청국장과 된장의 휘발성 향기성분 데이터베이스

Compilation of volatile flavor compounds in Cheonggukjang and Doenjang

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Abstract

Volatile flavor compounds of *cheonggukjang* and *doenjang*, which are the most representative Korean soybean fermented foods, were compiled throughout literature review. Total of 225 and 404 volatile flavor compounds were found in *cheonggukjang* and *doenjang*, respectively. The most characteristic volatile flavor compounds in *cheonggukjang* are thought to be pyrazine compounds. In addition, acids, such as 2-methyl propanoic acid, butanoic acid, 2-methyl butanoic acid, and 3-methyl butanoic acid, contribute to aroma characteristics of *cheonggukjang*. On the other hand, ester compounds are the most predominant volatile flavor compounds in *doenjang*. Ninety six ester compounds were detected in *doenjang* while 22 ester compounds were identified in *cheonggukjang*. Pyrazine compounds and acids also play an important role in the flavor of *doenjang*. Compilation of volatile flavor compounds from *cheonggukjang* and *doenjang* will provide basic information to food industry to understand and improve aroma characteristics of *cheonggukjang* and *doenjang*.

Keywords: volatile compounds, flavor, aroma, cheonggukjang, doenjang

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서론

향미(flavor)란 향(aroma)과 맛(taste)으로 이루어진 매우 복잡한 감각이다. 또한 시각, 청각, 텍스쳐(texture)나 온도에 의해서도 영향을 받는 복합적인 감각을 말한다(1). 멘톨(menthol)에 의한 청량감, 고추에 의한 매운 맛과 떫은 맛(astringent taste)까지도 넓은 의미에서 향미에 포함된다. 하지만 향미에 가장 큰 영향을 주는 것은 향기성분으로 향미의 80%는 향에 의해서, 20%는 맛에 의해서 좌우된다. 이처럼 향미에 있어서 향의 중요성으로 인해 향미연구는 식품의 휘발성 향기성분(volatile flavor compound)에 초점을 맞추어 왔다.

네덜란드의 TNO (Netherlands Organization for Applied Scientific Research)는 식품 중에 존재하는 휘발성 성분 데이터베이스를 제작하여 책으로 발간하였다. 1963년에 "Volatile Compounds in Food-Qualitative Data"를 시작으로 1982년에는 IOFI (International Organization of Flavor Industry) 후원으로 "Volatile Compounds in Food-Quantitative Data"를 간행했으며, 1996년 7차 개정판이 발간되었다. 식품 중 휘발성 성분 데이터는 식품종류별, 조리형태별로 세세히 분류되어 있으며, 휘발성 성분은 작용기 별로 정성 및 정량 데이터가 정리되어 있다. 다양한 식품에서 7,100개 이상의 휘발성 성분이 동정되어 데이터베이스화 되었으며(1-4), 현재는 Triskelion에서 online으로 서비스하고 있다(5).

한국 전통식품의 향미 특성에 대한 연구는 활발히 이루어지고 있으나 한국 전통식품의 휘발성 향기성분 데이터베이스를 작성하려는 시도는 아직 이루어지지 않고 있다. 한국 전통식품의 향미 특성을 개선하기 위한 기초자료로서 휘발성 향기성분의 데이터베이스 작성은 중요하다. 따라서 본 논문에서는 한국 전통식품의 휘발성 향기성분 데이터베이스를 작성하려는 첫 시도로써 한국 전통식품 중 특유의 향을 가지고 있는 청국장과 된장의 휘발성 향기성분 데이터베이스를 작성하고 이를 비교 분석하여 청국장과 된장의 독특한 향미특성의 차이를 알아보고자 하였다.

청국장과 된장의 휘발성 향기성분 데이터베이스 작성을 위해 국내외에 게재된 청국장과 된장의 휘발성 향기성분 관련 논문을 NDSL과 Scopus를 통해 검색하였다. 본 결과는 한국 전통식품의 향미 특성을 연구하는 연구자들에게 도움이 될 것으로 생각한다.

본론

1. 청국장의 휘발성 향기성분

청국장은 단기발효방법으로 제조되는 대두 발효식품으로 전통적 제조방법은 삶은 콩을 볏짚으로 발효시켜서 제조하고 있으며 개량식은 *Bacillus subtilis*를 이용하여 발효하고 있다. 청국장은 40-43℃에서 2-4일 동안 발효를 시키는데(6,7), 발효기간 동안 단백질이 *Bacillus subtilis*가 분비하는 효소에 의해 분해된다. 청국장은 건강기능성은 우수하나 특유의 불쾌취로 인해 소비량이 감소추세이며 젊은 세대가 기피하고 있는 실정이다. 따라서 청국장의 불쾌취를 저감화하려는 연구가 계속 진행되고 있다(8).

청국장의 휘발성 향기성분에 관해서 15편의 논문을 검토하였으며(9-23), 그 논문들을 검토하여 Table 1에 지금까지 청국장에서 동정된 휘발성 향기성분들을 정리하였다. 청국장의 휘발성 향기성분은 청국장 발효방법에 따라 차이가 있으며 전통적인 방식으로 발효를 한 것과 종균을 접종시켜 발효한 것을 구분하여 Table 1에 나타내었다. 또한 향기성분 추출방법에 따라서도 동정된 향기성분이 차이가 날 수 있기 때문에 향기성분 추출방법도 Table 1에

Table 1. Volatile flavor compounds of *cheonggukjang*

	Compound	Aroma description	Threshold[1] (μg/L in water)	Extraction method[2]	Sample[3]	Reference
Hydrocarbon	chloroform	-	-	A	a	9
	1-ethoxy-1-methoxy ethane	-	-	B	f	21
	ethoxy ethene	-	-	C	e	20
	2-ethoxy propane	-	-	C	e	20
	3-ethoxy-1-propene	-	-	C	e	20
	2-methoxy pentane	-	-	A	d	18
	5-methyl-3-hexane(?)[4]	-	-	C	c	16
	4-methyl-3-hexane(?)	-	-	C	c	16
	1H-indene	-	-	A	b	9, 13
	3-methyl heptane	-	-	C	c	16
	3,3,5-trimethyl heptane	-	-	C	c	16
	2,2,6,6-tetramethyl heptane	-	-	C	c	16
	octane	-	-	C	c	16
	2,2-dimethyl octane	-	-	C	c	16
	2,3,6-trimethyl octane	-	-	C	c	16
	2,2,7,7-tetramethyl octane	-	-	C	c	16
	2-octene	-	-	C	c	16
	nonane	-	-	A	b	10
	4-methyl nonane	-	-	C	c	16
	decane	-	-	A, C	b, c	10, 16
	2,2,6-trimethyl decane	-	-	C	c	16
	dodecane	-	-	A, D	b	10, 23
	tridecane	-	-	D	b	23
	tetradecane	-	-	C, D	b, c	16, 23
	pentadecane	-	-	A, D	b	10, 23
	nonadecane	-	-	A	a	12
	eicosane	-	-	A	a	12
	tricosane	-	-	A	d	18
	tetracosane	-	-	A	d	18
	pentacosane(?)	-	-	A	a, b	10, 12
	hexacosane(?)	-	-	A	b	10
	heptacosane(?)	-	-	A	a, b	10, 12
	octacosane(?)	-	-	A	a, b	10, 12
	methyl benzene (toluene)	-	-	A, C, D	a, b, c	9, 13, 16, 23
	ethyl benzene	-	-	A	a, b	9, 13
	1,2-dimethylbenzene (o-xylene)	-	-	A	a, b	9, 13
	styrene	-	730*	C, D	b, e	20, 23
	1-propenyl benzene	-	-	A	b	9

	Compound	Aroma description	Threshold[1)] (μg/L in water)	Extraction method[2)]	Sample[3)]	Reference
	2-ethenyloxy ethanol	-	-	C	e	20
	1-propanol	pungent	6,640-9,000	C	e	20
	2-propanol	-	-	C	e	20
	ethanol	ethanol-like	24,900-100,000	A, B, C, D	a, b, d, e	10, 12, 14, 17, 19, 20, 23
	2-propoxy ethanol	-	-	C	e	20
	2-butanol	-	-	C	e	20
	2-methyl-1-propanol (isobutanol)	solvent-like	1,000	C	c	16
	2-methyl-1-butanol	malty	320	A, C, D	b, c	10, 16, 23
	3-methyl-1-butanol (isoamyl alcohol)	malty	250–1,810	A, C, D	b, d, e	9, 11, 18, 20, 23
	2-methyl-2-buten-1-ol	-	-	A	a, d	13, 18
	3-methyl-2-buten-1-ol	-	-	A	b	9
	1,2-butanediol	-	-	A	a	11
	2,3-butanediol	-	-	A	a	12
	2-methyl-3-pentanol	-	-	A	a	12
	3-methyl-3-pentanol	-	-	C	e	20
	1-pentanol	-	-	A, C	a, b, c	10, 11, 16
	2-pentenol	-	-	A	a	11
Alcohol	1-hexanol	green, flowery	50-2,500	A, B, C	a, b, d, e	9, 13, 14, 17, 18, 20
	3-hexanol	-	-	A	d	18
	(*Z*)-3-hexen-1-ol	leaf-like	38.9-500	A, B	a	11, 15
	1-hexen-3-ol	-	-	C	e	20
	cyclohexanol	-	-	C	e	20
	2-methyl-2-hexanol	-	-	A	d	18
	5-methyl-3-hexanol	-	-	A	d	18
	1-heptanol	-	3*	A	b	10
	1-octanol	-	110-130*	D	d	23
	3-octanol	-	-	A	d	18
	1-octen-3-ol	mushroom-like	1	A, C, D	a, b, c, d	9, 11-13, 16, 18, 23
	7-octen-4-ol	-	-	A	d	18
	2-nonanol	-	-	D	b	23
	2-furanmethanol (furfuryl alcohol)	-	-	A	a, b, d	9-13, 18
	benzyl alcohol (benzenemethanol)	-	-	A	a, b	10, 11
	2-phenylethanol (β-phenylethyl alcohol, benzeneethanol)	honey-like, spicy	1,000	A, D	a, b, d	9, 10, 13, 18, 23

