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Full Length Article

Effects of Temperature on Volatile Profile and Aroma Quality in Rice

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Abstract

Aroma is an important grain quality trait of aromatic rice, controlled by a recessive gene which increases the accumulation of numerous volatile compounds to produce it. The aroma quality of rice grain also depends on the cultivation practice, genetic condition, environmental components and their interaction. Among the environmental components, the temperature is the vital component that can affect the aroma quality and chemical composition of aromatic rice. This study assessed the effects of different temperatures (ambient or 28°C, 25°C and 20°C) for the volatile profile and aroma quality of five aromatic and a non-aromatic rice genotypes by gas chromatography–mass spectrometry (GC-MS), gas chromatography- flame ionization detector (GC-FID) and organoleptic test. The results indicated that the aromatic rice genotypes contained more volatile compounds (15 compounds) and displayed the maximum aroma score (Score 4) at the 25°C temperature than ambient and 20°C temperature. The obtained information will be helpful for exploring possible reasons for variation in the biochemical composition as well as aroma quality of a genotype which might be used to improve grain quality of aromatic rice. © 2017 Friends Science Publishers

Keywords: Aroma score; Volatile compound; Temperature; 2-acetyl-1-pyrroline; Aromatic rice

Introduction

Aroma in rice differentiates aromatic rice with the non-aromatic rice by market value, grain quality and consumer preference. Aroma of a rice variety depends on the genetic factor, environmental element and their interaction (Jewel *et al.*, 2011; Hashemi *et al.*, 2013). A lot of environmental factors have been identified as influencing factors for aroma in rice such as the temperature, soil type, abiotic stress, water, CO_2, light, salinity, and shading (Itani *et al.*, 2004; Mo *et al.*, 2015). Among these factors, the temperature is regarded as the key factor which influences grain quality, growth, development, and yield of rice plant (Lur *et al.*, 2009). However, the critically low (<20°C) and high (>30°C) temperatures are destructive and adversely affected grain quality of rice (Yoshida, 1981; Rohilla *et al.*, 2000). Besides, the growth rate of rice plant increase linearly until 25°C and the grain yield decreased progressively after 26°C (Baker and Allen 1993; Baker, 2004). Hence, the optimum temperature range (20°C to 30°C) for rice (Yoshida and Hara, 1977; Yoshida, 1981) and aromatic rice (Oad *et al.*, 2006) might influence the volatile profile as well as the aroma quality of rice.

Aroma in rice depends on the composition of numerous volatile compounds along with the presence of a potent volatile compound termed as 2-Acetyl-1-pyrroline (2AP). Hence, biochemical profiling can explain the aroma status of a rice variety (Mahatheeranont *et al.*, 1995, 2001; Yang *et al.*, 2007; Maraval *et al.*, 2008; Sukhonthara *et al.*, 2009; Mahattanatawee and Rouseff, 2010; Park *et al.*, 2010; Pisithkul *et al.*, 2010; Bryant and McClung, 2011; Liyanaarachchi *et al.*, 2014). More than 200 volatile compounds were identified by previous researchers (Champagne, 2008), while Buttery *et al.* (1988) stated that nonanal, hexanal, 2AP, (E, E)-2, 4-decadienal, (E)-2-nonenal, 4-vinyl-guaiacol, 4-vinylphenol, octanal, and decanal were the key contributors of aroma in cooked rice. Jezussek *et al.* (2002) reported another two chemical compounds i.e. 4, 5-epoxy-(E)-2-decenal and 2-amino acetophenone as the major aroma compounds in rice. Maraval *et al.* (2008) found similar aroma profiles in aromatic genotypes but the level of volatile compounds were different. Yang *et al.* (2008) assumed that a total of 13 volatile compounds might be responsible for the differences in aroma. Liyanaarachchi *et al.* (2014) stated that volatile profiling of a rice genotype found necessary not only for rice breeding program but also for assessing the quality of rice grain or grain products in the market. They also added that the presence of volatile compounds depends on rice variety, agronomic practice, storage condition, post-harvest operation, and growing condition.

Thus, the aims of this research were to investigate the

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volatile profile and phenotypic aroma score of six rice genotypes (MRQ 50, Ranbir Basmati, Rato Basmati, E 7, E 13 and MR 219) at different temperatures (ambient or 28°C, 25°C, and 20°C) for evaluating the effects of temperature and identifying the possible reasons for variation in the chemical composition as well as the aroma quality of rice.

