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Volatile composition and sensory characteristics of onion powders prepared by convective drying

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ABSTRACT

Volatile composition and sensory characteristics of onion powders prepared by convective drying at different temperatures (50, 70, and 90 °C) were investigated. Dipropyl disulfide was the major volatile compound in fresh onion (77.70% of total volatile compounds). However it was considerably lost during drying, reaching 6.93–32.25 μg/g solids. Dipropyl disulfide showed a positive correlation with green sensory attribute perceived by descriptive sensory analysis. Thiophenes, which were responsible for caramel and sweet attributes, were produced by drying especially when the drying temperature was high. Aldehydes, another type of volatile compound found in fresh onion, showed a positive correlation with humidity. The aldehyde content in dried onion was the highest at the lowest drying temperature, possibly because the aldehydes were produced by the residual enzymes in fresh onion. Using a low temperature for drying was ideal to retain the aroma of fresh onion.

1. Introduction

Fresh onion (*Allium cepa*) bulbs are susceptible to postharvest pathogens and readily softened because of inherent enzymes, such as polygalacturonase and pectin methylesterase (Coolong, Randle, & Wicker, 2008). Drying fresh onion to powder or chip is one of the most effective processes to extend onion shelf life (Ahvenainen, 1996). According to the Food and Agriculture Organization (FAO, 2015), the global production of dry onion products in 2013 was about 87 million tons, which was approximately 1.5 times greater than the quantity produced in 2003. China is the largest producer of dry onion, contributing 22% of the total global production. Dry onion is widely used as an ingredient in a variety of commercial products, including sauces, snacks, frozen foods and retorted products (Arslan & Özcan, 2010).

In general, volatile compounds contribute to overall sensory characteristics of food products, often determining their acceptability and eating quality (King et al., 2010). Numerous studies have been carried out on the correlation between volatile compounds and sensory attributes of foods, proving the importance of volatile composition for sensory qualities (Johnson, Heymann, & Ebeler, 2015; Álvarez, González-Barreiro, Cancho-Grande, & Simal-Gándara, 2011). For fresh and dry onion products too, various volatile compounds have been identified (Bernhard, 1968; Boelens, De Valois, Wobben, & Van der Gen, 1971; Mondy, Duplat, Christides, Arnault, & Auger, 2002). Among the volatile components in onion, sulfur-containing compounds are known to be major volatiles in fresh onion, which are produced by the action of an inherent enzyme called alliinase. This enzyme catalyzes the hydrolysis of S-alk(en)ly-L-cysteine sulfoxide to produce sulfur-containing volatiles including mono, di and trisulfides (Colina-Coca, González-Peña, Vega, de Ancos, & Sánchez-Moreno, 2013). In addition, various aldehydes have been identified as another type of volatiles in fresh onion. It is widely known that various aldehydes are found in fruits and vegetables as the key aroma components (Gray, Prestage, Linforth, & Taylor, 1999; Noordermeer et al., 2002). Most of the volatile aldehydes consist of six to nine carbons (C6–C9), because the C6–C9 fatty acids are the substrates of the enzymes responsible for the aldehyde formation such as lipoxygenase and hydroperoxide lyase. Some of the volatile aldehydes, however, may induce off-flavor, especially when their residual amounts are too high (Petersen, Poll, & Larsen, 1999).

There have been several studies on the effects of different drying processes using sunlight, convection, vacuum and microwave on the quality of dry onion products (Adam, Mühlbauer, Esper, Wolf, & Spiess, 2000; Arslan & Özcan, 2010). Among the drying methods, convective drying (CD) is the most commonly used to make dry onion products because it is cost-effective and simple to operate. Volatile compounds in fresh onion, however, may be readily lost during convective drying especially when the drying is conducted at high temperature (Bernhard, 1968). However, no

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study has been reported on changes in volatile compounds and sensory qualities of onion during convective drying.

In the present study, volatile composition and overall sensory quality of dried onion prepared by convective drying at different temperatures were investigated. Also, the correlation between volatile composition and sensory attributes was statistically measured.

2. Materials and methods

2.1. Materials

Fresh onion (*Allium cepa*) was purchased from a local market in Seoul, Korea. The PDMS/DVB-coated solid-phase microextraction (SPME) fiber was supplied by Supelco (Bellefonte, PA). The C7–C40 saturated alkane standard solutions (1000 μg/mL in hexane) and allyl methyl sulfide were purchased from Sigma-Aldrich (St. Louis, MO).

