Characterization of the Volatile Compounds and Taste Attributes of Sesame Pastes Processed at Different Temperatures

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Abstract: Sesame paste is used as a condiment in many parts of the world because of its unique flavor. In the study, the volatile compounds and flavor characteristics of sesame pastes processed at different temperatures (140°C - 190°C) were analysed by application of solid phase microextraction - gas chromatography/mass spectrometry analysis, odor activity value evaluation and sensory evaluation. For all the sesame pastes processed at the different temperatures, the pyrazine group had the highest content. The amount of the volatiles increased by 4.15-fold when the roasting temperature increased from 140°C to 180°C, which was mainly attributed to the increase of pyrazines, alkenes, ketones, thiazoles and pentylfuran. And accordingly, sesame paste prepared at 180°C had the highest Odor Activity Value (OAV). Samples differed significantly in terms of aroma and total acceptability (p < 0.05). The sesame paste processed at 180°C had a moderate roasted and sweet aroma, and the highest acceptability, followed by that processed at 170°C. These results can be valuable for manufacturers to adjust the roasting process according to market demand for a particular flavor profile.

Key words: the volatile compounds, taste attributes, processing, sesame pastes

1 INTRODUCTION

Roasted sesame (Sesamum indicum L.) seed products are widely consumed in East Asia and the Middle East due to their unique flavor and considerable nutritional value. Of these products, sesame oil and sesame paste are two favorites. The aroma of roasted sesame seed products is widely appreciated, and closely connected with flavor.

So far, studies on the volatile components of sesame products have focused on sesame oils, sesame seeds and sesame flavor style Baijiu; pyrazines, pyrroles, thiazoles, and furans have been reported as the main contributors to the flavor of the roasted sesame oils1-6. Schieberle identified 2-acetyl-1-pyrroline, 2-furfurylthiol, 2-phenylethylthiol and 4-hydroxy-2,5-dimethyl-3(2H)-furanone as the key volatile odorants in roasted sesame seeds7,8. In contrast, there has been very little work on sesame pastes. Shahidi studied the volatiles of pastes made from dehulled sesame seeds that had been variously subjected to roasting, steaming, or microwaving, and concluded that the flavor of the paste made from roasted seeds was the most acceptable and strongest9. 26 aroma compounds were confirmed to contribute to the typical sesame aroma of Zhima aroma-type Baijiu, such as ethyl hexanoate, 3-methylbutanal, ethyl pentanoate, and so on10. And while ethyl hexanoate, ethyl butanoate, 3-methyl-1-butanol, 3-methylbutanal, methional, and dimethyl trisulfide might be main compounds related with the unique sesame flavor of Meilanchun baijiu11. However, the specific effects of seed roasting temperature on the volatiles of the sesame paste have not been reported. It is known that the roasting temperature have an important effect on the characteristic aroma of food products12-14. This study, therefore, was performed to investigate the effect of the roasting temperature on the volatile compounds, and to characterize the sensory attributes of the sesame pastes prepared from seeds roasted at different temperatures.

2 EXPERIMENTAL

2.1 Materials

Sesame seeds were obtained from Weifang Ruiifu Oil Seasoning Co. Ltd. (Weifang, China).

The used standards were 2,5-dimethyl pyrazine (purity ≥
98%), 1-octen-3-ol (purity ≥ 98%), nonanal (purity ≥ 96%), 2-nonenal (purity ≥ 99%) , 2-undecenal (purity ≥ 99.5%) and tridecane (purity ≥ 99.5%), all purchased from Shanghai Aladdin Bio-chem Technology Co. Ltd., (Shanghai, China). Chromatographic grade ethanol was obtained from Tianjin Kemiou Chemical Reagent Co. Ltd., (Tianjin, China). The “Cuizi” sesame paste (Shandong Weifang Ruifu Oil Seasoning Co. Ltd., China) was bought in a local supermarket.

2.2 Roasting process of sesame seeds, and preparation of sesame paste

The sesame seeds (500 g) were rinsed with the tap water, naturally drained the water, and roasted with continuous stirring using Automatic Roasting Machine (Zhucheng Hong-nuo Mechanical Technology Co. Ltd., Weifang, China) for 40 min at 140°C, 150°C, 160°C, 170°C, 180°C, and 190°C respectively.

