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# Flavor and Taste-Active Compounds in Blue Mussel Hydrolysate Produced by Protease

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Abstract

**Volatile flavor compounds in hydrolyzed blue mussel(HBM) produced by Optimase™ APL-440, with untreated blue mussel(UBM) were compared. A total of 100 volatile compounds were detected in both HBM and UBM, consisting mainly of 25 aldehydes, 16 ketones, 17 alcohols, 8 nitrogen-containing compounds, 11 aromatic compounds, 8 terpenes, and 15 miscellaneous compounds. Levels of aromatic compounds decreased after hydrolysis, whereas levels of 7 nitrogen-containing compounds increased. The compounds, 3-methylbutanal, (Z)-4-heptenal, and (E,Z)-2,6-nonadienal, had the highest odor values in both samples. Total free amino acids in HBM were 21.89%(w/w) and increased by 3.4 times higher than UBM. Glutamic acid and aspartic acid, having sour tastes, were the major taste-active compounds in HBM.**

**Key words:** blue mussel, hydrolysate, volatile flavor compounds, taste-active compounds

## INTRODUCTION

Coupled with rising energy costs and the problem of availability and conservation of natural resources, nowadays, this forces the food industry to constantly develop new technology and sources of raw materials to meet these needs. In addition, there is the desire for the raw materials to be natural and harmless to consumer. One of the increasingly important and widely sought sources of food is seafood, paticularly shellfish.

Blue mussel, having a desirable taste and aroma, is an important marine resource in Korea(1). However, in recent years processing utilization of blue mussel has declined due to decreasing harvesting yields associated with marine environmental contamination. Therefore, an alternative use of blue mussel, such as production of flavorants via enzymatic hydrolysis, for having a supplementary value may be a fundamental benefit to seafood industry.

Several studies have addressed the production of seafood flavorings by enzymatic hydrolysis(2,3). Developing natural seasoning agents from blue mussel with commercial proteases was also attempted by many researchers(4-6). However, a better understanding of flavor compounds in blue mussel hydrolysate is needed if alternative products are to be produced.

The objective of this study was to compare taste-active and volatile flavor compounds of enzyme hydrolyzed blue mussel(HBM) with those of untreated blue mussel(UBM).

## MATERIALS AND METHODS

### Materials

A fresh blue mussel(*Mytilus edulis*) was purchased from a fish market in Masan, Korea and transported on ice in polyethylene bags to the Flavor Lab., Changwon National University within 1 hr. The sample was refrigerated(4°C) until analysis. Blue mussel hydrolysate was produced by Optimase™ APL-440(Solvay Enzymes, Inc., Elkhart, USA) at optimal hydrolysis conditions, e.g. pH 9.8, 58°C, 2.9 hr reaction time, 46.8%(w/v) substrate concentration, 0.34%(v/w) enzyme/substrate ratio, as described in previous paper(6). Standard flavor compounds were obtained from Aldrich Chemical Co.(Milwaukee, USA).

### Analysis of free amino acids

Fifteen grams of untreated(UBM) or 30ml of hydrolyzed blue mussel(HBM) were treated with 50ml of 10% TCA solution and then rinsed with redistilled diethyl ether to remove lipid and pigments. The aqueous extract was evaporated to dryness on vacuum rotary evaporator

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(Bibby Science Co., England), dissolved in buffer solution (pH 2.2), and then volume adjusted to 25ml prior to analysis of free amino acids(FAAs). FAAs were determined by an automatic amino acid analyzer(Pharmacia Biochrom 20, England) equipped with $Li^+$ type high performance ultra pack. Duplicate analysis were performed on each sample.

