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ORIGINAL ARTICLE

Emission Characteristics of Odors and Odorants Released from Grilling Mackerel and Pork Belly by Different Cooking Tools

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Abstract

It is known that mackerel and pork belly release a strong odor in the process of roasting. We evaluated a dilution factor of odor arising during roasting mackerel or pork belly and the relative odor strength using several cooking tools and analyzed compounds causing odors with gas chromatograph / mass detector.

Roasting pans used were grill with lid, electric grill without lid and general roasting pan, and a grill with lid can attach the activated carbon charcoal deodorant at the inside of lid. And all electric grills have a drip tray under the heater. We investigated characteristics of odor emission depending on the presence of water and deodorants in these cooking tools. Study has shown that roasting mackerel produces approximately 36 time more odors than roasting pork belly, and the reduced odor emission when roast with water. And it shows the reduced deodorant effect when cooked with water after attaching activated carbon charcoal in the cooking pan. Major odor causing compounds arising when cooking mackerel and pork belly were aldehydes with high boiling point such as octyl aldehyde with a low odor threshold value.

Key words : Grilled food, Odor concentration, Odor intensity, Odorous substances

1. Introduction

It is a recent trend that demand of luxurious high-rise apartments is on the rise. And the living space of closed-type structure that inhibits the influx of outside air in order to save energy is gaining a lot of attention (Seoul government, 2013). To this end, there have been much attentions on indoor air pollutants as closed-type structure is gaining more popularity (Jo and Sohn, 2009; Peng et al., 2009; Zhang et al., 2010) and studies to find means to reduce indoor air pollution has been also gaining some steams vigorously (Sohn et al., 1995; Hyttinen et al., 2007).

And in the mean time, according to surveys conducted by Matsui (1991), Nagai and Igarashi (2004) along with Japan Association of Odor Association (Iwasaki, 2009), a living space that people smell odor the most was found to be kitchen and Korea will not differ too much in that as well. Cooking odors arising indoor will not only cause psychological impact but also can give very unpleasent feeling to residents and to visitors if they remain indoor after cooking. Therefore, there is growing perception that we need to control odor arising from the indoor cooking process (Kabir and Kim, 2011). As for the studies conducted on odor arising in the cooking process, Tanamura et al.

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(2011) presented various surveys on kitchen structure, ventilation fan or hood, cooking tools and strength of seasonal cooking method, etc. and measurements. In addition, there have been studies on the changes of odorous compounds depending on the cooking method of tomato (Wang and Kays, 2000) and the generation of hazardous pollutants when cooking fish (Choi et al., 2011).

There have been studies done on the characteristics of hazardous materials arising pork belly cooking by Kim et al. (2014), their studies are noted for focusing on hazardous pollutants such as benzene or PAH (polyaromatic hydrocarbon), organic solvents such as toluene, xylene and VFAs (volatile organic acids) described in Korean Offensive Odor Control Law. In this study, dilution factor of odor and relative odor strength arising in the cooking process of mackerel and pork belly which Koreans enjoy and known to have a relative strong odor was measured by a sensory evaluation scheme, and investigated VOCs (volatile organic compounds) that cause odors through chemical analysis and estimated the relative contribution to the odor by each compound. Especially, we observed dilution factor and relative odor strength depending on the presence of cooking tools used in the cooking process, water or deodorants, and noted on the odor reduction measures arising from roasting food from the result.

2. Material and methods

2.1. Cooking materials

We selected mackerel which is the most consumed and best known roast fish and that also expected to have the highest odor emission rate as an odor -releasing sample. And pork belly was also selected for the study in meat category. We bought fresh from a large discount store with a short shelf life and pork belly and mackerels purchased were ready for cooking without any further preparation work. Samples bought were stored in refrigerator to keep the freshness, and experiments were conducted within 1~2 days within the purchase. And quantity of mackerel was prepared in 95g and 200g for port belly per 1 cooking.

