage. Biostimulants come in a wide range of compounds which either cause the crop to produce a defence response, change their hormone production or they may be plant hormones that are applied directly to the crop. Recognised plant growth regulators are the plant hormones: auxins, gibberellin, cytokinins, abscisic acid and ethylene.

There are many published papers on the use of biostimulants in oil crops. Application of growth regulators through sprays can have varied effects, increasing and decreasing concentration of certain oils and affecting the total content.

Jasmonic acid is linked with pathogen attack and herbivory, and can be applied to elicit responses equivalent to these stresses. Giberellins have a general effect involved in stress response. Benzyladenine has been shown to have good potential to increase yield and quality of essential oils through changing the formation of glandular hairs which are important to the the production of terpenes. Naphthalene acetic acid (NAA), cytokinins and methyl jasmonate have all been explored in terms of modifying the volatile oils produced by a range of plants, including in basil where they increased the quantity and quality of oil [1]. All of these are available as constituent of commercially available plant extracts. A good source of further information is Prins et al. [2].

Growth factors and biostimulants have a great potential to modify the flavour of crops, however the response of crops to each growth factor is highly specific and variable between cultivars. Because of this, it is very difficult to make broad suggestions without individual testing on a case-by-case basis.

Light quality

Available light affects the growth of plants, in particular two systems exist to alter a plant's response to light and shade. The red:far red ratio gives the plant information about shading, and causes physical and chemical changes in the plant accordingly. UV-A and UV-B also give the plant information about its shade and location. UV can damage the plant directly through oxidation, damaging DNA and other functions, and many herbs are adapted to produce volatile compounds to intercept these rays. Plants adapted to high altitude and exposed locations often respond to intense UV-B by producing volatiles as a way of protecting cellular products from damage, and these volatiles are typically terpenes and phenylpropanoids which impact on flavour.

Harvest time

Harvesting when temperatures are cool, and careful handling reduce the level of post-harvest respiration, stress and susceptibility of the herbs to infection. This will in turn reduce the presence of breakdown products, such as aldehydes, which may impact on flavour post-harvest and prevent the loss of flavour compounds. As sugar content has also been positively linked to increased shelf life, varieties with higher sugar content (or which have been harvested at the end of the day when more carbohydrates are present) may be preferable. Higher sugars not only maintain good leaf quality, but mask bitter polyphenols and other undesirable tastes. However, crops are often harvested early in the day to reduce field heat, which can lead to higher respiration and a more rapid degradation of the leaf.

Post-harvest deterioration

As leaves decompose at the end of their shelf life, lipids within the plant degrade. The first stage of deterioration is typically by one of these routes:

Autoxidation Free oxygen in the atmosphere interacts with lipids causing oxidative action. High oxygen content, temperature and lack of antioxidants in the plant can increase the risk of this occurring. Oxygen scavengers and modified atmosphere packaging (MAP) can be used in storage and in transit, however the requirements are specific to the herb. Oxygen is also produced by the plant as it respires, further causing loss of quality.

Photo-oxidation Photons from light can cause oxidation, though typically they are low energy, and so require sensitisers in the leaf to form the first stage of decomposition. Chlorophyll acts as a sensitiser, and so light can cause a leaf to degrade more quickly. For most fresh produce, including herbs, storage in dark conditions is advisable.

Microbial degradation Microbes produce enzymes to break down cell walls and decompartmentalise cellular products, leading to product degradation.

After the first stage of these interactions, enzymes can interact with lipids, causing oxidation and breakdown of fatty acids into aldehydes and ketones, some of which impart a poor taste to herbs. Characteristic aromas reported by consumer panels include 'wet dog', 'cardboard' or 'rancidity' and are often detectable at low concentrations.

In addition, the bacterial or fungal microbe may itself produce off-flavours such as oxalic acid which breaks down cells in the leaf and lowers pH. This can cause an acidic taste which, coupled with the rancid aroma of oxidised fatty acids, leads to the loss of palatability in the product. The relatively high sensory threshold of some of these compounds means that they can affect the flavour of the herb before physical damage is obvious.

It is important to reduce respiration of the cut herb. This is best achieved by reducing the temperature and, in most cases, modifying the atmosphere by raising the content of carbon dioxide. The specific requirements vary depending on the crop.

Conclusion

- The most important general factors needed to maintain good flavour quality in herbs are to choose a variety which is capable of producing the ideal flavour composition in sufficient quantity and growing varieties which are suited to production methods
- Biostimulants may represent a means of modifying flavour, but they need to be researched on an individual basis, as the response varies greatly between species and varieties
- Harvesting at a time when field heat can be rapidly reduced will limit post-harvest losses in yield and quality. There is some evidence to suggest that harvesting late in the day will lead to increased sugar content, and subsequently better taste and shelf life
- Maintaining the post-harvest cool chain is also important to preserve flavour; it limits deterioration in shelf life and reduces waste

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References

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