

Optimising flavour in chives



Figure 1. Ensure that chives have adequate amounts of sulphur for good flavour development

Action points

- Use appropriate varieties to suit your growing conditions and market
- Fertilise appropriately. Sulphur is the nutrient most critical to the normal development of flavour compounds, and a lack of sulphur may elicit a stress response (Figure 1)
- Maintain temperatures of 0–2°C throughout the post-harvest chain to reduce crop respiration
- Take extra care to avoid physical damage to the crop as off-flavours form when cells are damaged

Chives (*Allium schoenoprasum*) are grown and marketed as live pot plants and cut herbs in the UK. They differ from many other *Allium* crops in that their main use is the green part of the leaves (scapes) rather than the bulbs (as with onion or garlic) or the white part of the leaves, as in leeks. Other species known as chive, such as Chinese or garlic chive (*Allium tuberosum*), are not covered in this review although the chemistry involved in flavour is consistent across the *Allium* family.

Introduction

This review focuses on flavour and potential routes to improve flavour quality pre-harvest. Additionally it documents how off-flavours can occur if plants are mismanaged post-harvest. Chives are comparatively understudied as they are a minor crop, however, as they are related to onion, there is some information on the formation of flavour. More research is required specifically to understand consumer preference.

Flavour in chives is of a similar basis to other edible *Allium* species. Precursor molecules S-alk(en)yl-cysteine sulphoxides (ACSOs) are separated from enzymes, primarily isoallinase, in the cytoplasm of each cell. When the cell is damaged, the two become mixed, allowing for production of a wide range of sulphur-based compounds which have strong anti-microbial and anti-feedant effects in the plant. This is a defence mechanism from moulds and insects, but it is also responsible for the characteristic flavour. The ACSO and enzyme involved can both affect flavour.

The main ACSOs in chives are isoallicin, allicin and methiin, with their chemical names shown in Table 1. These develop into flavour compounds shown in Table 2, which are referred to in this guide as thiosulphates (but sometimes known as organosulphur molecules). Ultimately thiosulphates break down into pyruvate (Figure 2), which gives a bitter taste to old or damaged chives.

Dipropyl disulphide is the most abundant compound accounting for up to 80 per cent of the total ACSO derivatives in chives, while dipropyl trisulphide often accounts for up to 30 per cent. In addition to the aroma and odour listed above, these compounds and their derivatives have a bitter taste, and can cause a burning sensation at high concentrations which adversely affects flavour.

Chives are high in alliin and isoalliin. There is little reported difference between the relative proportions in different cultivars. Methiin, another ACSO is present but it is mostly associated with low sulphur fertilisation and low light stress, and negatively correlates to polyphenols. Methiin typically degrades to methylated thiosulphates, such as methyl propyl disulphide. These are associated with cabbage-like off-flavours [3] and should be avoided.

Sugar content is an important flavour parameter in chives, with a content of up to 6 per cent of the fresh weight [4]. Sugars mask undesirable tastes, particularly bitter flavours in foods, and in chives represent a balance to the pungent sulphurous chemicals. The overall flavour is dependent on the mixture of sugars and thiosulphates.

Small changes in thiosulphate concentration do not appear to be detectable by consumers, who are unable to distinguish between medium and high concentration of thiosulphates. The most likely reason for this is that there is an interaction between sugars and thiosulphates which limits how consumers perceive pungency.

Table 1. ACSOs found in chives – alternative names may be seen in other research. Isoallicin is the most abundant in normal conditions, while methiin is produced at higher levels when the crop is stressed

Full chemical name	Abbreviation	Chemical referred to as:
trans-(+)-S-(1-propenyl)-l-cysteine sulphoxide	1-PECSO	Isoallicin
(+)-S-(1-propenyl)prop-2-ene-1-sulphinothioate	2-PECSO	Allicin
(+)-S-Methyl-L-cystene-S-oxide	MCSO	Methiin
S-(2-Propenyl)cysteine sulphoxide	PCSO	Alliin

Table 2. Common compounds and their relative percentage of chive essential oil by abundance [1, 2]