Materials and Methods

Experimental Material

Six rice genotypes (Table 1) used in this experiment were collected from the International Rice Research Institute (IRRI) and the Malaysian Agricultural Research Development Institute (MARDI). Rice seeds were sown in small plastic pots containing 500 g black soil and after three weeks, seedlings were transplanted into medium sized pails. The pails were filled with loam soil and kept inside the glass house of the Institute of Biological Sciences, University of Malaya, Malaysia, from April 2014 to August 2014. The recommended fertilizer dose and management practices were followed for raising the plants (Chatterjee and Maiti, 1981; Razak *et al.*, 2012). At the initial physiological maturity stage when rice grains turned into brown colour, the grains were collected and kept at -80°C for investigation.

Experimental Design and Treatments

The experiment layout was Completely Randomized Design (CRD) where rice plants grown under three temperature conditions (ambient, 25°C and 20°C) with three replications. The environmental weather data (rainfall, temperature, relative humidity and day length) were recorded in experimental site and compared to the data from the Meteorological Department of Malaysia (Meteorologi, 2014). The growth chambers were built under transparent plastic tin shade room and were surrounded by the net orientated to east–west direction at the Rimba Ilmu botanical garden of the University of Malaya, Malaysia. The length, width, and height of growth chambers were 4.57×1.83×2.13 m, respectively. A 1.83 m space was kept between the chambers to avoid mutual shading and proper ventilation. Thick and transparent plastic with steel structure were used to construct the framework of growth chamber. Two air conditioners (Wall Mounted 1.5HP Air Conditioner, Acson Malaysia Sales & Service Sdn. Bhd., Malaysia), four fans (two inlets and two outlets) and four tube lights were positioned at an upper portion of each chamber to maintain the temperature, humidity, and light supply. Four doors were equipped in each chamber for cultural practice.

Organoleptic Test

Aroma score of grain samples was estimated using forty grains from each genotype. The grain samples had been soaked in a petri dish containing 10 mL 1.7% KOH solution for an hour at room temperature. After soaking, the samples were scored on the 1–4 scale where 1, 2, 3 and 4, correspond to an absence of aroma, mild aroma, moderate aroma and strong aroma, respectively. The samples were sniffed and scored by three well-trained panellists (Golam *et al.*, 2011).

Extraction of Volatile Compounds

Rice grains was hulled and kept at -20°C before use in the solvent extraction method. About 1 g of rice grains was ground in mortar and pestle with liquid nitrogen. The ground samples were transferred into 125 mL conical flask which contained 40 mL of 20 ppm 2, 4, 6-tri methyl pyridine (TMP, Sigma-Aldrich Chemical Co., Germany). The TMP was used as an internal standard for which the supplied TMP was dissolved in 0.1 M HCl solution to give a 20.00 ppm concentration (Tanchotikul and Hsieh, 1991; Mahatheeranont *et al.*, 2001). The mixture (40 mL TMP and 1 g ground rice) was stirred 30 min then filtered into 50 mL centrifuge tubes. Three millilitres (3 mL) of 1.0 M NaOH solution were added in each 25 mL filtrate to make the solution slightly basic. After centrifugation at 6000 rpm for 10 min, the supernatant liquor was transferred to a 250 mL pear-shaped separatory funnel. Dichloromethane (50 mL) solvent was added to the supernatant liquor and the extraction was followed twice which resulted in a 100 mL of dichloromethane solution. The solution was dehydrated by anhydrous sodium sulfate and further concentrated to 1 mL solution using a rotary evaporator (Eyela N-2100, Tokyo Rikakikai Co., LTD, Japan) under reduce pressure (300 hPa) and temperature (26°C). From the concentrated extract 1 µL was taken for qualitative analysis by GC-MS and quantitative analysis by GC-FID using GC-MS/FID system (GC-QP2010W, Shimadzu, Japan).

Gas Chromatography

The extracted samples were analysed on GC-MS or GC-FID system (GC-QP2010W, Shimadzu, Japan). The injector and interface temperatures were adjusted at 250°C and 220°C, respectively. A DB5 capillary column of 30 m × 0.25 mm id and 0.25 µm film thickness (J & W Scientific, Folsom, CA) was used for chromatographic separation. The starting temperature was set at 30°C after split less injection of samples. The initial temperature (30°C) was held for 1 min then ramped up to 185°C at a rate of 5°C/min. After holding 2 min at 185°C, the temperature was increased to 220°C at a rate of 7°C/min. The program was withheld after 20 min.

Volatile Compound Identification

A volatile compound was identified primarily by comparing its mass spectra with the corresponding mass spectra of the reference compound compiled in the Wiley and NIST mass spectral libraries. The volatile compound was then determined by their mass spectra with corresponding spectra

of the standard compounds. Retention time, concentration and retention indexes of identified compounds were also compared to the compounds reported in the literature. The data of three biological replications and three technical replications were compared to finalize the volatile profiles.