	Compound	Aroma description	Threshold[1] (μg/L in water)	Extraction method[2]	Sample[3]	Reference
Aldehyde	acetaldehyde	pungent, fruit	15-25	C	c	16
	2-methyl propanal (isobutanal)	green, pungent	0.97-10	C	c	16
	3-(methylthio) propanal (methional)	potato-like	0.2-1.8	D	b	23
	2-methyl butanal	green, almond-like	1-3.7	C, D	b, c	16, 23
	3-methyl butanal	malty	0.2-3.1	C, D	b, c, e	16, 20, 23
	pentanal	pungent, almond-like	12-42	C, D	b, c, e	16, 20, 23
	hexanal	tallowy, leaf-like	4.5-50	A, C, D	b, c	10, 16, 23
	heptanal	fatty	3-5.8	C, D	b, e	20, 23
	2-hexenal	apple-like	17-50.5	C	e	20
	2-heptenal	fatty, almond-like	13-51	C, D	b, c	16, 23
	(*E*)-2-octenal	fatty, nutty	4	D	b	23
	nonanal	tallowy, fruity	1-5	D	b	23
	decanal	orange skin-like, flowery	0.1-5	D	b	23
	(*E*)-2-decenal	tallowy, orange-like	0.3-0.4	D	b	23
	(E,E)-2,4-heptadienal	fatty	-	A	d	18
	2,4-decadienal	deep-fried	0.07-0.2	A, D	b, d	10, 18, 23
	benzaldehyde	almond-like	350-3,500*	A, C, D	a, b, c, d, e	9-13, 16, 18, 20, 23
	2-hydroxy-6-methyl benzaldehyde	-	-	A	a	9
	2-furancarboxaldehyde (furfural)	sweet	3,000	A, D	a, b, d	9, 10, 12, 13, 18, 23
	5-methyl-2-furancarboxaldehyde	-	-	C	e	20
	2-phenylethanal (benzeneacetaldehyde)	honey-like, flowery	4	A, D	a, b, d	9, 13, 18, 23
	tetradecanal	-	-	D	b	23
	heliotropine (piperonal)	-	-	A	b	10
Ketone	2-propanone (acetone)	-	-	B, C, D	a, b, c, d	12, 14, 16, 17, 19, 23
	2-butanone	etheric	23,200-50,000	C	c, e	16, 20
	3-hydroxy-2-butanone (acetoin)	buttery	800-5,000	A, C, D	a, b, e	12, 20, 23
	3-methyl-2-butanone	-	-	C	e	20
	3-hydroxy-3-methyl-2-butanone	-	-	C	e	20
	2,3-butanedione (diacetyl)	buttery	4-15	A, C	a, b, c, e	10, 12, 16, 19, 20
	2-pentanone	-	70,000*	A, C	a, b, e	9, 13, 20
	3-methyl-2-pentanone	-	-	C	e	20

	Compound	Aroma description	Threshold[1)] (μg/L in water)	Extraction method[2)]	Sample[3)]	Reference
Ketone	2-hydroxy-3-pentanone	-	-	A	a	12
	2-heptanone	soapy, fruity	5-140	A, C, D	a, b, c	9, 16, 23
	2-octanone		50*	C	e	20
	3-octanone	-	28*	A, D	b, d	9, 18, 23
	2-nonanone	fruity, soapy	5-200	C	e	20
	decanone	-	-	A	d	18
	2-tridecanone	-	-	A	d	18
	5-tridecanone	-	-	A	d	18
	2-tetradecanone	-	-	A	d	18
	2-pentadecanone	-	-	A	d	18
	6,10,14-trimethyl-2-pentadecanone	-	-	A	d	18
	2-dodecanone	-	-	A	d	18
	dihydro-2(3H)-furanone (γ-butyrolactone)	-	-	C	e	20
	3-hydroxy-2-methyl-4H-pyran-4-one (maltol)	caramel-like	9,000-35,000	B, D	b, f	21, 23
	2,3-dihydro-3,5-dihydroxy-6-methyl-4H-pyran-4-one	-	-	B	f	21
	1-(2-hydroxy-5-methylphenyl) ethanone	-	-	A	d	18
	1-(2,6,6)-trimethyl-2-buten-1-one	-	-	A	a	12
	4-hydroxy-3-methylacetophenone	-	-	A	d	18
Acid	acetic acid	vinegar-like, pungent	22,000-50,000	C, D	a, b, e	12, 19, 20, 22, 23
	cyano acetic acid	-	-	C	e	20
	ethanedioic acid	-	-	C	e	20
	propanoic acid	fruity, pungent	2,190-20,000	C	e	20
	2-methyl propanoic acid	sweaty	50-8,100	A, D	a	11, 12, 22
	butanoic acid	sweaty, rancid	50-2,150	A	a, b	9, 10
	2-methyl butanoic acid	sweaty, sweet	50-6,600	B, D	a, b, f	12, 21, 22, 23
	3-methyl butanoic acid (isovaleric acid)	sweaty	132-1,600	A, B, D	b, f	9, 21, 23
	pentanoic acid (valeric acid)	sweaty	2,100	A	a, b	10, 11
	hexanoic acid (caproic acid)	goat-like, sweaty	290-5,000	A	b	10
	heptanoic acid	-	-	A	b	10
	octanoic acid (caprylic acid)	sweaty	3,000	A	b	9
	hexadecanoic acid	-	-	A	b, d	10, 18
	benzoic acid	-	-	A	b	10
Ester	methyl acetate	-	-	C	c	16
	ethyl acetate	solvent-like, fruity	5-19,900	A, D	a, b	9, 13, 23
	ethenyl acetate	-	-	C	e	20

	Compound	Aroma description	Threshold[1] (μg/L in water)	Extraction method[2]	Sample[3]	Reference
Ester	ethyl propanoate	fruity	10-20	C	e	20
	ethyl 2-methylpropanoate	fruity, sweet	0.02-0.1	D	b	23
	ethyl 2-methylbutanoate	fruity	0.15-0.3	C	e	20
	ethyl 3-methylbutanoate	fruity	0.20	C	e	20
	ethyl 2-methylbutenoate	-	-	C	e	20
	hexyl formate	-	-	C	e	20
	hexyl acetate	fruity	2-5	A	b	9
	methyl benzeneacetate	-	-	A	b	9, 18
	ethyl benzeneacetate (ethyl phenylacetate)	fruity, sweet	650*	A	d	18
	ethyl 4-heptenoate	-	-	A	d	18
	ethyl tetradecanoate	-	-	A	d	18
	methyl pentadecanoate	-	-	A	d	18
	methyl hexadecanoate	-	-	A	d	18
	ethyl hexadecanoate	-	>2000*	A	d	18
	methyl heptadecanoate	-	-	A	d	18
	methyl benzoate	-	-	D	b	23
	ethyl heptadecanoate	-	-	A	d	18
	2-phenylethyl acetate	flowery, fruity	20#	A	b	9
	ethenyl acetate (vinyl acetate)	-	-	B	f	21
Pyrazine	2-methyl pyrazine	-	60-105,000*	A, B, D	a, b, d	10, 13, 14, 15, 17, 23
	2,3-dimethyl pyrazine	-	2,500-35,000*	A, B, D	a, b, d	10, 13, 14, 17, 18, 23
	2,5-dimethyl pyrazine	-	800-1,800*	A, B, C, D	a, b, d, e	9-15, 17, 18, 20-23
	2,6-dimethyl pyrazine	-	200-9,000*	A, B, C, D	a, b, d	10-12, 14, 15, 17, 19
	methyl ethyl pyrazine	-	-	A	b	10
	2-ethyl-5-methyl pyrazine	-	100*	A	a, b	10, 13
	2-ethyl-6-methyl pyrazine	-	-	D	b	23
	2-ethyl-3,5-dimethylpyrazine	potato-like	0.04-0.16	A, D	a, b, d	10, 11, 13, 18, 22
	2-ethyl-3,6-dimethylpyrazine	potato-like	0.4-8.6	A	a, b, d	10, 11, 18
	5-ethyl-2,3-dimethyl pyrazine	-	-	A	a	9
	3,5-diethyl-2-methyl pyrazine	-	-	A	a, b	9, 13
	2,6-diethylpyrazine	-	-	A	d	18
Pyrazine	trimethyl pyrazine	potato-like, musty	91-400	A, B, C, D	a, b, d, e, f	9-11, 13-15, 17, 18, 20-23
	2-ethyl-3,5,6-trimethylpyrazine	-	-	A, D	a, b, d	11, 18, 22, 23