### Vacuum simultaneous steam distillation-solvent extraction(V-SDE)

V-SDE was conducted under vacuum(540~580atm, b.p. 55~60°C) using the apparatus described by Chung and Cadwalladar(7). One liter of HBM plus 90.8μg of internal standard(2,4,6-trimethylpyridine, TMP) and 1L of distilled water(or 500g of UBM plus 1.5L of distilled water) were extracted for 2.5 hr with 200ml of redistilled diethyl ether. V-SDE extracts were kept at -20°C overnight to facilitate water removal. The details were described by Cadwallader et al.(8). Extracts were dried over 2g of anhydrous sodium sulfate and concentrated under a gentle stream of $N_2$ to 0.3 ml before analysis. Duplicate extractions were carried out on each sample.

### Gas chromatography/mass spectrometry(GC/MS)

One μl of each V-SDE extract was injected into an HP 5890A GC/HP 5971 mass selective detector(MSD) (Hewlett-Packard Co.)(splitless mode; 30s valve delay; injector temperature 155°C) with a fused silica open-tubular column(Supelcowax 10, 60m×0.25mm i.d.× 0.25mm film thickness; Supelco, Inc., Bellefont, USA). Oven temperature was programmed from 40°C to 175°C at 2°C/min with initial and final holding times of 5 and 30 min, respectively; oven temperature was then further increased to 195°C at 5°C/min and held for 25 min. Other GC conditions and MSD parameters have been described elsewhere(9,10). Duplicate analysis were performed on each extract.

### *Identification and relative abundance of compounds*

Volatile compounds were identified by matching retention indices(RI)(11) and mass spectra of unknowns with those of authentic standard compounds. Tentative identifications were based on standard MS library data (12). Concentration of each volatile compound was calculated by mean relative content(n=4) to TMP concentration per gram of sample(factor=1).

## RESULTS AND DISCUSSION

### Free amino acid compositions in UBM and HBM

Free amino acids in protease hydrolysed blue mussel (HBM) with those of untreated blue mussel(UBM) are shown in Table 1. Total free amino acids(FAAs) in HBM was 21.88g%(w/w) on a dry weight basis and was 3.4 times higher than UBM(6.36g%). As shown in Table 1, taurine was comprised over half of the total FAAs in UBM, and was unchanged after hydrolysis. However, taurine was reported to have essentially no taste impact (13), nor any effect on formation of aroma active components(14). In addition to taurine, glycine, alanine, arginine and glutamic acid also were found at high levels, and comprised 76.1% of the total amino acids in UBM. Konosu and Yamaguchi(13) reported that alanine and glycine were the major free amino acids in most species of mussel. After taurine, leucine was in the highest abundance in HBM, followed by arginine, alanine, lysine, asparagine, glutamic acid, and glycine. From the result of taste values(TVs) calculated, however, glutamic acid and aspartic acids, having sour tastes(15), had the highest TVs and the lowest thresholds in both samples, followed by arginine(bitter), lysine(sweet), valine(bitter), alanine(sweet), and methionine(bitter) in HBM. Glutamic acid, a known flavor enhancer, was as being in the highest abundance in various hydrolysates, such as hydrolysed vegetable protein(HVP) and soysauce(16). Cha and Cadwallader(17) reported that glutamic acid, aspartic acid, arginine, and lysine contribute greatly to the characteristic taste of skipjack tuna sauce through TVs test. Most amino acids, including glutamic acid, glysine, alanine, and lysine, are known to be important aroma precursors that react primarily through Maillard reactions with other compounds(14,16,18). A lot of reactive amino acids in Maillard reaction, especially basic amino acids, should be considered to play an important role in the development of the characteristic aroma in blue mussel hydrolysate(14).