2.2. Cooking tools

Heating tools of 4 types used in this study are shown in Fig.1. Electric grills (A, B) that have heater on both pan and lid so that it does not need to flip the fish or meat, and a heating tool that has heater on the pan only (C), and the pan for roasting only (D) that heats with general gas burner. Cooking tools, A, B and C has a drip pan for water under to cook meat and attach activated carbon charcoal inside the lid (Fig. 2 h and i) to reduce the odor. Structures of cooking pan A and B are similar and are slightly different in the shape of deodorant. However, in the manual of A specifies that you pre-heat before cooking meats. And D has the structure that collects oil that is generated during the cooking process and

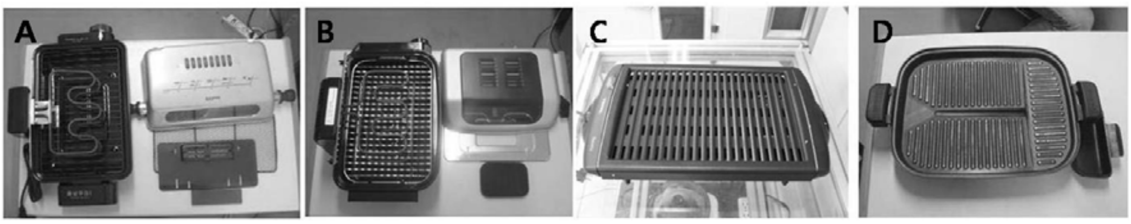


Fig. 1. Cooking tools used for grilling fish and meat
(A and B: Electric grill, C: Electric pan, D: Grill-pan)

release it to outside.

2.3. Sampling and analysis of odors

1) Preparation of odor sample

For mackerel, in order to find the unique odor compounds of mackerel before heating, put mackerel in to a glass jar of 1.2L with lid, poured high purity nitrogen gas (Modern Gas, Korea) at a rate of 2.0 L/min into the glass jar and collected 10 L of air released from the glass jar into polyester bag (Fleks Sampler, 38㎛, 10 L, OMI Odor-Air Service, Japan) (Fig. 2 a). That was blank odor sample of mackerel before roasting. And mackerel was roast using heating tools A and B, pre-heated A for 5 minutes before roasting mackerel, sampled odors released into 10 L sample bag depending on the use of water and deodorants. Odor samples released for 7 minutes after heating mackerel were collected while paper funnel on the heating tool was connected to the suction box as shown in Fig. 2 c) & f). When heating tool C was used, sample was collected of the odor released for 7 minutes and used as the grilling sample, and the burnt sample was collected from the odor released for 5 minutes from the point of generating black spots by cooking continuously past the 7 minute mark. For pork belly, heating tools A, B, D were used and samples were selectively taken depending on the use of water and deodorants in A & B.