Name	Chemical class	Aroma	Typical relative concentration (%)
Dipropyl disulphide	Thiosulphate	Sulphurous, green onion, burnt	25–80
Dipropyl trisulphide	Thiosulphate	Green onion, garlic, tropical	15–30
Methyl propyl trisulphide	Thiosulphate	Onion, garlic, metallic, cabbage	8
1-Propenyl propyl disulphide	Thiosulphate	Sulphurous, cooked onion	6
Ethyl propyl disulphide	Thiosulphate	Fermented, fruity	4
α -Farnesene	Monoterpene	Woody, green, herbal	3
Methyl propyl disulphide	Thiosulphate	Sulphurous, radish, mustard	2–11
Allyl propyl trisulphide	Thiosulphate	Garlic, onion	2
(E)- β -Farnesene	Monoterpene	Woody, citrus, sweet	2
Propyl-1-(propylthio)ethyl trisulphide	Thiosulphate	Cooked onion	1

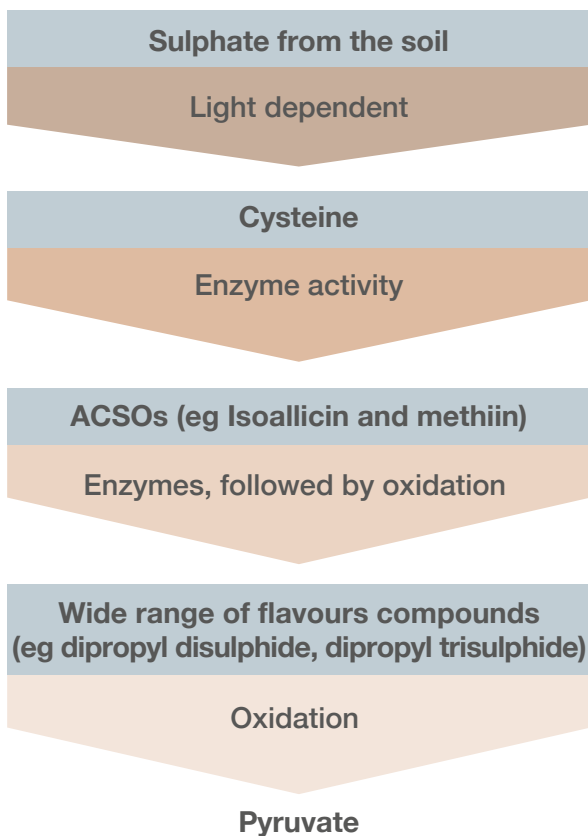


Figure 2. Simplified pathway involved in the generation of flavour from environmental sulphate

Sensory threshold is a factor of a compound which determines how much sample needs to be present for the flavour to be detected. This is highly variable between chemicals, therefore concentration alone does not determine the influence that a chemical has on flavour. Absolute concentration of thiosulphates is low at 0.02 per cent of the essential oil, however many are easily detected by consumers at low levels. The exact detection thresholds of these compounds in chives is not currently known, however it is thought that the most potent are propenyl sulphides which account for the majority of flavour compounds in chives [3].

Other factors influencing taste are polyphenols which may impart a bitter taste. In chives, these are predominantly the flavonols – kaempferol and quercetin and their glycosides – which are produced at higher quantities when the crop is stressed [5]. Aldehydes such as hexanal, which is typical of ‘green’ or ‘grassy’ aromas associated with leaves and ketones, are also present.

Environmental effects and agronomic impacts

The ACSO-allinase system is thought to be an insect defence system. When under stress, and particularly stresses which limit the production of the typical ACSOs of alliin and isoallicin, there is an upregulation of the ACSO methiin. Methiin-based thiosulphates are associated with off-flavours, and cabbage or mustard-like aromas, and are generally undesirable. Normal growing conditions without stresses are beneficial to the optimisation of flavour, as it allows for maximum sugar production and minimised methiin production which relates to off-flavours. Sulphur fertilisation is strongly correlated with the content of ACSOs and therefore is a major determiner of flavour intensity.

Healthy growth will result in robust plants with a typical flavour profile. Micronutrients should be monitored to maintain good quality, with especial emphasis on sulphur.

Cultivar

Choice of cultivar is one of the main ways of ensuring a high quality product. While there is not much variation in the composition of ACSOs under ideal environmental conditions, there is high variability in the total concentration of these between varieties. Thiosulphate composition will change with cultivar as it is dependent on the available enzymes and other cellular factors, such as availability of water, temperature and pH, although the interaction is complex and poorly understood. Cultivar differences determine to what extent ACSOs are accumulated in the leaves, with studies of American onion varieties showing that the cultivars used could vary by up to six times in the total accumulation of ACSOs.