### Volatile flavor profiles in blue mussel hydrolysate

Volatile flavor compounds in HBM and UBM were compared. A total of 100 volatile compounds were detected of which 96 were positively identified(Table 2). Eighty-four compounds were detected in HBM and 75 in UBM. These compounds were composed of 25 aldehydes, 16

**Table 1. Free amino acids and taste values in UBM and HBM[1)]**

| Compound | Concentration[2)] | | Taste threshold[3)] (g/dl) | Taste value[4)] | |
|---|---|---|---|---|---|
| | UBM | HBM | | UBM | HBM |
| Aspartic acid | 0.067 | 0.285 | 0.003 | 22.3 | 95.0 |
| Threonine | 0.122 | 1.117 | 0.26 | 0.5 | 4.3 |
| Serine | 0.095 | 1.148 | 0.15 | 0.6 | 7.7 |
| Asparagine | 0.139 | 1.407 | 0.1 | 1.4 | 14.1 |
| Glutamic acid | 0.294 | 1.307 | 0.005 | 58.8 | 261.4 |
| Proline | 0.046 | 0.073 | 0.3 | 0.2 | 0.2 |
| Glycine | 0.647 | 1.241 | 0.13 | 5.0 | 9.5 |
| Alanine | 0.424 | 1.706 | 0.06 | 7.1 | 28.4 |
| Valine | 0.049 | 1.142 | 0.04 | 1.2 | 28.6 |
| Cystine | 0.123 | N/D[4)] | N/A[7)] | | |
| Methionine | 0.064 | 0.736 | 0.03 | 2.1 | 24.5 |
| Isoleucine | 0.040 | 0.989 | 0.09 | 0.4 | 11.0 |
| Leucine | 0.060 | 1.899 | 0.19 | 0.3 | 10.0 |
| Tyrosine | 0.088 | 1.237 | N/A | | |
| Lysine | 0.119 | 1.592 | 0.05 | 2.4 | 31.8 |
| Arginine | 0.368 | 1.725 | 0.05 | 7.4 | 34.5 |
| Histidine | 0.068 | 0.327 | 0.02 | 3.4 | 16.4 |
| Ammonia | 0.011 | 0.024 | N/A | | |
| Ornithine | 0.023 | 0.026 | N/A | | |
| Phosphoserine | 0.056 | 0.160 | N/A | | |
| Taurine | 3.102 | 3.221 | N/A | | |
| Urea | 0.328 | 0.380 | N/A | | |
| Anserine | 0.001 | 0.070 | N/A | | |
| Hydroxyproline | 0.001 | 0.020 | N/A | | |
| 3-Methylhistidine | -[6)] | N/D | N/A | | |
| α-Aminoadipic acid | - | 0.007 | N/A | | |
| β-Alanine | 0.024 | 0.028 | N/A | | |
| DL*-Allohydroxylysine | 0.001 | 0.021 | N/A | | |
| Total | 6.360 | 21.888 | | | |

[1)]UBM, Untreated blue mussel; HBM, enzyme hydrolyzed blue mussel with Optimase™ APL-440
[2)]Concentrations are on a dry weight basis in g/100g and g/100ml of UBM and HBM, respectively
[3)]Kato et al.(15), [4)]Taste value : compound concentration divided by taste threshold
[5)]N/D : Not detected, [6)]Trace(<1mg), [7)]N/A : Not available

ketones, 17 alcohols, 8 nitrogen-containnig compounds, 11 aromatic hydrocarbones, 8 terpenes, and 15 miscellaneous compounds.

As shown in Table 2, the number and relative abundance of aldehydes were higher than the other classes of compounds in both samples. Levels of aldehydes increased 1.8 fold in HBM compared with UBM. Certain aldehydes, such as (E)-2-methyl-2-butenal, 2-furancarboxaldehyde, (E,E)-2,4-heptadienal, decanal, 4-ethylbenzaldehyde, and (E,E)-2,4-decadienal, were detected only in HBM. Three compounds, 3-methylbutanal, (Z)-4- heptenal, and benzaldehyde were notably high in both samples. As shown in Table 2, however, benzaldehyde may not contribute to the characteristic flavor of blue mussel with its high threshold. On the other hand, the compounds, 3-methylbutanal(dark chocolate-like)(17), (Z)-4-heptenal (rancid, crab-like)(8), and (E,Z)-2,6-nonadienal(cucumber-like)(17), having lower thresholds, may positively affect to the overall flavor of HBM. The alkanals and alkenals detected in both samples might have been due to oxidation of PUFA during sample treatment and hydrolysis (19-21). These compounds are known to contribute fatty-oily, slighty rancid odors, while the dienals contribute pleasant fried-fatty aromas(22,23). Levels of 2-methyl butanal, 3-methylbutanal, and (Z)-4-heptenal increased after hyrolysis. The compound (Z)-4-heptenal was reported to be produced from (E,Z)-2,6-nonadienal by retro-aldol condensation(24).