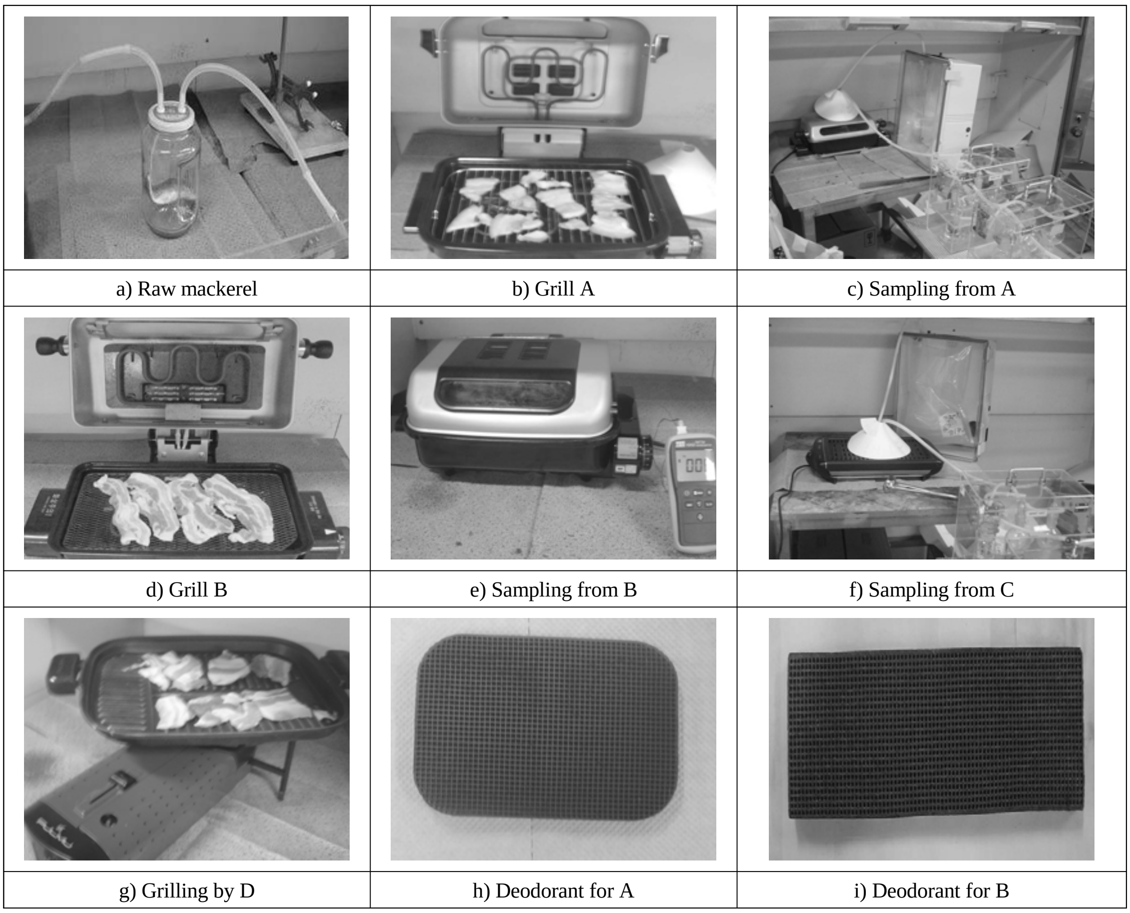


Fig. 2. Pictures of experimental procedure

2) Measurement of dilution factor and odor strength

Odor measurement by sensory on the odor sample collected in the cooking process, in other words, odor strength and dilution factor were measured. In order to select a panelist for sensory evaluation, 5 standard odorous compounds (OMI Odor-Air Service, Japan) specified in Japanese official method of measuring odor concentration, Ministry of the Environment Government of Japan were used, and 6 panelists who have normal olfactory sense were chosen. To measure dilution factor on the samples collected, triangular odor bag method was used, and 6 scale of odor strength on each odor sample was also measured.

3) Analysis of odorants by GC/MS

Volatile organic compounds on the identical sample used in sensory evaluation was analyzed using gas chromatograph/mass detector, analysis method of Yu et al.(2002) was employed.

Analytical instrument used connected automated thermal desorber (ATD, Perkin Elmer Turbo Matrix 350) to GC/MSD (HP 5890 series Ⅱ/HP5971A MSD), Tenax-TA tube (Supelco Cat. No. 25055) was used for an absorption material of volatile organic compounds. In order to condense volatile organic compounds from the odor sample collected from each cooking process, 5.0 L was absorbed onto a Tenax-TA tube at a flow rate of 0.5 L/min in the air of polyester bag. The tube concentrated with VOCs (volatile organic compounds) was analyzed by introducing to GC/MSD via ATD (Automated Thermal Desorber) which is set to -30℃.

Some of the VOCs appeared in the GC/MS total ion chromatogram were identified and quantified from calibration lines prepared with the standard gas used in EPA TO-14 method (Calibration Mix 1, 1 ppm in nitrogen, Supelco, USA) and another standard gases manufactured from standard materials purchased from Sigma-Aldrich (Seoul, Korea). For the odorant proposed by mass spectrum library among VOCs appeared in the total ion chromatogram but in the absence of standard gas, the concentrations was expected by using the calibration line of standard gas that has the most similar molecular formula while having functional group.

3. Results and discussion

3.1. Sensory evaluation

Dilution factors measured from the odor samples collected by roasting mackerel and pork belly in cooking heater and odor strength are shown in Table 1. The odor strengths of samples were too strong for direct sensory measurement. Therefore, the samples for evaluating their odor strength were prepared from diluting a 300-fold from original odors and evaluated with 6 scale odor strength.

In order to find the relationship defined by Weber-Fechner law between dilution factor and odor strength of each sample collected when roasting, vertical axis refers to odor strength, horizontal axis refers to a log value of dilution factor and presented in Fig. 3.

