

The Influence of Spices on the Volatile Compounds of Cooked Beef Patty

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Abstract

The aim of this study is to examine the influences of spices on the amounts and compositions of volatile compounds released from cooked beef patty. Beef patty with 0.5% of spice (nutmeg, onion, garlic, or ginger powder, w/w) was cooked by electronic pan until they reached an internal temperature of 75°C. A total of 46 volatile compounds (6 alcohols, 6 aldehydes, 5 hydrocarbons, 6 ketones, 9 sulfur compounds, and 14 terpenes) from cooked beef patties were detected by using purge-and-trap GC/MS. The addition of nutmeg, onion, or ginger powder significantly reduced the production of the volatile compounds via lipid oxidation in cooked beef patty when compared to those from the control. Also, the addition of nutmeg and garlic powder to beef patty generated a lot of terpenes or sulfur volatile compounds, respectively. From these results, the major proportion by chemical classes such as alcohols, aldehydes, hydrocarbons, ketones, sulfur compounds, and terpenes was different depending on the spice variations. The results indicate that addition of spices to the beef patty meaningfully changes the volatile compounds released from within. Therefore, it can be concluded that spices can interact with meat aroma significantly, and thus, the character of each spice should be considered before adding to the beef patty.

Key words: beef patty, aroma, volatile compounds, spice

Introduction

Aromas of cooked meat are important flavor attribute and the initial sensory trait with the appearance of cooked meat. It affects not only appetite but also the pleasure of eating. Aromas of cooked meat are predestined from volatile compounds (Resconi *et al.*, 2013). When meat is cooked, various volatile compounds are released by heat-induced reactions, mainly Strecker and Maillard reaction, lipid oxidation and degradation, thiamin degradation, and interaction between lipid-oxidized products with Strecker and Maillard products (Resconi *et al.*, 2013). Therefore, various factors such as fat content, fatty acid composition,

amino acid content and composition, and reducing sugar content and composition of meat, which are affected by breed, sex, and maturity of animals, and aging time with proteolytic and lipolytic enzyme activities of meat, significantly influence the aromas of cooked meat (Gianelli *et al.*, 2012; Golovnya *et al.*, 1983; Lieske and Konrad, 1994; Mottram, 1998).

In the meat processing, spices are used to improve shelf life, appearance, or flavor of meat products (Brown, 2009). Spices have unique taste and odor. Therefore, the aromas of meat product could be mainly influenced by added spices. Previous studies reported that various volatile compounds in meat product were originated from spices (Demirok *et al.*, 2013; Gianelli *et al.*, 2012). In this sense, it is noteworthy to understand the change of volatile compounds by each spice in meat product for producing meat product with desirable aroma. However, the change in the amount and the composition of volatile compounds from

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meat product by adding each spice have not been reported.

Therefore, this study was carried out to investigate the change in the amount and composition of the volatile compounds from cooked beef patty with added spice such as nutmeg, onion, garlic, or ginger, which are globally familiar spices used in meat products.

Materials and Methods

Sample preparation

Raw ground beef and spices (nutmeg, onion, garlic, and ginger powder) were purchased from local market. The ground beef was mixed with each spice (0.5%, w/w), and individually vacuum-packaged (-650 mmHg) in low-density polyethylene/nylon vacuum bags (oxygen permeability of 22.5 mL/m²/24h atm at 60% RH/25°C, water vapor permeability of 4.7 g/m²/ 24 h at 100% RH/25°C). The vacuum-packaged ground beef was stored at 4°C for 24 h. After storage, beef patty was made (200 g, 1 cm thickness). The beef patty was cooked for 2 min on a preheated electric pan until they reached an internal temperature of 75°C.

Volatile compounds

A purge-and-trap apparatus (Solatek 72 and Concentrator 3100; Tekmar-Dohrmann, USA) connected to a gas chromatograph/mass spectrometer (HP 6890/HP 5973; Hewlett-Packard Co., USA) was used to analyze the volatiles produced. The beef patty sample (3 g) was placed in a 40 mL sample vial, and the vial was flushed with helium gas (40 psi) for 5 s. The maximum waiting time of a sample in a refrigerated (4°C) holding tray was less than 4 h to minimize oxidative changes before analysis. The meat sample was purged with helium gas (40 mL/min) for 14 min at 40°C. Volatiles were trapped using a Tenax-charcoal-silica column (Tekmar-Dohrmann) and desorbed for 2 min at 225°C, focused in a cryofocusing module (-80°C), and then thermally desorbed into a capillary column for 60 s at 225°C.