After the roasting, the roasted sesame seeds were cooled using the electric fan at room temperature for about 15 min, and then ground to paste using stone mills (Zhangqiu Xianlin Stone Mill Machinery Factory, Zhangqiu, China).

2.3 Headspace solid-phase microextraction (HS-SPME) of sesame paste volatiles

Activating the extraction fiber: Before first use, the extraction fiber of the solid-phase microextraction (SPME) (DVB/CAR/PDMS solid microextraction fiber, 50 μm, Supelco, Bellefonte) was placed at the sample inlet of the gas chromatograph (GC/MS-QP2010), and aged at 270°C for 1 h. Thereafter, the extraction fiber was desorbed at 250°C for 0.5 h to remove the residue completely.

Headspace solid-phase microextraction: Each sesame paste sample of 5 ± 0.1 g was stirred for 5 min, and then placed into a 10 mL headspace vial and sealed using a silica gel pad lined with polytetrafluoroethylene. Afterwards, the sesame paste was stirred magnetically in a thermostatic water bath, and the activated extraction fiber was injected for capture of volatile flavor components.

2.4 GC-MS analysis

Analyses were performed in a GC-MS QP2010 (Shimadzu, Japan). The enriched SPME extraction fiber was inserted into the front inlet of the gas chromatography–mass spectrometry (GC-MS), and then was desorbed at 250°C for 0.5 h. An Rtx-5MS chromatographic column (30 m × 0.25 mm × 0.25 μm, Agilent Technologies, USA) was used. The conditions were as follows: inlet temperature, 250°C; sampling method, splitless; carrier gas, helium (purity ≥ 99.99%); flow rate, 1.0 mL/min. Temperature program was as follows: initial temperature, 40°C; held for 1 min; temperature increased to 100°C at a rate of 3°C/min; held for 5 min; temperature increased to 230°C at a rate of 10°C/min; temperature increased to 290°C at a rate of 15°C/min; finally held for 5 min.

Mass spectrometry conditions were as follows: ionizing mode (EI); electronic energy, 70 eV; ion source temperature, 230°C; port temperature, 250°C; scanning based acquisition model; and scanning range, 40–500 m/z.

2.5 Compound identification and quantification

The volatiles were identified based on comparison with NIST14.lib and NIST14s.lib Mass Spectral Database (Hewlett-Packard Co., Palo Alto, CA, USA), and confirmed by comparing their retention indices and mass spectra with those of authentic reference standards.

The quantification was performed by combining internal standard and external standard methods. Briefly, the standards were dispersed in ethanol to prepare the stock solution of 100 mg/mL, which was then mixed with the deodorized sesame paste sample to obtain the final concentrations of 2.5 μg/mL, 5 μg/mL, 10 μg/mL, 50 μg/mL, 100 μg/mL, 200 μg/mL, 400 μg/mL, 500 μg/mL, 600 μg/mL, 800 μg/mL, and 1000 μg/mL, respectively. Each concentration was measured in triplicate using GC-MS, and a calibration curve was generated. The standards were added to samples for internal calibration.

2.6 Determination of odor activity value (OAV)

OAV was calculated according to Erten and Cadwallader, the odor detection threshold was based on van Germerm and other relevant literatures:

Odor activity value = the concentration of olfactory component / thresholds of each component

2.7 Sensory evaluation

An evaluation group consisting of fifteen semi-trained panelists was recruited from the graduate students and university faculty and staff (female/male ratio: 2:1, age range: 22-50). Samples were assessed based on flavor traits according to Lykomitros, Fogliano, and Capuano and slightly modified; that is, the aroma attributes tested here were: roasted, burnt, sweet, oily, meat-like and fruity aroma. Each trait was scored on a scale of 0-5, with 0, 1, 2, 3, 4, 5 representing the odor intensities of none, very weak, weak, moderate, strong and very strong, respectively. The commercial sesame paste of “Cuizi” brand (Shandong Weifang Ruifu Oil Seasoning Co. Ltd., China), which has received good acceptability among consumers and was ranked first in our previous study, was used as the reference. Testors rinsed their mouth with pure drinking water between tastes to make sure their evaluations were independent of previous tastings.