As shown in the figure below, correlation factor between two factors is high, 0.925, it is reasonable to evaluate samples diluted by a 300-fold rather than to evaluate original odor. Table 1 shows odor strengths of odor samples collected during cooking and dilution factor were measured, Fig. 4 show odor strength of each sample in a line graph and dilution factor in a bar graph based on Table 1. As shown in Fig. 4, overall odor strength of mackerel roast is greater than pork belly roast by more than 1 degree of odor strength, and dilution factor of mackerel is also much greater than pork belly. And for mackerel, if there is no deodorant regardless the presence of water, dilution factor increases by about a 30,000 -fold, and it can be confirmed that odor strength and dilution factor all reduce if water is added.

Table 1. Measured dilution factors and odor strengths to cooking apparatus and cooking condition

Material	Apparatus	Water[1)]	Deodorant[1)]	Dilution Factor	Odor Strength[2)]
Mackerel	A	×	×	30,903	4.8
			○	13,183	3.7
		○	×	30,903	4.2
			○	13,183	3.8
	C	×	-	30,903	4.2
		○	-	22,909	4.0
Pork belly	A	×	×	13,032	3.5
			○	4,121	2.3
		○	×	2,318	2.3
			○	5,495	2.5
	B	×	×	3,694	2.7
			○	1,462	1.5
		○	×	2,318	2.0
			○	3,090	1.7
	D	-	-	7,328	3.3

1) X means no water, O means using water. And - refers to a cooking tool without deodorants originally.

2) Odor strength is taken from originals diluted by a 300-fold.

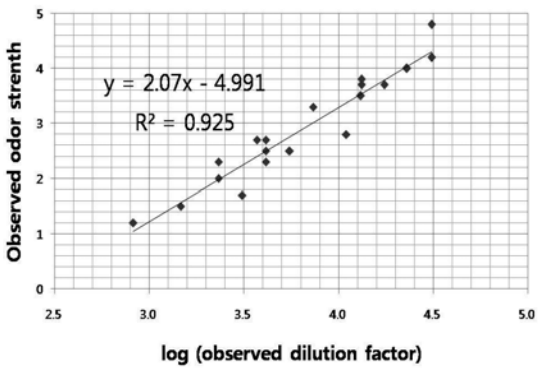


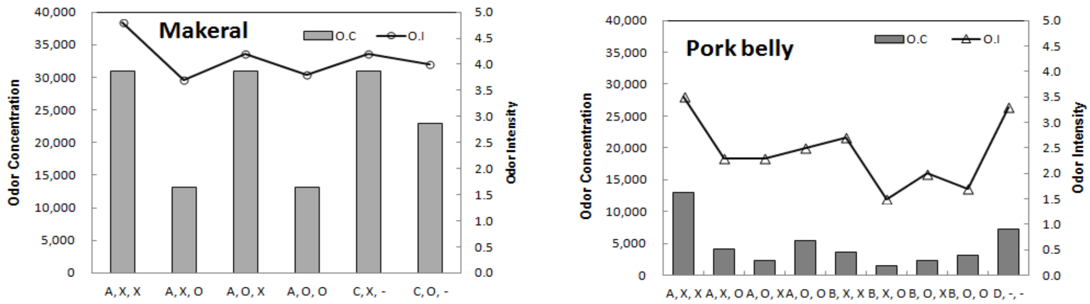
Fig. 3. Correlation line of dilution factor and odor strength.

And it shows a heater with lid, A, emits lower odor than a heater with no lid, C, when water is added. Dilution factor and odor strength showed a lower value when water is added than without it when cooking pork belly using A & B, there were some deodorant effect if deodorants were added in the absence of water, however, its effect was insignificant even if deodorants were added where water was added. The difference between similar heaters A and B in pork belly was that A has much higher dilution factor and odor strength. It is estimated that a 5 minute pre-heating before cooking meat caused the increase emissions of volatile organic compound.

3.2. Analysis of odorants

1) Mackerel roast

Three odor samples were taken mackerel odor before cooking, odor generated during 7 minutes of cooking, odor of burnt mackerel, and elements and concentration of volatile organic compound were measured using GC/MSD. TIC (Total Ion Chromatogram) example of volatile organic compound of mackerel is shown in Fig. 6. These elements appeared on chromatogram are classified by functional group and concentration of each elements are shown in Table 2. Threshold values in Table 2 were quoted from the measurement of Nagata (2003).



※ (1) A, B, C : grills

(2) Central OX means with and without water and third OX with and without charcoal deodorant.

