Diversity in volatile components in beef tissue cooked at different temperature

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Abstract

Present study was designed to evaluate the effect of cooking temperature on volatile compounds of beef longissimus muscle. The longissimus muscle was cooked at 50, 70 and 90^{0}C respectively for 1 hr in pre-heated water bath. The volatile aroma compounds of the cooked samples were analyzed using solid-phase microextraction- gas chromatography-mass spectrometry (SPME-GC/MS). Twenty-eight volatile compounds (9 aldehydes, 2 ketones, 3 alcohols, 13 hydrocarbons, and 1 furan) were detected and identified in present investigation. However, the number and concentration of most of the detected compounds considerably increased with increase in cooking temperature. Among the volatile compounds produced, nonanal, hexanal and benzaldehyde, the lipid -oxidized products were mostly dominant. The current data indicated that differences in number and concentration of the volatile compounds with rise in cooking temperature will possibly make diversity in flavor of cooked beef. Some parts of this data are submitted to Korean Journal of Food Science and Animal Resources by Je et al. (2010).

Key words: aroma, volatile, SPME-GC/MS, cooking temperature. Beef, longissimus muscle.

Introduction

Presently, there has been immense increase in Beef consumption due to increase in world population and boost up in people's income particularly in developed countries. Concurrently, consumers continue to demand beef and its products with high quality, healthiness and variety of sensory traits such as tenderness and flavor, amongst which flavor occupies an important level in consumer's acceptability (Robbins et al., 2003). Flavor is the combination of aroma and tastes, in which aroma is contributed by volatile compounds that are detected by olfactory receptors in the passages at the back of the nose. Macleod, 1994 reported that the volatile compounds with aroma are derived from flavor precursors (amino acids, sugar, vitamin, nucleotides, fatty acid) in meat by three main reactions such as Maillard reaction; lipid oxidation and thermal degradation of thiamine during cooking. Many volatile compounds have been detected and identified in cooked beef with variety of aroma notes such as 2-ethyl-3,5-dimethyl pyrazine and 2,3-diethyl-5-methylpyrazine have roasty, caramel-like, burnt and earthy notes in roasted beef (Cerny and Grosch, 1992). Similarly 2-Methyl-3-furanthiol, methional, 1-octen-3-one, phenylacetaldehyde, (*E*)-2-nonenal, (*E*,*E*)-2,4,decadienal are potent odorants from boiled beef (Gasser and Grosch, 1988). Whereas some volatile compounds like, 2-pentylfutran and pentanal were positively correlated with rancid-off flavor (Stetzer, Cadwallader, Singh, Mckith & Brewer, 2008). In conclusion, several significant factors such as pH, temperature, ageing, diet have been reported to contribute in production of volatile compounds with particular aroma. Ames, Guy & Kipping, (2001) demonstrated that pH considerably affects the formation of volatile classes. Whereas, cooking method and temperature strongly affects the formation of volatile compounds which in turn makes the overall difference in meat flavor (Maclead & Seyyedian-Ardebili 1981). Meinert, Andersen, Bredie, Bjergegaard & Aaslyng, (2007) have described the effects of high cooking temp (above 100^{0}C) on volatile components formation, however, the effect of below 100^{0}C cooking temperature on volatile formation in cooked beef has been unknown. The objectives of the present study were to investigate the effect of cooking temperatures on formation of aroma volatile compounds in beef.