	Compound	Aroma description	Threshold[1)] (μg/L in water)	Extraction method[2)]	Sample[3)]	Reference
Pyrazine	tetramethyl pyrazine	-	1,000-10,000*	A, B, C, D	a, b, c, d, e	9-13, 15, 16, 18, 20, 22, 23
	2-methyl-3-propylpyrazine	-	-	A	d	18
	2-isoamyl-6-methylpyrazine	-	-	A	d	18
	2-acetyl pyrazine	roasty	62	A	b	10
Nitrogen- containing compound	2-methylpyridine (2-picoline)	-	-	A	a, d	9, 13, 18
	3-methylpyridine (3-picoline)	-	-	A	a	9
	4-methylpyridine (4-picoline)	-	-	A	a	13
	5-ethyl-2-methylpyridine	-	-	A	a	9, 13
	4-methyl pyrimidine	-	-	B	a, d	14, 17
	1H-pyrrole	-	49,600*	C	e	20
	2-acetyl pyrrole	-	170,000*	A	b	10
	2-formylpyrrole	-	-	D	b	23
	Indole	sweet, burnt	90	D	b	23
	1,2,6-trimethyl piperidine	-	-	A	a, d	9, 18
Sulfur compound	dimethyl disulfide	cabbage-like	0.16-12	A, C, D	a, b, c, e	13, 16, 20, 23
	dimethyl trisulfide	sulfury	0.01	A, D	b, d	18, 23
	2-acetyl thiazole	roasty, sulfury	10	D	b	23
	2,4,5-trimethyl thiazole	earthy	50	A	a, d	9, 13, 18
	4,5-dimethyl-2-butyl thiazole	-	-	A	d	18
	4,5-dimethyl-2-(2-methylpropyl) thiazole	-	-	A	d	18
	3,5-dimethyl-1,2,4-trithiolane	-	-	A	d	18
	2-methyl benzothiazole	-	-	A	d	18
Phenol	phenol	phenolic	5,900	A, D	a, b, d	9-11, 13, 18, 23
	4-vinylphenol	-	10*	A	a	12
	2-tert-butyl-4,5-dimethylphenol	-	-	A	a	13
	2-(1,1-dimethylethyl)-4-methyl phenol	-	-	A	a, b	9, 13
	2,4-bis(1,1-dimethylethyl) phenol	-	-	A	d	18
	2-methoxyphenol (guaiacol)	smoky, sweet	2.5-3	A, D	a, b, d	9, 10, 12, 13, 18, 23
	2-methoxy-4-(2-propenyl) phenol (eugenol)	spicy, honey-like	6-30	A	b	10
	4-ethyl-2-methoxy phenol (4-ethyl guaiacol)	clove-like	50	A	a, b, d	9, 18
	2-methoxy-4-vinylphenol (4-vinyl guaiacol)	clove-like	20-100	A, D	a, b, d	10, 12, 29
Furan	2-pentyl furan	buttery, green bean-like	6	A, C, D	a, b, c, d	9, 10, 12, 13, 16, 18, 23
	2-heptyl furan	-	-	D	b	23
	2-octyl furan	-	-	D	b	23

	Compound	Aroma description	Threshold[1] (μg/L in water)	Extraction method[2]	Sample[3]	Reference
Furan	2-acetyl furan	-	10,000*	A	b	10
	2,3-dihydrobenzofuran	-	-	A, D	b, d	18, 23
	2-furfuryl pyrrole	-	-	A	b	10
Miscellaneous	dibutyl phthalate	-	-	A	a, d	12, 18
	limonene	citrus-like	10-200	B	a, d	14, 17
	α-pinene	terpeny	6*	C	c	16
	β-pinene	terpeny	140*	C	c	16
	ethylene carbonate	-	-	B	f	21
	trimethyl oxazole	-	-	A, C	a, c, d, e	9, 13, 16, 18, 20
	butylated hydroxytoluene	-	-	A, B	d, f	18, 21
	2-methyl benzo quinoline	-	-	C	e	20
	pentadecylamine	-	-	C	e	20
	1-octanamine	-	-	C	e	20
	pentamethyldisilane	-	-	C	e	20
	(1-phenylethyl) trimethylsilane	-	-	C	e	20
	N-(1-methylheptyl)-2-octanamine	-	-	C	e	20
	ammonium oxalate	-	-	C	e	20
	dimethylamine	-	-	C	e	20
	butanamide	-	-	C	e	20
	1-(trimethyl)-1H-indole-3-acetonitrile	-	-	C	e	20
	2,4,5-trimethyl-3-oxazoline	-	-	A	a	13

[1] Reference 24.
* Orthonasal threshold in water (μg/L).
# Retronasal threshold in water (μg/L).
[2] A: SDE, B: solvent extraction, C: headspace method, D: solid phase microextraction (SPME).
[3] a: *cheonggukjang* fermented with Bacillus sp., b: traditional *cheonggukjang*, c: commercial *cheonggukjang* powder, d: commercial *cheonggukjang*, e: *cheonggukjang* fermented with mixed culture of Bacillus natto and Bacillus licheniformis, f: not specified.
[4] The identification is questionable.

명시하였다. 냄새특성과 역치(threshold)는 Rychlik 등(24)의 자료를 참조하여 함께 정리하였다.

청국장의 휘발성 향기성분은 총 225개가 동정되었으며 어떤 휘발성 향기성분은 한 편의 논문에서만 동정되고 어떤 휘발성 향기성분은 여러 편의 논문에서 일관되게 동정되고 있는데 여러 편의 논문에서 동정된 휘발성 향기성분은 동정의 신뢰도와 특징적 향기성분으로서 중요성이 큰 휘발성 향기성분으로 생각된다.

작용기별로 분류하여 볼 때 탄화수소(hydrocarbon)가 38개 동정되어 가장 많은 갯수가 동정되었다. 탄화수소는 청국장 제조방법과 향기성분 추출방법에 상관없이 동정되었지만 톨루엔(toluene)을 제외한 대부분의 탄화수소는 특정 논문에서만 동정되어 정확한 동정이 의문시 된다. 많은 경우에 용매나 기타 요인에 의한 인공물(artifact)일 가능성이 높다고 생각된

다. 탄화수소는 역치가 높기 때문에 대부분은 청국장 향에 중요한 역할을 하지 못할 것으로 생각된다.

알코올(alcohol)은 에탄올(ethanol), 2-메틸-1-뷰탄올(2-methyl-1-butanol), 3-메틸-1-뷰탄올[3-methyl-1-butanol, 아이소아밀알코올(isoamyl alcohol), 1-펜탄올(1-pentanol), 1-헥산올(1-hexanol), 1-옥텐-3-올(1-octen-3-ol), 2-퓨란메탄올(2-furanmethanol) 및 2-페닐에탄올(2-phenyl ethanol) 등이 여러 편의 논문에서 동정되었다. 알데하이드(aldehyde)는 3-메틸뷰탄알(3-methyl butanal), 펜탄알(pentanal), 헥산알(hexanal), 2,4-데카다이엔알(2,4-decadienal), 벤즈알데하이드(benzaldehyde), 2-퓨란카복스알데하이드(2-furancarboxaldehyde) 및 2-페닐에탄알(2-phenylethanal) 등이 발효방법 및 향기성분 추출방법에 상관없이 여러 편의 논문에서 보고되고 있다. 케톤(ketone)은 2-프로판온(2-propanone), 3-하이드록시-2-뷰탄온[3-hydroxy-2-butanone, 아세토인(acetoin)], 2,3-뷰테인다이온[2,3-butanedione, 다이아세틸(diacetyl)], 2-헵탄온(2-heptanone) 및 3-옥탄온(3-octanone) 등이 청국장에서 보고되고 있다.

산(acid) 중에는 아세트산(acetic acid), 2-메틸프로판산(2-methyl propanoic acid), 뷰탄산(butanoic acid), 2-메틸뷰탄산(2-methyl butanoic acid), 펜탄산(pentanoic acid) 등이 여러 편의 논문에서 일관되게 보고되고 있다. 특히, 2-메틸프로판산, 뷰탄산, 2-메틸뷰탄산 및 3-메틸뷰탄산은 다른 산에 비해 낮은 역치를 가지고 있으며 불쾌한 냄새특성을 가지고 있다. Park 등(25)은 이러한 산이 청국장의 특징적인 냄새에 중요한 역할을 한다고 생각하고 청국장에서 발효기간에 따른 산의 함량을 stable isotope dilution assay (SIDA)법을 이용하여 정량하였다. 산의 함량은 발효 후반으로 갈수록 증가하였으며, 분지산(branched-chain acid)의 함량이 직쇄산(straight chain) 보다 더 높았다. 에스터(ester) 화합물 중에는 아세트산에틸(ethyl acetate) 만이 여러 편의 논문에서 동정된 에스터 화합물이었다.

청국장에서 가장 특징적인 것은 피라진(pyrazine) 화합물이 많이 들어 있는 점이었다. 총 18개의 피라진 화합물이 동정되었으며, 특히 2,5-다이메틸피라진(2,5-dimethyl pyrazine), 트라이메틸피라진(trimethyl pyrazine)과 테트라메틸피라진(tetramethyl pyrazine)은 거의 모든 청국장 논문에서 보고되고 있는 휘발성 향기성분이다. 피라진 화합물의 함량은 청국장이 된장보다 4.3배 더 많았다(23).