Authentic Standard Compounds

The chemical compounds used as the standard compound, were collected from the organic chemistry laboratory of the University of Malaya, Malaysia. The laboratory has collected the analytical reagent grade with 99% purity of the standard from different companies. Only the purified 2AP standard compound was collected from the BOC Science (BOC Science, NY 11967, USA).

Results

Effect of Temperature on Volatile Profile

The qualitative and quantitative analysis of extracted compound from six rice genotypes showed the presence of more volatile compounds at 25°C compared to the ambient and 20°C temperature (Fig. 1, Table 2 and 3).

In the ambient condition, the Malaysian local aromatic rice genotype (MRQ 50) exhibited the presence of 6 compounds with more abundance of Tetradecamethyl-cycloheptasiloxane while Ranbir Basmati demonstrated 12 compounds (more abundant Nonadec-1-ene), Rato Basmati 2 compounds (more abundant Methyl tetradecanoate), E 7 genotype 4 compounds (more abundant Methyl 14-methylpentadecanoate), E 13 genotype 4 compounds (more abundant Methyl 14-methylpentadecanoate), and the Malaysian local non-aromatic rice genotype (MR 219) produced 5 compounds (more abundance of Heptadec-1-ene). At 25°C temperature, MRQ 50 genotype exhibited the presence of 13 compounds (abundance of Octacosan-1-ol), Ranbir Basmati 15 compounds with the higher abundance of Nonadec-1-ene, Rato Basmati genotype produced 10 compounds (abundance of Nonadec-1-ene and Octacosan-1-ol), E 7 genotype 14 compounds (abundance of Heptacosan-1-ol) and E 13 genotype produced 13 compounds with the more abundance of Heptadec-1-ene (Table 3).

Table 1: Rice genotypes used for this experiment

Genotype	Designation	Crossing information	Origin
MRQ 50	MRQ 50	Variety	Malaysia
Ranbir Basmati	Ranbir Basmati	Land race	India and Pakistan
Rato Basmati	Rato Basmati	Land race	Nepal
E 7	IR 77734-93-2-3-2	NSIC RC 148/PSB RC 18//NSIC RC 148	IRRI
E 13	IR 77512-2-1-2-2	IR 68726-3-3-1-2/IR 71730-51-2	IRRI
MR 219	MR 219	Variety	Malaysia

Table 2: Retention indices of volatile compound present under different temperature

Compound	MF	MW	RT		Compound	MF	MW	RT	
			Exp.	Ref.				Exp.	Ref.
(E)-hex-3-en-1-ol	$C_6H_{12}O$	100	6.1	6.0	Octadecane	$C_{18}H_{38}$	254	33.8	33.5
1H-pyrazole	$C_3H_4N_2$	68	11.6	11.5	Methyl 14-methylpentadecanoate	$C_{17}H_{34}O_2$	270	35.6	35.0
2,4,6-trimethylpyridine*	$C_8H_{11}N$	121	12.0	12.0	Tetracosan-1-ol	$C_{24}H_{50}O$	354	36.8	36.5
2-acetyl-1-pyrroline	C_6H_9NO	111	12.4	12.2	Heptadecane	$C_{17}H_{36}$	240	37.0	37.0
Dodec-1-ene	$C_{12}H_{24}$	168	17.4	17.0	Nonadecan-1-ol	$C_{19}H_{40}O$	284	37.5	37.5
Dodecan-1-ol	$C_{12}H_{26}O$	186	17.9	17.5	Nonadecane	$C_{19}H_{40}$	268	37.8	37.9
Tridecane	$C_{13}H_{28}$	184	18.1	18.0	Methyl (E)-octadec-6-enoate	$C_{19}H_{36}O_2$	296	38.5	38.5
Dodecane	$C_{12}H_{26}$	170	18.8	18.5	Methyl 16-methylheptadecanoate	$C_{19}H_{38}O_2$	298	39.0	39.0
Dodecamethylcyclohexasiloxane[a]	$C_{12}H_{36}O_6Si_6$	444	21.3	21.0	Nonadec-1-ene	$C_{19}H_{38}$	266	41.6	41.0
Tridec-1-ene	$C_{13}H_{26}$	182	23.5	23.0	Docosan-1-ol	$C_{22}H_{46}O$	326	44.6	44.0
Tetradecane	$C_{14}H_{30}$	198	23.7	23.5	Hexadecamethylheptasiloxane[c]	$C_{16}H_{48}O_6Si_7$	532	44.9	44.9
Hexadecane	$C_{16}H_{34}$	226	23.7	23.8	Octacosan-1-ol	$C_{28}H_{58}O$	410	47.2	47.0
Tetradecamethyl-cycloheptasiloxane[b]	$C_{14}H_{42}O_7Si_7$	518	25.6	25.5	Tetracosane	$C_{24}H_{50}$	338	47.6	47.5
2,4-ditert-butylphenol	$C_{14}H_{22}O$	206	26.4	26.0	Docosane	$C_{22}H_{46}$	310	47.9	47.9
Pentadec-1-ene	$C_{15}H_{30}$	210	28.2	28.0	Hexadecamethyl-cyclooctasioxane[d]	$C_{16}H_{48}O_8Si_8$	592	50.7	50.0
Hexadec-1-ene	$C_{16}H_{32}$	224	28.5	28.5	Heptacosan-1-ol	$C_{27}H_{56}O$	396	58.8	58.0
Methyl tetradecanoate	$C_{15}H_{30}O_2$	242	31.7	31.0	Tetradecamethylhexasiloxaned[e]	$C_{14}H_{42}O_5Si_6$	458	60.2	60
Heptadec-1-ene	$C_{17}H_{34}$	238	33.1	33.0					