Levels of ketones were 2.8 fold high in HBM compared with UBM. The compounds, 2-nonanone, 6-methyl-5-

**Table 2. Volatile flavor compounds and odor values in UBM and HBM**

| Compound name by class | Retention index | Concentration(ng/g)[1] | | Odor threshold (ng/g)[2] | Odor value[3] | |
|---|---|---|---|---|---|---|
| | | UBM | HBM | | UBM | HBM |
| Aldehydes(25) | | | | | | |
| Butanal | 858 | 12.85( 5.51) | 53.24( 25.70) | N/A[5] | | |
| 2-Methylbutanal | 908 | 11.02( 3.67) | 141.37( 60.59) | 3[6] | 3.67 | 47.12 |
| 3-Methylbutanal | 911 | 47.74(20.20) | 216.65(121.18) | 0.2[6] | 238.68 | 1083.24 |
| Pentanal | 971 | 22.03(14.69) | 34.88( 23.87) | 12[6] | 1.84 | 2.91 |
| 2-Butenal | 1032 | 36.72(11.02) | | N/A | | |
| Hexanal | 1071 | 18.36( 9.18) | 29.38(23.87) | 5[7] | 3.67 | 5.88 |
| (E)-2-methyl-2-butenal | 1083 | | 20.20(12.85) | N/A | | |
| (E)-2-Pentenal | 1119 | 77.11(16.52) | 11.02( 7.34) | N/A | | |
| 2-Methyl-(E)-2-pentenal | 1146 | 7.34( 7.34) | 9.18( 7.34) | N/A | | |
| Heptanal | 1175 | 20.20(11.02) | 40.39(11.02) | 3[7] | 6.73 | 13.46 |
| (E)-2-Hexenal | 1206 | 69.77(23.87) | 29.38(11.02) | 17[8] | 4.10 | 1.73 |
| (Z)-4-Heptenal | 1231 | 69.77( 3.67) | 112.00(58.75) | 0.04[6] | 1744.20 | 2799.90 |
| Octanal | 1278 | 18.36( 7.34) | 45.90(18.36) | 0.7[7] | 26.23 | 65.57 |
| Nonanal | 1388 | 16.52( 7.34) | 53.24(31.21) | 1[7] | 16.52 | 53.24 |
| (E,E)-2,4-Hexadienal | 1394 | 11.02( 7.34) | | 60[9] | 0.18 | |
| (E)-2-Octenal | 1415 | 34.88(11.02) | | 3[8] | 11.63 | |
| 2-Furancarboxaldehyde | 1454 | | 27.54(14.69) | N/A | | |
| (E,E)-2,4-Heptadienal | 1483 | | 23.87(12.85) | 778[10] | | 0.03 |
| Decanal | 1496 | | 16.52( 5.51) | N/A | | |
| Benzaldehyde | 1513 | 64.26( 5.51) | 183.60(73.44) | 350[8] | 0.18 | 0.52 |
| (E,Z)-2,6-Nonadienal | 1576 | 18.36(16.52) | 29.38(14.69) | 0.01[11] | 1836.00 | 2937.60 |
| (E,E)-2,4-Octadienal | 1579 | 66.10(12.85) | 100.98(18.36) | N/A | | |
| 3-Thiophenecarboxaldehyde | 1666 | | 11.02( 3.67) | N/A | | |
| 4-Ethylbenzaldehyde | 1690 | 40.39(25.70) | | N/A | | |