질소 함유 화합물 중에는 2-메틸피리딘(2-methyl pyridine)이 여러 편의 논문에서 동정된 휘발성 향기성분이었고, 황 함유 화합물 중에는 다이메틸다이설파이드(dimethyl disulfide)와 2,4,5-트라이메틸싸이아졸(2,4,5-trimethyl thiazole)이, 페놀(phenol) 화합물 중에는 페놀, 2-메톡시페놀(2-methoxyphenol, 구아이아콜, guaiacol), 2-메톡시-4-바이닐페놀[2-methoxy-4-vinylphenol, 4-바이닐구아이아콜(4-vinyl guaiacol)] 및 4-바이닐페놀(4-vinylphenol)이 청국장의 휘발성 향기성분으로 동정되었다. 퓨란(furan)은 2-펜틸퓨란(2-pentyl furan)이, 기타화합물로는 트라이메틸옥사졸(trimethyl oxazole)이 여러 편의 논문에서 동정되었다.

2. 된장의 휘발성 향기성분

된장은 메주를 사용해서 만드는 재래식 된장과 *Aspergillus oryzae* 등의 국균을 사용하여 만드는 개량식 된장으로 나눌 수 있으며 풍미 증진을 위해 *Bacillus subtilis* 균주를 사용하기도 한다(6,7). 재래식 된장은 삶은 콩을 1-2개월 발효시켜 메주를 제조한 후 소금물을 붓고 숙성 시킨 후 간장을 걸러내서 제조하며, 개량식 된장은 삶은 쌀, 보리, 콩 등에 *Aspergillus oryzae*를 인위적으로 접종하여 30℃에서 3일간 배양하여 된장 고지(koji)를 만든 후 메주 대신 사용한다(26). 재래식 된장의 고유 풍미는 *Bacillus subtilis*에 의해 생성되는데 개량식 된장은

*Aspergillus oryzae*만을 사용하므로 재래식 된장의 고유풍미가 생성되지 않는다(27,30,33).

된장의 휘발성 향기성분에 관해서는 15편의 논문을 검토하였으며(23,26-39), Table 2에 지금까지 된장에서 동정된 휘발성 향기성분들을 정리하였다. 된장의 휘발성 향기성분은 총 404개가 동정되었는데, Ba 등(23)은 된장과 청국장의 휘발성 향기성분을 비교한 논문에서 된장에서 더 많은 개수의 휘발성 향기성분이 동정되었으나 휘발성 향기성분의 함량은 청국장이 더 높았다고 보고하였다.

알코올은 에탄올, 2-메틸-1-프로판올(2-methyl-1-propanol), 1-뷰탄올(1-butanol), 2-메틸-1-뷰탄올, 3-메틸-1-뷰탄올, 2,3-뷰테인다이올(2,3-butanediol), 1-헥산올, 3-옥탄올(3-octanol), 1-옥텐-3-올, 2-퓨란메탄올, 2-페닐에탄올 및 벤질알코올(benzyl alcohol) 등이 여러 편의 논문에서 동정되었다. 된장에서 동정된 대부분의 알코올은 청국장에서도 동정된 화합물로 알코올은 된장과 청국장에서 큰 차이를 보이지 않았다. 알코올은 1-옥텐-3-올을 제외하고는 대부분 냄새 역치가 높아 청국장과 된장의 향에 크게 기여하지 못할 것으로 생각된다. 알데하이드는 2-메틸뷰탄알, 3-메틸뷰탄알, 헥산알, (*E*)-2-헵텐알[(*E*)-2-heptenal], 노난알(nonanal), 벤즈알데하이드, 2-페닐-2-뷰텐알(2-phenyl-2-butenal), 5-메틸-2-페닐-2-헥센알(5-methyl-2-phenyl-2-hexenal), 알파-에틸리덴 벤젠아세트알데하이드(α-ethylidene benzeneacetaldehyde), 2-퓨란카복스알데하이드 및 2-페닐에탄알(2-phenylethanal) 등이 여러 편의 논문에서 보고되고 있다. 케톤은 3-하이드록시-2-뷰탄온, 2-헵탄온, 3-옥탄온, 감마-노나락톤(γ-nonalactone) 및 말톨(maltol) 등이 보고되었다.

산은 아세트산, 프로판산(propanoic acid), 2-메틸프로판산, 뷰탄산, 2-메틸뷰탄산, 3-메틸뷰탄산, 펜탄산, 4-메틸 펜탄산(4-methyl pentanoic acid), 헥산산(hexanoic acid), 헵탄산(heptanoic acid), 옥탄산(octanoic acid) 및 페닐아세트산(phenylacetic acid) 등이 동정되었다. 청국장에서는 14개의 산이 동정되었으나 된장에서는 29개의 산이 동정되었다. 된장에는 청국장보다 더 많은 종류의 산이 들어 있어 된장과 청국장의 향미 차이에 영향을 줄 것으로 생각된다. Shukla 등(40)은 전통된장의 냄새에 중요한 역할을 하는 아세트산, 프로판산, 뷰탄산과 3-메틸뷰탄산을 정량하였는데, 그 양은 각각 91.7, 70.1, 29.5 및 19.8 mg% 라 하였다.

된장의 휘발성 향기성분에서 가장 특징적인 것은 에스터 화합물이 많다는 것이었다. 청국장에서는 22개의 에스터 화합물이 동정된 반면, 된장에서는 96개의 에스터 화합물이 동정되었다. 아세트산에틸, 뷰탄산에틸(ethyl butanoate), 2-메틸뷰탄산에틸(ethyl 2-methylbutanoate), 3-메틸뷰탄산에틸(ethyl 3-methylbutanoate), 헥산산에틸(ethyl hexanoate), 헵탄산에틸(ethyl heptanoate), 옥탄산에틸(ethyl octanoate) 등 많은 에스터 화합물이 된장에서 동정되었다. 에스터 화합물의 종류 및 함량은 된장의 제조방법에 따라 차이가 크며 이는 메주나 고지의 미생물상(microflora)의 차이에 기인한다(29,32,33). 청국장에 비해서 월등히 많은 에스터 화합물이 된장에서 동정되었으며 이러한 에스터 화합물은 향미특성 뿐 아니라 낮은 역치로 인해 청국장과 된장의 향미특성 차이에 중요한 역할을 할 것으로 생각된다.

총 15개의 피라진 화합물이 된장에서 동정되었으며 2-메틸피라진(2-methyl pyrazine), 2,3-다이메틸피라진(2,3-dimethylpyrazine), 2,5-다이메틸피라진, 2,6-다이메틸피라진(2,6-dimethylpyrazine), 3-에틸-2,5-다이메틸피라진(3-ethyl-2,5-dimethylpyrazine), 2,3,5-트라이메틸-6-에틸피라진(2,3,5-trimethyl-6-ethylpyrazine), 트라이메틸피라진 및 테트라메틸피라진 등이 된장에서 동정된 주요 휘발성 향기성분이다. 된장에서 동정된 대부분의 피라진 화합물은

Table 2. Volatile flavor compounds of *doenjang*

	Compound name	Aroma description	Threshold[1)] (μg/L in water)	Extraction method[2)]	Sample[3)]	Reference
Hydrocarbon	1,1-diethoxy ethane	-	-	A	c	31
	3-ethoxy-1-propene	-	-	C	b, c	26
	2-methyl-3-propoxy-1-propene	-	-	A	e	30
	1-ethoxybutane	-	-	A	c	31
	2-methylpentene	-	-	A	c	28
	5-butoxy-2-pentene	-	-	A	c	31
	hexane	-	-	D	d	38
	2,3-dimethylhexane	-	-	A	c	28
	3-methyl-1-heptene	-	-	A	e	30
	5-methyl-1-heptene	-	-	A	e	30
	octane	-	-	D	b, d	34, 39
	1-octene	-	-	D	d	32, 39
	2-octene	-	-	D	b, d	34, 39
	3-methyl-5-propylnonane	-	-	A	c	31
	undecane	-	-	D	d	23
	1-undecene	-	-	D	d	38
	dodecane	-	-	B, D	b, d, f	23, 34, 39
	1-dodecyne	-	-	A	c	27
	5-dodecyne	-	-	A	e	30
	tridecane	-	-	B, D	b, d, f	23, 34, 39
	tetradecane	-	-	B, D	b, d	23, 34, 39
	(*E*)-5-tetradecen-3-yne	-	-	A	c	27
	pentadecane	-	-	B, D	d, f	23, 39
	eicosane	-	-	A	c	31
	3-eicosene	-	-	A	c	31
	9-eicosene	-	-	A	c	31
	1,2-diethyl cyclobutane	-	-	B	d	39
	ethyl cyclopentane	-	-	A	c	28
	cyclohexadecane	-	-	A	c	31
	benzene	-	-	D	b, d	34, 38, 39
	methyl benzene (toluene)	-	-	B, C, D	a, b, c, d, f	26, 34, 39
	ethenyl benzene (styrene)	-	730*	B, D	b, d, e, f	23, 34, 35, 37, 39
	1,2-dimethyl benzene (o-xylene)	-	-	B, C, D	a, b, d, f	26, 34, 39
	1,3-dimethyl benzene (m-xylene)	-	-	B, D	b, d, f	34, 39
	1,4-dimethyl benzene (p-xylene)	-	-	A, B, D	b, c, d, f	31, 34, 39
	ethylbenzene	-	-	A, B, D	b, c, d, f	31, 34, 39
	1-ethyl-4-methylbenzene	-	-	B, D	d	39
	1,2,4-trimethylbenzene	-	-	B, D	b, d, f	34, 39