An HP-624 column (8.5 m × 0.25 mm i.d., 1.4 µm nominal), an HP-1 column (60 m × 0.25 mm i.d., 0.25 µm nominal; Hewlett-Packard Co.), and an HP-Wax column (6.5 m × 0.25 mm i.d., 0.25 µm nominal) were connected using zero dead-volume column connectors (J&W Scientific, USA). Ramped oven temperature was used to improve volatile separation. The initial oven temperature of 30°C was held for 6 min. After that, the oven temperature was increased to 60°C at 5°C/min, increased to 180°C at 20°C/min, increased to 210°C at 15°C/min, and then held

for 5 min at the temperature. Constant column pressure at 22.5 psi was maintained. The ionization potential of the mass selective detector (Model 5973; Hewlett-Packard Co.) was 70 eV, and the scan range was 19.1 to 400 m/z. Identification of volatiles was achieved by comparing the mass spectral data of the samples with those of the Wiley Library (Hewlett-Packard Co., USA). Standards were used to confirm the identification by the mass selective detector. The area of each peak was integrated using the ChemStation (Hewlett-Packard Co.), and the total peak area (pA*seconds × 10⁴) was reported as an indicator of volatiles generated from the sample.

Statistical methods

This study was performed in triplicate. The raw data of the total peak area (pA*seconds × 10⁴) was changed to Log₁₀ value. Analysis of variance was performed using the raw data, and the mean values and standard error of the means (SEM) were calculated by the Statistical Analysis System (SAS version 9.3, SAS Institute Inc., USA). Differences among the means were determined by Tukey's multiple range test with $p < 0.05$.

Results and Discussion

Totally 46 volatile compounds (6 alcohols, 6 aldehydes, 5 hydrocarbons, 6 ketones, 9 sulfur compounds, and 14 terpenes) were identified in cooked beef patties (Table 1). In the volatile compounds detected in the present study, alcohols could be generated by lipid oxidation and bacterial action in meat (Resconi *et al.*, 2013). Aldehydes, hydrocarbons, and ketones are mainly originated from lipid oxidation in meat (Mottram, 1998). Aldehydes (2-methylbutanal, 3-methylbutanal), ketone (2,3-butanedione), and sulfur compounds are originated from Strecker and Maillard reaction (Farmer, 1996; Resconi *et al.*, 2013). Mottram (1998) reported that the volatile compounds originated from Strecker and Maillard reaction have more influence on aroma of meat than those from lipid oxidation. Also, since sulfur compounds have very low detection thresholds, their contribution to aroma of meat is very important (Mottram, 1994).

Most of the volatile compounds detected in the present study showed significant difference except for 2-propanol among treatments ($p < 0.05$). The control, cooked beef patty without spice, released 18 volatile compounds including 4 alcohols (1-propanol, 2-propanol, 2-ethyl-1-hexanol, and ethanol), 5 aldehydes (2-methylbutanal, 3-methylbutanal, heptanal, hexanal, and pentanal), 4 hydrocarbons (decane,

heptanes, nonane, and octane), 2 ketones (2-butanone and 2,3-butanedione), and 3 sulfur compounds (dimethyl disulfide, dimethyl trisulfide, and methyl 2-propenyl-disulfide). And, the area percentages of different chemical classes were 44.6% alcohols, 29.3% aldehydes, 14.6% hydrocarbons, 6.2% sulfur compounds, and 5.3% ketones, in order of high proportion.