Material and method

Lumbar vertebrae LL muscle of Australian Black Angus was used for the preset investigation. The fresh muscles were imported and sampled from the Incheon airport and transported to the meat science laboratory at the Chonbuk National University and stored at -20℃ in a freezer until use. The Volatile components in cooked longissimus muscle of beef were analyzed following the method as described by Ba, Oliveros, Ryu & Hwang (2010) with suitable modifications. Briefly, one gram of powdered sample was placed in a 40 ml headspace vial sealed with PTFE-faced silicone septum (Supelco Co., USA) and cooked at a pre-heated water bath maintained at 50, 70 or 90°C for 1 hr and the control samples were also kept in parallel at room temperature (~ 20°C) for the same time period. The cooked sample was immediately cooled in an ice bath to prevent further aroma development. An octagonal magnetic stirring bar was put into the vial. Thereafter, it was placed into the 60°C water bath contained in a water jacket. After equilibration at 60°C for 10 min (Thermo recorder TR-52 T & D Corp., Japan), SPME needle (Carboxen/PDMS, 75 μm, Supelco Co., USA) was inserted into the PTFE/silicone septum and the fiber was exposed for 1 hr. At the end of extraction, the fiber was retracted and immediately exposed for 10 min in the GC-MS injector at 250°C (Agilent Technologies 6890N, 5973 MSD, USA). Prior to analysis the sample vial was spiked 1μl of internal standard, 2-methyl-3-heptanone, 0.816mg/ml in methanol). Samples were separated by a DB-5MS capillary column, 30 m x 0.25 mm i.d. x 0.25 μm film thickness (Agilent J & W Scientific, Model No. 122-5532, Folcom, USA) with a split ratio of 10:1 and split flow of 10 ml/min. Helium was used as the carrier gas in constant pressure mode at 7.03 psi, flow rate of 1.0 ml/min and average linear velocity of 36 cm/second. The area of each peak was integrated using the ChemStation software (Agilent Technologies, Version D.01.00, USA). Primarily, the eluted compounds were identified by comparison of their mass spectra with those already present in the Wiley Registry of Mass Spectral Data 7th edition (McLafferty, 2000; Agilent part no. G1035B, by Kovats indices calculated by applying a series of standard alkanes C8-C20 (Fluka, Cat. No. 04070, New Zealand). The calculated retention indices were compared with available literatures, and peaks were further confirmed by running various authentic standards of choice. Quantities of the volatile compounds were approximated by comparison of their peak areas with that of the 2-methyl-3-heptanone internal standard, using a response factor of 1.

Result and discussion

In present study we were able to detect and identify a total of 28 volatile compounds (Table1) from longissimus muscle of Australian Black Angus. Earlier workers [(Wettasinghe, Vasanthan, Temelli & Swallow (2001), Kim, Nam & Ahn (2002)] have also reported majority of these volatile compounds in beef, chicken and pork. It was also observed that the number and concentration of the detected compounds significantly ($p<0.05$) increased with increase in cooking temperature nearly in all chemical classes and our results are in agreement with the earlier results.{Ames, Guy & Kipping (2001)}. Moreover, it was also observed that the lipid-oxidized products viz, hexanal, octanal, nonanal, 3-hydroxy-2-butanone, hexane, 3-methylnonane, benzene, decane and toluene, were produced at all temperatures (50, 70 and 90°C) as well as in control samples, however, hexanal (AH-3), benzaldehyde (AH-5), and nonanal (AH-7) were found in highest concentration compared with other compounds (Fig.1). So it is given to understand from present study that the volatile compounds produced by lipid oxidation are formed at low temperature, even at room or storage temperature and when the temperature was increased the volatile component formation will also increase. Our data reveals that all compounds were present at 90^{0}C. Some hydrocarbon compounds such as benzene, heptadecane, 2, 4-dimethylheptane, 3-methylnonane and undecane were found only in low concentration and were also found independent of cooking temperature. Interestingly, the Maillard products such as furfural, heterocyclic nitrogen and/or sulfur-containing compounds were not produced with our cooking conditions throughout the study. They usually form in meat samples cooked at higher temperature i.e. above 100^{0}C (Ames, Guy & Kipping. 2001). The numbers and concentrations of detected volatile compounds in cooked beef at different cooking temperatures possibly will generate the diversity in beef flavor.

Conclusion

Our findings demonstrate that cooking temperature significantly affects the formation of specific aroma volatile compounds in cooked beef. Additionally, rise in cooking temperature appreciably increased the number and concentration of volatile compounds and vice versa.

