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Assessment of Flavor Volatiles of Iranian Rice Cultivars during Gelatinization Process

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ABSTRACT: A combined gas chromatography-mass spectrometry (GC-MS) with headspace solid-phase micro extraction (SPME) method has been employed for the analysis of the flavor volatiles of three different rice cultivar, including two modified Iranian rice cultivars and Hashemi rice cultivar during gelatinization. The proposed combination provided a powerful system for easy and rapid screening of a wide range of flavors in fragrant rice samples. In order to optimize the different experimental parameters, the effect of fiber composition, water content of rice samples and equilibrium time were investigated. As a result, while the gelatinization was in progress, the amount of the volatile compounds was increased as well. All of the free flavor volatiles, the bound flavor components and the compounds formed by the thermal decomposition of the non-volatile constituents existing in rice could be liberated during the gelatinization process. Therefore, a broad range of the flavor volatiles of rice could be extracted, concentrated and identified. Altogether, 75, 55 and 66 components were identified for Hashemi, HD5 and HD6 rice samples, respectively, which 58 unique compounds were not detected previously. The identified volatile components in the three Iranian rice cultivars belong to the chemical classes of aldehydes, ketones, alcohols and heterocyclic compounds, as well as fatty acids and esters, phenolic compounds and hydrocarbons.

Keywords: *Flavor Volatiles Components, Gas Chromatography (GC), Mass Spectrometry (MS), Rice (Oryza sativa L.), Solid-Phase Microextraction (SPME).*

Introduction

Rice is the major part of people's diet in many countries, which contributes 21% of the calorie intake. In this aspect, one of the most significant factors in market business and expenses is the aroma of 'fragrant rices'. This is a trait, which distinguishes it from ordinary rice (Fitzgerald *et al*., 2009; Laohakunjit & Kerdchoechuen, 2007).

There are many different volatile components in cooked rice grains, including those, which are the result of biochemically distinct pathways, and are very rich sources of hydrocarbons, organic acids, alcohols, aldehydes, ketones, esters and phenols. In some cases, there are chemically synthesized components, which are stored during the process of rice development. However, there are some other compounds, which are extracted because of chemical breakdowns. Among the latter, fatty acids are good samples (Bergman *et al*., 2000).

Aromatic compounds can have both positive and negative influences on people's tastes. The former can be flavor and fragrance components such as 2AP and the aromatic alcohols, and the latter can be off-flavors of hexanal and 2-pentylfuran (Lam & Proctor, 2003).

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Among those aromatic compounds, which have been identified in many studies, 2-acetyl-1-pyrroline (2AP) is known as the most important key flavor component of rice aroma (Buttery *et al*., 1983b; Jezussek *et al*., 2002; Laksanalamai & Ilangantileke, 1993; Paule & Powers, 1989). Its structure consists of a five-carbon N-heterocyclic ring, which was first determined in cooked rice and the volatile oil of freeze-dried Pandan leaf with a threshold value of 0.1nl/l water, which was very low comparing other components (Buttery *et al*., 1983a; Buttery *et al*., 1988; Wongpornchai *et al*., 2003).

The concentration value was high up to 0.09 mg/kg, which was 10 times more than non-fragrant rice value (<0.006-0.008 mg/kg). This amount was identified in all parts of fragrant rice, but not in roots (Buttery *et al*., 1983b).

In order to provide sample preparation methods and analytical techniques, Solid-phase microextraction (SPME) is introduced as a rapid, sensitive and reliable technique for the extraction and concentration of volatile compounds from different sample matrices. SPME consists of two separate steps. The first step deals with partitioning the target analytes between the sample matrix and the fiber surface, whereas the second step deals with the direct desorption of absorbed analytes into injection port by means of chromatographic techniques (Djozan & Ebrahimi, 2008).

This technique has many advantages including less time for extraction, ease of use, preventing the loss of analytes and field sampling with portable field sampler (Djozan *et al*., 2009; Mehdinia *et al*., 2006).

This technique has a great sensitivity particularly in the study of identifying flavor indicators of rice, since the extracted fraction on the fiber is statistically introduced into the gas chromatography (GC) by thermal desorption (Bergman *et al*., 2001; Grimm *et al*., 2004). For instance, Laguerre *et al*., (2007) suggested an analytical technique for the analysis of the volatile fraction using SPME-MS (Laguerre *et al*., 2007).

In our current study, our main purpose is to use HS-SPME-GC-MS device as a reliable system for effective trapping and screening of a wide range of volatile flavor compounds in the headspace of Iranian rice samples during the gelatinization process.

Materials and Methods

Rice Samples

Three Iranian fragrant rice samples were used in this study, including two new modified varieties (HD5, HD6) and one Hashemi variety (HD1), which are predominantly consumed in Iran.

These samples were collected from Rice Research Institute. All samples were harvested in July 2009 and contained 20% moisture. After 24 h from harvesting, the samples were sun-dried to about 12-13% moisture content, then they were dehulled at the growing area and were transported to the laboratory and stored in nylon bags and placed in the refrigerator at 4ºC until the experiments were completed.