This strong cultivar component is also important to determining pungency in chives. It is also reasoned that there will be an important difference in cultivars’ ability to utilise sulphur. Varietal differences are likely to exist for sugar content as well, as is seen in onions, although no data is available on the sugar content of chives.

Growers are advised to choose varieties that perform well with their specific growing systems and climate, and which are suited to the end use of the product. Varieties which readily take up sulphur by the roots will minimise methiin production, and will typically have a strong flavour, without cabbage-like aromas.

Fertiliser and nutrition

The majority of the available sulphur in alliums is used in forming S-alkyl-cysteine sulphoxides; where in other plant families, up to 90 per cent of sulphur is usually used in the formation of the amino acids cysteine and methionine [6]. This places a high demand on sulphur in chives and other Allium species. Under-fertilisation with sulphur will lead to a poor flavour as the element is limited to essential primary metabolites, such as sulphur-containing amino acids, and the production of methiin. Flavour intensity increases proportionally to the level of available sulphur. At low sulphur fertilisation, methiin is predominant and is the main sink of available sulphur while, at higher sulphur fertilisation, isoallicin becomes the predominant compound [6].

Growers should ensure that there is an adequate supply of sulphur for chives, which is required at higher concentration than other herbs. The most consistent factor governing flavour in chives is the ability to take up sulphur, whether this be a factor of cultivar or sulphur-content available to the plant.

High nitrogen will increase vegetative growth and alter the metabolite profile, increasing methiin and decreasing isoallicin, although this can be overcome by higher sulphur fertilisation.

Sufficient nitrogen levels should be maintained to ensure optimal growth, alongside sulphur fertilisation.

High selenium content in the soil appears to lower pungency in onion through competitive absorption and inhibition of sulphur [7] which, in turn, also leads to the formation of greater content of methiin, and lowers other ACSOs. As this inhibition is of a chemical basis, it is expected that the same is true in chives.

As selenium may competitively inhibit sulphur uptake, its concentration in the soil should be monitored.

Biostimulants and growth regulators

Mycorrhizae may aid growth in general, especially in substandard soils. However, there has been no reported effect on flavour, with studies showing no difference when treated with mycorrhizae [8].

In studies using cell cultures, the use of salicylic acid increased the production of ACSO significantly, although it is not known if there is any effect on commercially-produced plants.

Very little is understood in chives or other alliums as to the benefits of treatments with biostimulants or growth regulators.

Irrigation

Chives are fairly drought-tolerant and have the ability to regenerate after a period in the absence of water [9], although this does slow growth and affects yields.

A reduction in yield and no clear effect on the flavour means that deficit irrigation cannot be recommended to improve flavour.

Light quality

At low light levels, methiin is upregulated which is detrimental to flavour. Light quality, such as wavelength or availability of red:far red ratio [6] or UV [10], appears to have no influence on the biosynthesis of ACSOs; however the formation of these compounds from sulphur is light dependent so light intensity affects the production of these accordingly.

Day length

The UK outdoor cut chive season is given in Figure 3. There is no specific information on the effect of day length in chives, however the beneficial flavour compounds are sugars and isoallicin derivatives which are strongly linked to photosynthesis and light intensity respectively. Longer days allow for higher synthesis of sugars and isoallicin. An increase in photosynthetic potential is strongly linked to increasing total sugar content and is driven by adequate lighting. Long days allow for greater accumulation of sugar and ACSOs, although more research is needed to see if the effect of this is significant.

Temperature

Sulphur utilisation increases with temperature increases, up to 30°C. Pungency roughly doubles with a temperature increase from 10°C to 30°C, due to the extra ACSOs produced [6]. Supplementary heating in cold times of the year could increase growth and flavour.