	Compound name	Aroma description	Threshold[1] (μg/L in water)	Extraction method[2]	Sample[3]	Reference
Hydrocarbon	1,3-bis(1,1-dimethylethyl)benzene	-	-	B	d, f	39
	methoxybenzene (anisole)	sweet, phenolic	50	A	c	31
	1,2-dimethoxybenzene	-	-	A, B, D	a, c, d, e	27, 29, 32, 37, 39
	1,3-dimethoxybenzene	-	-	A, D	c, d, e	29, 32, 38
	ethoxybenzene	-	-	A	c	31
	1-ethyl-4-methoxybenzene	-	-	A	c	31
	1-ethenyl-4-methoxy benzene	-	-	A	c	27
	naphthalene	-	-	A	c	27, 31
	1-methylnaphthalene	-	-	A	c	31
	1-methylhexyl hydroperoxide	-	-	A	c	27
	2-ethyl-3-methyl oxetane	-	-	A	b, c	27
	tetrachloroethane	-	-	A	c	28
	1,1-bis(2-methylpropyl)hydrazine	-	-	C	b	26
	3-ethyl-2-methyl-1,3-hexadiene	-	-	D	d	23
Alcohol	methanol	-	-	A	c	31
	ethanol	ethanol-like	24,900-100,000	A, C, D	a, b, c, d, e, f	23, 26, 27, 31, 32, 37-39
	2-(2-ethoxyethoxy) ethanol	-	-	A	e	29
	1-propanol	pungent	6,640-9,000	A, D	c, d	23, 31
	2-methyl-1-propanol	solvent-like	1,000	A, D	c, d, e	27, 29, 32, 37
	2-methyl-2-propanol	-	-	A	c	31
	1-methoxy-2-methyl-2-propanol	-	-	A	c	31
	3-(methylthio)-1-propanol(methionol)	potato-like	5#	A, D	b, c, e	29, 34
	1-butanol	fruity	500-1,280	A, C, D	b, c, d, e	26, 27, 29, 32, 34 37
	2-butanol	-	-	A	c	27, 31
	2-methyl-1-butanol	malty	320	D	a, d	23, 32, 38,
	2-methyl-2-butanol			A	c	31
	3-methyl-1-butanol (isoamyl alcohol)	malty	250–1,810	A, C, D	a, b, c, d, e, f	23, 26-30, 32-35, 37, 38
	3-methoxy-2-butanol	-	-	A	c	28
	2,2-dimethyl-1-butanol	-	-	D	d	32
	1,3-butanediol	-	-	A	c	28
	2,3-butanediol	-	-	C, D	a, b, c, d	26, 32, 36, 37
	1-pentanol	-	-	A	b	27
	2-pentanol	-	-	A	c	31
	3-methyl-1-pentanol	-	-	A	c	27
	4-methyl-1-pentanol	-	-	A	c, e	28, 30

	Compound name	Aroma description	Threshold[1)] (μg/L in water)	Extraction method[2)]	Sample[3)]	Reference
Alcohol	3-penten-2-ol	-	-	A	c, e	29
	2-methyl-1-penten-3-ol	-	-	A	c	31
	2,3,4-trimethyl-3-pentanol	-	-	D	a	32
	1-hexanol	green, flowery	50-2,500	A, D	a, b, c, d, e	29, 32, 34, 37, 38
	(*E*)-2-hexenol	-	-	D	b	34
	(*E*)-3-hexenol	-	-	D	b	34
	(*Z*)-3-hexenol	leaf-like	38.9-500	D	b	34
	5-methyl-2-hexanol	-	-	A	c	27
	2-ethyl-1-hexanol	-	270,000*	A, D	b, e	29, 34
	1-heptanol	-	3*	D	b	34
	4-methyl-3-heptanol	-	-	A	b, c	27
	1-octanol	-	110-130*	D	b, d	23, 34
	2-octanol	-	-	D	a, d	32
	3-octanol	-	-	A, D	b, c, d, e	29, 30, 32, 34 36, 38
	1-octen-3-ol	mushroom-like	1	A, D	a, b, c, d, e, f	23, 27-30, 32-36, 38
	1-nonanol	-	50	D	b	34
	2-nonanol	-	-	A, D	d, e	23, 39
	1-nonen-3-ol	-	-	A	c	31
	10-undecen-1-ol	-	-	A	c	31
	1-tridecyn-4-ol		-	A	c	27
	2-pentadecanol	-	-	D	a	32
	9,12-octadecadien-1-ol	-	-	A	c	31
	phenethyl alcohol (2-phenyl ethanol, benzeneethanol)	honey-like, spicy	1,000	A, B, D	a, b, c, d, e, f	23, 27-30, 32, 34-39
	benzyl alcohol (benzenemethanol)	-	10,000	A, B, D	a, b, c, d, e, f	28-30, 32, 34 37, 39
	2-methyl benzenemethanol	-	-	A	e	30
	α-methyl benzenemethanol	-	-	A	c	28
	2-furanmethanol (furfuryl alcohol)	-	-	A, C, D B	a, b, c, d, e, f	23, 26-30, 32, 34, 39
	1-aziridineethanol	-	-	A	b	27
	8-amino-2-naphthalenol	-	-	A	b	27
Aldehyde	acetaldehyde	pungent, fruit	15-25	D	d, f	39
	hydroxyacetaldehyde	-	-	C	a	26
	3-(methylthio) propanal (methional)	potato-like	0.2-1.8	A, D	c, d	23, 28
	2-methylbutanal	green, almond-like	1-3.7	D	b, d, f	23, 34, 39

	Compound name	Aroma description	Threshold[1)] (μg/L in water)	Extraction method[2)]	Sample[3)]	Reference
Aldehyde	3-methylbutanal	malty	0.2-3.1	A, C, D	a, b, c, d, f	23, 26, 31, 34, 36, 37, 39
	2-methyl-2-butenal	-	-	D	d, f	23, 39
	pentanal	pungent, almond-like	12-42	C, D	c, d	23, 26
	hexanal	tallowy, leaf-like	4.5-50	A, D	a, b, c, d, e	23, 27-29, 33, 34, 37, 39
	heptanal	fatty	3-5.8	A, D	c, d	23, 31
	(*E*)-2-heptenal	fatty, almond-like	13-51	A, D	c, b, d	23, 28, 34
	octanal	fatty	0.7-8	D	b	34
	(*E*)-2-octenal	fatty, nutty	4	D	b	34
	nonanal	tallowy, fruity	1-5	A, D	b, c, d	23, 28, 31, 32, 34,
	(*E*)-2-nonenal	tallowy, cucumber-like	0.15	A	c	27, 28
	decanal	orange skin-like, flowery	0.1-5	D	d	23
	(*E*)-2-decenal	tallowy, orange-like	0.3-0.4	D	d	23
	(*Z*)-7-hexadecenal	-	-	D	d	32
	(*E*)-11-hexadecenal	-	-	D	a	32
	(*E*,*E*)-2,4-decadienal	deep-fried	0.07-0.2	A, D	c, e, d	23, 29
	tetradecanal	-	-	D	d	23
	benzaldehyde	almond-like	350-3,500*	A, B, D	a, b, c, d, e f	23, 27-39
	2-methyl benzaldehyde	-	-	D	a, d	32, 37
	3-methyl benzaldehyde	-	-	D	a	32
	4-methyl benzaldehyde	-	-	B	d, f	39
	2-hydroxy-6-methylbenzaldehyde	-	-	A	c	31
	2-aminobenzaldehyde	-	-	B	d	39
	2-phenyl-2-butenal	-	-	A, D	b, c, d, e	29, 34, 35
	5-methyl-2-phenyl-2-hexenal	-	-	A, D	c, d, e	23, 29, 30, 32, 35, 37,
	α-ethylidene benzeneacetaldehyde	-	-	A	c, d, e	27, 30, 31, 37
	phenylacetaldehyde (2-phenylethanal, benzeneacetaldehyde)	honey-like, flowery	4	A, B, D	a, b, c, d, e, f	23, 27-39
	2-furancarboxaldehyde (furfural)	sweet	3,000	A, C, D	a, b, c, d, e, f	23, 26-30, 32-35, 37-39
	5-methyl-2-furancarboxaldehdye	-	-	A, C, D	a, b, c, d, e	23, 26, 27, 29, 30, 35,