2.2. Convective drying

Onions were cut into slices of approximately 3 mm using a stainless steel knife. One hundred and twenty grams of the onion slices were spread evenly on a stainless steel tray (31 cm × 22 cm × 2 cm), and then dried in a laboratory convective dryer (MOV-112F, Sanyo, Japan) at different temperatures (50, 70, and 90 °C). Drying times of 2.5–48 h were required to reach residual moisture content of 12.46–15.94% (Table 1). The dried onion samples were then ground into powders in a mortar filled with liquid nitrogen. The moisture content of the powders was determined by drying at 105 °C for 20 h. The color of the onion powders was measured by a colorimeter (CR-10; Konica Minolta Sensing Inc., Japan), and the browning index (BI) was calculated using the color values expressed as *L* (whiteness or brightness/darkness), *a* (redness/greenness) and *b* (yellowness/blueness) as described by Maskan (2001) (Table 1):

$$BI = \frac{100(x - 0.31)}{0.17}$$

where

$$x = \frac{a + 1.75L}{5.645L + (a - 3.012b)}$$

2.3. Headspace solid-phase microextraction (HS-SPME)

An HS-SPME analysis of the volatile compounds in fresh onion and dried samples was performed as described in a previous study (Chin et al., 2008) with minor modifications. Five grams of the ground fresh onion or aqueous suspension (10% *w/w* dry solids in distilled water) of dried onion powder were transferred into a 20-mL glass vial. An internal standard solution was prepared by dissolving allyl methyl sulfide in distilled water at a concentration of 1.967 mg/mL (Colina-Coca et al., 2013). An aliquot (20 μL) was subsequently added into the vial. The vial was immediately sealed with a PEFE-silicone septum (Supelco, Bellefonte, PA) and then magnetically stirred at 25 °C for 30 min. A PDMS/DVB-coated (65 μm) SPME fiber which was selected according to a previous study (Zhang, Du, & Li, 2012) was inserted through the septum into the vial to collect the volatile compounds in the headspace of the vial during stirring, which was carried out at 25 °C for 30 min. The fiber was then quickly removed from the vial and inserted into the injector of a gas chromatography for desorption.

Table 1
Moisture content and browning index of onion samples dried under different conditions.

Drying temperature (°C)	Drying time (h)	Moisture content (%)	Browning index
Fresh	0	91.87 ± 0.55	25.76 ± 1.87
50	12	15.94 ± 0.21[a]	30.18 ± 0.98[f]
	24	14.18 ± 0.13[b]	31.20 ± 0.96[f]
	48	12.70 ± 0.11[d]	31.52 ± 0.71[f]
70	4.5	15.85 ± 0.16[a]	37.34 ± 0.79[e]
	6	13.53 ± 0.06[c]	40.71 ± 4.23[de]
	10	12.60 ± 0.14[d]	45.53 ± 1.72[d]
90	2.5	15.86 ± 0.17[a]	52.96 ± 1.70[c]
	2.66	13.49 ± 0.12[c]	58.94 ± 1.01[b]
	3	12.46 ± 0.11[d]	65.54 ± 2.21[a]

Values with different alphabets in the same column are significantly different ($p < 0.05$).

2.4. GC–MS analysis

Identification of volatile compounds was conducted using a gas chromatography (7890A, Agilent Technologies, Santa Clara, CA) coupled to a mass spectrometer (5975C; Agilent Technologies). The volatile compounds isolated by the SPME fiber were separated on a DB-Wax column (30 m length, 0.25 mm ID, 0.25 μm film thickness, J&W Scientific, Agilent). Thermal desorption into the injector was performed by heating at 250 °C for 5 min in splitless mode, using an SPME liner. The GC oven temperature was set at 45 °C for 10 min, increased to 200 °C at a rate of 6 °C /min, and was then maintained at 200 °C for 5 min. Helium was used as a carrier gas with a constant flow rate of 1 mL/min. The mass detector operated in an electron impact (EI) mode at 70 eV. Tentative identifications were based on comparing mass spectra of unknowns with that in the Wiley 07 library with 80% as a minimum matching factor. Identifications of components were confirmed by comparison of their linear retention indices (RI) with those of reference compounds; RI were determined using C7–C40 alkane standards (Van den Dool & Kratz, 1963). Relative concentration of a compound was calculated as follows:

$$Relative\ concentration\left(\frac{\mu g}{g\ dry\ solids}\right) = \frac{peak\ area\ of\ unknown\ compound}{peak\ area\ of\ IS} \times \frac{39.347\mu g\ of\ IS}{amount\ of\ dry\ solids\ (g)}$$

2.5. Sensory analysis

A descriptive sensory analysis (DSA) was carried out to profile the main odor characteristics of onion samples. Fresh onion and dried onion samples prepared at 50 °C for 12 h (CD50_12H), and at 90 °C for 3 h (CD90_3H) were chosen for sensory analysis because the total amount of volatile sulfur and aldehyde compounds in these samples differed significantly. The sensory analysis was performed by 12 panelists (5 male, 7 female, ages 24–30). During training sessions, the panelists smelled fresh and dried onion samples in a blind trial and discussed odor attributes (Coste, Bauzá, Picallo, & Sance, 2010). They determined a final list of 11 descriptive terms by consensus (Table S1). The odor attributes, including pungent, humidity, sulfurous, green, fat, burnt, earthy, cooked vegetables, sweet, onion and caramel attributes as well as general intensity and desirability were evaluated. For a correlation analysis, samples were prepared in the same way as they had been prepared for SPME. The DSA was performed along a scoring line ranging from 0 (none) to 9 (very strong) in triplicate and two samples were present for each analysis.