Gelatinization process

Some glass balls were poured into a glass of 275ml water and put under primary heating until they reach the boiling point. 50g of the tested sample was added into the boiling water and stirred. After 7min, 10 rice grains were chosen randomly and put on a glass plate with equal distances, and covered, slipped and gelatinized. The number of gelatinized rice grains were observed and counted after 8min. The experiment was repeated every one minute to determine all the ten gelatinized grains. This method was used for all the samples in this study. This method was performed for the first time.

Rice cooking

The traditional Iranian rice cooking was used, by which 150g of white rice and 400ml of distilled water were added. The whole process was divided into 4 stages, including all the steps from the beginning until the end of gelatinization process. The cooking time of this process was determined by the temperature at which crystalline structure melting occurred. Rice with high GT required more time to cook, whereas rice with low GT, required less time; usually up to 4 min. The former had an unacceptable texture (Fitzgerald et al., 2009).

Headspace Solid-phase micro extraction sampling

Using SPME, a sampling device was designed in order to collect the volatiles during the course of gelatinization. The volatiles during gelatinization were released out through the first side arm, while SPME fiber was located in the second side of the sampling device with a flexible septum. In all stages of the gelatinization, the fiber was placed in the manually operated SPME holder, and the septum was covered with a Teflon-coated silicone in order to prevent the release of volatile compound from the septum. The fiber was lowered in the sampling port to adsorb flavor volatile compounds of rice and desorb them thermally in the injection port of GC-MS instrument for 10 min at 250°C. Afterwards, the fiber was exposed to the SPME fiber conditioner at 250°C for 1hr for reconditioning before being subjected to the next volatile samples.

SPME fiber with PDMS (100µm, non-bonded), CAR/PDMS (75µm, bonded) and DVB/CAR/PDMS (65µm, bonded) coating, provided by Supelco (Bellefonte, PA, USA) was used as commercial fiber and was preconditioned in an SPME fiber conditioner (GL Sciences) at 250°C for 1hr before the first measurement.

Gas Chromatography-Mass Spectrometry

Gas chromatography separation was performed on a HP-6890 GC system (HEWLETT PACKED, USA), equipped with a mass detector (HP-5973, USA), and a HP-5MS (5% Phenyl dimethyl siloxan) column. The injector temperature was set at 250°C and purified Helium at 99.99% was selected as a carrier gas at a flow rate of 1ml/min. Temperature programming was performed at 60°C for 3min, and increased to 220ºC at the rate of 5°C/min and maintained at 220°C.

The mass selective detector was applied in an electron impact ionization mode at 70ev.

The interface temperature was 230°C. An alkane mixture with C8-C20 alkane and concentration of 40mg/ml in hexane was purchased from Fluka. The mixture was used to estimate retention indices (RI), and it was injected into the fiber for 5min by the headspace extraction from a 10ml SPME vial, including 1ml HPLC-grade water spiked with 10µl of the mixture.

The volatile compounds were positively identified by matching their mass spectra, with the spectra of reference compounds in Adams Mass Spectra Library (9th edition) and verified based on mass spectra and RI values reported in the literature (Buttery & Ling, 1998; Buttery *et al*., 1999; Fan & Qian, 2006).

Results and Discussion

Cooking time

The cooking time of rice is determined by the temperature at which the crystalline structure of the starch begins to melt. This is called gelatinization temperature (GT). In the samples, GT was 55-85˚C. Hashemi rice sample with high GT required more time to cook. Lowering the GT of the modified (HD5, HD6) rice grains could decrease the average cooking time.

Regarding tables 1, 2 and 3 the figures 1, 2 and 3 were designed and gelatinization time for 0%, 50%, 90% and 100% of the whole grains was identified and during this time, SPME fiber was injected. The whole process was divided into four stages: I, 17'; II, 20':49"; III, 24':37"; IV, 28' which were assigned to Hashemi rice sample leading to the gelatinization of 0, 50, 90, and 100 percent of rice grains. For HD5, variety at cooking stages: I, 15'; II, 18':12"; III, 20':28"; IV, 23' which could lead to the gelatinization of 0, 50, 90 and 100 percent of rice grains. In HD6, variety at cooking stages: I, 15'; II, 17':38"; III, 21':28"; IV, 24' which could lead to the gelatinization of 0, 50, 90 and 100 percent of rice grains.

Table 1. Hashemi rice samples

Cooking time (min)	Gelatinized grains for each sample					Average of gelatinized grains (Gn%)	First equalize Sum (Gn%)	Second equalize Sum (Gn, Gpn%)
	1	2	3	4	5			
8	1	1	1	1	2	12		
							18	
19	2	2	3	2	3	24		24.5
							31	
20	4	3	4	4	4	38		38.5
							46	
21	5	6	6	5	5	54		52.5
							59	
22	6	7	7	6	6	64		64
							69	
23	7	8	8	7	7	74		74.5
							80	
24	8	9	9	8	9	86		85
							90	
25	9	10	9	9	10	94		93.5
							97	
26	10	10	10	10	10	100		98.5
							100	
27	10	10	10	10	10	100		