[a]Dodecamethylcyclohexasiloxane: 2,2,4,4,6,6,8,8,10,10,12,12-dodecamethyl-1,3,5,7,9,11-hexaoxa-2,4,6,8,10,12-hexasilacyclododecane; [b]Tetradecamethyl-cycloheptasiloxane: 2,2,4,4,6,6,8,8,10,10,12,12,14,14-tetradecamethyl-1,3,5,7,9,11,13-heptaoxa-2,4,6,8,10,12,14-heptasilacyclotetradecane; [c]Hexadecamethylheptasiloxane: bis[[[dimethyl(trimethylsilyloxy)silyl]oxy-dimethylsilyl]oxy]-dimethylsilane; Tetradecamethyl-cycloheptasiloxane: 2,2,4,4,6,6,8,8,10,10,12,12,14,14-tetradecamethyl-1,3,5,7,9,11,13-heptaoxa-2,4,6,8,10,12,14-heptasilacyclotetradecane; [d]Hexadecamethyl-cyclooctasioxane: 2,2,4,4,6,6,8,8,10,10,12,12,14,14,16,16-hexadecamethyl-1,3,5,7,9,11,13,15-octaoxa-2,4,6,8,10,12,14,16-octasilacyclohexadecane; [e]Tetradecamethylhexasiloxane: [dimethyl(trimethylsilyloxy)silyl]oxy-[[dimethyl(trimethylsilyloxy)silyl]oxy-dimethylsilyl]oxy-dimethylsilane; MF, Molecular formula; MW, Molecular weight; RT, Retention time and *, Internal Standard