During training, the panelists were asked to read the definitions of related sensory attributes, and the samples were labeled with the random numbers and presented to testors randomly. The training was terminated when the commercial sesame paste of “Cuizi” brand always ranked
first in acceptability trait.

2.8 Data analysis

GC-MS analysis was performed triplicately. The concentrations of volatile compounds and sensory data were subjected to analysis of variance (ANOVA) using SPSS (Version 16.0, USA). The difference was considered statistically significant when $p < 0.05$.

3 RESULTS AND DISCUSSION

3.1 Volatile flavor compounds

The volatile compounds extracted by HS-SPME were subjected to GC-MS analysis. A total of 56 volatile compounds were identified, including 15 pyrazines, 3 pyridines, 4 pyroles, 2 thiophenes, 2 thiazoles, 7 aldehydes, 4 ketone, 3 alkanes, 5 esters, 5 alkanes, and 6 other miscellaneous compounds. The total contents of the volatiles increased by 4.15-fold when the roasting temperature increased from 140°C to 180°C.

Pyrazines are likely formed during the Maillard reaction between sugar, proteins, lipid and their lysates. Of all the volatile compounds, the pyrazine group had the highest content in the sesame pastes. The contents of total pyrazines increased as the roasting temperature increased from 140°C to 180°C, which is the same as with the sesame oil reported by Dong et al. Sesame paste processed at 180°C had the highest content of almost every individual pyrazine, except 2-methylpyrazine and 2,6-dimethylpyrazine. The sample processed at 180°C had the highest content of 2-pentylpyridine, i.e. 4.74 µg/g. The other nitrogen-containing heterocyclic group was pyroles. Pyroles, which impart burnt and earthy odors, are typically present in the volatiles of heated foods. There were 2 pyroles present in these samples. 1-4-methylphenyl-pyrole was more abundant, present in the samples processed at 150°C and 160°C with concentrations of 3.31 and 2.97 µg/g, respectively. The most abundant pyrole in the sesame oil was pyrrole-2-carboxaldehyde, which was present in the range of 0.098 – 0.265 µg/g.

Thiazoles have nutty, green and vegetable-like aromas. 2,4-dimethyl-2-thiazoline and 4-propylthiazole were present in the samples roasted at higher temperature, i.e., 180°C and 190°C, which was similar to the results reported by Su et al.

A total of 7 aldehydes were present in the sesame pastes. As shown in Table 1, aldehyde compounds dominated the volatiles of sesame paste roasted at 140°C; they mainly comprised benzaldehyde, benzeneacetaldehyde and nonanal. The amounts of aldehydes, except nonanal and α-ethylidene-benzeneacetaldehyde, decreased with the increase of roasting temperature. This result is in agreement with one previous report; however, it is at variance with another of Su et al. The variance could be attributed to the different processing procedures used in the latter, which included steaming before pressing the roasted sesame seeds.

Ketones are reported to be responsible for the sweet and fruity flavor of foods. All sesame paste samples contained 2-nonanone, which has been previously reported to be present in sesame oil and sesame paste. Another three ketones, acetophenone, 4-hydroxy-3-methylacetophenone, and 4-hydroxy-2-methylacetophenone, were also present. A total of 5 esters was present in the volatiles, and 1,2-benzendicarboxylic acid, bis (2-methylpropyl) ester was present in all the samples. The amount of esters was highest in the sample processed at 180°C.

Furthermore, other miscellaneous compounds including 2-pentylfuran, dimethyl-trisulfide, 4-(1H)-quinazolinone, indole, 4-mequinoi and 2-ethyl-1H-benzimidazole, were present in the sesame pastes. Dimethyl-trisulfide was present only in the sesame paste roasted at 190°C.