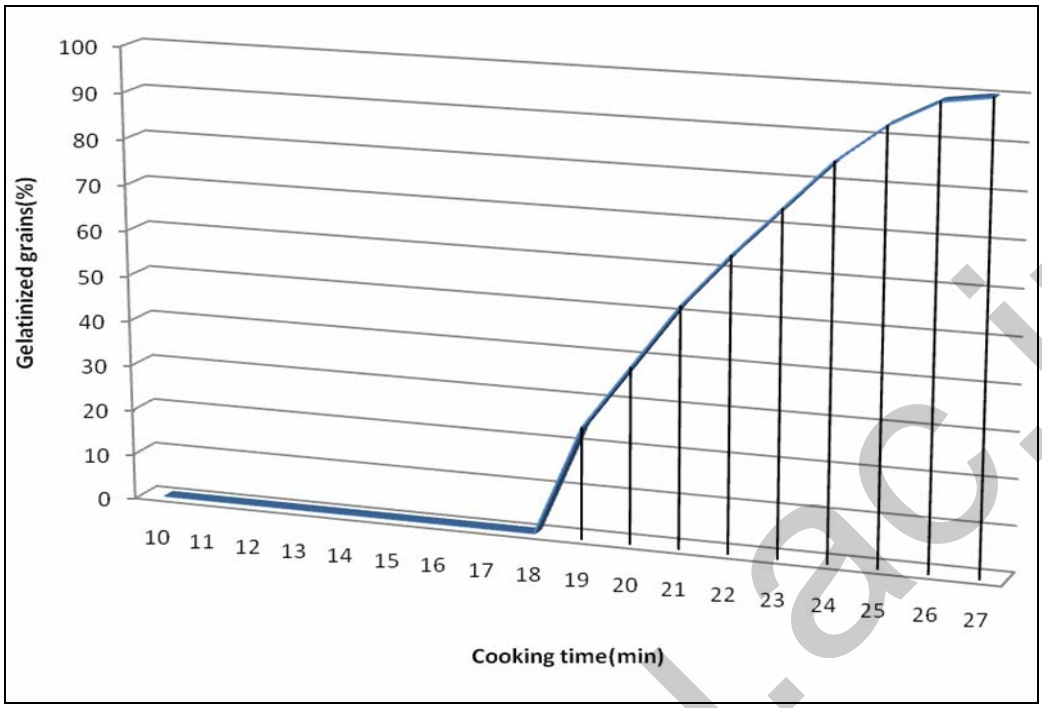

Fig. 1. Gelatinization profile of Hashemi rice samples

Table 2. HD5 rice samples

Cooking time (min)	Gelatinized grains for each sample					Average of gelatinized grains (Gn %)	First equalize sum (Gn %)	Second equalize sum (Gn, Gpn %)
	1	2	3	4	5			
16	2	1	2	1	2	16		
							22	
17	3	3	3	2	3	28		29.5
							37	
18	5	4	5	4	5	46		46
							55	
19	7	6	6	6	7	64		65
							75	
20	9	8	8	9	9	86		84
							93	
21	10	10	10	10	10	100		96.5
							100	
22	10	10	10	10	10	100		

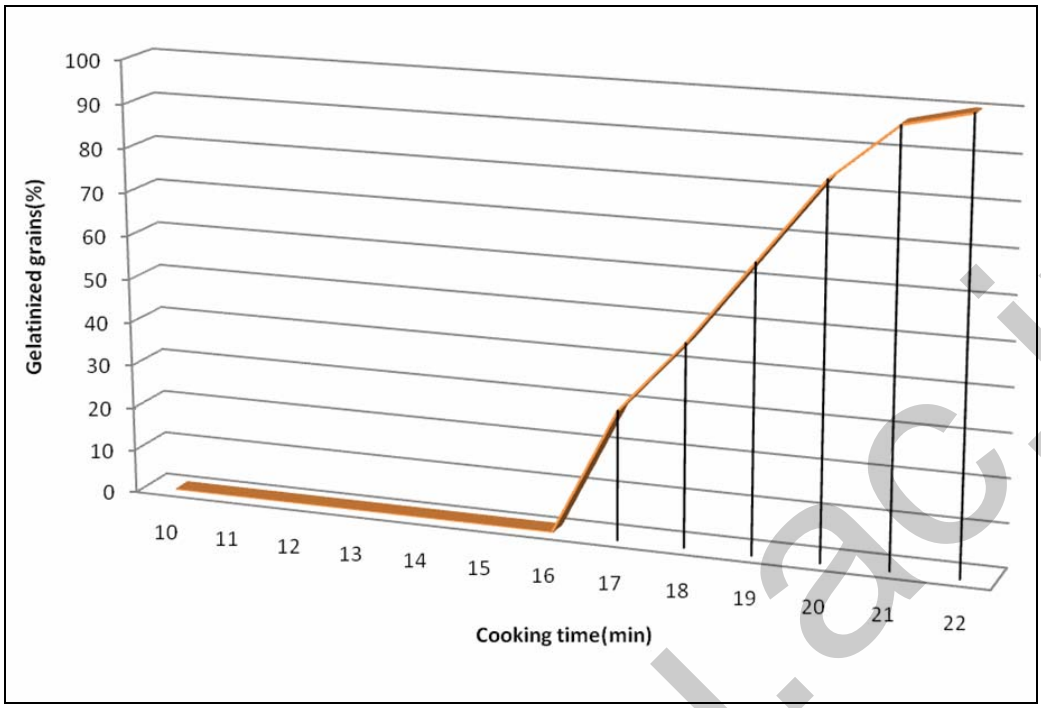

Fig. 2. Gelatinization profile of HD5 rice samples

Table 3. HD6 rice samples

Cooking time (min)	Gelatinized grains for each sample					Average of gelatinized grains (Gn %)	First equalize sum (Gn %)	*Second equalize sum (Gn, Gpn %)*
	1	2	3	4	5			
16	2	2	2	2	3	22		
							30	
17	4	4	4	3	4	38		37
							44	
18	5	6	5	4	5	50		50.5
							57	
19	6	7	6	6	7	64		63.5
							70	
20	7	8	7	8	8	76		75.5
							81	
21	8	9	8	9	9	86		86
							91	
22	9	10	9	10	10	96		94.5
							98	
23	10	10	10	10	10	100		99
							100	
24	10	10	10	10	10	100		100

