Not so sweet berries under global warming

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- Sugars are a major component of flavour and taste in strawberries
- Higher temperatures under global warming are likely to decrease levels of sugar and eating quality
- Efforts need to be made to develop heat-tolerant cultivars with high and stable concentrations of sugar

Global warming will decrease the yields and quality of many crops. Eating quality in strawberry is related to the concentrations of several components in the fruit, including the sugars, organic acids and volatiles.

Higher temperatures under global warming could lead to lower concentrations of the main sugars in strawberry in south-east Queensland. This will the affect the eating quality of the berries in the marketplace. Efforts need to be made to develop heat-tolerant cultivars with high and stable concentrations of sugar.

Introduction

The main scenarios for global climate change include an increase in the concentration of carbon dioxide (CO_2) and an increase in average temperatures.

Higher temperatures will affect many aspects of growth and development in strawberry plants. Overall yields and quality will be lower under higher temperatures than under current conditions.

This article explores the relationship between fruit sugars and temperature. A review of the available evidence suggests that higher temperatures under global warming will decrease the concentrations of the main sugars.

Earlier research in Queensland demonstrated that average fruit weight decreased as temperatures increased. This suggests that the fruit will be smaller and less sweet under global warming.

Main sugars in strawberry

There are different sugars in strawberry. The main sugars in ripe fruit include sucrose, glucose and fructose, and these account for about 99% of all the sugars.

Among these major sugars, the concentration of sucrose is associated with fruit development, whereas the concentrations of glucose and fructose are less associated with fruit development. The three main sugars have different levels of sweetness. Fructose and sucrose are 2.30 and 1.35 times sweeter than glucose.

The concentration of the sugars is usually reported on a fresh weight basis (mg/g FW). More than 15 other sugars have been detected in ripe fruit, including galactose, ribose, maltose, inositol and sorbitol. The concentrations of these minor sugars are lower than 0.1 mg/g FW, whereas the concentrations of each of the major sugars are higher than 20 mg/g FW.

Akšić et al. (2019) provided information on the concentration of sugars in three strawberry cultivars growing under conventional and organic production in Europe. The concentration of glucose ranged from 25 to 61 mg/g FW, the concentration of fructose ranged from 46 to 66 mg/g FW and the concentration of sucrose ranged from 16 to 68 mg/g FW. These authors noted 14 other minor sugars with concentrations below 3.0 mg/g FW.

Some studies report data on soluble solids content (SSC) rather than on the concentrations of the sugars. There is a strong relationship between the two measures of sweetness. Soluble solids content increases with an increase in the concentrations of sugars. Soluble sugars account for 80 to 90% of the soluble solids. Values of SSC typically range from 6 to 12%.

Variations in the concentrations of sugars

The concentrations of sugars in ripe fruit vary with the cultivar, production system and growing season. The concentrations of sugars also vary across different fruit on the same plant and across different fruit on the same fruit cluster. Sugars are usually lower in plants with heavy yields than plants with low yields. Sugars also decrease as fruit size increases. These variations in sugar content make it difficult to compare fruit quality across studies. The sugars in ripe berries are not distributed evenly throughout the fruit. The concentrations of sugar are higher in the apex of the fruit than near the peduncle. In contrast, the concentrations of organic acids are similar throughout the fruit. This imbalance in the distribution of the sugars and acids can influence the perception of sweetness and flavour.

Liu et al. (2020) examined the concentrations of sugars across 154 cultivars and breeding lines in China. The mean concentration of the main sugars ranged from 0.67 to 136 mg/g FW for sucrose, from 11 to 84 mg/g FW for fructose and from 7 to 71 mg/g FW for glucose. The mean concentration for all the sugars ranged from 21 to 254 mg/g FW.

There is some information on the heritability of sugar content in strawberry. These studies can indicate how readily a trait can be passed on from parents to progeny in a breeding population. Values of heritability typically range from zero (poor heritability) to one (high heritability). High values of heritability indicate that the trait is readily passed on from parents to their progeny. The heritability of mean sugar content is moderately high. Ohtsuka et al. (2004) indicated that heritability was 0.568 for a population of strawberry in Japan.

Whitaker et al. (2012) investigated the heritability of soluble solids content (SSC) in a population of strawberry at two sites in Florida. They found that narrow-sense heritability (h^2) and broad-sense heritability (H^2) were relatively low (0.21 or 0.30). In contrast, the heritability for some of the other traits such as average fruit weight was high (0.52 or 0.53). Hasing et al. (2013) indicated that heritability for a stable SSC across the season in a population of strawberry in the same area was low (h^2 = 0.06). However, the stability of SSC and mean SSC were independent, with some cultivars having both stable and high levels of SSC.

Relationship between soluble solids content and temperature

A few reports provide data on the relationship between soluble solids content (SSC) and temperature in strawberry. Overall, the studies indicate that SSC decreases as the temperature increases.

Osatuke and Pritts (2021) examined the performance of plants across 16 fields in New York. They found that SSC decreased from 8.5% to 6.2% as the lowest temperature recorded between first flower and green fruit increased from about 1°C to 10°C. However, the data were highly variable with a value of r in the correlation of – 0.42. Values of r range from zero (no correlation) to one (strong correlation). Overall, the correlation between sugars and temperature was weak.

Hoppula and Karhu (2006) investigated the quality of three cultivars growing under plastic tunnels or in the open field in Korea. They found that SSC was negatively correlated with average daily mean temperature in the two weeks before harvest (r = -0.63). In contrast, SSC was positively correlated with total solar radiation received over the same period (r = 0.59). These results suggested that both temperature and solar radiation affected the accumulation of sugars.

Mackenzie et al. (2011) conducted a similar experiment in Florida to those conducted in New York and Korea, with data on SSC and temperature collected over several seasons. These authors found a strong negative linear relationship between SSC and average daily mean temperature in the eight days before harvest (R^2 = 0.73). Soluble solids content decreased from 9.5% to 6.0% as the temperature increased from about 10°C to 21°C. Values of R^2 in linear regressions range from zero (no relationship) to one (strong relationship).

High sugars levels contribute to aroma and flavour in strawberry. Photo credit: Chris Menzel

Sugar levels vary over the growing season and with the weather. Photo credit: Chris Menzel

Krüger et al. (2012) investigated the performance of two cultivars across five locations from Norway to Italy in Europe. Average daily mean temperatures over the two growing seasons ranged from 14.6°C to 16.6°C across the sites. Mean SSCs ranged from 6.6% to 10.3% in 'Elsanta' and from 7.1% to 10.2% in 'Korona'. '

There were strong negative correlations between SSC and average daily mean temperature in the three weeks before harvest (r = -0.78 or -0.70). Soluble solids content decreased as the temperature increased.

Conclusions

Eating quality in strawberry is related to the concentrations of several components in the fruit, including the sugars, organic acids and volatiles.

There are large variations in concentrations of sugars, depending on the cultivar, growing system and weather. Research in north America, Asia and Europe has shown that high temperatures decrease the concentration of soluble sugars.

This analysis suggests that eating quality in south-east Queensland could decline under global warming. Experiments are currently underway on the Sunshine Coast to confirm the results reported from overseas. Efforts need to be made to develop heat-tolerant cultivars with high and stable concentrations of sugars.

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