Fig. 4. Odor concentrations and intensities of grilling mackerel and pork by heating tools

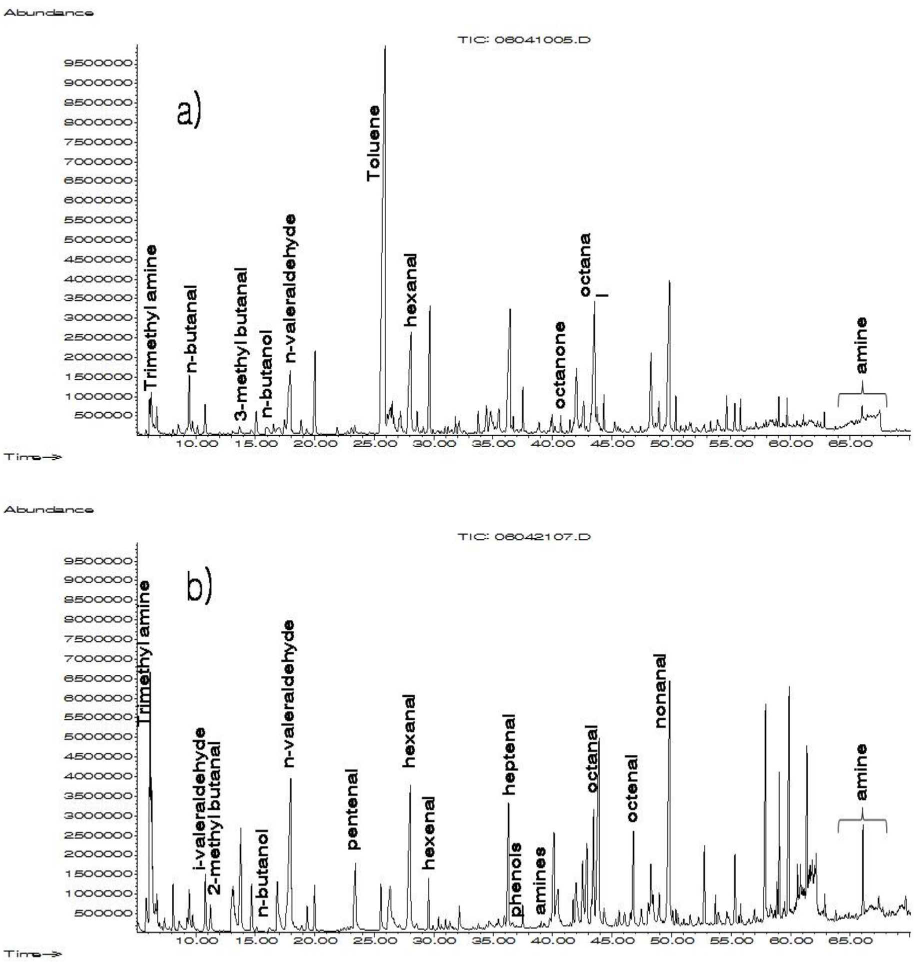


Fig. 5. Total ion chromatogram of VOCs from grilled mackerel.

a) without water b) with water

Table 2. Concentrations of odorous compounds in smoke of grilled mackerel (unit : ppb)