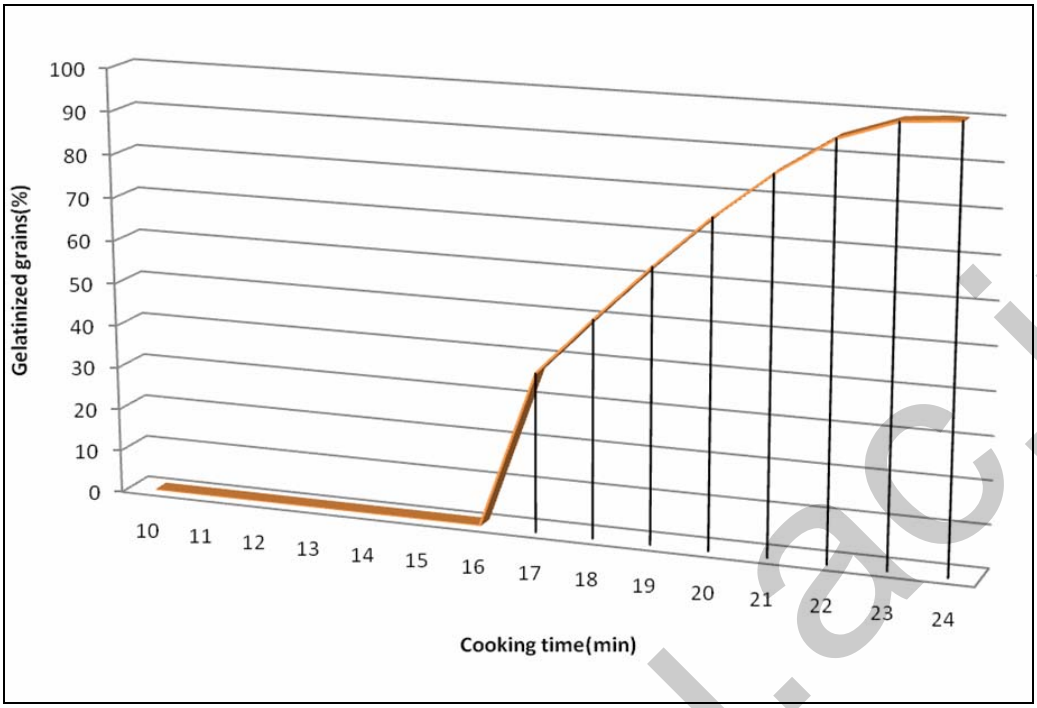

Fig. 3. Gelatinization profile of HD6 rice samples

Flavor volatiles in the three Iranian rice cultivars

Using headspace SPME method, the flavor volatiles in the three Iranian rice cultivars were extracted during the gelatinization, and analyzed by GC-MS. These compounds were determined by comparing their mass spectra and RI values with an authentic compound, whereas others were identified by their corresponding mass spectra (Adams Mass Libraries) and RI values, when RI values on the HP-5MS capillary column were available in the literature (Buttery & Ling, 1998; Buttery *et al*., 1999; Fan & Qian, 2006). A whole range of 75, 55 and 66 compounds were identified for Hashemi, HD5 and HD6, respectively. For HD5, 23, 11, 23 and 36 compounds were identified at stages I, II, III and IV, respectively. Also regarding HD6, 14, 19, 47 and 32 compounds were identified at the stages as HD5, and 14, 42, 37 and 43 compounds for Hashemi.

Altogether, the volatile compounds in the three Iranian rice samples during the gelatinization belong to the chemical classes of aldehydes, ketones, hydrocarbons, esters and phenols, etc., which corresponds with those chemical classes of compounds previously mentioned in non- Iranian rice using various methods of extraction.

58 new and unique compounds were detected and identified in the samples as presented in the tables 4, 5 and 6.

Variation in flavor volatiles of rice during four different cooking stages

Significant differences were investigated in the volatile compounds of rice during the four different gelatinization stages.

Two major compounds were detected at stage I known as nonanal and hexanal. The latter is known as an important lipid oxidation product in rice. However, there are other components, which have been identified only at stage I, such as ethanol, in contrast with hexadecanoic acid, which was identified as a predominant compound at stage II. Moreover, pentacosane were detected at stage III & IV.

Primary heating of rice at gelatinization stages I and II resulted in the evaporation of aldehydes in rice, and fatty acids in steam distillation, respectively. However, excess steam and heat have debilitative influence on the extraction of low-boiling-point volatiles. Thus, further heating at stages III and IV, increased the rate of evaporation of a broad range of the flavor volatiles of rice.