Nutmeg is an aromatic spice and generally added to

meat product (Krishnamoorthy and Rema, 2000). In the volatile compounds detected from cooked beef patty with nutmeg, alcohols (1-propanol, 2-ethyl-1-hexanol, and ethanol), aldehydes (heptanal, hexanal, and pentanal), hydrocarbons (decane, heptanes, and nonane), ketones (2-butanone) were not detected. These are mainly originated from bacterial action or lipid oxidation (Ercolini *et al.*, 2009; Resconi *et al.*, 2013). Therefore, this result may be attrib-

Table 1. Volatile compounds from cooked beef patty with different spice

Compounds	Beef	Beef with nutmeg	Beef with onion	Beef with garlic	Beef with ginger	SEM
Alcohols						
1-Pentanol	_ ^b	_ ^b	_ ^b	2.8 ^a	_ ^b	0.25
1-Propanol	2.7 ^a	_ ^c	_ ^c	1.5 ^b	_ ^c	0.15
2-Propanol	4.2	4.1	4.0	4.2	4.1	0.07
1-Propene-2-ol	_ ^b	_ ^b	_ ^b	2.6 ^a	_ ^b	0.22
2-Ethyl-1-hexanol	2.3 ^a	_ ^b	_ ^b	_ ^b	_ ^b	0.01
Ethanol	3.1 ^a	_ ^b	3.5 ^a	2.7 ^a	2.8 ^a	0.30
Total	4.2 (44.6%)	4.1 (16.2%)	4.1 (52.5%)	4.3 (12.4%)	4.2 (75.4%)	0.06
Aldehydes						
2-Methyl-butanal	3.5 ^a	1.4 ^b	_ ^c	3.4 ^a	2.8 ^a	0.25
3-Methyl-butanal	3.5 ^a	2.4 ^b	2.3 ^b	3.2 ^{ab}	2.9 ^{ab}	0.22
Butanal	_ ^b	_ ^b	_ ^b	2.2 ^a	_ ^b	0.06
Heptanal	3.2 ^a	_ ^c	_ ^c	2.9 ^{ab}	2.3 ^b	0.19
Hexanal	2.6 ^b	_ ^c	2.3 ^b	3.4 ^a	_ ^c	0.12
Pentanal	3.1 ^a	_ ^d	_ ^d	2.8 ^b	2.2 ^c	0.06
Total	4.0 ^a (29.3%)	2.4 ^b (0.6%)	2.6 ^b (1.7%)	4.0 ^a (6.6%)	3.2 ^{ab} (10.1%)	0.19
Hydrocarbons						
1-Octene	_ ^b	_ ^b	_ ^b	2.2 ^a	_ ^b	0.06
Decane	2.1 ^a	_ ^b	_ ^b	2.2 ^a	_ ^b	0.04
Heptane	2.7 ^a	_ ^b	_ ^b	_ ^b	_ ^b	0.03
Nonane	3.6 ^a	_ ^b	_ ^b	_ ^b	_ ^b	0.03
Octane	3.0 ^a	2.6 ^{ab}	2.3 ^b	3.0 ^a	2.7 ^{ab}	0.14
Total	3.7 ^a (14.6%)	2.6 ^{bc} (0.6%)	2.3 ^c (1.0%)	3.1 ^{ab} (0.9%)	2.7 ^{bc} (2.5%)	0.14
Ketones						
2-Butanone	3.1 ^a	_ ^b	_ ^b	_ ^b	_ ^b	0.03
2-Oxazolidinethione	_ ^b	_ ^b	_ ^b	2.4 ^a	_ ^b	0.10
2-Pentanone	_ ^c	_ ^c	_ ^c	3.5 ^a	3.1 ^b	0.06
2-Propanone	_ ^b	_ ^b	2.3 ^a	_ ^b	_ ^b	0.11
2,3-Butanedione	2.7 ^a	3.0 ^a	_ ^b	_ ^b	_ ^b	0.08
Methyl propyl 2-pentanone	_ ^b	_ ^b	2.7 ^a	_ ^b	_ ^b	0.15
Total	3.3 (5.3%)	3.0 (1.4%)	2.9 (3.9%)	3.5 (2.2%)	3.1 (6.2%)	0.14
Sulphur compounds						
2-Propen-1-thiol	_ ^b	_ ^b	_ ^b	4.0 ^a	_ ^b	0.08
3-(methylthio)-1-Propene	_ ^b	_ ^b	0.8 ^b	4.2 ^a	_ ^b	0.35
3,3-Thiobis-1-propene	_ ^b	_ ^b	_ ^b	4.1 ^a	_ ^b	0.26
Di-2-propenyl disulfide	_ ^b	_ ^b	_ ^b	3.5 ^a	_ ^b	0.37
Dimethyl disulfide	3.3 ^b	_ ^d	4.0 ^a	4.3 ^a	2.4 ^c	0.15
Dimethyl trisulfide	2.2 ^a	_ ^b	_ ^b	2.5 ^a	_ ^b	0.16
Methyl 2-propenyl-disulfide	2.1 ^b	_ ^c	_ ^c	4.0 ^a	_ ^c	0.08
Methyl-thiirane	_ ^b	_ ^b	_ ^b	3.5 ^a	_ ^b	0.05
Ethaethioic acid S-methyl ester	_ ^b	_ ^b	1.6 ^{ab}	2.9 ^a	_ ^b	0.40
Total	3.3 ^b (6.2%)	_ ^d	4.0 ^b (40.9%)	5.0 ^a (78.0%)	2.4 ^c (1.9%)	0.16

