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Composition of key offensive odorants released from fresh food materials

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HIGHLIGHTS

- Many common foods well known for flavor and aroma can also release diverse malodorant components.
- A list of key offensive odorants that can be released from common food materials were analyzed.
- The basic characteristics of food-related odorants exposed in our everyday life activities are discussed.

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ABSTRACT

A refrigerator loaded with a variety of foods without sealed packaging can create quite an olfactory nuisance, and it may come as a surprise that fresh foods emit unpleasant odorants just as those that are decaying. To learn more about nuisance sources in our daily lives, we measured a list of 22 compounds designated as the key offensive odorants (e.g., reduced sulfur, nitrogenous, volatile fatty acid (VFA), and carbonyls) from nine types of common food items consumed in S. Korea: raw beef, raw fish, spam, yolks and albumin of boiled eggs (analyzed separately), milk, cheese, onions, and strawberries. The odor intensity (OI) of each food item was computed initially with the aid of previously used empirical equations. This indicates that the malodor properties of target foods tend to be governed by a few key odorants such as VFA, S, and N compounds. The extent of odorant mixing of a given food was then evaluated by exploring the correlation between the human olfaction (e.g., dilution-to-threshold (*D*/*T*) ratio) and the odor potential determined indirectly (instrumentally) such as odor activity value (OAV) or sum of odor intensity (SOI). The overall results of our study confirm the existence of malodorant compounds released from common food items and their contribution to their odor characteristics to a certain degree.

1. Introduction

Many foods are well known for their favorable aromas that are not only present after cooking but also within the raw foods themselves. However, some of these foods can also act as source of unpleasant odorants, even while maintained in fresh conditions. For instance, one can experience offensiveness by opening the refrigerator door even if certain food items have been stored over a relatively short duration to accumulate an unpleasant odor. As such, many odorants released from fresh or undecayed foods can also be differentiated by their pleasantness impact (Calanche et al., 2013; Frenkel et al., 2012).

As greater emphasis has been placed on the assessment of favorable aromas of fresh foods, many studies have also been undertaken to characterize stenches of food items (Imafidon and Spanier, 1994; Jung et al., 1998). However, collecting definitive information on offensive odorants associated with fresh food has attracted relatively little scientific attention. The existence of certain odorants from fresh foods can lead to a nuisance, although such effect may be temporary soon after food removal. On the other hand, some food-related odorants can lead to a more significant impact such as allergic reactions or symptoms, which may persist even after short exposure (Sampson, 2004).

In this work, we investigated a list of key offensive odorants that can be released from common food materials. For the purpose of this study, we focused on a total of 22 offensive odorants that are currently subject to administrative regulation by the malodor prevention law (Korean Ministry of Environment (KMOE), 2008). The concentrations of these malodor compounds were measured

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from many types of common food items that are commonly consumed in daily life. The results of our study will offer some insights into the basic characteristics of malodorant components of food items which we are exposed in our everyday life activities.

2. Materials and methods

2.1. Selection of target components and food materials

For the purpose of our testing, we considered some food items that are commonly stored in a refrigerator (at 4 °C) that are either consumed raw or after being cooked: fresh beef, fresh fish, spam, yolks and albumin of boiled eggs (analyzed separately), milk, cheese, onions, and strawberries.

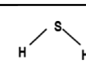
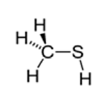
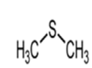
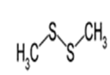
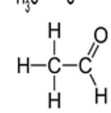
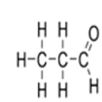
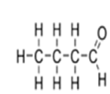
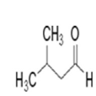
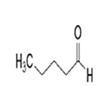
To investigate malodorant components associated with these selected food items, we considered a total of 22 compounds designated as key offensive odorants by the malodor prevention law in Korea (KMOE, 2008). These 22 odorants can be divided into five chemical groups: (1) reduced sulfur compounds (RSCs: H_2S, CH_3SH, DMS, and DMDS), (2) carbonyls (acetaldehyde (AA), propionaldehyde (PA), butyraldehyde (BA), isovaleraldehyde (IA), and valeraldehyde (VA)), (3) nitrogenous compounds (ammonia and trimethylamine (TMA)), (4) VOCs (toluene (T), styrene (S), xylene (meta- (m-X), para- (p-X), and o-xylene (o-X)), methyl ethyl ketone (MEK), methyl isobutyl ketone (MIBK), butyl acetate (BuAc), and isobutyl alcohol (i-BuAl)), and (5) volatile fatty acids (VFA: propionic acid (PPA), butyric acid (BTA), isovaleric acid (IVA), and valeric acid (VLA)). Note that xylene belongs to a member of 22 offensive odorants without designation of specific isomeric forms. Hence, its three isomers (m-, p-, and o-xylene) are counted as one for 22 for the sake of simplicity.

The basic physicochemical properties (e.g., chemical formula, structural formula, molecular weight, CAS number, etc.) of all these compounds are summarized briefly in Table 1. As the threshold values are given for each target compound, it can be used as valuable reference for our measured concentration data (Table 2). In addition, although our analysis of odorants is intended for their quantitation, the KMOE regulation guideline value of each odorant can also be used as a Supplementary Reference to assess its intensity. Apart from these 22 compounds, total hydrocarbon (THC), sulfur dioxide (SO_2), carbon disulfide (CS_2), formaldehyde (FA), and benzene (B) were also analyzed additionally as reference compounds (e.g., analogous to chemicals added as internal standards). The basic information concerning sample collection and analysis of these target odorants is summarized briefly in Table 3. In addition, the detailed information of analytical procedures for each odorant group is described in Supplementary Information (SI) along with operation conditions of all instrumental systems (Table 1S).

2.2. Sample collection

For the purpose of this study, all foods were purchased fresh from a local market on the day of the experiment for the preparation of nine sample types as discussed above. In case of boiled egg, the yolk and albumin were separated after cooking and treated independently. The strawberries for this study were purchased (one day after harvesting in Jinju-si, Korea) from a local market. The collection of odorant samples from each food type was made within approximately 6 h after purchase.

Table 1
Physico-chemical properties of the target odorous compounds investigated in this study.

Order	Group	Full name	Short name	Chemical formula	Structural formula	CAS number	Molecular weight (g mole^{-1})
1	Reduced sulfur compounds (RSC)	Hydrogen sulfide	H_2S	H_2S		7783-06-4	34.1
2		Methane thiol	CH_3SH	CH_3SH		74-93-1	48.1
3		Dimethyl sulfide	DMS	$(CH_3)_2S$		75-18-3	62.1
4		Dimethyl disulfide	DMDS	$(CH_3)_2S_2$		624-92-0	94.2
5	Carbonyl compounds	Acetaldehyde	AA	CH_3CHO		75-07-0	44.0
6		Propionaldehyde	PA	CH_3CH_2CHO		123-38-6	58.08
7		Butyraldehyde	BA	$CH_3(CH_2)_2CHO$		123-72-8	72.11
8		Isovaleraldehyde	IA	$(CH_3)_2CHCH_2CHO$		590-86-3	86.13
9		Valeraldehyde	VA	$CH_3(CH_2)_3CHO$		110-62-3	86.13