3.2 Odor activity values (OAVs)

The amount of a volatile compound present does not necessarily correlate with its contribution to flavor. The odor thresholds of different volatile compounds vary considerably. The odor activity values (OAVs) can be used to reveal the main compounds contributing to the flavor of a particular food. Considering that the sesame paste contain a high amount of lipid, OAVs were calculated based on published odor detection thresholds determined in oil, when available.

The OAVs of volatile components in sesame pastes were displayed in Table 2.

The OAVs of 13 volatile compounds were >1; 3-ethyl-2,5-dimethylpyrazine and 2,3-diethyl-5-methylpyrazine contributed most to the OAVs of the various samples, except for the sample prepared at 140°C. 2-Pentylpyrididine had the OAVs of 318 and 948 for the sesame pastes processed at 140°C and 180°C, respectively. 2-Pentylpyrididine contributes to the fatty and tallowy aroma of the sample.

The OAV of nonanal was the highest for the sample processed at 180°C, which is consistent with the finding of Alasalvar, Shahidi, and Cadwallader that the content of nonanal in Turkish Tombul Hazelnut increased significantly after roasting.

The total OAVs of sesame paste varied with roasting temperature. The sesame paste prepared at 180°C had the highest OAVs, and these OAVs were primarily attributed to pyrazines, followed by 2-pentylpyridine and aldehydes.