| (E,E)-2,4-Decadienal | 1798 | 9.18( 5.51) | | 0.07[8] | 131.14 | |
| Ketones(16) | | | | | | |
| 2-Butanone | 894 | 5.51( 5.51) | | N/A | | |
| 1-Penten-3-one | 1014 | 25.70(14.69) | 31.21(31.21) | N/A | | |
| 1-(2-Furanly)-ethanone | 1022 | 3.67( 3.67) | 25.70(25.70) | N/A | | |
| 2,3-Pentanedione | 1053 | 11.02(11.02) | 36.72(31.21) | N/A | | |
| 3-Penten-2-one | 1116 | 9.18( 5.51) | | 1.5[7] | 6.12 | |
| 2-Heptanone | 1171 | | 29.38(20.20) | 140[11] | | 0.21 |
| 2-Octanone | 1273 | | 18.36(12.85) | 50[7] | | 0.37 |
| (E)-3-Hepten-2-one | 1288 | | 64.26(42.23) | 56[11] | | 1.15 |
| 6-Methyl-5-heptene-2-one | 1325 | 23.87(11.02) | 77.11(23.87) | N/A | | |
| 2-Nonanone | 1376 | 25.70( 7.34) | 86.29(34.88) | 200[7] | 0.13 | 0.43 |
| (E)-3-Octen-2-one | 1395 | | 16.52(12.85) | N/A | | |
| 2-Decanone | 1485 | | 47.74(20.20) | N/A | | |
| (E,E)-3,5-Octadien-2-one | 1560 | 14.69( 3.67) | 40.39(25.70) | 150[9] | 0.10 | 0.27 |
| 2-Undecanone | 1584 | 23.87(11.02) | 22.03(12.85) | N/A | | |
| 1-Phenylethanone | 1638 | | 14.69( 9.18) | N/A | | |
| 5-Ethenyldihydro-5-methyl-2(3H)-furanone[4] | 1656 | 18.36(12.85) | | N/A | | |
| Alcohols(17) | | | | | | |
| Ethanol | 923 | 459.00(425.95) | 339.66(372.71) | 100000[9] | 0.00 | 0.00 |
| Propanol | 1034 | 211.14( 60.59) | 47.74( 40.39) | N/A | | |
| Butanol | 1133 | 11.02( 5.51) | 3.67( 3.67) | 500[8] | 0.02 | 0.01 |
| 1-Penten-3-ol | 1151 | 576.50( 99.14) | 400.25(123.01) | 400[8] | 1.44 | 1.00 |
| Pentanol | 1238 | 23.87( 9.18) | 23.87( 9.18) | 4000[9] | 0.01 | 0.01 |
| 1-Hexen-3-ol | 1240 | 42.23( 5.51) | 16.52( 14.69) | N/A | | |
| (Z)-2-Penten-1-ol | 1299 | 45.90( 27.54) | 71.60( 25.70) | N/A | | |
| (E)-2-Penten-1-ol | 1309 | 660.96( 99.14) | 602.21(227.66) | N/A | | |
| Hexanol | 1340 | 27.54( 5.51) | 14.69( 12.85) | 2500[12] | 0.01 | 0.01 |
| (Z)-3-Hexen-1-ol | 1370 | 33.05( 5.51) | 14.69( 7.34) | 70[8] | 0.47 | 0.21 |
| (E)-2-Hexen-1-ol | 1401 | 12.85( 7.34) | 14.69( 9.18) | 400[9] | 0.03 | 0.04 |
| 1-Octen-3-ol | 1439 | 75.28( 7.34) | 42.23( 7.34) | 1[7] | 75.28 | 42.23 |