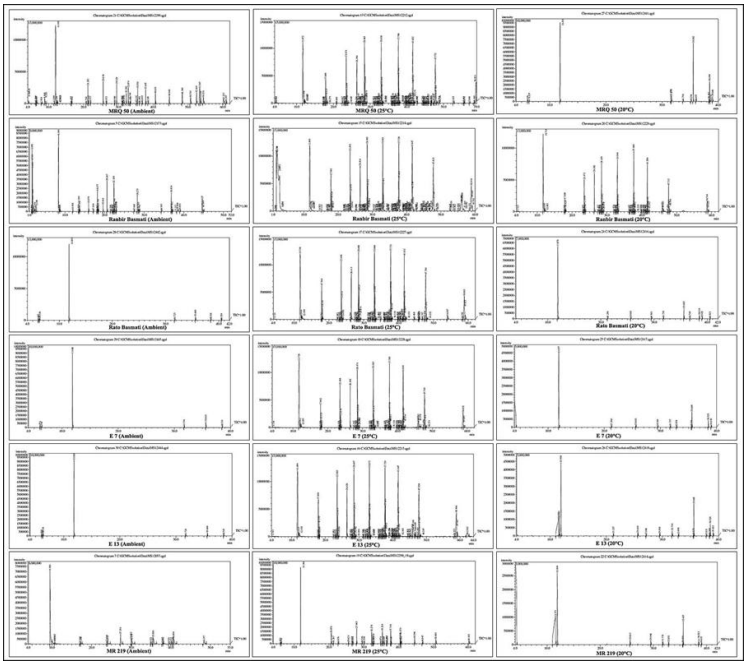

Fig. 1: Selected chromatograms for volatile compound identification by GC-MS

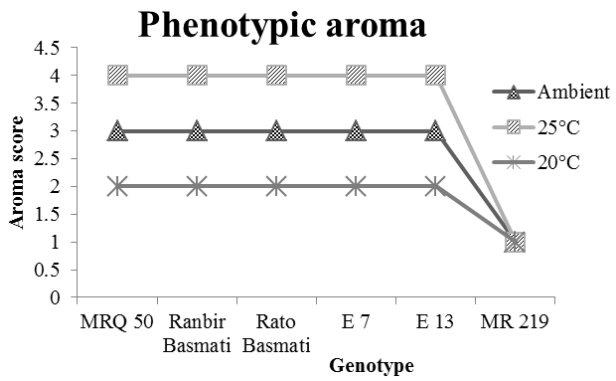

Fig. 2: Phenotypic expression of aroma in rice grain. Aroma score 1, absence of aroma; 2, mild aroma; 3, moderate aroma; 4, strong aroma

At 20°C temperature, MRQ 50 genotype represented 3 compounds (abundance of Methyl-E-octadec-6-enoate), Ranbir Basmati 12 compounds (abundance of Octacosan-1-ol), Rato Basmati genotype produced 2 compounds (more abundant Methyl 14-methylpentadecanoate), E 7 genotype 5 compounds (abundance of Methyl 14-methylpentadecanoate) and E 13 genotype produced 5 compounds (more abundance of Methyl 14-methylpentadecanoate).

However, the MR 219 genotype exhibited presence of 5 compounds at the ambient condition (Table 3), 6 compounds at 25°C (abundance of Tetradecamethyl-cycloheptasiloxane) and 3 compounds at 20°C temperature with a higher abundance of 1H-pyrazole. Moreover, the 2AP was identified in MRQ 50 and Ranbir Basmati genotype at ambient condition and only in Ranbir Basmati genotype at 20°C temperature. Besides, all aromatic rice genotypes exhibited the presence of 2AP at 25°C temperature.

The GC-MS or GC-FID analysis represented the maximum number of the volatile compound as well as the quantifiable amount of 2AP at 25°C temperature which also discriminated the volatile profiles of aromatic with the non-aromatic rice.

Effect of Temperature on Aroma

Phenotypic aroma of studied genotypes were evaluated by the organoleptic test of grains obtained from three different temperatures, represented different aroma score under different temperature conditions (Fig. 2).

Aromatic genotype demonstrated strong aroma (score 4) at 25°C temperature, mild aroma (score 2) at 20°C temperature, and moderate aroma (score 3) at the ambient condition (Fig. 2).

Therefore, the organoleptic test of grain aroma demonstrated that the temperature affected the aroma quality as well as the phenotypic aroma of tested rice genotypes.

Discussion

Aroma is a potential grain quality of aromatic rice, but its superiority and expression depend on several factors including cultivation practice, genetic and environmental factors. Searching a single factor for superior aroma expression is complicated and requires an extensive study with the integrated approach (Rohilla *et al.*, 2000).