	Compound name	Aroma description	Threshold[1)] (μg/L in water)	Extraction method[2)]	Sample[3)]	Reference
Ketone	2-propanone (acetone)	-	-	C, D	a, b, c	26, 32
	2-butanone	etheric	23,200-50,000	D	b, d	34, 39
	(*E*)-3-penten-2-one	-	1.5*	A	c, e	29, 31
	2-hexanone	-	-	A	c	31
	4-methyl-3-hexanone	-	-	D	f	39
	2-heptanone	soapy, fruity	5-140	A, D	b, c, d, e, f	23, 28, 29, 31, 34, 39
	4-methyl-2-heptanone	-	-	D	b	34
	3-heptanone	-	-	D	b	34
	2-octanone	-	50*	A, D	b, c, e	29, 34
	3-octanone	-	-	A, B, D	c, d, e	23, 29, 32, 35, 37, 39
	1-octen-3-one	mushroom-like, metallic	0.005	A, D	b, c	28, 34
	2,3-butanedione (diacetyl)	buttery	4-15	C, D	a	26, 32
	1-hydroxy-2-propanone	-	-	A, C	b, c, e	26, 29
	2-nonanone	fruity, soapy	5-200	A	c, e	29
	2-decanone	-	-	D	b	34
	2-undecanone	fruity	7*	D	d	38
	3-hydroxy-2-butanone	buttery	800-5,000	A, C, D	a, b, c, e	26, 29, 32
	2,3-hexadione	-	-	A	b	27
	1-phenylethanone (acetophenone)	-	65*	D	a	32
	1-(2-hydroxy-5-methylphenyl) ethanone	-	-	A	c	27, 31
	1-(1H-pyrrol-2-yl) ethanone	-	-	C, D	a, b, c, d, f	26, 39
	6-methyl-4H-pyran-4-one	-	-	C	b, c	26
	4-phenyl-2-butanone	-	-	A	b	27
	1-phenyl-2-propanone	-	-	B, D	d	39
	dihydro-2-methyl-3(2H)-furanone	-	-	A, C	b, c, e	26, 29
	dihydro-2(3H)-furanone (γ-butyrolactone)	-	-	B	d, f	39
	4-methyl-2H-furan-5-one	-	-	D	b	34
	dihydro-5-methyl-2(3H)-furanone (γ-valerolactone)	-	-	B	d	39
	dihydro-5-ethyl-2(3H)-furanone (γ-hexalactone)	sweet	1,600	A, B	c, d, e, f	29, 39
	dihydro-5-propyl-2(3H)-furanone (γ-heptalactone)	-	400*	A	c	28
	dihydro-5-pentyl-2(3H)-furanone (γ-nonalactone)	fruity, peach-like	30-65	A, D	a, b, c, e	29-32, 34

	Compound name	Aroma description	Threshold[1] (μg/L in water)	Extraction method[2]	Sample[3]	Reference
Ketone	dihydro-5-hexyl-2(3H)-furanone (γ-decalactone)	fruity, peach-like	5-11	A, D	a, c	31, 32
	dihydro-5-(2-octenyl)-2(3H)-furanone	-	-	B	d	39
	3-hydroxy-2-methyl-4H-pyran-4-one (maltol)	caramel-like	9,000-35,000	A, B, D	a, b, c, d, e, f	23, 29, 32, 34, 35, 37, 39
	methyl maltol	-	-	B	d, f	39
	dihydro-6-methyl-2H-pyran-3(4H)-one	-	-	B	d, f	39
	2,3-dihydro-3,5-dihydroxy-6-methyl-4H-pyran-4-one	-	-	B	d, f	39
	β-damascenone	honey-like, fruity, sweet	0.00075-0.002	A	c, e	29
	5-penoxymethyloxol-3-en-2-one (?)[4]	-	-	A	e	30
	2-pentadecanone	-	-	D	d	32
	2-hydroxy-3-methyl-2-cyclopenten-1-one (cyclotene)	-	300*	B	d, f	39
	cyclohexanone	-	-	A	c	31
	4-isopropyl-1,3-cyclohexanedione	-	-	B	d, f	39
	1,2,3-trimethylcyclohexane	-	-	B	d, f	39
	2-cyclohexen-1-one	-	-	B	d	39
	3-methyl-2-cyclohexen-1-one	-	-	A	c	31
Acid	acetic acid	vinegar-like, pungent	22,000-50,000	A, B, C, D	a, b, c, d, e, f	23, 26, 27, 29, 32, 35-39
	propanoic acid	fruity, pungent	2,190-20,000	A, B, D	c, d, e, f	29, 30, 32, 35, 37-39
	2-methyl propanoic acid	sweaty	50-8,100	A, B, D	c, d, e, f	29, 30, 32, 35, 37, 39
	3-(methylthio)propanoic acid	-	-	B	d	39
	butanoic acid	sweaty, rancid	50-2,150	A, B, C, D	b, c, d, e, f	26, 27, 29, 30, 32, 33, 35, 37-39
	2-methyl butanoic acid	sweaty, sweet	50-6,600	A, D	c, d, e	23, 29, 35
	3-methyl butanoic acid (isovaleric acid)	sweaty	132-1,600	A, B, C, D	a, b, c, d, e, f	23, 26, 27, 29, 30, 32, 35, 37, 39
	2-methyl-2-butenoic acid			B	d, f	39
	3-methyl-2-butenoic acid			B	d, f	39
	pentanoic acid (valeric acid)	sweaty	2,100	A, B, D	a, b, c, d, e	29, 30, 32, 34, 39
	3-methyl pentanoic acid			D	d	32
	4-methyl pentanoic acid			A, B, D	c, d, e, f	29, 35, 39
	hexanoic acid (caproic acid)	goat-like, sweaty	290-5,000	A, B, D	a, b, c, d, e	27, 29, 30, 32, 34, 37, 39
	heptanoic acid	-	-	A, D	b, d, e	30, 32, 34, 37

	Compound name	Aroma description	Threshold[1)] (μg/L in water)	Extraction method[2)]	Sample[3)]	Reference
Acid	octanoic acid (caprylic acid)	sweaty	3,000	A, B, D	a, d, e	30, 32, 37, 39
	nonanoic acid	-	3,000	D	a, d	32
	tetradecanoic acid	-	-	D	f	38
	hexadecanoic acid	-	-	A, D	a, c, d, f	28, 31, 33, 38
	2,4-hexadienoic acid (sorbic acid)	-	-	A, D	d, e, f	30, 38
	benzoic acid	-	-	A, B, D	b, c, d, e, f	27, 29, 30, 32, 38, 39
	2-hydroxy benzoic acid	-	-	D	c	36
	3-nitropropanoic acid	-	-	D	a	32
	8,11-octadecadienoic acid	-	-	A	c	33
	(*Z*,*Z*)-9,12-octadecadienoic acid	-	-	A, D	c, e	28, 32, 33
	14-pentadecenoic acid*	-	-	D	e	32
	phenylacetic acid (benzeneacetic acid)	sweet, honey-like	1,000-10,000	B, D	d, f	32, 38, 39
	benzenepropanoic acid	-	-	B	f	39
	3-hydroxymandelic acid	-	-	D	f	38
	2-furancarboxylic acid	-	-	A	c, e	29
Ester	ethyl formate	-	-	A	c	31
	ethyl acetate	solvent-like, fruity	5-19,900	A, C, D	a, b, c, d, e, f	23, 26, 30-32, 34, 37-39
	methoxy ethyl acetate	-	-	D	e	32
	ethyl propanoate	fruity	10-20	D	b, d, f	34, 39
	ethyl 2-methylpropanoate	fruity, sweet	0.02-0.1	D	b, d, f	23, 34, 39
	ethyl-2-methylpropenoate			D	b	34
	ethyl butanoate	fruity	0.005-13.6	A, B, C, D	b, c, d, e, f	26, 29, 31, 32, 34, 35, 37, 39
	ethyl 2-methylbutanoate	fruity	0.15-0.3	A, B, D	b, c, d, e, f	29, 31, 32, 34, 35, 37, 39
	ethyl 3-methylbutanoate	fruity	0.20	A, B, D	b, c, d, e, f	29, 31, 32, 34, 35, 37, 39
	ethyl (*Z*)-2-butenoate	-	-	D	b	34
	ethyl pentanoate	-	1.5-5*	A, B, D	c, d, e, f	39, 37, 39
	ethyl 2-methylpentanoate	-	-	D	e	32
	ethyl 4-methylpentanoate	-	-	B, D	d, f	32, 39
	ethyl hexanoate	fruity	0.05-5	A, B, D	b, c, d, e, f	23, 29, 31, 32, 34, 35, 37-39
	ethyl heptanoate	fruity	2.2	A, D	b, c, e	29, 34, 35
	ethyl octanoate	fruity, fatty	70	A, B, D	b, c, d, e, f	29, 32, 34, 35, 37, 39
	ethyl 4-methyloctanoate	-	-	D	d, e	32, 37