**Table 2.** (Continued)

| Compound name by class | Retention index | Concentration(ng/g)[1] | | Odor threshold (ng/g)[2] | Odor value[3] | |
|---|---|---|---|---|---|---|
| | | UBM | HBM | | UBM | HBM |
| Heptanol | 1444 | 33.05( 12.85) | 36.72( 11.02) | N/A | | |
| 2-Ethyl-1-hexanol | 1480 | 20.20( 9.18) | 189.11( 49.57) | N/A | | |
| Octanol | 1548 | 33.05( 14.69) | 27.54( 16.52) | 110[12] | 0.30 | 0.25 |
| 2-Furanmethanol | 1650 | 11.02( 5.51) | 22.03( 20.20) | N/A | | |
| Benzenemethanol | 1866 | | 12.85( 3.67) | N/A | | |
| N-Containing compounds(8) | | | | | | |
| Pyridine | 1167 | 185.44( 18.36) | 47.74(42.23) | 2000[7] | 0.09 | 0.02 |
| Pyrazine | 1200 | | 9.18( 5.51) | N/A | | |
| 2-Methylpyridine | 1202 | | 3.67( 3.67) | N/A | | |
| Methylpyrazine | 1249 | | 22.03(20.20) | N/A | | |
| 2,5-Dimethylpyrazine | 1304 | | 33.05(16.52) | 1700[6] | | 0.02 |
| 2,3-Dimethylpyrazine | 1330 | | 7.34( 5.51) | 2500[6] | | 0.00 |
| Trimethylpyrazine | 1390 | | 18.36(22.03) | 23[6] | | 0.80 |
| 3-Ethyl-2,5-dimethylpyrazine | 1428 | | 12.85( 3.67) | N/A | | |
| Aromatic hydrocarbones(11) | | | | | | |
| Toluene | 1028 | 42.23(34.88) | 99.14(80.78) | N/A | | |
| Ethylbenzene | 1114 | 5.51( 3.67) | 5.51( 5.51) | N/A | | |
| *p*-Xylene | 1123 | 9.18( 5.51) | 7.34( 7.34) | N/A | | |
| *m*-Xylene | 1129 | 12.85( 9.18) | 5.51( 7.34) | N/A | | |
| *o*-Xylene | 1170 | 18.36( 7.34) | | N/A | | |
| 4-Ethyltoluene | 1212 | 3.67( 3.67) | | N/A | | |
| Styrene | 1244 | 11.02( 7.34) | | N/A | | |
| 1,2,4-Trimethylbenzene | 1266 | 14.69( 1.84) | 11.02( 9.18) | N/A | | |
| Naphthalene | 1721 | 23.87(11.02) | 16.52( 5.51) | N/A | | |
| 2-Methylnaphthalene | 1838 | 20.20(14.69) | | N/A | | |
| *o*-Cresol | 2066 | 36.72( 3.67) | 47.74(16.52) | N/A | | |
| Terpenes(8) | | | | | | |
| α-Pinene | 1009 | 3.67( 1.84) | 11.02( 5.51) | N/A | | |
| Limonene | 1195 | | 12.85( 9.18) | 10[11] | | 1.29 |
| (E)-Caryophyllene[4] | 1584 | 29.38( 9.18) | 44.06(69.77) | N/A | | |
| (Z)-Citrl | 1668 | | 60.59(89.96) | N/A | | |
| α-Muurolene[4] | 1709 | 89.96(14.69) | | N/A | | |
| (E)-Citral | 1716 | 38.56(16.52) | 38.56(16.52) | N/A | | |
| δ-Cadinene[4] | 1749 | 130.36(77.11) | | N/A | | |
| Geranylacetone | 1845 | 33.05(22.03) | 12.85( 9.18) | 60[6] | 0.55 | 0.21 |
| Micellaneous compounds(15) | | | | | | |
| Ethylacetate | 867 | 218.48(99.14) | 370.87(302.94) | 5000[9] | 0.04 | 0.07 |
| Nonane | 891 | 3.67( 5.51) | 11.02( 9.18) | N/A | | |
| 2-Ethylfuran | 943 | 11.02(11.02) | 9.18( 5.51) | N/A | | |
| Decane | 993 | 5.51( 5.51) | 12.85( 5.51) | N/A | | |
| Dimethyldisulfide | 1053 | | 27.54( 27.54) | 12[9] | | 2.30 |
| Undecane | 1095 | 9.18( 9.18) | 7.34( 3.67) | N/A | | |
| Dodecane | 1196 | 29.38(18.36) | 18.36( 1.84) | N/A | | |
| 2-Pentylfuran | 1221 | 5.51( 1.84) | 7.34( 5.51) | 6[8] | 0.92 | 1.22 |
| Tridecane | 1295 | 22.03(25.70) | 20.20( 11.02) | N/A | | |
| Dimethyltrisulfide | 1363 | | 27.54( 20.20) | 0.01[9] | | 2754.00 |
| Tetradecane | 1396 | 38.56(14.69) | | N/A | | |
| Pentadecane | 1502 | 14.69(14.69) | 20.20( 20.20) | N/A | | |
| Hexadecane | 1599 | 22.03( 3.67) | | N/A | | |
| 2-Acethylthiazole | 1635 | | 150.55(108.32) | 10[13] | | 15.06 |
| Hexanoic acid | 1842 | | 20.20( 5.51) | 3000[14] | | 0.01 |