Compounds	Calibration line[3)]	Threshold value	Raw	Heating by C	Over heated by C	Grilled by A[4)] No water.	Grilled by A[4)] Water
Amines[2)]	TMA	0.01	**159.3**	**439.0**	n.d.	3.2	3.0
Dimethyl sulfide	DMS	3.0	n.d.	n.d.	**45.5**	n.d.	n.d.
Dimethyl disulfide	DMDS	0.22	n.d.	**331.8**	**9,354.3**	n.d.	n.d.
Propenal	AcAl	3.6	n.d.	n.d.	n.d.	2.2	**46.0**
Propanal	PrAl	1.0	n.d.	3.2	n.d.	n.d.	**18.2**
Butenal	BuAl	23	n.d.	n.d.	n.d.	1.4	n.d.
Butanal		0.67	n.d.	n.d.	**1,297.4**	3.7	**36.9**
2-Pentenal	PeAl	-	n.d.	398.8	1,140.4	211.2	21.2
Pentanal		0.10	n.d.	**337.7**	**745.7**	**112.3**	**15.4**
2-Hexen-1-al	HeOH	-	n.d.	26.5	n.d.	n.d.	n.d.
Hexanal		0.28	2.2	**262.5**	**943.5**	**72.1**	**2.1**
2-Hepten-1-al		-	15.3	310.1	n.d.	102.3	19.3
Heptanal		0.18	**4.9**	**52.1**	n.d.	**23.0**	**67.6**
2-Octen-1-al	OcOH	-	n.d.	158.5	n.d.	**5.5**	**13.5**
Octanal		0.010	n.d.	257.2	n.d.	**125.0**	**38.6**
2-Nonenal		-	n.d.	77.2	n.d.	n.d.	n.d.
Nonanal		0.34	n.d.	**577.6**	n.d.	**6.0**	**44.4**
Ethanol	EtOH	520	9.3	n.d.	299.9	n.d.	n.d.
Propanol	PrOH	94	n.d.	31.1	n.d.	n.d.	n.d.
Butanol	BuOH	38	n.d.	34.8	n.d.	n.d.	n.d.
2-Methly propanol		11	n.d.	64.1	178.4	n.d.	n.d.
2-Pentenol		-	n.d.	1,669.0	n.d.	n.d.	n.d.
Pentanol		100	2.7	n.d.	n.d.	n.d.	n.d.
2-Methyl butanol		290	n.d.	**254.7**	n.d.	n.d.	n.d.
Cyclopentanol	HeOH	-	1.95	n.d.	n.d.	n.d.	n.d.
2-Hexen-1-ol		-	n.d.	19.9	n.d.	n.d.	n.d.
Hexanol		6.0	n.d.	1.3	n.d.	n.d.	n.d.
2-Octen-1-ol	OcOH	-	n.d.	**333.2**	n.d.	n.d.	n.d.
Octanol		2.7	n.d.	**169.9**	n.d.	n.d.	n.d.
Nonanol		0.90	n.d.	**1.8**	n.d.	n.d.	n.d.
Furans	HeOH	-	4.7	14.5	64.3	2.1	104.0
Phenols[2)]	PhOH	0.1	**2,649.5**	**753.0**	**181.2**	**192.5**	**82.5**
Methyl ethyl ketone	MEK	440	n.d.	n.d.	**76,767.0**	2.0	10.3
Methyl n-propyl ketone		28	n.d.	n.d.	**21,215.2**	n.d.	n.d.
3-Octen-2-one	OcOH	-	n.d.	56.5	n.d.	n.d.	n.d.
2-Octanone		-	n.d.	13.5	n.d.	n.d.	n.d.
Hexane	Tol	1500	12.8	967.5	n.d.	n.d.	n.d.
Toluene		330	1.3	23.1	n.d.	n.d.	n.d.
Heptane		670	2.4	207.7	n.d.	n.d.	n.d.
Octane		1700	33.0	89.0	1,329.2	n.d.	n.d.

1) Bold-type numbers are the compounds detected with more than their odor threshold values.
2) These compounds consist of several similar compounds, and the odor threshold values used are values of representative materials.
3) It means a calibration line and its abbreviation are following compounds.
TMA; Trimethyl amine, DMS; Dimethyl sulfide, DMDS; Dimethyl disulfide, AcAl; Acetaldehyde,
PrAl; n-Propyl aldehyde, BuAl; n-Butyl aldehyde, PeAl; Pentyl aldehyde, HeOH; n-Hexanol,
OcOH; n-Octanol, EtOH; Ethanol, PrOH; n-Propanol, BuOH; n-Butanol, HeOH; n-Hexanol,
OcOH; n-Octanol, PhOH; Phenol, MEK; Methyl ethyl ketone, Tol; Toluene
4) Charcoal deodorant was not used.

Amines among the compounds measured means a generic term for low-boiling amines as trimethyl amine, diethyl amine, for those compounds do not fully separate on chromatogram and therefore are expressed as amines, the odor threshold value indicates that of trimethyl amine. For phenols, since there is no threshold value of each isomers, the odor threshold values of these compounds were presented as that of phenol. For the compounds shown in Table 2 that are higher in concentration than odor threshold value are expressed in bold-type letters. And those compounds that do not have the odor threshold value are expressed with "-".

The concentrations shown in Table 2 were divided by their odor threshold values. And then, the expected odor concentrations were calculated and shown in Table 3. For the compound that do not have odor threshold values in this Table, its odor threshold values were estimated from that of the compound which has the same functional group and similar molecular formula. If expected odor concentration of each compound is summed, it is possible to estimate the total odor dilution factor, the compounds with high expected odor concentration will contribute to the odor significantly (Ko et al., 2013).

