Volatile organic compound modification by lactic acid bacteria in fermented chilli mash using GC-MS headspace extraction

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Abstract. This study was conducted to assess the volatile compound generated in fermented chili using the static headspace gas chromatography (GC-MS). Three types of lactic acid bacteria (LAB) inoculant were used; Lactobacillus plantarum ALo1, Lactobacillus pentosus ALo2 and Lactobacillus platarum Au2 for the lactic acid fermented chili mash. Raw chili and natural fermented chili mash were served as negative and positive control. The volatile compound was grouped into 7 main compounds consist of ester, alcohol, alkane, acid, hydrocarbon, ether and nitrogen-containing group. Study showed that LAB inoculated chili mash has lower amount of ethanol as compared to naturally fermented chili mash. Besides, volatile compound generated among each inoculant was different. A compound known as n-Hexadecanoic acid was the primary compound detected in all LAB-inoculated chili mash. Result proved that LAB can be used as the potential starter culture in modifying the aroma of fermented chili mash.

1. Introduction
Flavor compounds that imparts aroma to chillies is influenced by volatile organic compounds. Chili flavours were characterised as a mixture of volatile organic compound (VOC) build from pyrazines such as 3-isopropyl-2-methoxypyrazine, 3-butyl-2-methoxypyrazine and 3-isobutyl-2-methoxypyrazine [1]. The pungency is contributed by capsaicinoids, synthesised from vanillyl amides of various acids. The presence of volatile organic compound (VOC) interfered directly to the sensory quality of the fresh chilli fruit as well as the processed product. Detection of aromatic component in food is generally conducted by GC-MS [2]. The simplest way of extracting the volatile compound from a sample is using the headspace extraction technique. This technique has been used to extract VOC from a variety of natural products and it is now considered a matured extraction technique. It is able to quantitatively quantify wide numbers of volatile compounds in passion fruit juice, rice, chilli cultivars, orange and blackcurrant [3, 4 and 5]. The beauty of applying this technique is aroma detected directly from the portion of the air in contact with the odor source, without any other sample treatment step. Due to this, volatile flavour detected by static headspace GC-MS provide volatile profiles close to the aroma profiles perceived by humans.

Applying the fermentation process can alter the VOC of a wide range of food products. Adding starter culture such as lactic acid bacteria (LAB) has proven to produce a more complex aroma as the bacteria can convert the complex structure of carbohydrate, fats and protein into simpler compounds. Research conducted by Abolhassani et al. (2009) [6] found out Lactobacillus plantarum and Lactobacillus bulgaricus generate volatile organic compound in fermented curry paste. Inoculation of
LAB has modified the flavour of the Merlot wines by the production of different VOC such as ester and di-acetyl in winemaking [7]. LAB has excellent potential to be applied as starter culture for development of fermented chili mash as it can improve the microbial quality as well as odor profile perceived by hedonic test [8, 9]. Inoculated LAB can survive well in the fermented chili mash instead of controlling the mold and yeast growth (Figure 1) [8]. However, the knowledge of volatile compound generated by the LAB inoculant is remain unknown. Understanding the volatile components generated in the fermented chili mash will differentiate the capability of LAB in flavor modification and the optimal starter culture. Therefore, this study was conducted to evaluate the capability of different LAB strain to modify the flavour compound in fermented chili mash using GC-MS static headspace.

2. Materials and methods

2.1. Preparation of lactic acid fermented mash

Cilibangi™ fruits were selected to make free from blemishes, defects, and insect damage. Fruits were cleaned and pericarp removed. The chillies were washed with tap water to remove any impurities then ground using a food blender (Panasonic) with 6% rock salt added. Fermentation was conducted using 150 ml Schott bottle each containing 100 g of pepper mash inoculated with log 10 cfu/mL 24 h cultures of LAB (1% v/v) adapting Shahidah et al. (2016) [8] method for 14 days at 30°C. Three LAB strain were used; Lactobacillus plantarum Alo1 isolated from home-made yoghurt, Lactobacillus pentosus Alo2 isolated from raw cow milk and Lactobacillus plantarum Au2 isolated from fermented chili mash. Spontaneous fermentation with no LAB inoculated chilli mash served as positive control while the raw chilli served as the negative control.