Similarities and differences among the three different Iranian rice cultivars

By comparing the volatile matters shown in tables 4, 5 and 6, one might have a better understanding of the similarities and differences in the rice samples.

There were no significant differences in the profiles of flavor volatiles; however, less volatile compounds were identified in two modified rice samples as compared to Hashemi. For instance, some components such as Phthalic acid, Farnesol, Ethanol, alpha-Pinene and Camphene were detected in two modified samples, whereas Hashemi major compounds were beta.Bisabolene, Cyclosativene, Methyl isoeugenol, Isobutyl salicylate, Turmerone, lilia, <cis-2-tert-butyl->Cyclohexanol acetate, 2-phenyl- 2-methyl- Aziridine, 4-ethyl- 3,4- dimethyl-Cyclohexanone, n- Octyl- Cyclohexane, 9-methyl- Nonadecane, 2- methyl- Tridecane, (E,E)-2,4-Decadienal, Indol.

Optimization of different experimental parameters

Hexanal was employed as a target to optimize the conditions of flavor compounds.

Initially, three types of commercial fibers (PDMS, CAR/PDMS and DVB/CAR/PDMS) were selected in order to extract volatiles from the headspace above the rice samples in the beginning of the experiment. The DVB/CAR/PDMS fiber was used in all applications and is known as the most effective compound in the extraction of flavor volatile (Fig. 4).

In order to estimate the effect of water content of rice samples on the SPME, different volumes of water were added to 150g rice samples and SPME experiments were performed. The results in figure 1 indicate that increasing water content up to 400ml was in agreement with the extraction efficiency and consequently an increase in hexanal. However, addition of higher amount of water showed a great decrease in extraction efficiency, since this would result in producing an adhesive mixture which did not easily agitate and made the diffusion more difficult. On the other hand, addition of lower quantity of water was not sufficient for cooking rice. Therefore, 400 ml of water was selected as a suitable amount for the rest of the experiment (Fig. 5).

To investigate the effect of time, the rice samples were extracted for 5-30min. As figure 6 indicates, with an increase in equilibrium time, the extracted amounts of hexanal were increased into a maximum threshold after 30 min. Therefore 30 min was considered as the optimum period to reach the equilibrium for hexanal (Fig. 6).

Conclusion

The volatiles in the three rice cultivars during gelatinization were directly extracted using an HS-SPME method and analyzed by GC-MS. Altogether, 75, 55 and 66 compounds were identified for Hashemi, HD5 and HD6 rice samples, respectively.

Further studies should be carried out to consider future separation and identification on these compounds, as well as comparing these compounds among Iranian, non-Iranian and modified samples

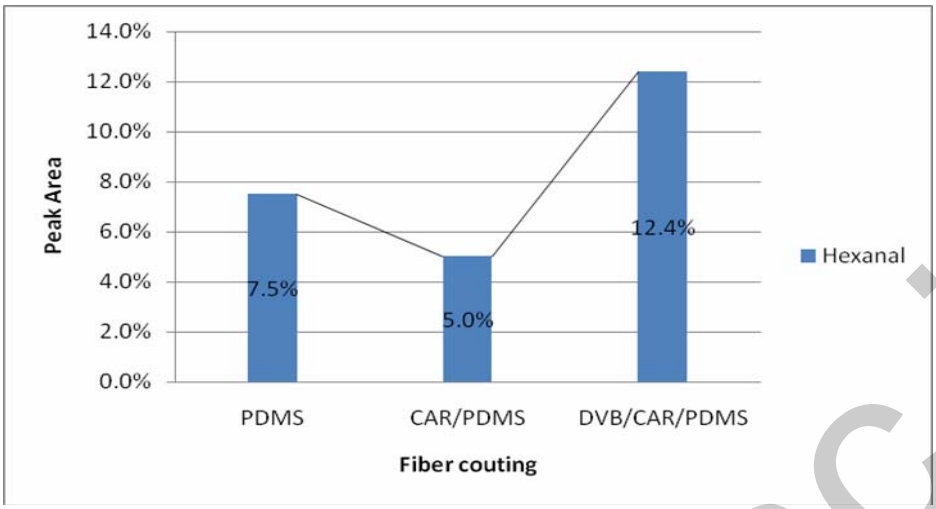

Fig. 4. Comparison of the extraction efficiencies of the PDMS, CAR/PDMS and DVB/CAR/PDMS fibers for volatile compounds in the headspace of rice sample

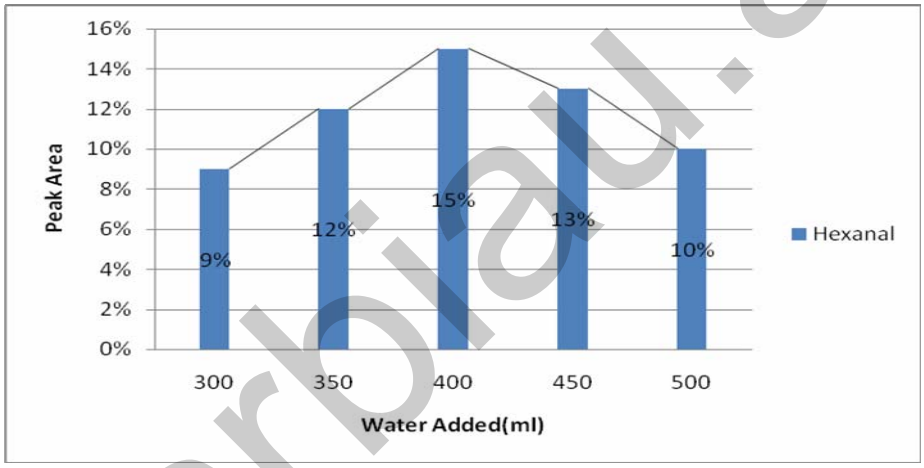

Fig. 5. Comparison of the extraction efficiencies of the various additions of water