3.3 Sensory evaluation

The sesame paste samples were evaluated and scored by semi-trained panelists, and the profile of their sensory
| Volatiles                              | Concentration (µg/g) |
|---------------------------------------|----------------------|
|                                       | 140°C | 150°C | 160°C | 170°C | 180°C | 190°C |
| 2-Methylpyrazine                      | 294.27 ± 8.89       | 51.24 ± 3.63 | 47.01 ± 3.35 | 112.92 ± 5.43 | 257.89 ± 9.58 | 106.57 ± 5.79  |
| 2,5-Dimethylpyrazine                  | 187.45 ± 8.22       | 249.20 ± 7.58 | 231.75 ± 8.97 | 512.48 ± 21.06 | 755.54 ± 28.66 | 246.92 ± 7.92  |
| 2,6-Dimethylpyrazine                  | 11.49 ± 0.59        | 7.82 ± 0.41   | 7.25 ± 0.37   | 1.72 ± 0.11    | 1.26 ± 0.07    | 0.86 ± 0.04    |
| 2-ethyl-6-methylpyrazine              | 0.14 ± 0.01         | 0.70 ± 0.21   | 14.75 ± 1.07   | 10.32 ± 1.54 | 81.73 ± 2.35   | 18.04 ± 0.89   |
| 2,3,5-trimethylpyrazine               | 0.98 ± 0.02         | 138.64 ± 6.84 | 122.99 ± 6.46 | 264.63 ± 9.46 | 398.53 ± 11.35 | 10.35 ± 0.02  |
| Acetylpyrazine                        |                 |                 |                 |                 |                 | 0.0     |
| 3-Ethyl-2,5-dimethylpyrazine          | 0.83 ± 0.01         | 144.86 ± 6.28 | 152.54 ± 6.33 | 258.35 ± 10.02 | 367.66 ± 12.48 | 100.74 ± 5.11  |
| 2-Ethyl-2,5-dimethylpyrazine          |                 |                 |                 |                 |                 | 0.0     |
| 2,3-Dimethyl-5-ethylpyrazine          |                 |                 |                 |                 |                 | 0.0     |
| Acetylthiazole                        |                 |                 |                 |                 |                 | 0.0     |
| 3-Ethyl-2,5-dimethylpyrazine          | 0.59 ± 0.01        | 1.89 ± 0.01    | 3.57 ± 0.02    | 14.22 ± 1.26    | 21.11 ± 0.25   | 0.84 ± 0.01   |
| 3,5-Dimethyl-2-methylpyrazine         | 5.86 ± 0.03        | 6.20 ± 0.77    | 14.03 ± 1.53   | 23.16 ± 1.87    | 3.77 ± 0.03    | 0.84 ± 0.01   |
| Total pyrazines                       | 495.16             | 633.63         | 568.34         | 1226.87         | 1983.12        | 518.13       |
| (The relative amount of total pyrazines) | (89.70%)         | (82.64%)       | (88.57%)       | (94.95%)        | (86.60%)       | (85.95%)     |
| 2-Butylpyridine                       |                 |                 |                 |                 |                 | 0.40 ± 0.01  |
| 2-Pentylpyridine                      |                 |                 |                 |                 |                 | 0.0     |
| 4-Phenylpyridine                      |                 |                 |                 |                 |                 | 0.0     |
| Total pyridines                       |                 |                 |                 |                 |                 | 0.83 ± 0.01  |
| (The relative amount of total pyridines) | (0.39%)          | (0.25%)        | (0.0015%)      | (0.21%)         | (0.02%)        | (0.22%)     |
| 2-Phenyl-1H-pyrole                    |                 |                 |                 |                 |                 | 0.84 ± 0.01  |
| 1H-Pyrrole-1-(4-methylphenyl)         | 3.51 ± 0.02       | 2.97 ± 0.02    |                 |                 |                 | 0.0     |
| 2-N-Methylpyrrole-2-carboxaldehyde    |                 |                 |                 |                 |                 | 0.70 ± 0.01  |
| 2-Pyrrolidone                         | 5.27 ± 0.03       | 4.07 ± 0.03    |                 |                 |                 | 1.94 ± 0.01  |
| Total pyroles                         | 5.27              | 7.38            | 2.97            | 6.60            | 3.47            |
| (The relative amount of total pyroles) | (0.95%)           | (0.96%)        | (0.46%)         | (0.29%)         | (0.58%)         |
| 2-Phenylothioephene                   |                 |                 | 1.75 ± 0.01    | 2.51 ± 0.02    |                 | 2.13 ± 0.02  |
| 3-Phenylothioephene                   |                 |                 | 3.88 ± 0.05    |                 | 2.13 ± 0.02    | 2.13 ± 0.02  |
| Total thiophenes                      |                 |                 | 1.75            | 2.51            | 3.88            | 2.13          |
| (The relative amount of total thiophenes) |                 |                 | (0.27%)        | (0.19%)        | (0.17%)         | (0.35%)     |
| 2,4-Dimethyl-2-thiazoline             |                 |                 |                 |                 |                 | 24.22 ± 2.15 |
| 4-Propylthiazole                      |                 |                 |                 |                 |                 | 3.31 ± 0.02  |
| Total thiazoles                       |                 |                 |                 |                 |                 | 52.58 ± 4.22 |
| (The relative amount of total thiazoles) |                 |                 |                 |                 |                 | (2.30%)     |
| Benzaldehyde                          | 3.52 ± 0.03       | 0.90 ± 0.01    | 0.22 ± 0.01    | 0.80 ± 0.01    |                 |                 |
| Benzenecacetaldehyde                  | 2.09 ± 0.02       | 1.26 ± 0.01    | 0.50 ± 0.01    | 0.16 ± 0.01    |                 |                 |
| Nonanal                               | 5.41 ± 0.04       | 1.81 ± 0.01    | 0.63 ± 0.01    |                 | 15.54 ± 0.98    |                 |
| Decanal                               | 0.54 ± 0.01       |                 |                 |                 |                 | 0.86 ± 0.04   |
| α-Ethylidene-benzenecacetaldehyde     | 0.78 ± 0.01       | 0.48 ± 0.01    |                 | 0.42 ± 0.01    | 2.99 ± 0.01    | 0.40 ± 0.01   |
| (E,E)-2,4-Decadienal                  | 0.65 ± 0.01       | 0.06 ± 0.01    | 0.03 ± 0.00    | 0.12 ± 0.01    | 0.30 ± 0.01    | 0.30 ± 0.01   |
| 5-Methyl-2-phenyl-2-hexenal           | 0.38 ± 0.01       | 0.16 ± 0.01    |                 |                 |                 | 0.86 ± 0.04   |
| Total aldehydes                       | 13.37             | 4.67            | 1.38            | 1.50            | 18.53           | 0.70          |
| (The relative amount of total aldehydes) | (2.42%)          | (0.61%)        | (0.22%)         | (0.12%)         | (0.81%)         | (0.12%)      |