Where possible, maintain daytime temperatures from 25°C to 30°C to increase the thiosulphate concentration, but higher temperatures will ultimately damage enzymes and

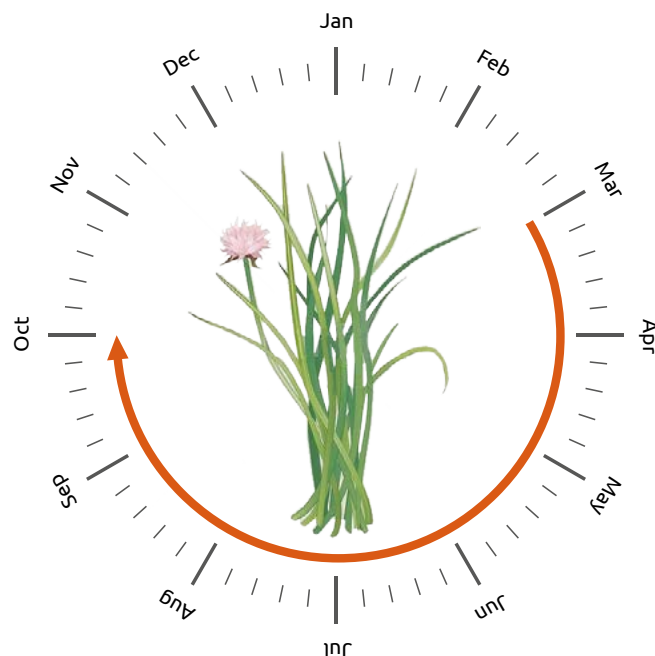


Figure 3. UK cut chive season shown in red [11]. Chives are typically field grown from early spring through to November

result in stomatal closure, reducing the photosynthetic potential and ability of the plant to produce sugars, especially where the rise in heat is a sudden shock. Glasshouse producers should take action to avoid heat stress in the summer and may wish to supplement heating at colder times in the production cycle.

Harvest time

Effects of the time of harvest are not well understood, although common practice is to harvest early while there is less field heat to reduce overall quality. Sugar content will be higher at the end of the day and may aid flavour, but removal of field heat needs to be taken into account.

There is little known on the impact of harvest time on flavour.

Plant physiology

The leaves show more variability of compounds compared to other plant tissues. Once thiosulphates have been generated by enzymatic activity, a wide range of compounds can be produced in the leaves according to the conditions. Higher heat and humidity leads to more rapid degradation and oxidation of the compounds.

The leaf grows from the base, with the youngest part of the leaf at the bottom. This is chemically the least pungent and most succulent, although ACSOs are present in all parts of the plant. Mature leaves have more sulphate and thiosulphates, and consequently a stronger pungency [4].

Chives are harvested before flower initiation due to the absence of the tough flower stem. It is not known how the chemical composition changes with flowering. Chives are thought to have a stronger flavour in successive cuts due to a stress response. It is not known currently how this impacts on the plants chemical composition nor its quality.

It is best to harvest plants when yield is optimum. Consumers cannot detect differences in flavour due to plant age.

Post-harvest

Maintaining consistent temperatures of about 2°C throughout the supply chain, harvesting when temperatures are low, and careful handling of the herb will reduce the level of post-harvest respiration, reduce stress and susceptibility to disease. 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. As sugar content has also been linked to increased shelflife, varieties with higher sugar content may be preferable. Crops are often harvested early in the day to reduce field heat, and quick cooling slows detrimental enzyme activity.

Storage in the short term does not appear to influence levels of flavour components, with loss of marketability through water loss apparent before appreciable changes in the intensity of flavour [12]. Longer term storage affects the perception of 'green' flavours and 'onion' flavour. It is essential to store chives in a way that minimises damage, to avoid the breakdown of ACSOs and ultimately the formation of bitter pyruvate.

Heat and pH affect the rate of enzyme action. The enzymes which degrade ACSOs are non-specific and varied in terms of pH and temperature adaptation. The environment in which the chives are packaged and consumed therefore affects the flavour.

Conclusion

- Use appropriate varieties to suit your growing conditions and market
 - The most significant element in flavour of chives is the ability of the plant to accumulate sulphur from the soil. Ensure there is sufficient sulphur available to the plant to avoid the production of methiin. This may require a specific fertiliser regime if growing different herbs in the same system
 - Store at cool temperatures and avoid damage to leaves to limit development of bitter flavours after cutting
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Authors

Martin Chadwick, the University of Reading

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Produced for you by:

AHDB Horticulture
Stoneleigh Park
Kenilworth
Warwickshire
CV8 2TL

T 024 7669 2051
E comms@ahdb.org.uk
W horticulture.ahdb.org.uk
🐦 @AHDB_Hort

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