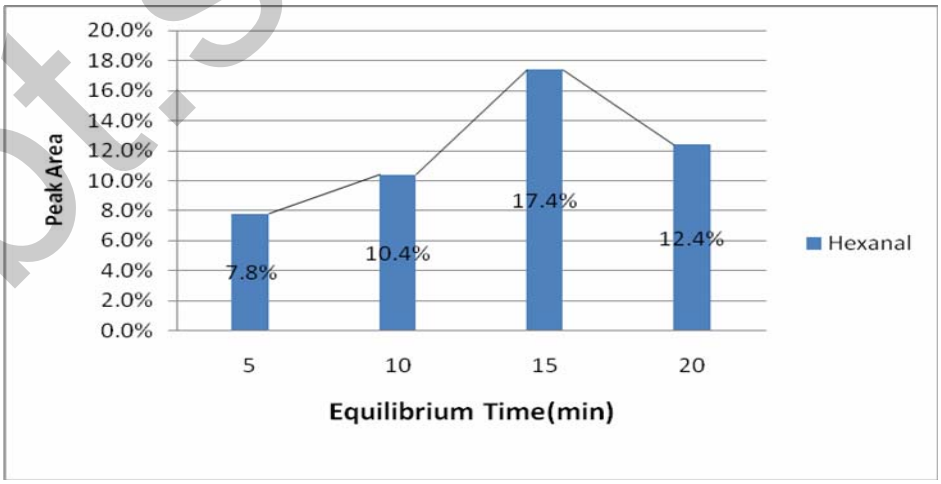

Fig. 6. Equilibrium time profile

Table 4. Hashemi rice sample

NO	Compound	odor description	KI in expriment	KI in litereture	I (%)	II (%)	III (%)	IV (%)
1	N-Hexanal	Green, grass-like	805	802	31.2	3.8	7.4	12.4
2	2-Butylfuran		881	890	4.3			
3	2- phenyl- 2- methyl- Aziridine		888					0.6
4	2-acetyl-1-pyrroline		915	920			3.7	5.8
5	Benzaldehyde	Nutty, bitter	960	960		2.1		1.3
6	<6-methyl->Heptan-2-ol		960	965		1.5		
7	1-Octen-3-ol	Raw mushroom	982	979				0.9
8	2-Pentylfuran	Nutty, bean	998	990		1.2		3.2
9	1,2,4-Trimethyl benzene		999	994		0.8		0.3
10	Octanal	Green, citrus-like	1007	999	2.1	0.9	1.6	3.5
11	Limonene		1042	1029				1.3
12	1-Nitro-hexane		1051			2.0	2.3	2.4
13	1.3-Diethyl-benzene		1065	1059		1.2		
14	N-Octanol		1072	1068				1.8
15	N-Nonanal	Soapy, citrus-like	1110	1101	5.9	6.0	7.7	10.4
16	(E)-2-Nonenal	Fatty, tallowy	1166	1162			1.2	0.6
17	Naphthalene		1173	1181		2.2		
18	2,6-Dimethylaniline		1179	1168		0.5		
19	Dodecane		1201	1200			1.4	1.6
20	Decanal	Green, soapy	1207	1207			2.7	2.4
21	(E,E)-2,4-Nonadienal	Fatty, waxy	1207	1212		1.8		
22	2-Penthylfuran	Nutty,bean	1220	1231			1.6	
23	(E,E)2,4-Octadienal		1223				0.8	1.5
24	(E)-2-Decenal	waxy	1270	1264		5.9		2.0
25	(E,Z)-2,4-Decadienal	Fatty, green	1283	1293		6.8		
26	Indol	Sweet,burnt, floral	1289	1291		0.4		
27	<cis-2-tert-butyl->Cyclohexanol acetate		1302	1293		1.2	1.4	0.6
28	Tridecane		1303	1300	1.6		3.3	3.4
29	(E,E)-2,4-Decadienal	Fatty, waxy	1310	1317		3.0	3.3	
30	2-Methyl-naphthalene		1324			1.2	1.3	0.3
31	1-Methoxy-naphthalene		1343	1346		1.1		0.7
32	2,6-Dimethoxy-phenol		1355	1349		3.3		
33	2- methyl- Tridecane		1366					0.4
34	Methyl isoeugenol		1369	1354				0.5
35	Cyclosativene		1371	1383				0.4
36	Undecanol		1372	1370			0.6	1.9
37	2,6,10,14-tetramethyl-Hexadecane		1379				2.5	3.1
38	Tetradecane		1402	1400	3.7	4.8	7.8	6.9
39	4-ethyl- 3,4- dimethyl- Cyclohexanone		1405					0.4
40	(E)-2-Octenal	Green, fatty	1420	1425		1.7	1.5	1.3
41	2,6-Dimethylnaphthalene		1427	1431		2.6	1.0	1.4
42	Isobutyl salicylate		1429	1425	3.1	2.1		
43	1,3- dimethyl- Naphthalene		1434			1.3		
44	2-Pentadecanone		1441	1451	9.2			
45	1,4-Dimethylnaphthalene		1450			4.2	5.1	0.8
46	n- octyl- Cyclohexane		1459					1.0
47	9- methyl- Nonadecane		1463					1.6
48	Geranyl acetone	Magnolia, green	1464	1455		2.9		
49	<2E->Dodecenal		1468	1466			4.2	
50	3-methyl-Tetradecane		1472				2.4	0.4
51	(E,E)-2,4-Heptadienal	fatty,hay-like	1485			1.2		
52	1- ethyl- Naphthalene		1487			1.0		
53	Pentadecane		1499	1500	1.8	2.7	3.1	3.3
54	N.D		1516				1.3	
55	beta.Bisabolene		1525	1506			1.0	0.5
56	lilia		1535	1529		1.2		
57	N.D		1548				1.4	
58	Diethylphthalate		1556	1565	5.7			
59	1-Octanol	Fruity, floral	1560	1565		1.7	1.6	
60	2,3,6-Trimethyl-naphthalene		1565			1.7	1.8	
61	3-methyl-Pentadecane		1573				0.9	2.2
62	2,3,5-Trimethyl-naphthalene		1582			1.0	2.2	
63	Hexadecane		1602	1600	7.7	4.4	5.1	2.4
64	2-acetyl-naphthalene		1615	1609		2.5		
65	N.D		1628			0.9		
66	2,6,10-Trimethyl-pentadecane		1640	1644		1.0	1.2	0.3
67	Turmerone		1675	1669		1.6		
68	Heptadecane		1703	1700		3.8	4.0	0.2
69	N.D		1704				2.3	
70	2,6,10,14-tetramethyl-Pentadecane		1712				1.6	1.0
71	(E)-2-Undecenal	Fatty, sweet	1755	1750		5.7	5.0	
72	Octadecane		1800	1800	10.0			
73	Nonadecane		1890	1900	5.0			1.6
74	2-Methoxy-4-vinylphenol	Spicy,clove-like	2195	2180			2.3	4.6
75	Tetracosane		2409	2400	7.6	3.1		
Total					99.0	99.8	99.6	93.0