Table 3: Volatile profile and area percentage (% ± SD) at different temperatures

Compound	MRQ 50			Ranbir Basmati			Rato Basmati			E 7			E 13			MR 219		
	Amb	25°C	20°C	Amb	25°C	20°C	Amb	25°C	20°C	Amb	25°C	20°C	Amb	25°C	20°C	Amb	25°C	20°C
(E)-hex-3-en-1-ol	nd	nd	nd	nd	nd	nd	nd	nd	nd	0.4±0.1	Nd	nd	0.5±0.2	nd	nd	nd	nd	nd
1H-pyrazole	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	1.8±0.1	nd	nd	4.4±0.3
2,4,6-trimethylpyridine*	52.4±2.6	53.4±3.3	55.0±4.3	52.6±3.8	52.4±2.9	53.5±4.2	52.3±1.9	55.5±3.2	54.7±2.9	55.1±2.7	54.2±1.8	57.3±2.1	54.4±0.7	56.4±4.5	52.6±2.2	55.0±4.8	52.6±3.1	54.4±2.5
2-acetyl-1-pyrroline	1.0±0.2	1.4±0.6	nd	0.6±0.1	0.9±0.1	0.7±0.1	nd	1.6±0.2	nd	nd	1.3±0.3	nd	nd	1.8±0.1	nd	nd	nd	nd
Dodec-1-ene	nd	1.5±0.3	nd	1.7±0.1	nd	nd	nd	nd	nd	nd	nd	nd	nd	1.5±0.1	nd	0.8±0.2	nd	nd
Dodecan-1-ol	nd	nd	nd	nd	1.6±0.1	0.7±0.2	nd	1.5±0.2	nd	nd	1.4±0.2	nd	nd	nd	nd	nd	nd	nd
Tridecane	nd	0.5±0.2	nd	nd	0.6±0.1	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Dodecane	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0.5±0.1	nd	nd	0.5±0.2	nd	nd	nd	nd
Dodecamethylcyclohexasiloxane	1.1±0.3	nd	nd	1.4±0.2	nd	nd	nd	nd	nd	nd	nd	0.3±0.2	nd	nd	nd	nd	nd	nd
Tridec-1-ene	nd	2.6±0.3	Nd	3.7±0.2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	2.6±0.2	nd	nd
Tetradecane	nd	1.6±0.3	nd	nd	nd	0.5±0.2	nd	nd	nd	nd	0.6±0.3	nd	nd	0.7±0.3	nd	nd	nd	nd
Hexadecane	nd	nd	nd	nd	0.8±0.2	0.6±0.2	nd	nd	nd	nd	0.7±0.1	nd	nd	nd	nd	nd	nd	nd
Tetradecamethyl-cycloheptasiloxane	1.6±0.2	nd	nd	1.4±0.3	nd	nd	nd	nd	nd	nd	nd	0.3±0.2	nd	nd	nd	nd	6.5±0.3	nd
2,4-ditert-butylphenol	nd	2.6±0.2	nd	5.6±0.2	2.7±0.2	2.6±0.3	nd	3.6±0.3	nd	nd	2.6±0.4	nd	nd	3.1±0.4	nd	nd	nd	nd
Pentadec-1-ene	nd	3.5±0.4	nd	5.4±0.6	3.4±0.5	2.0±0.3	nd	nd	nd	nd	2.4±0.5	nd	nd	nd	nd	5.2±0.3	nd	nd
Hexadec-1-ene	nd	nd	nd	nd	nd	nd	nd	4.6±0.1	nd	nd	nd	nd	nd	3.0±0.3	nd	nd	nd	nd
Methyl tetradecanoate	nd	nd	3.1±0.3	nd	nd	nd	0.6±0.2	nd	nd	0.8±0.2	nd	nd	0.4±0.3		0.4±0.2	nd	nd	nd
Heptadec-1-ene	nd	nd	nd	nd	5.5±0.4	nd	nd	nd	nd	nd	nd	nd	nd	5.6±0.3	nd	10.6±0.3	nd	nd
Octadecane	nd	1.4±0.3	nd	nd	nd	nd	nd	1.4±0.4	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Methyl 14-methylpentadecanoate	nd	nd	nd	nd	nd	nd	nd	nd	0.7±0.2	3.5±0.4	nd	0.8±0.2	1.6±0.1	nd	2.6±0.4	nd	nd	0.7±0.3
Tetracosan-1-ol	nd	nd	nd	5.4±0.2	nd	nd	nd	nd	nd	nd	4.6±0.2	nd	nd	5.3±0.2	nd	nd	nd	nd
Heptadecane	nd	nd	nd	0.8±0.1	1.1±0.4	0.7±0.1	nd	1.3±0.2	nd	nd	0.8±0.1	nd	nd	1.2±0.2	nd	nd	nd	nd
Nonadecan-1-ol	nd	nd	nd	nd	5.5±0.3	3.7±0.2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Nonadecane	nd	1.3±0.2	nd	nd	1.2±0.1	nd	nd	nd	nd	nd	nd	nd	nd	1.2±0.1	nd	nd	nd	nd
Methyl (E)-octadec-6-enoate	nd	nd	8.3±0.2	nd	nd	nd	0.5±0.1	nd	0.4±0.3	0.6±0.1	nd	0.4±0.2	0.4±0.3	nd	0.8±0.2	nd	nd	0.3±0.2
Methyl 16-methylheptadecanoate	nd	nd	2.3±0.2	nd	nd	nd	nd	nd	nd	nd	nd	0.6±0.4	nd	nd	0.5±0.1	nd	nd	nd
Nonadec-1-ene	nd	5.8±0.1	nd	5.8±0.1	5.8±0.1	2.8±0.1	nd	5.8±0.1	nd	nd	4.7±0.1	nd	nd	nd	nd	9.3±0.2	1.2±0.2	nd
Docosan-1-ol	nd	nd	nd	4.5±0.3	nd	nd	nd	5.7±0.3	nd	nd	4.7±0.2	nd	nd	nd	nd	nd	1.5±0.4	nd
Hexadecamethylheptasiloxane	0.9±0.1	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	3.6±0.1	nd
Octacosan-1-ol	nd	6.4±0.2	nd	nd	1.4±1.0	3.8±0.1	nd	5.8±0.1	nd	nd	1.4±0.4	nd	nd	4.5±0.2	nd	nd	nd	nd
Tetracosane	nd	1.1±0.2	nd	nd	0.7±0.2	nd	nd	nd	nd	nd	nd	nd	nd	0.9±0.1	nd	nd	nd	nd
Docosane	nd	nd	nd	nd	0.8±0.2	0.6±0.1	nd	1.2±0.3	nd	nd	0.8±0.1	nd	nd	nd	nd	nd	nd	nd
Hexadecamethyl-cyclooctasioxane	1.4±0.5	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	4.8±0.2	nd
Heptacosan-1-ol	nd	4.3±0.1	nd	1.7±0.1	5.1±0.3	0.8±0.1	nd	nd	nd	nd	4.8±0.1	nd	nd	1.2±0.3	nd	nd	nd	nd
Tetradecamethylhexasiloxane	1.3±0.3	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	3.5±0.2	nd