[1]Concentration of each compound was calculated with relative content to internal standard concentration(factor=1), numbers in parentheses represent relative standard deviations

[2]Odor thresholds in water, [3]Odor value : compound concentration divided by odor thresholds

[4]Compound tentatively identified by mass spectrum, [5]Not available

[6]Buttery et al.(30) [7]Buttery et al.(31) [8]Buttery et al.(32) [9]Hansen et al.(33) [10]Tamura et al.(34)

[11]Buttery et al.(35) [12]Takeoka et al.(36) [13]Schutte(37) [14]van Gemert and Nettenbreijer(38)

heptene-2-one, (E)-3-hepten-2-one, 2-decanone, and (E,E)-3,5-octadien-2-one were the most abundant ketones in HBM. These ketones may have resulted from thermal oxidation/degradation of PUFA(20). Kubota et al.(25) also reported that carbonyl compounds, resulting mainly from lipid and amino acid degradation, contributed strong seaweed-like odor to cooked krill.

Levels of alcohols in UBM decreased after hydrolysis. Ethanol, 1-penten-3-ol, and 2-ethy-1-hexanol were the most abundance in both samples. 1-Penten-3-ol was reported to contribute a heavy and plant-like aroma to oyster(26). Except for 1-octen-3-ol, having mushroom-like odor, however, alcohols may not contribute to the overall flavor of blue mussel hydrolysate because of their high threshold values(Table 2)(23).

Six pyrazines detected were only found in HBM. Methylpyrazine, 2,5-dimethylpyrazine and trimethyl-pyrazine were found in high abundance. However, these compounds may not greatly contribute to the overall flavor of HBM because of their low odor values. These heterocyclic compounds might have to be formed from various nitrogen sources by Maillard and pyrolysis reactions during hydrolysis and subsequent heat treatment (19,27).

Eleven aromatic hydrocarbons were detected in UBM and 7 in HBM. Toluene was found high abundance in both HBM and UBM. Levels of several hydrocarbons were reduced after hydrolysis and heat treatment.

Two compounds, δ-cadinene and α-muurolene, were in high abundances in UBM. These compounds, generally derived from essential oils of plants, might have originated from algae via the food chain. Among the miscellaneous compounds identified, three sulfur compounds, consisting of dimethyldisulfide(DMD), dimethyl-trisulfide(DMTS), and 2-acetylthiazole(2-AT) were found only in HBM. DMD and DMTS are known to produce strong sulfurous odors(28) and may be undesirable to the flavor profile of HBM, while 2-AT, having a nutty/popcorn-like aroma(29) was thought to make a positive contribution.

Blue mussel hydrolysate could be converted a valuable alternative product such as flavoring agent on the basis of flavor profiles, e.g. producing of Maillard reaction flavor. However, further research is needed to determine the relative significance of the sensory components in this interesting flavor system.

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