Table 1. Volatile compounds from cooked beef patty with different spice (continued)

Compounds	Beef	Beef with nutmeg	Beef with onion	Beef with garlic	Beef with ginger	SEM
Terpenes						
α -Pinene	- ^c	3.1 ^a	- ^c	- ^c	2.2 ^b	0.11
α -Terpinene	- ^b	4.0 ^a	- ^b	- ^b	- ^b	0.09
α -Thujene	- ^b	3.0 ^a	- ^b	- ^b	- ^b	0.16
α -Terpinolene	- ^b	2.9 ^a	- ^b	- ^b	- ^b	0.22
α -phellandrene	- ^b	3.4 ^a	- ^b	- ^b	- ^b	0.04
β -Pinene	- ^b	2.9 ^a	- ^b	- ^b	- ^b	0.11
Camphene	- ^b	2.6 ^a	- ^b	- ^b	2.8 ^a	0.16
γ -Terpinene	- ^b	4.0 ^a	- ^b	- ^b	- ^b	0.12
Limonene	- ^b	3.7 ^a	- ^b	- ^b	- ^b	0.07
Myrcene	- ^b	2.9 ^a	- ^b	- ^b	- ^b	0.09
<i>o</i> -cymene	- ^b	4.1 ^a	- ^b	- ^b	- ^b	0.06
Sabinene	- ^b	3.5 ^a	- ^b	- ^b	- ^b	0.10
Terpinolene	- ^b	3.0 ^a	- ^b	- ^b	- ^b	0.06
Tricyclene	- ^b	2.2 ^a	- ^b	- ^b	- ^b	0.07
Total	- ^c	4.7 ^a (81.2%)	- ^c	- ^c	2.9 ^b (3.9%)	0.10
Total volatile compounds	4.6 ^b (100%)	4.8 ^{ab} (100%)	4.4 ^b (100%)	5.1 ^a (100%)	4.3 ^b (100%)	0.12

¹Standard errors of mean (n=15).

^{a-d}Different letters within same row differ significantly ($p < 0.05$).

uted by antimicrobial and antioxidant reaction of nutmeg. Gupta *et al.* (2013) reported that nutmeg had antimicrobial and antioxidant potential. Adding nutmeg also, inhibited the production of the volatile compounds such as 2-methyl-butanal, 3-methyl-butanal, and sulfur compounds originated from Strecker and Maillard reaction when compared to the control ($p < 0.05$). However, the reason for the reduction of compounds in beef patty by adding nutmeg is uncertain. Terpenes (81.2%) were found in the highest proportion in total area of the volatile compounds. Terpenes has aroma such as fruity, floral, fresh, and spicy (Demirok *et al.*, 2013). The generation of terpenes in the volatile compounds from meat has two possible ways: animals fed green forages and use of spice (Demirok *et al.*, 2013; Vasta *et al.*, 2006). However, a large production of terpenes in meat product was mainly originated from the use of spice. Nutmeg especially has various terpenes (Krishnamoorthy and Rema, 2000).