2.2 Identification of volatile organic compounds

Five grams of each fermented chilli mash was introduced into a 10 ml headspace vial. VOC in fermented chilli mash samples were identified using Agilent-Technologies 7890A GC system equipped with Agilent-Technologies 5975C Inert MSD with triple-axis detector and Agilent-Technologies G1888 Network headspace sampler (Agilent-Technologies, Little Falls, CA, USA). GC/MS analysis of volatile compounds was performed using DB-WAX column (30 m × 0.25 mm × 0.25 μm) (J&W Scientific, Folsom, CA, USA). The volatile compounds were identified by comparing and matching mass spectra fragment with the NIST08 MS library (80-100 % similarity). The extraction protocol by direct injection method was modified by Aimi et al. (2013) [13] and simplified in Table 1. The static headspace GC-MS was carried out in duplicate.

Table 1. Extraction protocol for GC and headspace condition.

| GC Condition | Headspace Extraction Condition |
|--------------|--------------------------------|
| Mass range of m/z | 29–450 | Oven temperature 80 °C |
| Split ratio | 10:1 | Loop line 90 °C |
| Oven temperature | Set at 37 °C for 6 min, Heated to 100 °C at 10°C/min for 5 min, Ramp 200 °C at 15°C/min for 10 min, Final 230°C at 20°C/min for 2 min | Transfer line temperature 100 °C |
| GC injector line | 250 °C | MS quad 230 °C |
| MS transfer line | 230 °C | MS source 150 °C |
| Helium flow rate | 1 ml/min | Timing for vial equilibration 15.0 min |
| Run time | 35.8 min | Pressurisation 0.20 min |
| Injection mode | Split ratio 10:1 | Loop fill 0.20 min |
| Mass range of m/z | 29–450 | Loop equilibrium 0.05 min |

3. Results and discussions

Table 2 shows the number of compound and the respective total peak area corresponding to each chemical class detected by GC-MS. The components were classed into 7 components consisting of
alcohol, alkane, acid and hydrocarbon. The volatile profiles show diverse qualitative patterns. Alcoholic group was dominating the fermented chili mash in both spontaneous and LAB inoculated chili mash with total peak area around 35.50-40.92% as compared to raw chilli. Vice versa, nitrogen containing compound was detected in high amount in raw chilli with 88.32% total peak. There was absence of alkane in fermented chili mash inoculated with Lactobacillus plantarum Alo1 and ether in fermented chili mash inoculated with Lactobacillus plantarum Alo1 and Lactobacillus plantarum Au2.

Levels of individual volatile compounds related to the aroma profile were largely influenced by the presence of fermentation process and LAB (Table 2). Ethanol was the major compound present in all fermented chili mash but not in raw chili. Few types of methyl alcoholic compound such as 1-butanol, 3-methyl, 1-propanol, and 2-methyl alcoholic group present in fermented chilli mash inoculated with Lactobacillus plantarum Alo1. A compound of α-terpineol was only detected present in spontaneous fermentation with 9.91% total peak area (Table 3). Research conducted by Nam et al. (2009) [11] & Gomez et al. (2006) [12] observed the presence of alcohols during fermentation resulted from carbohydrate metabolism by the yeast in the presence of LAB. Additionally, methyl alcohols could be originated from activities of endogenous enzymes and residual enzymes from microorganisms [13]. The compounds could be generated from reduction of propanal, 2-methyl-1-propanal, pentanal, 4-methyl-1-pentanal [14].

The volatile acids detected present in LAB-inoculated fermented chilli mash were L-(+)-ascorbic acid, trans-13-octadecanoic acid, pterin-6-carboxylic acid, hydroxy acetic acid (Table 3). Ascorbic acid is a common volatile detected present in different variety of raw chilli cultivars quantified by GC-MS solid phase micro extraction [15]. However, this study did not detect any ascorbic acid in both raw chili and spontaneous fermentation (Table 3). Only fermented chili mash inoculated with L. plantarum Alo1 produced L-(+)-ascorbic acid with 5.16% peak area. The absent of the ascorbic acid in raw chilli might be due to incapability of static headspace GC-MS to detect the compound. The headspace condition during extraction may have resulted in the conversion of ascorbic acid to benzene through decarboxylation process [16].

Each of LAB isolates produced different compound of volatile organic compound. The compounds of L-(+)-ascorbic acid, cyclopropane tetradecanoic acid and 2-octyl-methyl ester were only detected present in Lactobacillus plantarum Alo1 inoculated fermented chili mash with 5.16% and 0.48% total peak area respectively. On the other hand, 1,1'-bicyclopropyl-2-octanoic acid was only detected present in fermented chili mash inoculated with Lactobacillus plantarum Alo1 and Lactobacillus plantarum Au2 with 0.50% and 0.54% total peak area. The trans-13-octadecenoic acid only present in fermented chilli mash inoculated with Lactobacillus plantarum Au2. The variation be influenced by unique LAB interaction with the chili substrate. The bacterial can alter the enzyme that responsible for flavour generation [17].