Amb, Ambient temperature; nd, not detectable at the quantifiable amount and*, Internal Standard

Table 4: Qualitative analysis of volatile compounds from previous studies

Liyanaarachchi *et al.* (2014)	Pisithkul *et al.* (2010)	Mahattanatawee and Rouseff (2010)	Park *et al.* (2010)	Yang *et al.* (2007)	Mahatheeranont *et al.* (1995)	
α-terpeneol	Benzaldehyde	Decanal	Decanal	Benzaldehyde	Benzene ethanol	Octanoic acid
Benzaldehyde	Benzyl alcohol	Ethyl hexanoate	Hexanal	Benzothiazole	Benzothiazole	Pentadecane
Benzyl alcohol	n-decanal	Hexanal	Methional	Decanal	Butyl acetate	Pentylcyclopropane
Hexanal	n-dodecane	Linalool	Nonanal	*d*-limonene	Decanal	Phenol
Hexanol	*n*-heptanal	Methional		Guaiacol	Diethyl carbonate	Tetracosane
Indole	*n*-hexanal	Neral		Heptanal	Dodecane	Tetradecane
Limonene	n-nonanal	Octanal		Hexanal	Ethyl benzene	Tricosane
Linalool	n-tetradecane	β-Damascenone		Indole	Hexadecane	Undecane
n-octanol	n-tridecane			Naphthalene	Hexanal	
Octanal				Nonanal	Isocyanato methylbenze	
Phenol				Octanal	Methyl benzene	
				Phenylacetaldehyde	N,N-dimethyl formamide	
				p-xylene	Nonanal	
				Toluene	Octadecane	

Table 5: Qualitative analysis of volatile compounds from previous studies

Bryant and McClung (2011)	Sukhonthara *et al.* (2009)		Maraval *et al.* (2008)	Mahatheeranont *et al.* (2001)
Benzothiazole	Benzaldehyde	n-hexadecane	Acetophenone	
Butylated hydroxytoulene	Benzoic acid	n-hexanol	Benzaldehyde	Benzothiazole
Cyclodecanol	Benzothiazole	n-nonadecane	Benzothiazole	Benzyl carbinol
Decyl benzene	Biphenyl	n-nonanol	Butan-1-ol	Butyl acetate
Diethyl phthalate	Cadina-1,4-diene	n-octadecane	Butanoic acid	Decanal
Dotriacontane	Capric acid	n-octanol	Butylbenzene	Diethyl carbonate
Eicosanol	Caproic acid	Nonanal	Decanal	Ethylbenzene
Heptadecane	Caprylic acid	n-pentadecane	Ethanoic acid	Heptadecane
Heptanal	Decanal	n-pentanol	Ethylbenzene	Hexadecane
Heptylcyclohexane	Dihydroactinidiolide	n-tetradecane	Hept-2-enal (isomer)	Hexanal
Hexadecyl ester, 2,6-difluro-3-methyl benzoic acid	Dodecanal	n-tridecane	Heptanoic acid	Hexanoic acid
Hexanal	Enantic acid	n-undecanal	Hexan-1-ol	Isocyanatomethylbenzene
Hexanol	Epi-α-muurolol	n-undecane	Hexanal	Methylbenzene
Hexylpentadecyl ester-sulphurous acid	Ethyl hexadecanoate	o-cresol	Hexanoic acid	*N*,*N*-dimethylformamide
Indole	Ethyl tetradecanoate	Octanal	Indole	Naphthalene
Isobutyl hexadecyl ester oxalic acid	Furfural	Oleic acid	Longifolene	Nonanal
Isobutyl nonyl ester oxalic acid	Furfurylalcohol	Palmitic acid	Methional	Octanoic acid
Methoxy-phenyl-oxime	Geranylacetone	p-cresol	*N* ,*N*-diethylformamide	Pentadecane
N,N-dimethyl chloestan-7-amine	Guaiacol	*p*-cymene	Non-2-enal	Pentylcyclopropane
N,N-dinonyl-2-phenylthio ethylamine	Heptanal	Pelargonic acid	Nonan-2-one	Phenol
Naphthalene	Hexanal	Pentadecanal	Nonanal	Tetracosane
n-Heptadecylcyclohexane	Isovaleric acid	Pentadecylic acid	Nonanoic acid	Tetradecane
n-Nonadecanol	Lauric acid	Phenethyl alcohol	Oct-1-en-3-ol	Tricosane
Nonadecane	Limonene	Phenol	Oct-1-en-3-one	Undecane
Nonene	Linalool	p-menthan-3-one	Oct-2-enal	
Octadecyne	Linoleic acid	Stearic acid	Oct-3-en-2-one	
Octanal	Linolenic acid	Tetradecanal	Octa-3,5-dien-2-one	
O-decyl hydroxamine	Longifolene	Tridecanal	Octan-1-ol	
Pentacontonal	Methyl hexadecanoate	Tridecylic acid	Octanal	
Pentadecanal	Methyl linoleate	Valericacid	Pent-3-en-2-ol	
Pentanal	Methyl oleate	α-cadinol	Pentan-1-ol	
Propiolonitrile	Methyl tetradecanoate	α-muurolene	Pentanoic acid	
Pyrolo[3,2-d]pyrimidin-2,4(1H,3H)-dione	Myristic acid	α-terpineol	Phenol	
Tetrahydro-2,2,4,4-tetramethyl furan	Naphthalene	β-cyclocitral	Phenylacetaldehyde	
Tritetracontane	n-butanol	β-ionone	Propanoic acid	
Z-10-pentadecen-1-ol	n-dodecane	β-myrcene	Vanillin	
	n-heptadecane	δ-cadinene	*γ*-decalactone	
	n-heptanol		*γ*-nonalactone	
	n-hexadecanal		*δ*-decalactone	