Park *et al.* (2008) confirmed the antioxidant and antimicrobial activity of onion in pork. In the present study, the volatile compounds originated from lipid oxidation or bacterial action such as 1-propanol, 2-ethyl-1-hexanol, heptanal, pentanal, decane, heptane, nonane, and 2-butanone were not detected in cooked beef patty with onion. However, adding onion to beef patty released new ketones such as 2-propanone and methyl propyl 2-pentanone produced via lipid oxidation in cooked beef fatty. Gorraiz *et al.* (2002) reported that high proportion of 2-propanone in

volatile compounds from beef generated strong livery and bloody flavor. In the volatile compounds originated from Strecker and Maillard reaction, 2-methyl-butanal and 3-methyl-butanal were undetected and significantly decreased, respectively. Also, 2,3-butanedione was not detected in cooked beef patty with onion. Yang *et al.* (2011) confirmed that adding 0.5% onion to ground beef resulted in the increase in sulphur compounds in the volatile compounds from ground beef after cooking. In the present study, three sulfur volatile compounds were identified in cooked beef patty with onion. However, the sulfur compounds constituted 40.9% of the total area of volatile compounds from cooked beef patty with onion while the control had 6.2% sulfur compounds.

Garlic is generally used for enhancing the flavor of meat product. Addition of garlic had no influence on the amount of alcohols, aldehydes, hydrocarbons, and ketones in the volatile compounds from cooked beef patty even though it influenced the compositions of the volatile compounds. This result partially agreed with a previous study. Yang *et al.* (2011) confirmed that adding garlic to ground beef did not influence the amount of alcohols, hydrocarbons, and ketones in the volatile compounds from ground beef after cooking. Garlic has various sulfur compounds, and the abundant amount of sulfur compound in garlic is alliin (*S*-allylcysteine sulfoxide) (Lawson, 1998). In the volatile compounds from cooked beef patty with garlic, various sulfur compounds were identified and their amo-

unt was extremely high. From these result, the sulfur compounds constituted 78.0% of the total area of the volatile compounds from cooked beef patty with garlic. Previous study reported that the amount and compositions of sulfur volatile compounds were greatly increased in the volatile compounds from cooked ground beef when garlic was added to ground beef (Yang *et al.*, 2011). The detection thresholds of the sulfur volatile compounds are low, and the sulfur volatile compounds generated meat flavor at low levels. However, high levels of the sulfur volatile compounds in meat are related to the undesirable odor of meat (Hogan, 2002).

Addition of ginger to beef patty significantly decreased the amount of hydrocarbons produced via lipid oxidation in the volatile compounds from cooked beef patty. In addition, 1-propanol, heptanal, hexanal, pentanal, and 2-butanone produced via lipid oxidation were undetected or decreased when compared to those from the control although the amount of alcohols, aldehydes, and ketones was not significantly different with those from the control ($p < 0.05$). Asimi *et al.* (2013) confirmed the antioxidant activity of garlic and ginger spices, and reported that garlic spice had stronger antioxidant activity than ginger spice. In the present study, garlic did not show antioxidant activity. However, ginger decreased some volatile compounds originated from lipid oxidation in beef patty. Adding ginger also inhibited the production of the volatile compounds originated from Strecker and Maillard reaction such as 2,3-butanedione, and sulphur compounds when compared to those of the control ($p < 0.05$). Terpenes such as α -pinene, and camphene were identified in the volatile compounds from cooked beef patty with ginger. Generally, various terpenes were contained in ginger (Yang *et al.*, 2009).

The spices used in this study significantly influenced the amount and the composition of the volatile compounds released from cooked beef patty. Nutmeg and garlic generated characteristic volatile compounds such as terpenes and sulphur compounds, respectively. In addition, nutmeg, onion, and ginger inhibited the production of the volatile compounds via lipid oxidation. From these results, it was found that the major proportion among chemical classes such as acids, alcohols, aldehydes, hydrocarbons, ketones, sulphur compounds, and terpenes was different depending on the spice. Therefore, it can be concluded that spices can interact with meat aromas significantly, thus the character of each spice should be considered before use on beef patty.