For instance, pectin esterase is present in plant tissue which specifically affects methyl groups on linear chain of pectin producing the methyl ester compound group. LAB is believed to play important role to synthesise ester via esterification reaction in which fatty acyl groups from glycerides is transferred to alcohols [18]. LAB esterase producer such as Lactobacillus plantarum and Lactobacillus pentosus have the ability to hydrolyse and synthesise ester. Esterolytic activity liberated by the esterases contributed to wine aroma can increase in wine quality [19].
Figure 1. Microbial profile of spontaneous and LAB inoculated fermented chili mash.

Table 2. Volatile compounds identified in spontaneous and LAB inoculated chili mash after two weeks of fermentation using headspace GC-MS.

| Chemical Class | Raw Chili | Spontaneous | Lactobacillus plantarum A01 | Lactobacillus pentosus A02 | Lactobacillus plantarum A02 |
|----------------|-----------|-------------|-----------------------------|---------------------------|-----------------------------|
| Ester          | 3         | 27.27%      | 14.00%                      | 12.20%                    | 10.84%                      |
| Alcohol        | 3         | 27.27%      | 4.72%                       | 3.93%                     | 4.27%                       |
| Alkane         | 1         | 9.09%       | 6.56%                       | 6.07%                     | 6.07%                       |
| Acid           | 2         | 18.18%      | 4.08%                       | 3.93%                     | 3.93%                       |
| Hydrocarbon    | 1         | 9.09%       | 1.16%                       | 1.36%                     | 1.07%                       |
| Ether          | 0         | 0.00%       | 0.00%                       | 0.00%                     | 0.00%                       |
| Nitrogen       | 1         | 9.09%       | 88.32%                      | 76.98%                    | 67.46%                      |

N= Number of compound
%N = Percent number of compound;
A= Total peak area;
%A= percent number of peak area
| Volatile Compounds                      | Group | Raw Chili | Spontaneous | Lactobacillus plantarum Al01 | Lactobacillus pentosus Al02 | Lactobacillus plantarum Au2 |
|----------------------------------------|-------|-----------|-------------|-------------------------------|-----------------------------|----------------------------|
| Methyl alcohol                         | Alcohol | 3.24      | 1.98        | ND                            | ND                          | 3.24                       | 0.49                       |
| Ethanol                                | Alcohol | ND        | ND          | 3.84                          | 32.59                       | 3.84                       | 0.48                       |
| 2-methyl-1-propanol                    | Alcohol | ND        | ND          | ND                            | 8.37                        | ND                         | ND                         |
| 3-methyl-1-butanol, 2-methyl-1-hexadecanol (3α,5Z,7E), 9,10-secocholest-5,7,10(19)-triene-3,24,25-triol | Alcohol | ND        | ND          | ND                            | ND                          | ND                         | ND                         |
| 1-pentanol                             | Alcohol | 7.11      | 1.31        | 7.12                          | 1.05                        | 5.78                       | 1.26                       |
| 4-methyl-1-pentanol                    | Alcohol | ND        | ND          | 11.59                         | 0.79                        | 11.88                      | 1.12                       |
| 1,7,7-trimethylbicyclo[2.2.1]heptan-2-ol | Alcohol | 11.87     | 2.13        | ND                            | ND                          | ND                         | ND                         |
| α-terpineol                            | Alcohol | ND        | ND          | 11.92                         | 9.91                        | ND                         | 11.92                      | 4.34                       |
| n-hexadecanoic acid                   | Acid   | ND        | ND          | ND                            | 14.59                       | ND                         | ND                         | 9.10                       |
| Hydroxyacetic acid, hydrazide          | Acid   | ND        | ND          | ND                            | 3.24                        | ND                         | ND                         | 7.97                       |
| 1,1′-bicyclopropyl]-2-octanoic acid   | Acid   | 24.04     | 2.09        | ND                            | ND                          | ND                         | 24.42                      | 0.66                       |
| L-(+)-ascorbic acid                   | Acid   | ND        | ND          | ND                            | 24.88                       | ND                         | ND                         | 28.40                      | 4.02                       |
| Trans-13-octadecenoic acid             | Acid   | ND        | ND          | ND                            | 14.61                       | ND                         | ND                         | 14.62                      | 8.85                       |
| Z-(13,14-Epoxytetradec-11-en-1-o-Acetate | Acid   | 21.61     | 1.99        | ND                            | ND                          | ND                         | ND                         | 24.42                      | 0.66                       |
| Octaethylene glycol monododecyl ether  | Ether  | ND        | ND          | 27.91                         | 0.68                        | ND                         | 26.70                      | 1.74                       |
| 2-octyl-methyl ester cyclopropanetetradecanoic acid | Ester | ND        | ND          | 24.38                         | 0.48                        | ND                         | ND                         | 28.40                      | 4.02                       |
| [1,1′-bicyclopropyl]-2-octanoic acid,2′-hexyl0-methyl ester | Ester | 0.56      | 0.56        | 0.56                          | 0.56                        | 12.11                      | 0.56                       | 24.42                      | 0.66                       |
| Methoxyacetic acid, 4-tetradecyl wter | Ester  | 8.85      | 1.16        | ND                            | ND                          | ND                         | 8.85                       | 0.60                       |
| Methoxyacetic acid, 2-tridecyl ester   | Ester  | ND        | ND          | ND                            | 8.85                        | ND                         | ND                         | 8.85                       | 0.60                       |
| 12,15-Octadecadiynoic acid, methyl ester | Ester | 4.59      | 23.97       | 4.59                          | 19.13                       | 4.59                       | 8.15                       | 2.46                       |
| 3,7-dimethyl-4-Chloro-3-n-hexyloctadecane | Ester | 20.09     | 1.34        | ND                            | ND                          | ND                         | ND                         | 24.42                      | 0.66                       |