Table 5. HD5 rice sample

NO	Compound	Odor description	KI in experiment	KI in literature	I (%)	II (%)	III (%)	IV (%)
1	n-Hexanal	Green, grass-like	801	802	62.3	56.7	38.9	22.2
2	n-Octane		809	800	0.7			
3	n-Hexanol	Herbaceous	869	871				1.1
4	n-Heptanal	Fruity, fatty	899	902	1.9			3.3
5	2- Acetyl- 1-pyrroline		915	920	1.4			
6	Anizole		917	918	1.8	3.3	3.5	3.9
7	Ethanol	sweet	920	925	0.9			
8	Benzaldehyde	Nutty,bitter	974	960	0.9			
9	Hepten-2-ol<6-methyl-5->		982	992	1.0			
10	2-Pentylfuran	Nutty, bean	985	990	4.0	11.2	3.3	4.3
11	1-Octen-3-ol	Raw mushroom	989	979				2.4
12	1,3,5-trimethyl-Benzene		990	996	0.8	4.8		
13	n-Octanal	Green, citrus-like	993	999	2.6		2.7	4.4
14	n-Decane		1009	1000			1.6	1.7
15	Limonene		1022	1029			6.2	
16	Undecane		1091	1100	0.6			
17	n-Nonanal	Soapy, citrus-like	1100	1101	6.1	7.6	8.8	11.7
18	Octyl formate		1140	1131				1.9
19	(E)-2-Nonenal	Fatty, tallowy	1157	1162				1.4
20	1,3-dimethoxy-Benzene		1178	1169	1.2			
21	Dodecane		1200	1200	2.5	1.6	0.5	1.1
22	Tridecane		1297	1300	0.4	3.2	1.7	2.4
23	(E)-2-Heptenal	Herbaceous	1320	1318				1.4
24	Hexyl furan		1322	1329				2.1
25	2,6-Dimethoxy-phenol		1340	1349				3.5
26	2- Methyl- undecanal		1366	1368				0.9
27	n- Undecanol		1372	1370				0.8
28	N.D		1379				0.9	
29	N.D		1379					0.7
31	Tetradecane		1391	1400		4.0	4.1	3.0
32	(E)-2-Octenal	Green,fatty	1432	1425				2.6
33	2,6-Dimethyl-naphthalene		1442	1431				1.3
34	Geranyl acetone	Magnolia, green	1463	1455				1.6
35	1-Heptanol	Green,fatty	1466	1457			1.6	
36	N.D		1469					1.7
37	N.D		1491		0.4			
38	Pentadecane		1500	1500		3.6	6.3	3.6
39	Butyleted hydroxytoluene		1524	1516				1.5
40	1-Octanol	Fruity, floral	1560	1565	0.6		1.0	
41	Hexadecane		1600	1600		2.2	4.8	2.1
42	1-Nonanol	Floral, citrus-like	1670	1671				1.1
43	n-Tetradecanol		1670	1673				1.0
44	Heptadecane		1700	1700			0.6	1.0
45	Phthalic acid		1703		3.4			
46	Farnesol		1710	1718	2.2			
47	1-Octadecene		1799	1790				0.6
48	n-Nonadecane		1905	1900				0.7
49	n-Nonadecane		1907	1900			4.1	
50	n-Eicosane		1995	2000	0.3		2.0	
51	n-Heneicosane		2101	2100		1.9	0.7	1.2
52	Docosane		2209	2200	0.5		0.7	3.5
53	n-Tricosane		2291	2300			2.0	
54	Tetracosane		2411	2400	0.6		2.2	0.6
55	Pentacosane		2510	2500			1.8	1.3
Total					97.0	100.0	99.9	99.3

