Scientia Horticulturae 243 (2019) 385–391

Contents lists available at ScienceDirect

Scientia Horticulturae

journal homepage: www.elsevier.com/locate/scihorti

Short communication

Impacts of minimal processing and hot water dipping of 'Sonata' strawberries on volatiles emitted during storage

Oluwafemi J. Caleb[a,b,*], Kathrin Ilte[a], Werner B. Herppich[a], Martin Geyer[a], Pramod V. Mahajan[a]

[a] Leibniz Institute for Agricultural Engineering and Bioeconomy (ATB), Department of Horticultural Engineering, Potsdam-Bornim, 14469 Potsdam, Germany
[b] Post-Harvest and Agro-Processing Technologies (PHATs), Agricultural Research Council (ARC), Infruitec-Nietvoorbij, Stellenbosch 7599, South Africa

ARTICLE INFO

Keywords:
Heat treatment
Puree
Esters
Methyl ketones
Gas chromatography-mass spectrometry
Fragaria x ananassa

ABSTRACT

Strawberries flavour attributes are important quality parameters that have a significant impact on consumer acceptability. Minimal processing and postharvest treatments in many cases neglect the importance of flavour attributes or sacrifice them for better appearance and/or longer shelf life. In addition, only few information is available on the impact of postharvest handling on flavour attributes. Thus, the objectives of this paper were to investigate: i) the effects of minimal processing on changes in composition and relative abundance (%) of volatile organic compounds (VOCs) emitted from strawberries; and ii) the effects of hot water treatments (45 °C) at different dipping duration (5 and 10 min) on the shift in VOC composition of 'Sonata' strawberries. Based on gas chromatography-mass spectrometry (GC–MS) analysis, the volatile profiles obtained for strawberries were significantly ($p \leq 0.05$) influenced by minimal processing. Aldehydes were most abundant in strawberry puree (34.1%) compared to sliced samples (17.5%) and none were detected in the headspace of intact fruit. Esters were most abundant in the sliced samples (62.9%) compared to intact strawberries (51.2%) and fruit puree ($\approx$ 49%) samples. Hot water treatment and dipping durations had significant impact on the synthesis of methyl and ethyl esters and acetaldehyde in comparison to the untreated (control) samples ($p \leq 0.05$). At the end of storage, concentrations of methyl acetate (4.9 ± 0.86 mg mL^{-1}), methyl butanoate (6.7 ± 0.05 mg mL^{-1}), ethyl butanoate (0.6 ± 0.37 mg mL^{-1}), and acetaldehyde (3.1 ± 0.99 mg mL^{-1}) were lowest in strawberries dipped in hot water at 45 °C for 10 min. In contrast, hot water treatment with dipping duration of 5 min best maintained and enhanced the synthesis of methyl butanoate and prevented the accumulation of methyl isobutyl ketone. This study showed that minimal processing had a significant impact on the volatile profile of 'Sonata' strawberries, and that hot water treatments play a crucial role on the emission of volatile compounds.

1. Introduction

Strawberries (*Fragaria x ananassa* Duch.) are delicate and highly perishable fruit, often susceptible to mechanical injury, physiological disorders, and postharvest decay during storage (Lara et al., 2006). These limitations result in significant economical and postharvest losses along the strawberry value chain. Various hurdle techniques have been investigated over the years to maintain the nutritional and overall quality of strawberries, control decay and extend the storage life. These include the use of UV radiation and various forms of heat treatments (Dotto et al., 2011; Nechet et al., 2015; Caleb et al., 2016), acetic acid vapour (Hassenberg et al., 2010, 2011) and phenyl ethyl alcohol treatment to control decay (Mo and Sung, 2007). Others are edible coatings (Hernández-Muñoz et al., 2006), and modified or controlled atmosphere systems (Bovi et al., 2018).