Table 1 Volatile compounds identified in sesame pastes (µg/g) made from seeds roasted at different temperatures.
Table 1  Continued.

| Relative time/min | Volatiles                      | Concentration (µg/g) * |
|-------------------|--------------------------------|------------------------|
|                   | 140°C      | 150°C      | 160°C      | 170°C      | 180°C      | 190°C      |
| 15.815             | Acetophenone          | –          | 6.20 ± 0.5° | –          | –          | 42.22 ± 3.79° | 10.01 ± 1.26°|
| 17.213             | 2-Nonanone           | 5.77 ± 0.6° | 4.64 ± 0.3° | 2.07 ± 0.1° | 0.75 ± 0.1° | 14.81 ± 0.01° | 1.09 ± 0.01°|
| 28.934             | 4-Hydroxy-3-methylacetophenone | 12.54 ± 1.13° | –          | 12.14 ± 0.88° | –          | 35.28 ± 3.01° | –          |
| 28.935             | 4-Hydroxy-2-methylacetophenone | –          | 16.62 ± 1.77° | –          | 14.69 ± 1.38° | –          | 11.34 ± 1.16°|
|                   | Total ketones      | 18.31 ± 1.65 | 27.46 ± 2.03 | 14.21 | 15.44 | 92.31 | 22.44 |
|                   | (The relative amount of total ketones) | (3.32%) | (3.58%) | (2.21%) | (1.19%) | (4.03%) | (3.72%)|
| 14.542             | Trans-β-ocimene     | –          | 20.36 ± 1.98° | 15.27 ± 1.01° | 12.22 ± 0.76° | –          | –          |
| 15.042             | 3,7-Dimethyl-1,3,6-octatrien | 0.80 ± 0.01° | 43.09 ± 4.31° | 23.11 ± 1.82° | 26.85 ± 2.13° | 71.25 ± 6.43° | –          |
| 38.234             | 3,7,11-Trimethyl-2,6,10-dodecatrrien | –          | 3.55 ± 0.03 | –          | –          | –          | –          |
|                   | Total alkenes       | 0.80 | 67.00 | 38.38 | 39.07 | 71.25 | –          |
|                   | (The relative amount of total alkenes) | (0.14%) | (8.74%) | (5.98%) | (3.02%) | (3.11%) | –          |
| 37.721             | Tetradecanoic acid, ethyl ester | – | 1.59 ± 0.01 | – | – | – | – |
| 38.539             | 1,2-Benzeneedicarboxylic acid, bis (2-methylpropyl) ester | 5.10 ± 0.04° | 2.66 ± 0.01° | 1.64 ± 0.01° | 2.11 ± 0.01° | 7.10 ± 0.05° | 1.19 ± 0.01°|
| 39.623             | Dibutyl phthalate    | 3.44 ± 0.03° | 1.63 ± 0.01° | 0.47 ± 0.01° | 2.08 ± 0.02° | 6.53 ± 0.07° | –          |
| 39.737             | 9-ethylhexadecenoate | – | 0.84 ± 0.01 | – | – | – | – |
| 40.007             | Hexadecanoic acid ethyl ester | 1.18 ± 0.01° | 0.85 ± 0.01° | 0.35 ± 0.01° | – | 1.68 ± 0.01° | 0.30 ± 0.00°|
|                   | Total esters        | 9.72 | 7.57 | 2.46 | 4.19 | 15.31 | 1.49 |
|                   | (The relative amount of total esters) | (1.76%) | (0.99%) | (0.38%) | (0.32%) | (0.67%) | (0.25%)|
| 28.74              | Tridecane           | 6.53 ± 0.05° | 2.49 ± 0.01° | 2.72 ± 0.02° | – | 5.87 ± 0.04° | – |
| 28.741             | Pentadecane         | – | – | – | – | 1.47 ± 0.01 | – |
| 31.625             | Tetradecane         | – | 0.17 ± 0.01° | 0.11 ± 0.00° | – | 0.47 ± 0.01° | – |
| 36.582             | Heptadecane         | – | – | – | – | – | 0.12 ± 0.01 |
| 36.584             | Hexadecane          | – | 0.08 ± 0.00° | 0.05 ± 0.00° | – | 0.35 ± 0.00° | – |
|                   | Total alkanes       | 6.53 | 2.74 | 2.88 | – | 6.69 | 1.59 |
|                   | (The relative amount of total alkanes) | (1.18%) | (0.36%) | (0.45%) | (0.29%) | (0.26%) | (0.25%)|
| 11.098             | Dimethyl-trisulfide | – | – | – | – | – | 1.62 ± 0.05 |
| 12.272             | 2-Pentylfuran       | 2.87 ± 0.02° | 10.79 ± 1.13° | 6.41 ± 0.05° | – | 26.29 ± 2.04° | 2.61 ± 0.02°|
| 26.499             | 4(1H)-Quinazolinone | – | – | – | – | – | 1.30 ± 0.01 |
| 28.16              | Indole              | 2.52 ± 0.02° | 1.35 ± 0.01° | – | – | 0.40 ± 0.00° | – |
| 16.842             | 4-Mequinol          | – | – | – | – | – | 14.98 ± 1.36 |
| 30.997             | 2-Ethyl-1H-benzimidazole | – | – | 2.51 ± 0.02° | 8.52 ± 0.05° | 3.08 ± 0.03° | – |
|                   | Total volatiles     | 552.03 | 766.76 | 641.72 | 1292.11 | 2289.82 | 602.82 |