	Compound name	Aroma description	Threshold[1] (μg/L in water)	Extraction method[2]	Sample[3]	Reference
Ester	ethyl nonanoate	-	-	A, D	b, c, d, e	29, 34, 37
	ethyl decanoate	-	-	D	b	34
	ethyl dodecanoate	-	-	A, D	b, c, e	29, 34, 35
	ethyl tridecanoate	-	-	D	e	32
	ethyl tetradecanoate	-	-	A, B, C, D	a, b, c, d, e, f	26, 29, 31, 32, 34, 35, 39
	ethyl pentadecanoate	-	-	A, D	b, c, d, e	29, 30, 32, 34, 35
	ethyl hexadecanoate	-	>2,000*	A, B, C, D	a, b, c, d, e, f	26, 28-32, 34, 35, 37, 39
	ethyl heptadecanoate	-	-	D	b, e	32, 34, 35
	ethyl octadecanoate	-	-	A, B, D	b, c, d, e, f	30-32, 34, 39
	ethyl (Z)-9-octanoate(?)	-	-	A	e	30
	ethyl 9-hexadecenoate	-	-	A, C, D	a, b, c, d, e	26, 29, 34, 35
	ethyl E11-hexadecenoate	-	-	D	e	32
	ethyl 9-octadecenoate (ethyl oleate)	-	-	A, B, D	b, c, d, e, f	30-32, 34, 38, 39
	ethyl 9,12-octadecadienoate (ethyl linoleate)	-	-	A, B, D	a, b, c, d, e, f	28, 30, 32, 34, 38, 39
	ethyl 9,12,15-octadecatrienoate	-	-	A, D	b, d, e	30, 32, 34
	ethyl benzeneacetate (ethyl phenylacetate)	fruity, sweet	650*	A, B, D	b, c, d, e, f	23, 27, 29-31, 34, 35, 37, 39
	ethyl lactate	-	14,000*	A, D	c, e	29, 32, 35
	ethyl 3-phenylpropionate (ethyl benzenepropanoate)	-	-	A, B, D	b, c, e, f	29, 34, 39
	ethyl 3-(methylthio) propionate	-	7*	D	e	35
	ethyl benzoate	-	60	A, B, D	b, c, d, e, f	29, 30, 32, 34, 35, 37, 39
	ethyl sorbate	-	-	A, D	d, e, f	30, 38
	ethyl cinnamate	fruity	0.06#	B, D	f	39
	ethyl vanillate	-	-	B	f	39
	ethyl N-allylcarbamate	-	-	D	f	38
	ethyl 2-hydroxy-3-phenylpropanoate	-	-	B	f	39
	ethyl nicotinate	-	-	B, D	f	39
	ethyl 2-cyclopenten-1-undecanoate	-	-	A	e	30
	methyl 2-methylpropanoate	fruity, sweet	6.3-7	A	c	31
	methyl 2-methylpropenoate	-	-	D	b	34
	methyl butanoate	fruity, sweet	5-60	A, D	c, d	31, 39
	methyl 2-methylbutanoate	apple-like	0.25-2.0	D	d	39
	methyl 3-methylbutanoate	-	-	D	d	39
	methyl 3-methyl-2-butenoate	-	-	D	b	34

	Compound name	Aroma description	Threshold[1)] (μg/L in water)	Extraction method[2)]	Sample[3)]	Reference
	methyl 4,6,10,14-tetramethyl pentadecanoate	-	-	A	c	27
	methyl 4-methyl-2-oxo pentanoate	-	-	A	c	27
	methyl undecanoate	-	-	A	c	31
	methyl tetradecanoate	-		A	c	31
	methyl hexadecanoate	-	-	A, C, D	b, c, d, e	26, 28, 31, 32, 34, 35
	methyl octadecanoate	-	-	A	c	31
	methyl 9-octadecenoate	-	-	A, D	c, d, e	28, 31, 32
	methyl 9,12-*Z*,*Z*,-octadecadienoate	-	-	A, C, D	a, b, c, d, e	26, 28, 31, 32, 34
	methyl 9,12,15-octadecatrienoate	-	-	A, C	a, c, e	26, 30
	methyl 11,14-eicosadienoate	-	-	A	c	27, 28
	methyl 2-methyl hexadecanoate	-	-	A	b	27
	methyl 14-methyl pentadecanoate	-	-	D	e	32
	methyl benzoate	-	-	A, B, D	b, c, d, e, f	23, 31, 34, 35, 39
	methyl phenylacetate	-	-	D	d	37
	methyl 2-hydroxybenzoate	-	-	A	c	31
	diethyl succinate (diethyl butanedioate)	-	-	A, B, D	b, c, e, f	29, 34, 38, 39
	triethyl borate(?)	-	-	A	e	30
Ester	isobutyl acetate	-	66*	D	b	34
	isobutyl butanoate			D	d	39
	isoamyl acetate	-	2*	A, D	b, c, d, e, f	29, 34, 37, 39
	isoamyl butyrate	-	-	D	d	37
	isoamyl hexanoate	-	-	D	b	34
	isoamyl octanoate	-	-	D	b	34
	isoamyl 2-methylbutanoate	-	-	D	d	38
	2-phenylethyl acetate	flowery, fruity	20#	A, B, D	b, c, d, e	29, 34, 39
	2-acetyl ethylhexanoate	-	-	C	c	26
	bis(2-ethyl-)1,2-benzenecarboxylic acid	-	-	A	e	30
	(*Z*,*Z*)-2,3-dimethyl 9,12-octadecadienoic acid(?)	-	-	A	e	30
	dimethyl butanedioate	-	-	A	c	31
	propyl acetate	-	-	D	d	39
	propyl butanoate	-	18-124*	B, D	d	39
	propyl 2-methylbutanoate	-	-	D	d	39
	propyl 3-methylbutanoate	-	-	B, D	d	39
	butyl butanoate	-	100*	A	c	28, 31
	butyl isobutyrate	-	80*	D	d	39
	butyl hexadecanoate	-	-	D	b	34
	butyl benzoate	-	-	D	d	32

	Compound name	Aroma description	Threshold[1] (μg/L in water)	Extraction method[2]	Sample[3]	Reference
Ester	pentyl propanoate	-	-	D	b	34
	2-octyl benzoate	-	-	D	a, d	32
	dimethyl 1,2-benzenedicarboxylate	-	-	A	c	31
	dibutyl 1,2-benzenedicarboxylate	-	-	A	c	31
	dipentyl 1,2-benzenedicarboxylate	-	-	A	c	31
	2-methylpropyl 2-methylpropanoate	-	-	D	a	32
	2-methylhexyl propanoate	-	-	D	a	32
	butyl heptadecyl sulfuroate	-	-	D	a	32
	hexadecyl trichloroacetate	-	-	D	a	32
Pyrazine	2-methylpyrazine	-	60-105,000*	A, B, C, D	b, c, d, e	23, 26, 29-31, 34, 37-39
	2,3-dimethylpyrazine	-	2,500-35,000*	A, B, D	c, d, e	23, 29, 31, 35, 37-39
	2,5-dimethylpyrazine	-	800-1,800*	A, B, D	a, c, d, e, f	23, 28-30, 32, 33, 35, 37-39
	2,6-dimethylpyrazine	-	200-9,000*	A, B, D	c, d, e	29, 31, 35, 37, 39
	2-ethyl-5-methylpyrazine	-	100*	B, D	d	39
	2-ethyl-6-methylpyrazine	-	-	A, D	c, d, e	29, 37
	2-ethyl-3,5-dimethylpyrazine	potato-like	0.04-0.16	D	d, e	35, 38
	3-ethyl-2,5-dimethylpyrazine	potato-like	0.4-8.6	A, B, D	c, d, e	28, 29, 31, 35, 39
	2,3,5-trimethyl-6-ethylpyrazine	-	-	A, B, D	c, d, e, f	23, 29, 35, 37-39
	2,3,5-trimethyl-6-propylpyrazine	-	-	A, B	c, f	28, 39
	trimethylpyrazine	potato-like, musty	91-400	A, B, D	a, b, c, d, e, f	23, 27-30, 32, 33, 35-39
	tetramethylpyrazine	-	1,000-10,000*	A, B, D	b, c, d, e, f	23, 27-32, 35-39
	2,6-diethylpyrazine	-	-	D	d	37
	acetyl pyrazine	roasty	62	D	d	23
	2,5-dimethyl-3-propylpyrazine	-	-	A	c	31
Nitrogen-containing compound	1H-pyrrole	-	49,600*	A	c	27, 28, 39
	acetyl pyrrole	-	170,000*	A, D	c, d, e	29, 35, 37
	2-formyl pyrrole	-	-	D	d	23
	1-methyl-2-pyrrolidone	-	-	B	d, f	39
	1-methyl-2,5-pyrrolidinedione	-	-	B	f	39
	pyridine	-	2,000*	A	c, e	29, 30, 31
	N,N,-dimethylformamide	-	-	C	c	26
	3-methyl benzonitrile	-	-	A	c	31
	1-butyl-1H-pyrrole	-		A	c	31
	9-octadecanamide	-	-	A	c	31
	1H-indole	sweet, burnt	90	A, B, D	b, c, d, f	23, 28, 34, 39