Previous studies demonstrated that effects of heat treatment on strawberries are dependent on maturity stage, cultivar, type of heat treatment applied and storage conditions (Vicente et al., 2002; Jing et al., 2010; Caleb et al., 2016). Vicente et al. (2006) showed that the hot air treatment (45 °C, 3 h) of 'Selva' strawberries had no immediate effect on ascorbate peroxidase and superoxide dismutase activities. The authors observed a higher activity of these enzymes during storage, which showed that the hot air oven treatment had an influence on the fruit oxidative metabolic processes. However, during heat treatment or thermal stress of tomato fruit tissues, the expression of housekeeping and ripening related genes have been shown to decrease, while genes associated with heat shock proteins increases (Lurie et al., 1996). Limited literature in available on the impact of heat treatment or shock

* Corresponding author at: Post-Harvest and Agro-Processing Technologies (PHATs), Agricultural Research Council (ARC), Infruitec-Nietvoorbij, Stellenbosch 7599, South Africa.
E-mail address: calebo@arc.agric.za (O.J. Caleb).

https://doi.org/10.1016/j.scienta.2018.08.054
Received 13 February 2018; Received in revised form 24 August 2018; Accepted 27 August 2018

on the synthesis of volatile organic compounds (VOCs) in strawberries.

Strawberry flavour and aroma are important quality attributes that have a significant impact on consumer acceptability. Accumulation of acetaldehyde, ethanol and ethyl acetate has been shown to play an important role in off-flavour development in fresh produce during storage (Kader, 2008; Pérez and Sanz, 2008; Caleb et al., 2013). Often, minimal processing and postharvest treatments in many cases neglect the importance of flavour attributes for better appearance and/or longer shelf life. Furthermore, volatile compounds emitted from fresh produce can be classified as primary or secondary compounds, this indicates whether the VOCs are present in fresh/intact fruit or are emitted as a result of postharvest storage/treatments (Vazquez-Cruz et al., 2012; Caleb et al., 2013). Many of these VOCs are produced in trace amounts and can be degraded or degenerated into new molecules (Khan et al., 2012). Hence, the loss in characteristic VOCs of fresh produce during postharvest storage remains a challenge. Often volatiles are released from fresh produce tissue after cell disruption, when enzymes and organic substrates formerly separated in different cellular compartments interact (Buttery, 1993; Løkke et al., 2012; El Hadi et al., 2013). Sampling of fresh produce for VOC analysis mostly focused on the use of juice samples obtained from the product (Pelayo-Zaldívar et al., 2007; Mota et al., 2012; Caleb et al., 2013), or frozen fruit powder (Farneti et al., 2015). This, however, influences the aroma profiles and final aroma interpretation (El Hadi et al., 2013). Thus, the objectives of this study were to investigate; a) the impact of tissue disruption on the volatile profile, and b) the effects hot water treatments (45 °C) at different dipping duration (5 and 10 min) on the shift in VOC composition of 'Sonata' strawberries.

2. Materials and methods

2.1. Plant material

Fresh strawberries (*Fragaria x ananassa* Duch. 'Sonata') were obtained at commercial maturity (fruit with more than 98% red colour on the surface) from Karls Erlebnis-Dorf Elstal, Wustermark, Germany and transported in cooled conditions to the Department of Horticultural Engineering Laboratory, Leibniz Institute for Agricultural Engineering and Bioeconomy, Potsdam, Germany. The strawberries were carefully sorted to eliminate damaged, overripe, and poor quality fruit in order to obtain samples of uniform size and colour. Sorting was carried out prior to minimal processing and hot-water treatment.

2.2. Sample preparation and hot-water treatment

To investigate the impact of processing on VOCs emitted from the intact fruit, slices, and puree, strawberries were randomly divided into three groups, respectively. Each group consist of 30 strawberries and 10 samples were randomly selected per treatments. From the first group ≈60 g each of intact fruit was placed in air-tight PVC jar (750 mL) fitted with a septum and stored under two different conditions: (a) at 25 °C overnight (≈12 h) in an incubator (Heraeus BK 6160, Thermo Fisher Scientific Inc., Schwerte, Germany); and (b) were placed in a thermo-regulated water bath (GFL 1083, Gesellschaft für Labortechnik mbH, Burgwedel, Germany) set at 35 °C for 2 h. These conditions were used in order to enhance the release of volatiles by the intact strawberry fruit. After storage 2 mL headspace gas composition was taken from the jars using a gastight syringe and injected into 20 mL sampling vials. The second group of strawberries were minimally processed into slices (2.1 × 0.8 x 0.6 cm). Sliced pieces of strawberries (5 g) were immediately placed in the 20 mL vials. Third group of strawberries were gently crushed using a hand-press into strawberry puree. From the puree obtained, 5 g was immediately transferred into the 20 mL vials.