Table1. Volatile components in longissimus muscle using SPME-GC/MS technique as a function of cooking temperatures at 50, 70 and 90℃ for 60 min with reference samples hold at room temperature (RT) for 60 min (μg/kg tissue)

ID	Compounds	RT	LRI	Reliability	Treatment (℃)				SE	Sig. level
					RT	50	70	90		
Aldehydes										
AH-1	Acetaldehyde	3.491	<800	ms	0	0	8.7	10.1	0.65	p<0.05
AH-2	Pentanal	7.019	<800	ms, IR,AC	0	0	0	37.8	0.68	p<0.05
AH-3	Hexanal	9.954	812	ms, IR,AC	10	61.7	83.7	443.3	12.4	p<0.05
AH-4	Heptanal	12.795	917	MS, IR	0	8.7	13.7	65.7	7.94	p<0.05
AH-5	Benzaldehyde	14.414	1098	MS, RI	0	9.7	78.7	260.7	12.6	p<0.05
AH-6	Octanal	15.295	1025	ms, IR,AC	7	14.3	23.3	75.7	12.9	p<0.05
AH-7	Nonanal	17.471	1126	ms, IR,AC	42.3	67	73.3	162	16.3	p<0.05
AH-8	E-2-decenal	20.448	1277	Ms, RI	0	0	0	6	1.89	p=0.132
AH-9	Propanal	12.948	926	ms	0	0	0	27.3	3	p<0.05
Ketones										
KT-1	2-propanone	3.907	<800	ms, RI	0	17.3	16	11.3	5.93	p=0.231
KT-2	3-hydroxy,2-Butanone	7.219	<800	ms, RI	46	29	32.3	22.7	7.99	p=0.282
Alcohols										
AL-1	1-octen-3-ol	14.759	2593	ms, AC	0	0	0	27.7	3.94	p<0.05
AL-2	1-octanol	16.698	1083	ms, IR,AC	0	7.3	1.7	13.3	1.22	p<0.05
AL-3	2-cyclohexen-1-ol	16.522	1306	ms	0	0	0	7.3	0.17	p<0.05
Hydrocarbons										
HC-1	Hexane	4.891	<800	ms, RI	19.7	93	63.3	47.7	30.5	p=0.438
HC-2	Benzene	6.116	<800	ms, RI	19	79.3	0	80	29.1	p=0.192
HC-3	Toluene	9.003	<800	ms, RI	6.7	15	9	32	4.44	p<0.05
HC-4	3-ethyl-2-Methyl-1,3-hexadiene	15.932	1110	ms	0	0	0	10.3	0.7	p<0.05
HC-5	Propylbenzene	16.278	1199	ms	0	0	0	3	1.5	p=0.441
HC-6	Undecane	17.355	1121	ms, RI	3.7	1.7	1.3	7.3	1.67	p=0.113
HC-7	Dodecane	19.314	1223	ms, RI	2.3	3.3	2.7	9	2.06	p=0.152
HC-8	Tridecane	21.117	1323	ms, RI	0	3.3	1.7	6.3	1.22	p<0.05
HC-9	Decane	15.190	1002	ms, RI	2.7	6	1.7	12.7	4.76	p=0.407
HC-10	3,5-dimethyloctane	16.614	1075	ms	0	0	0	5.7	1.59	p=0.085
HC-11	3-methylnonane	16.415	1062	ms	6.7	3.7	5.7	7.7	3.05	p=0.814
HC-12	Heptadecane	15.987	1100	ms	6.3	0	0	0	0.6	p<0.05
HC-13	2,4-dimehtylheptane	15.669	1056	ms	6.7	0	0	0	1.69	p<0.05
Furan										
F	2-pentylfuran	14.989	1004	ms, RI	0	0	0	28.7	5.33	p<0.05

MS: Tentatively identified by matching sample spectrum with the spectrum in the Wiley 7N Edition (Agilent part no. G1035B)

AC: The compounds verified by using authentic standard compounds

LRI: Retention index was determined using some hydrocarbons (C8-C20) on the fused silica column (DB-5MS)

RI: Approximate identification in comparison with retention index calculated by literature references.