	Compound name	Aroma description	Threshold[1)] (μg/L in water)	Extraction method[2)]	Sample[3)]	Reference
Nitrogen-containing compound	2,3-indole	-	-	D	d	38
	6-methyl-2-phenylindole	-	-	D	a	32
	4-phenyl pyridine	-	-	D	d	32
	N,N'-diethylidene-1,1'-diaminoethane	-	-	A	c	28
	phenylacetonitrile (benzeneacetonitrile, benzyl nitrile)	-	-	A, B, D	b, d, f	27, 37, 39
	benzenepropanenitrile	-	-	B, D	f	39
Sulfur compound	dimethyl disulfide	cabbage-like	0.16-12	D	b, d, e, f	23, 32, 34, 39
	dimethyl trisulfide	sulfury	0.01	A, D	b, c, d, e	23, 27, 29, 34, 36, 39
	2-acetyl thiazole	roasty, sulfury	10	D	d	23
	trimethyl thiazole	earthy	50	A	c, e	29, 31
	2-methyl thiazole	-	-	A	c	31
	4-ethyl-2,5-dimethyl thiazole	-	-	A	c	31
	thiophene	-	-	D	b	34
	2-methylthiophene	-	-	D	b	34
	4,5-dimethyl-2-isopropyl thiazole	-	-	A	c	31
	methanesulfonic anhydride	-	-	D	a	32
	allyl isothiocyanate	-	-	B, D	e, f	32, 39
	1,3-dimethylthioindole	-	-	D	e	32
	dimethyl sulfone	-	-	B	d	39
	ethyl thioisobutyrate	-	-	D	e, f	32, 39
	1-docosanethiol	-	-	D	a	32
	n-ethyl hydrazinecarbothioamide	-	-	D	a	32
	thialdine	-	-	A	e	29
Phenol	2-methylphenol (o-cresol)	phenolic	650	A, D	a, c, d	28, 32
	3-methylphenol (m-cresol)	-	680*	A	c, e	29
	4-methylphenol (p-cresol)	smoky, phenolic	55	A	c	28
	2,6-dimethyl phenol	-	-	A	c	28
	2-ethylphenol	-	-	A, D	c, d, e	27, 30, 32
	4-ethylphenol	-	-	A, B, D	c, d, e, f	23, 28, 29, 32, 35, 37-39
	5-ethylphenol	-	-	A	e	30
	4-vinylphenol	-	10*	A, B, D	a, b, c, d, e, f	23, 29, 32, 34, 35, 39
	2-propyl phenol	-	-	A	c	28
	5-methyl-2-(1-methylethyl) phenol	-	-	A	e	30
	2-methoxy phenol (guaiacol)	smoky, sweet	2.5-3	A, B, D	a, b, c, d, e, f	23, 27-30, 32, 34, 35, 37-39

	Compound name	Aroma description	Threshold[1)] (μg/L in water)	Extraction method[2)]	Sample[3)]	Reference
Phenol	2-methoxy-4-vinylphenol (4-vinyl guaiacol)	clove-like	20-100	A, B, D	a, b, c, d, e, f	23, 29, 32, 34, 35, 38, 39
	2-methoxy-4-(2-propenyl) phenol (eugenol)	spicy, honey-like	6-30	A, B	c, d, e	29, 39
	4-ethyl-2-methoxy phenol (4-ethyl guaiacol)	clove-like	50	A, B, D	c, d, e, f	27-30, 32, 35, 37-39
	2,6-dimethoxy phenol	-	1,850*	B, D	a, d, f	23, 32, 39
	2,6-bis(1,1-dimethylethyl) phenol	-	-	A	c	28
	3,5-bis(1-methylethyl) phenol	-	-	A	c	31
Furan	2-methylfuran	-	-	D	b, d	34, 38, 39
	2,5-dimethylfuran	-	-	D	d	39
	2-ethylfuran	-	-	D	b, d	34, 39
	2-ethenylfuran	-	-	D	b	34
	2-butylfuran	-	-	D	d	39
	2-pentyl furan	buttery, green bean-like	6	A, B, D	a, b, c, d, e	23, 28, 29, 32, 33, 34-37, 39
	2-heptyl furan	-	-	D	d	23
	2-octyl furan	-	-	D	d	23
	2-acetyl furan	-	10,000*	A	c, e	29
	1-(2-furanyl) ethanone	-	-	C, D	b, c, d	26, 39
	furfuryl acrolein	-	-	A	e	30
	2-methyl-3-β-furyl propanal(?)	-	-	A	e	30
	furfurylideneacetone	-	-	A	e	30
	4-methyl-2,3-dihydrofuran	-	-	D	d	39
	2,3-dihydro benzofuran	-	-	A, D	a, c	28, 32
	tetrahydro-2-methylfuran	-	-	A	c	31
Miscellaneous	decanoic acid, silver(+) salt(?)	-	-	A	e	30
	trimethyloxazole	-	-	D	d	39
	cadinene	-	-	A	c	31
	3,4-dihydro-2H-pyran	-	-	B	f	39
	cadina-1,4-diene	-	-	B	d	39
	(+)-epi-bicyclosesquiphellandrene	-	-	B	d	39
	1,1-bis(2-methylpropyl) hydrazine	-	-	C	b	26
	β-caryophyllene	-	64*	B	f	39
	N-(2-methyl-2propyl) ethanamide	-	-	B	f	39
	N-(3-methylbutyl) acetamide	-	-	B	f	39
	N, *N*-dimethylformaide	-	-	C	b, c	26
	3(2H)-pyridazinone	-	-	A	c	28
	maleic hydrazide	-	-	B	d, f	39

	Compound name	Aroma description	Threshold[1)] (μg/L in water)	Extraction method[2)]	Sample[3)]	Reference
Miscellaneous	*N,N*-bis(1-methylethyl) acetamide	-	-	B	f	39
	N-methyl-n-propyl-1-butylamine	-	-	B	f	39
	N-phenethyl acetamide	-	-	B	d	39

1) Reference 24.
* Orthonasal threshold in water (μg/L).
# Retronasal threshold in water (μg/L).
2) A: SDE, B: solvent-assisted flavor evaporation (SAFE), C: headspace method, D: solid phase microextraction (SPME).
3) a: doenjang fermented with Bacillus koji, b: doenjang fermented with Aspergillus koji, c: traditional doenjang fermented with meju, d: commercial traditional doenjang fermented with meju, e: commercial doenjang fermented with Aspergillus koji, f: commercial doenjang fermented with koji.
4) The identification is questionable.

청국장에서도 동정되었으며 함량에 있어서는 청국장이 된장보다 4.3배 더 많았다(23).

질소 함유 화합물 중에는 1H-피롤(1H-pyrrole), 아세틸피롤(acetyl pyrrole), 피리딘(pyridine), 1H-인돌(1H-indole) 및 페닐아세토나이트릴(phenylacetonitrile) 등이 된장에서 자주 동정되는 휘발성 향기성분이다. 황 함유 화합물 중에는 다이메틸다이설파이드와 다이메틸트라이설파이드(dimethyl trisulfide), 페놀화합물 중에는 페놀, 4-에틸페놀(4-ethylphenol), 4-바이닐페놀(4-vinylphenol), 2-메톡시페놀(2-methoxyphenol), 2-메톡시-4-바이닐페놀(2-methoxy-4-vinylphenol) 및 4-에틸-2-메톡시페놀(4-ethyl-2-methoxy phenol, 4-에틸구아이아콜(4-ethyl guaiacol)) 등이 된장의 주요 휘발성 향기성분으로 보고되었다. 퓨란은 2-메틸퓨란(2-methyl furan)과 2-펜틸퓨란 등이 동정되었다.

한국 전통식품의 휘발성 향기성분을 데이터베이스화하는 일은 우리 전통식품의 향미특성을 이해하고 개선하는데 있어서 중요한 일이라고 생각된다. 외국은 자기나라 식품의 향기성분 데이터베이스를 잘 구축하고 있어 식품향 개발이나 이취문제 해결에 중요한 자료로 활용하고 있으나 우리나라는 아직 미흡한 실정이다. 한편 관능검사나 GC-MS를 이용한 휘발성 향기성분 분석을 통해 한국 전통식품의 향미특성을 이해하려는 연구는 어느 정도 이루어지고 있으나 향 활성 화합물(aroma-active compound)을 밝히려는 연구는 아직 구체적으로 이루어지지 않고 있다.

결론

한국 전통식품의 휘발성 향기성분을 데이터베이스화하는 작업의 일환으로 국내외 논문검색을 통해 청국장과 된장의 휘발성 향기성분 데이터베이스를 작성하였다. 지금까지 청국장과 된장에서 각각 225개와 404개의 휘발성 향기성분이 동정되었다. 청국장과 된장의 휘발성 향기성분은 제조방법, 발효기간 및 향기성분 추출방법에 따라 차이가 있었으며 휘발성 향기성분의 종류와 구성 비율에 따라 청국장과 된장의 향미특성에 차이가 있었다. 청국장에서 가장 특징적인 휘발성 향기성분은 피라진 화합물이었으며, 2-메틸프로판산, 뷰탄산, 2-메틸뷰탄산 및 3-메틸뷰탄산 같은 산도 청국장의 향미특성에 크게 기여할 것으로 생각된다. 된장의 휘발성 향기성분에서 가장 특징적인 것은 에스터 화합물이 많다는 것이었다. 청국장에서는 22개의 에스터 화합물이 동정된 반면, 된장에서는 96개의 에스터 화합물이 동정되었다. 산과 피라진 화합물도 된장의

향미특성에 중요한 역할을 할 것으로 생각된다. 청국장과 된장의 휘발성 향기성분 데이터베이스는 청국장과 된장 및 이를 이용한 조미소재의 향미특성을 이해하는 기초 자료로 활용될 수 있을 것이다. 또한 청국장과 된장의 향미특성을 개선하는 기초자료로도 활용될 수 있을 것이다. 앞으로 청국장과 된장 이외의 한국 전통식품에 대해서도 휘발성 향기성분 데이터베이스를 작성하는 작업이 계속 이루어지기를 바라며, 아울러 가스크로마토그래피-후각측정법(gas chromatography-olfactometry)을 이용하여 한국 전통식품의 향 활성 화합물을 동정하는 연구가 활발히 이루어져야 할 것으로 생각된다.

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