Table 6. HD6 rice sample

NO	Compound	odor description	KI in expriment	KI in litereture	I (%)	II (%)	III (%)	IV (%)
1	Pentanal	Woody,fruity	710	706			1.5	
2	Octane		801	800			1.4	
3	N-Hexanal	Green, grass-like	802	802	49.0	42.2	14.2	36.3
4	N-Heptanal	Fruity, fatty	900	902	3.0	2.2		2.2
5	<2-acetyl>Furan		911	913				1.8
6	Anizole		919	918	5.3	7.1	5.2	2.5
7	alpha-Pinene		935	939				1.5
8	Camphene		951	954				1.1
9	Benzaldehyde	Nutty, bitter	960	960			2.0	1.2
10	2-Pentylfuran	Nutty, bean	981	990	6.6	4.4	3.8	5.3
11	1-Octen-3-ol	Raw mushroom	982	979	1.9	2.0	2.2	1.3
12	Octanal	Green, citrus-like	990	999		4.7	2.3	
13	1,3,5-trimethyl-Benzene		992	996	4.0			2.8
14	Limonene		1020	1029				2.6
15	undecane		1091	1100			2.7	
16	N-Nonanal	Soapy, citrus-like	1095	1101	10.9	17.4	10.0	6.1
17	Octyl formate		1139	1131		1.7		0.9
18	(E)-2-Nonenal	Fatty, tallowy	1152	1162		0.9		0.5
19	1,3-Dimethoxy-benzene		1175	1169			0.4	1.1
20	Naphthalene		1187	1181			1.0	
21	Dodecane		1200	1200			0.3	
22	n- octyl- 1- iodo- Octane		1250			2.6		
23	(E)-2-Decenal	waxy	1260	1264			1.2	
24	(E,Z)-2,4-Decadienal	Fatty, green	1299	1293			1.3	
25	Tridecane		1300	1300	1.4	1.1	1.4	0.9
26	Undecanal	Fresh, lemon-like	1312	1307		0.6	0.3	
27	(E)-2-Heptenal	Herbaceous	1316	1318			0.8	0.7
28	2,6-Dimethoxyphenol		1357	1349	0.9	1.8	4.6	
29	2- butyl-2- Octenal		1383			0.7	1.0	
30	Biphenyl		1385	1377			0.6	
31	Tetradecane		1400	1400	2.2	2.3	2.1	1.6
32	2, 6, 10, 14- tetramethyl- Hexadecane		1421					3.0
33	(E)-2-Octenal	Green, fatty	1433	1425		1.4	1.7	1.7
34	2,6-dimethnaphthalene		1437	1431			1.2	
35	1-Methoxynaphthalene		1440	1446			1.2	
36	Neryl acetone		1441	1436		2.1	1.0	1.0
37	2- hydroxy, 2-methyl- Benzoic acid		1449					2.3
38	<2Z,6E>Dodecadiene-1-al		1455	1447			0.5	
39	2-Pentadecanone		1459	1451			7.5	
40	Geranyl acetone	Magnolia, green	1460	1455	1.4		2.2	
41	1,2- Benzenedicarboxylic acid		1469		2.4			
42	Pentadecane		1500	1500	2.1	2.6	2.7	1.3
43	<6-isopropyl>Quinoline		1519	1511				0.9
44	N.D		1539				0.6	
45	N.D		1553					2.7
46	1-Octanol	Fruity, floral	1570	1565			1.3	
47	N.D		1573				0.6	
48	N.D		1595					2.0
49	1-Hexadecene		1599	1590			0.7	
50	Hexadecane		1600	1600	2.1	2.4	4.4	4.0
51	2-acetylnaphthalene		1602	1609			1.6	
52	N.D		1612				0.8	
53	Tetradecanal		1617	1613			0.6	
54	N.D		1658				0.7	
55	N.D		1673				0.6	
56	ar-Turmerone		1675	1669			1.7	
57	1-Nonanol	Floral, citrus-like	1681	1671			0.7	
58	Heptadecane		1700	1700				0.9
59	(E)-2-Undecenal	Fatty, sweet	1759	1750			0.9	
60	Octadecane		1809	1800				3.1
61	2-Ethylhexyl-salicylate		1811	1807			1.8	
62	Tridecanal		1830	1821				0.7
63	Isopropyl tetradecanoate		1839	1830			1.3	2.1
64	Hexadecanoic acid		2006	1995				2.7
65	2-Methoxy-4-vinylphenol	Spicy,clove-like	2191	2180			1.0	
66	Docosane		2209	2200			1.0	
Total					93	100	92.3	98.7

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