Table 3. Volatiles compounds identified in the spontaneous and lab inoculated chili after two weeks of fermentation using headspace GC-MS.
Hexadecanoic acid was found to be the major constituent in fresh chili but found to be decreased and disappeared once the chili achieves maturation [20]. However, this compound is not detected in this study as this compound was absent in raw chili and spontaneous fermented chili mash. It is believed that N-hexadecanoic acid are metabolically synthesised by the presence of LAB as this compound present in all LAB inoculated chili mash. This compound was found to be the common secondary metabolites produced by LAB in malolactic wine fermentation [21]. The presence of LAB will convert the complex carbohydrate into simple glucose which then become the main precursor for generation of acetyl-CoA. Consequently, Acetyl-CoA caters the generation of Hexadecanoic acid [22].

Hydrocarbon 1,6-octadie-3-ol,3,7-dimethyl or commonly known as β-linalool was detected in all fermented chili (Table 2). This compound is naturally present in different type of spices such as coriander, chili and ginger [23]. It contributes to flowery and spicy odour in herbs. The study conducted by Shahidah & Zaition (2015) [9] found out both yeast and LAB were present in LAB-inoculated and naturally fermented chili mash. The present of this compound in all fermented chili was assumed to be metabolically synthesised by single yeast or interaction between LAB and yeast. Carrau et al. (2005) [24] discovered that 1,6-octadie-3-ol,3,7-dimethyl is a yeast metabolite in wine after alcoholic fermentation.

This study had detected a methyl ester; cyclopropane tetradecanoic acid 2-ocetyl-methyl ester, methoxyaceticacid, 2-tridecaryl ester, 2,15-octadecadiynoic acid, methyl ester, cyclopropanedodecenolic acid, 2-ocetyl-methyl ester, 9,12,15-octadecatrienoic acid, 2-(trimethyllysilyl)oxy)-methyl-ethyl ester] compound in both LAB inoculated and spontaneously fermented chili mash (Table 3). Ester can be derived from the raw chili and from the chemical esterification of alcohols and acid during the fermentation process [25]. Ageing of fermented chili mash during 14 days fermentation resulted in plant tissue breakdown. Pectin esterase is present in plant tissue which specifically affects methyl groups on linear chain of pectin producing the methyl ester compound group [26]. The common LAB esterase producers that has ability to convert the fatty acyl groups from glyceride to alcohol are Lactobacillus plantarum, Lactobacillus pentosus, Lactobacillus fermentum which can [19].