In the second experiment, fresh strawberries were randomly divided into homogenous groups of three batches representing number of treatments. Each batch consisted of 12 open polyethylene trays (with 20 strawberries per tray). Samples for two of the batches were pretreated using hot water (HW) at 45 °C with two different dipping durations of 5 and 10 min, respectively, and the third batch was not dipped in hot water to serve as the control. After the HW treatments, samples were aseptically air dried, packed in sterile polyethylene trays and stored at 4 °C and ≈ 90% relative humidity. Baseline analyses of physicochemical and VOC constituents were conducted on fresh and hot water treated strawberries prior to storage (day 0). Samples for further quality analyses were taken at regular intervals.

2.3. Gas chromatography-mass spectrophotometry analyses

The 20 mL vials containing puree of strawberries were allowed to equilibrate at 60 °C for 20 min in the HS-20 automated-sampler incubator (Shimadzu Europa GmbH, Duisburg, Germany). Static headspace (SHS) extraction was used in this study, gas samples (1 mL) were automatically withdrawn from the headspace of each vial by the HS-20 automated-sampler. The HS-20 automated-sampler condition was maintained as follows: the oven, sampling line and transfer line temperature were 50 °C, 150 °C and 150 °C, respectively. To increase the sensitivity of the SHS sampling method on the GC–MS, the vial shaking level of 3 (only for puree and sliced samples), injection time of 0.5 min, loading time of 30 s and split ratio (1:10) at constant pressurizing time of 30 s were set. Gas samples were then auto-transferred into the GCMS-QP2010 (Shimadzu Europa GmbH, Duisburg, Germany) for further analysis. The GC–MS system was equipped with Zebron™ capillary column 6% cyanopropylphenyl/94% dimethylpolysiloxane phase (ZB-624, Phenomenex, Aschaffenburg, Germany), with 30 m length, 0.25 mm inner diameter, and 1.4 µm film thickness.

The GC temperature was initially held at 50 °C for 1 min, then ramped up to 110 °C at 5 °C min^{-1}, then increased to 180 at 20 °C min^{-1} and held at this temperature for 3.5 min. Analyses were carried out using helium as carrier gas with a constant flow rate of 1.31 mL min^{-1}. The mass selective detector (MSD) in this study was operated in full scan mode and mass spectra in the 35–350 *m/z* range were recorded. The ion source and interface temperature were maintained at 200 °C and 230 °C, respectively. Individual volatile compound were tentatively identified by comparison of retention time (RT) and calculated retention index (RI) with those registered in the National Institute for Standards and Technology (NIST) mass spectral libraries (NIST v. 08 and 08 s, Gaithersbug, MD, USA). Only compounds with correlation coefficient ≥ 90% from the NIST MS library were considered. Relative concentrations of volatiles were calculated via standard curve extrapolation with known concentration (0.025-0.1 mg mL^{-1}) of 3-octanol diluted in absolute methanol. Standard curve linear equation: $y = (2 \times 10^6)x + 9419.5$, with $R^2 = 0.93$; where y = integrated peak area, x = relative concentration (mg mL^{-1}).

2.4. Individual sugar content

Individual sugars were quantified only for the second research objective (hot water treatment) of this study. Strawberry samples were placed in Erlenmayer flasks and diluted 1:10 (g/v) with Milli-Q water and shook for 30 min. To clear up the sample mixture, 2 mL of Carrez I solution (zinc sulfate, 300 g L^{-1}) was added and mixed, there after 2 mL of Carrez II (potassium hexacyanoferrate, 15 g L^{-1}) was added. After additional mixing of the solution, 100 mL Milli-Q water was added into the flask and before analysis the solutions were filtered using a membrane filter of 0.2 - 0.45 porosity. Sugar contents (glucose, fructose and sucrose) were determined by HPLC method using a DIONEX Ultimate 3000 liquid chromatograph fitted with Analytical Auto-sampler WPS-3000TSL (Thermo Fisher Scientific GmbH, Dreieich, Germany). The system is equipped with a refractive index detector SHODEX RI-101 (Showa Denko Europe GmbH, Munich, Germany). Sugars were separated on a Eurokat H column (300 x 8 mm and 10 µm diameter) (KNAUER Wissenschaftliche Geräte GmbH, Berlin,