*concentration (µg/g) values were expressed as the means ± SD (n=3). The values with the different letters within a row are significantly different (p < 0.05).

evaluation scores was shown in Fig. 1.

There were significant differences between samples for sweet, burnt, and roasted aroma attributes and total acceptability (p < 0.05). The sesame paste processed at 140°C had the sweetest note of all the samples (p < 0.05). The samples processed at 190°C had the highest score (average score of 4.67) for "burnt aroma" (p < 0.05), which obscured the other flavors, resulting in the lowest acceptability score. The sesame paste processed at 180°C had a moderate roasted and sweet aroma, and the highest acceptability, followed by that processed at 170°C.

3.4 Chemistry of aroma components of sesame pastes

When heated, the foods form the aroma components through the lipid oxidation / degradation, sugar degradation, and Maillard reaction. The flavor profiles are influenced by several factors, for example, including fermentation, roasting and age of cocoa tree for cocoa bean.

The samples processed at higher temperature (180°C / 190°C) had a greater number and abundance of pyrazines, pyridines, thiophenes than the sample processed at 140°C. Pyrazines result from Maillard reactions, in which a ditetrahydrobutylpyrazines intermediate are formed through condensation, then rearranged and cleaved to form alkylpyrazines. In our study, ethylpyrazines mainly
occurred when temperature was above 170°C, while the most abundant pyrazines identified in sesame paste processed at 140°C were methylpyrazines.

Decanal and Nonanal are the main degradation product of the unsaturated fatty acids, such as resulting from fission of the R-O bond of C18:1 25. The branched-chain aldehydes are suggested to be derived from Strecker degradation of amino acids. Sesame paste processed at 140°C was rich in the various straight-chain aldehydes and the branched-chain aldehydes, suggesting the volatiles of the sesame paste at 140°C mainly from the lipid degradation.

### 4 Conclusion

A total of 56 volatile compounds were identified in sesame pastes processed at six different temperatures. The main volatiles of the sesame pastes were pyrazines, alkenes, thiazoles, aldehydes, esters, and pentylfuran. Of all the volatile compounds, the pyrazine group had the highest content. The amounts of the volatiles increased when the degree of roasting increased. The sesame paste prepared at 180°C had the highest OAVs. The sesame paste processed at 180°C had a moderate roasted and sweet aroma, and the highest acceptability. The resulting data might be useful for the designing the optimal roasting process, improvement of product flavor and increase of consumer acceptability.
ACKNOWLEDGEMENT
This work was supported by the Henan Provincial Scientific and Technological Research Projects Grant No. 152102210272, 192102110103.

Conflicts of interest
None.

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