### Table 3. Continued.

| Volatile Compounds | Group | Raw Chili | Spontaneous | Lactobacillus plantarum Alo1 | Lactobacillus pentosus Alo2 | Lactobacillus plantarum Au2 |
|--------------------|-------|-----------|-------------|-----------------------------|----------------------------|----------------------------|
|                    |       | RT | Areaa (%) | RT | Areaa (%) | RT | Areaa (%) | RT | Areaa (%) | RT | Areaa (%) |
| 1,6-octadien-3-ol  | hydrocarbon | ND | ND | 10.06 | 2.57 | 10.04 | 2.36 | 10.04 | 1.92 | 10.04 | 1.90 |
| (2S,2'S)-2,2'-Bis[1,4,7,10,13-pentaoxacyclopentadecane | Alkane | ND | ND | 25.72 | 0.84 | ND | ND | ND | ND | ND | ND |
| 15,15'-Bi-1,4,7,10,13-penta-oxacyclohexadecane | Alkane | 29.32 | 1.56 | ND | ND | ND | ND | 31.49 | 0.48 | 29.98 | 0.50 |
| (2S,2'S)-2,2'-Bis[1,4,7,10,13-penta-oxacyclohexadecane | Alkane | ND | ND | 29.82 | 0.75 | ND | ND | 32.66 | 0.72 | ND | ND |
| Benzeneethanamine, N-butyl | Nitrogen Compound | 1.53 | 88.32 | 1.53 | 63.01 | 1.53 | 48.52 | 1.54 | 58.58 | 1.53 | 54.32 |
| Benzencesulfonamide, N-butyl | Nitrogen Compound | ND | ND | ND | ND | 26.71 | 6.58 | ND | ND | ND | ND |
| RT Retention time (in min); |
| a Average relative percentage of total peak area; |
| *ND Not detected |
This study shows that the three LAB has the ability to modify the VOC of fermented chili mash with different profile of fermented chili mash. Based on hedonic score conducted by Shahidah et al. 2016 [8], three LAB named as *Lactobacillus plantarum* Alo1, *Lactobacillus pentosus* Alo2 and *Lactobacillus plantarum* Au2 gained among the highest hedonic score. However, the score between these three LAB were not significantly different. Yet, in terms of microbial profile, the *Lactobacillus pentosus* Alo2 has a good microbial stability as it can maintain until 8 log 10 cfu/ml within 28 days fermentation. Besides that, *Lactobacillus pentosus* Alo2 also has the ability to suppress the growth of mould and yeast in fermented chilli mash (Figure 1) [9].

Considering the VOC alone to derive the best starter culture for fermented chilli mash is quite complex as generation of VOC is variable. Detail odour of specific VOC generated by each LAB need to be further validated by sensory analysis after isolation of single VOC compound. Thus, we suggest to combine the VOC profiling with previous microbial study obtained by Shahidah & Zaition (2015) [9] for choosing the optimal bacterial culture. By combining the volatile compound with the previous study, *Lactobacillus pentosus* Alo2 can be selected to be the optimal starter culture which can be useful for developing the fermented chilli mash as it posses the optimal microbial stability.

4. Conclusions
This study is the extension of work from the previous research conducted on fermented chilli mash. The VOC generated by each LAB was unique and useful in modifying the volatile organic compound. By relating this study and the work conducted previously, it can be concluded *Lactobacillus pentosus* Alo2 was the optimal strain to be used as a starter culture in fermented chilli mash.

References

[1] Murray K E and Whitfield F B 1975 The Occurrence of 3-alkyl-2-methoxypyrazines in raw vegetables Journal of Science Food Agriculture 26 973–86
[2] Ray H , Majumdar S, Biswas S P, Das A, Ghosh T K and Ghosh A 2014 Characterization of the volatile aroma compounds from the concrete and jasmine flower grown in india A publication of Italian Association of Chemical Engineering 40 259–269
[3] Braga G C, Prado A, Sebastião J, Pinto D S and de Alencan M D 2015 Volatile profile of yellow passion fruit juice by static headspace and solid phase micro extraction techniques Ciência Rural, Santa Maria 45 356–363
[4] Bryant R J and McClung A M 2011 Volatile profiles of aromatic and non-aromatic rice cultivars using SPME/GC–MS Food Chemistry 124 501–503
[5] Blythe J W, Heitz A, Joll C A and Kagi R I 2006 Determination of trace concentrations of bromophenols in water using purge-and-trap after in-situ Acetylation Journal of Chromatography A 1102 73–83
[6] Abolhassani Y, Ayub M K and Babji A 2009 Assessment of microbiological and modified aroma profiles of lactic acid bacteria (lab) fermented curry paste Asian Journal and Agro-Industry 2 63–71
[7] Antalic G, Perello M C and Reve G D 2013 Co-inoculation with yeast and LAB under winery conditions South African Journal of Enology and Viticulture 34 225–231
[8] Shahidah M N, Zaiton H, Ili F A H and Elshaafi I 2016 Local Malaysian isolates as potential culture for fermented chili mash IOSR Journal of Environmental Science Toxicology and Food Technology 10(5) 25–29
[9] Shahidah M N and Zaiton H 2015 Accelerated fermentation of ground chili by lactic acid bacteria 2015 Kosist
[10] Aimi R N, Bakar A F and Dzulkifly M H 2013 Determination of volatile compounds in fresh and fermented nipa sap (*Nypa fruticans*) using static headspace gas chromatography-mass spectrometry (GC-MS) International Food Research Journal 20(1) 369–376
[11] Nam Y D H W, Chang K H, Kim S W, Roh and Bae J W 2009 Metatranscriptome analysis of lactic acid bacteria during kimchi fermentation with genome-probing microarrays International. Journal of Food Microbiology 130 140–146