Expected O.C. (Odor Concentration)

$$= \frac{C_{i,\, measured\ value}}{C_{i,\, threshold}} \qquad \text{Equation (1)}$$

C_i, measured value : measured concentration of i component (ppb)

C_i, threshold : Odor threshold value of i component (ppb)

Table 3. Dilution factors of odorous compounds released from mackerel

Functional group	Compounds	Raw	Heating by D	Over heated by D	Grilled by A	
					No water.	Water
Amine	Amines	15,930	43,900	0	320	300
sulfide	Dimethyl sulfide	0	0	15	0	0
	Dimethyl disulfide	0	1,508	42,520	0	0
Saturated Alcohol	2-Methly propanol	0	6	16	0	0
	Octanol	0	63	0	0	0
Unsaturated Alcohol	2-Pentenol	0	17	0	0	0
	2-Octenol	0	123	0	0	0
Saturated aldehyde	Propanal	0	3	0	0	18
	Butanal	0	0	1,936	6	55
	Pentanal	0	3,377	7,457	1,123	154
	Hexanal	8	938	3,370	258	8
	Heptanal	27	289	0	128	376
	Octanal	0	25,720	0	12,500	3,860
	Nonanal	0	1,699	0	18	131
Unsaturated aldehyde	Propenal	0	0	0	1	13
	2-Pentenal	0	3,988	11,404	2,112	212
	2-Hexenal	0	95	0	0	0
	2-Heptenal	85	1,723	0	568	107
	2-Octenal	0	15,850	0	550	1,350
	2-Nonenal	0	227	0	0	0
Ketones	Methyl ethyl ketone	0	0	174	0	0
	Methyl n-propyl ketone	0	0	758	0	0
Phenol	Phenols	26,495	7,530	1,812	1,925	825
Expected Odor Concentration		42,545	107,056	69,462	19,509	7,409

Table 3 lists those materials with expected odor concentration of more than 10 from each compound calculated in Equation 1. Main contributing compounds to mackerel odor before cooking are phenol and amines, and if mackerel is heated using A or D, amines and aldehydes of more than low or mid boiling points are a source of odor.

For odor of burnt mackerel, a strong volatile amines vanishes and instead sulfur compounds such as dimethyl disulfide and aldehydes of more than low or mid boiling points, ketones of high boiling point have contributed. And if water is put in a cooking tool with lid, odor strength and dilution factor reduce as the concentrations of aldehyde of mid boiling point get also reduced.

2) Pork belly roast

Table 4 shows the concentrations of detected VOCs calculated through GC/MSD analysis of the odor samples generated during pork belly cooking. The compounds indicating the highest detected concentrations are furan and hexene, if examined by classifying into functional groups, most of them are saturated aldehydes and unsaturated aldehydes. After comparing the overall detected concentrations under experimental conditions with or without water and with or without activated carbon charcoal by cooking tool A, it was about 8.1 ppm without water & deodorant, and 5.2 ppm with water but no deodorant, 1.2 ppm with water but no deodorant, and 1.3 ppm if with water and deodorant.

In other words, in oder to reduce the odors generated while cooking meat, it is desirable to use cooking tool with a drip pan for water. And also, comparing odor dilutions and odor strength in a cooking tool with or without lid both with water, the one with lid generates less odor. Table 5 shows expected odor concentration per each material calculated by dividing detected material concentration by odor threshold value per pertinent material as was the case for mackerel. This table show that saturated aldehydes and unsaturated aldehydes that has a double bond contributed high relatively, alkenes that has a double bond, though weak, still contributed nonetheless.

When we examine expected odor concentration accordingly to the cooking condition of cooking tools, A and B, it was highest when there is no water and deodorants with lid with a 19,417-fold, a 4,679-fold with water but no activated carbon charcoal which tells us that approximately 76% of odor can be reduced in roasting meat by simply adding water. Also it show that you can reduce dilution factor by about 35% if you have deodorants, but no water.