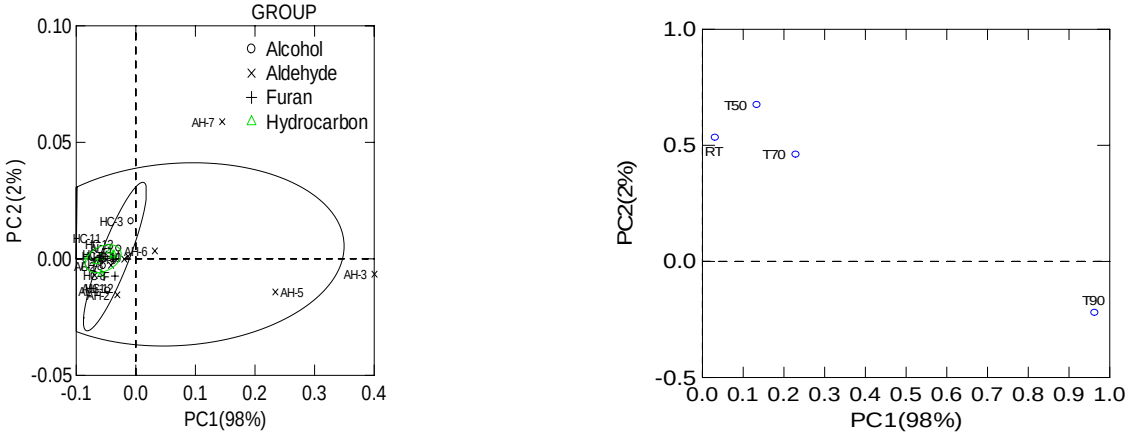

Fig.1. Plots of PCA of detectable volatile components for beef longissimus heated at various temperatures. Loading plots (right plane) of variables for heating temperatures at 50 (T50), 70 (T70) and 90 (T90) ℃ for 60 min. Values were differently marked between volatile groups. Circles were ellipse lines centered on the sample means of the x and y variables at 0.68.

References

1. Ames,J.M., Guy, R.C.E & Kipping, G.J. (2001). Effect of pH and Temperature on the Formation of Volatile Compounds in Cysteine/Reducing Sugar/Starch Mixtures during Extrusion Cooking. J. Agric. Food Chem. 49, pp. 1885-1894.

2. Ba, H. V., Oliveros, M. C., Ryu, K. S., & Hwang, I. H. (2010). Development of analysis condition and detection of volatile compounds from cooked Hanwoo beef by SPME-GC/MS analysis. *Korean J. Food Sci.* 30, pp. 73-86.

4. Cerny, C., & Grosch, W. (1992). Evaluation of potent odorants in roasted beef by aroma extract dilution analysis. Zeitschrift für Lebensmitteluntersuchung und Forschung A, 194, pp.322–325.

5. Gasser, U., & Grosch, W. (1988). Identification of volatile flavor compounds with high aroma values from cooked beef. Zeitschrift für Lebensmitteluntersuchung und Forschung A, 186,pp. 489–494.

6. Kim, Y.H., Nam, K.C & Ahn, D.U. (2002). Volatile profiles, lipid oxidation and sensory characteristics of irradiated meat from different animal species. Meat Science 61.pp, 257-265.

7. MacLeod, G. (1994). The flavor of beef. In F. Shahidi (Ed.), Flavor of meat and meat products (pp. 4–37). Glasgow: Chapman and Hall.

8. Maclead, G & Syyedain Ardebili, M.(1981). Natural and simulated meat flavor. Food science and nutrition, 14, pp. 309-381.

9. Meinert, L., Andersen, L.T., Bredie,W.L.P., Bjergegaard, C, & Aaslyng, M.D. (2007). Chemical and sensory characterisation of pan-fried pork flavour: Interactions between raw meat quality, ageing and frying temperature. Meat Science 75.pp 229–242.

10. Robbins, K., Jensen, J., Ryan, K. J., Homco-Ryan, C., McKeith, F. K., & Brewer, M. S. (2003). Consumer attitudes towards beef and acceptability of enhanced beef. Meat Science, 65,pp. 721–729.

11. Stetzer, A.J., Cadwallader, K., Singh, T.K., Mckeith, F.K & Brewer, M.S. (2008). Effect of enhancement and ageing on flavor and volatile compounds in various beef muscles. Meat Science, 79, pp.13–19.

12. Wettasinghe, M., Vasanthan, T., Temelli, F & Swallow, K. (2001). Volatile flavor composition of cooked by-product blends of chicken, beef and pork: a quantitative GC-MS investigation. Food research international, 34, pp.149-158.