[12] Gomez A H S, Garcia P G and Navarro L R 2006 Trends in table olive production, elaboration of table olives Grasas y Aceites 57 86

[13] Rottsatchakul P, Visesanguan W, Smitinont T and Chaiser S 2009 Changes in volatile compounds during fermentation of nham (thai fermented sausage) International Food Research Journal 16 391–414

[14] Frankel E N 1991 Volatile Lipid Oxidation Products Progress in Lipid Research 22 1–33

[15] Toontom N, Meenue M, Posri W and Lertsiri S 2012 Effect of drying method on physical and chemical quality, hottnes and volatile characteristic of dried chili International Food Research Journal 19 1023–1031

[16] Christof V P, Christ’l D, Jan F V B, Rudi V and Carlos V P 2008 Monitoring the benzene contents in soft drink using headspace gc chromatography-mass spectrometry: a survey of the situation on the belgian market Journal of Agriculture and Food Chemistry 56 4504–10

[17] McFeeters R F 2004 Fermentation microorganisms and flavor changes in fermented foods Journal of Food Science 69 35–37

[18] Nancy C F, Dawn V and Roy D P 2007 The effect of calcium on microbial quality and consistency of chile pepper (capsicum annum sc. mesilla cayenne) cash during Fermentation LWT-Food Science and Technology 40 142–1487

[19] Angela M, Grimaldi A, Walker M, Bartowsky E, Garbi P and Jiranek V 2004 Minireview lactic acid bacteria as potential as potential source of enzyme for use in vinification Applied and Environmental Microbiology 70 5715–31

[20] Rodriguez-Burruezo A, Kollmansbergberger H, González-as M C, Nitz S and Fernando N 2010 HS-SPME comparative analysis of genotypic diversity in the volatile fraction and aroma-contributing compound of Capsicum fruits from the annum-chinese frustaceans complex Journal agriculture of food chemistry 58 4388–4400

[21] Lee J E, Hong Y S & Lee C H 2009 Characterization of fermentative behaviors of lactic acid bacteria in grapes wines trough 1h nmr- gc-based metabolic profiling Journal Agriculture of Food Chemistry 11 4810–17

[22] Lambrechts M G and Pretorius I S 2000 Yeast and its importance to wine aroma South African Journal of Enology and Viticulture 21 97–129

[23] Jalal B Z and Nasroallah M K 2014 Physiological and pharmaceutical effects of ginger (zingiber officinale roscoe) as valuable medicinal plant Pelagia Research Library 4 87–90

[24] Carrau F M, Medina K, Boido E, Farina L, Gaggero C, Dellacassa E, Versini G and Henschje PA 2005 De novo synthesis of monoterpenes by Saccharomyces cerevisiae wine yeast FEMS microbiology Letter 1 107–115

[25] Apichartsrangkoon A, Chaikham P, Srisajjalertwaja S, Chuntanom P and Dajanta K 2013 Aroma volatile profiles of thai green chili paste (Nam Prig Noom) preserved by ultra-high pressure, pasteurization and sterilization International Food Research Journal 20 1739–1746

[26] Nancy C F, Dawn V and Roy D P 2007 The effect of calcium on microbial quality and consistency of chile pepper (Capsicum Annum Sc. Mesilla Cayenne) cash during fermentation LWT-Food Science and Technology 40 142–14

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