Previous researchers (Mahatheeranont *et al.*, 1995, 2001; Itani *et al.*, 2004; Maraval *et al.*, 2008; Sukhonthara *et al.*, 2009; Mahattanatawee and Rouseff, 2010; Park *et al.*, 2010; Pisithkul *et al.*, 2010; Bryant and McClung, 2011; Liyanaarachchi *et al.*, 2014) had characterized volatile compounds in rice. Hence, this study surveyed the volatile compounds identified by the previous researcher to compare the number of compounds and possible variation among the compounds. However, about 332 volatile compounds (Table 4 and 5) were identified and about 34 compounds in this experiment (Table 2 and 3). In present study, only the highest peak of a compound available in six replications

(three biological and three technical) of a genotype in a particular temperature was considered for the identification and recovery percent (%) estimation of volatile compounds.

This experiment also revealed that only volatile profile could not explain the aroma status completely in some rice varieties which also required organoleptic analysis of grain for appropriate aroma quality assessment.

The phenotypic aroma score of the studied genotypes (Fig. 2) indicated that 25°C temperature was favourable for the maximum aroma score which could be used to verify the presence of volatile compounds. Additionally, different phenotypic aroma score was observed at different temperatures, but the uniformity of aroma score was found within the same temperature condition. Vazirzanjani *et al.* (2011) stated that the sensory test was cheaper and simpler method for distinguishing aromatic with non-aromatic rice. Moreover, several scientists (Hossain *et al.*, 2008; Golam *et al.*, 2011; Sarhadi *et al.*, 2011) used grain sensory test for evaluating aroma in aromatic and non-aromatic rice. Golam *et al.* (2011) mentioned that aroma score of Basmati type rice demonstrated strong aroma (score 4) in Indian sub-continent (day-night average 22-23°C) and moderate aroma (score 2.5) in Malaysia (day-night average 28–30°C). Similar incidences were also observed by Golam *et al.* (2010).

Therefore, biochemical and organoleptic analysis of rice grain signified that the aroma of a rice genotype dependent on the environmental temperature. Besides, the 25°C temperature was identified as a suitable temperature for high-quality aroma assimilation and expression in rice.

Conclusion

Aromatic rice grains corresponded to the presence of numerous volatile compounds while composition of volatile compound determined the aroma status of a rice variety. Moreover, the aroma of rice genotypes was affected by the environmental temperature, which also influenced the numbers and variation of volatile constituents as well as the phenotypic aroma of rice. Hence, the 25°C temperature was observed to be the suitable temperature for better aroma quality in terms of the highest aroma score (score 4) and the presence of other volatile compounds in the studied genotypes. Therefore, volatile compound composition and the organoleptic test could be used to explain the aroma quality of a genotype in a particular environmental condition.

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