4. Conclusion

Dilution factors and odor strengths were measured for the odor samples generated when roasting mackerel and pork belly. As the odor strengths measured with the direct 6-scale of sensory method were always equal to or greater than over 5 degree, the collected samples when cooking were diluted a 300-fold from original odors and evaluated. Scattergram showing logarithm of diluted factor vs. diluted odor sample indicates a high correlation with 0.925, it is desirable to express relative odor strength for diluted odor samples with a 6-scale odor strength. We can confirm that much greater odors were generated when roasting mackerel than for pork belly. Odor dilution factors depending on the use of water during cooking show that heating with water can reduce the odor significantly than without water.

It is expected that adding water can reduce the release of volatile organic compounds by keeping the grill temperature low. And attaching deodorants can reduce the odor even in the absence of water, and this is due to the absorption of some volatile organic compounds by deodorants. However, it is confirmed

Table 4. Concentrations of odorants released from grilling pork by several cooking methods

Compound	Threshold value	A				C	
		no water no AC.	no water AC	water no AC	water AC	no water	water
Acetaldehyde	1.5	826.6	487.0	201.7	33.5	465.7	212.1
Ethanol	520	48.6	38.4	85.3	65.1	39.6	98.1
Acrolein	23	136.6	82.5	n.d.	40.5	106.0	23.6
Propanal	1.0	104.7	70.4	n.d.	n.d.	80.7	68.5
1-Pentene	100	234.4	219.5	51.0	72.3	193.7	19.6
Crotonaldehyde	23	36.5	30.7	n.d.	n.d.	28.8	11.2
i-Butanal	0.35	n.d.	n.d.	7.6	8.2	n.d.	n.d.
n-Butanal	0.67	354.6	271.2	31.3	42.2	143.1	62.6
n-Butanol	38	n.d.	n.d.	n.d.	n.d.	n.d.	22.5
M.E.K	440	327.9	230.8	77.2	164.1	86.8	n.d.
Furan	9900	1,030.7	674.1	206.3	386.9	1,070.9	168.7
Methyl propyl ketone	28	270.1	225.7	37.0	37.0	132.0	55.0
Hexene	140	2,436.2	1,368.4	n.d.	n.d.	2,322.4	119.2
2-pentenal	(0.35)	218.3	79.8	n.d.	n.d.	190.0	29.0
i-Valeraldehyde	0.35	310.1	283.8	49.1	n.d.	129.2	213.4
n-Valeraldehyde	0.41	438.4	350.8	83.1	103.5	318.9	274.9
2-Heptene	370	235.7	14.4	50.0	3.4	244.4	n.d.
Hexenal	(0.18)	22.6	76.8	1.9	n.d.	188.0	283.4
Hexanal	0.18	325.4	65.3	57.0	65.0	188.0	3.1
Octene	1.0	98.0	63.1	86.3	20.8	66.2	5.6
Heptanone	6.8	28.3	28.1	7.1	9.2	n.d.	10.6
Heptanal	0.18	151.8	130.2	28.7	36.1	98.2	85.0
Heptenal	(0.18)	75.3	59.0	14.3	15.0	35.1	113.1
Octanone	(6.8)	17.2	19.0	2.0	7.0	11.7	9.0
Octanal	0.010	116.3	32.4	24.6	29.3	68.0	41.2
Octenal	(0.01)	n.d.	38.6	7.7	11.7	18.4	38.3
Nonanal	0.34	235.5	243.2	64.0	67.4	131.5	116.1
Nonenal	(0.34)	n.d.	n.d.	7.1	6.8	14.0	29.1
Decanone	(6.8)	n.d.	n.d.	4.3	3.1	10.0	n.d.
Decanal	0.40	1.4	45.7	16.4	18.6	n.d.	n.d.
Undecanal	(0.40)	n.d.	n.d.	n.d.	13.7	7.8	n.d.
Dodecanal	(0.40)	n.d.	n.d.	n.d.	2.3	n.d.	n.d.
Dimethyl disulfide	2.2	15.9	n.d.	n.d.	n.d.	32.8	n.d.
Total Conc.(ppb)		8,097.1	5,228.9	1,201.0	1,262.7	6,421.9	2,112.9

that addition of water while deodorants are attached decreases the effect of deodorization and this was estimated that evaporated moisture blocks absorption pores of activated carbon charcoal.

When roasting mackerel, low boiling point amines and high boiling aldehydes, phenol and sulfur compounds are determined to be the source of odor, and per pork belly roast, mid boiling point aldehydes and sulfur compounds are the source of odor materials.

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