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References

- Asimi, O. A., Sahu, N. P., and Pal, A. K. (2013) Antioxidant activity and antimicrobial property of some Indian spices. *IJSRP* **3**, 1-8.
- Brown, P. M. (2009). Spices, Seasonings, and Flavors. In *Ingredients in meat products*. Rodrigo, T. (ed.), Springer, New York, pp. 199-210.
- Demirok, E., Kiralan, M., and Carbonell-Barrachina, A. A. (2013) Determination and classification of volatile compounds of pastirma using solid phase microextraction/gas chromatography/mass spectrometry. *JMBFS* **3**, 105-109.
- Ercolini, D., Russo, F., Nasi, A., Ferranti, P., and Villani, F. (2009) Mesophilic and psychrotrophic bacteria from meat and their spoilage potential *in vitro* and in beef. *Appl. Environ. Microbiol.* **75**, 1990-2001.
- Farmer, L. J. (1996) Interactions between lipids and the Maillard reaction. *Flavor-Food Interactions* **633**, 48-58.
- Gianelli, M. P., Salazar, V., Mojica, L., and Friz, M. (2012) Volatile compounds present in traditional meat product (charqui and longaniza sausage) in Chile. *Braz. Arch. Biol. Technol.* **55**, 603-612.
- Golovnya, R. V., Misharina, T. A., Garbuzov, V. G., and Medvedev, F. A. (1983) Volatile sulfur containing compounds in simulated meat flavor and their comparison with the constituents of natural aroma. *Nahrung* **27**, 237-249.
- Gorraiz, C., Beriain, M. J., Chasco, J., and Insausti, K. (2002) Effect of aging time on volatile compounds, odor, and flavor of cooked beef from Pirenaica and Friesian bulls and heifers. *J. Food Sci.* **67**, 916-922.
- Gupta, A. D., Bansal, V. K., Badu, V., and Maithil, N. (2013) Chemistry, antioxidant and antimicrobial potential of nutmeg (*Myristica fragrans* Houtt). *J. Genet. Eng. Biotechnol.* **11**, 25-31.
- Hogan, B. (2002) Putting punch in meat flavor profiles. *Food Product Design* July.
- Krishnamoorthy, B. and Rema, J. (2000). Nutmeg and mace. In *Handbook of herbs and spices*. Peter, K. V. (ed.), CRC Press, New York, pp. 238-247.
- Lawson, L. S. (1998). Garlic: a review of its medicinal effects and indicated active compounds. In *Phytomedicines of europe: chemistry and biological activity*, ACS Symposium series 691. Lawson, L. S. and Bauer, R. (eds.), American Chemical Society, Washington D. C., pp. 176-209.
- Lieske, B. and Konrad, G. (1994) Protein hydrolysis - the key to meat flavoring systems. *Food Rev. Int.* **10**, 287-312.
- Mottram, D. S. (1994). Some aspects of the chemistry of meat flavour. In *Flavor of meat and meat products*. Shahidi, F. (ed.),

- Blackie Academic & Professional, Glasgow, pp. 210-230.
15. Mottram, D. S. (1998) Flavour formation in meat and meat products: a review. *Food Chem.* **62**, 415-424.
 16. Park, S. Y., Yoo, S. S., Shim, J. H., and Chin, K. B. (2008) Physicochemical properties, and antioxidant and antimicrobial effects of garlic and onion powder in fresh pork belly and loin during refrigerated storage. *J. Food Sci.* **73**, C577-C584.
 17. Resconi, V. C., Escudero, A., and Campo, M. M. (2013) The development of aromas in ruminant meat. *Molecules* **18**, 6748-6781.
 18. Vasta, V. and Priolo, A. (2006) Ruminant fat volatiles as affected by diet. A review. *Meat Sci.* **73**, 218-228.
 19. Yang, H. S., Lee, E. J., Moon, S. H., Paik, H. D., and Ahn, D. U. (2011) Addition of garlic or onion before irradiation on lipid oxidation, volatiles and sensory characteristics of cooked ground beef. *Meat Sci.* **88**, 286-291.
 20. Yang, Z., Yang, W., Peng, Q., He, Q., Feng, Y., Luo, S., and Yu, Z. (2009) Volatile phytochemical composition of rhizome of ginger after extraction by headspace solid-phase microextraction, petroleum ether extraction and steam distillation extraction. *Bangladesh J. Pharmacol.* **4**, 136-143.

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