International Journal of Biological, Life and Agricultural Sciences
ISSN: 2415-6612
Vol:7, No:9, 2013

Quality Properties of Fermented Mugworts and Rapid Pattern Analysis of Their Volatile Flavor Components by Electric Nose Based On SAW (Surface Acoustic Wave) Sensor in GC System

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Abstract**—**The changes in quality properties and nutritional components in two fermented mugworts (*Artemisia capillaries* Thumberg, *Artemisiaeasiaticae* Nakai) were characterized followed by the rapid pattern analysis of volatile flavor compounds by Electric Nose based on SAW(Surface Acoustic Wave) sensor in GC system. There were remarkable decreases in the pH and small changes in the total soluble solids after fermentation. The L (lightness) and b (yellowness) values in Hunter's color system were shown to be decreased, whilst the a (redness) value was increased by fermentation. The HPLC analysis demonstrated that total amino acids were increased in quantity and the essential amino acids were contained higher in *A. asiaticae*Nakai than in *A. capillaries* Thumberg. While the total polyphenol contents were not affected by fermentation, the total sugar contents were dramatically decreased. Scopoletinwere highly abundant in *A. capillaris*Thumberg, however, it was not detected in *A. asiaticae*Nakai. Volatile flavor compounds by Electric Nose showed that the intensity of several peaks were increased much and seven additional flavor peaks were newly produced after fermentation. The flavor differences of two mugworts were clearly distinguished from the image patterns of VaporPrint^{TM} which indicate that the fermentation enables the two mugworts to have subtle flavor differences.

Keywords**—**Mugwort, Fermentation, Electric Nose, SAW sensor, Flavor.

I. Introduction

MUGWORTS (*Artemisia* sp.) are traditionally very common food ingredients and useful material for oriental herbal medicine in Korea. It is well known to have several pharmaceutical effects on anti-hyperlipidemia, high blood glucose and liver functions. The polyphenols in mugworts also contribute to the antioxidative and antibacterial effects [1].

Fermentation is one of the useful biological transformations to increase various functionalities of the raw materials. Many probiotics have been used in a wide range of fermented food products to increase the biological activities [2].

Electric nose has been evolved to the 2nd generation of surface acoustic wave sensor based on the gas chromatographic system. The selectivity and the sensitivity are extremely high so that the analysis can be achieved in a 30 seconds up to the level of ppb concentration. It is very useful tool in food process industry: rapid detection of the originality of oriental medical herbs, the deteriorated odor of the food materials and the flavor changes during storage and transportation [3], [4].

To develop functional foods using mugworts, two representative kinds of mugworts were fermented and the changes of the quality properties and the flavors were analyzed in this research.

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II. Materials and Methods

A. Materials

Two mugworts, *Artemisiacapillaris* Thumberg and *Artemisiaasiaticae* Nakai were purchased and fermented by Bacillus strains according to the previous research [5]. Four samples were compared in all the analysis: non-fermented (ACM) and fermented (AFM) of *A. asiaticae* Nakai, non-fermented (ICM) and fermented (IFM) of *A. capillaries* Thumberg.

B. pH, Total Soluble Solid Contents and Hunter's Color Value

pH and total soluble solid contents were determined with pH meter and hand refractometer, respectively. Hunter's spectrocolormeter was used to determine the color values.

C. Amino Acid Composition

Amino acid composition were analyzed with PicoTag system.

D. Total Polyphenol, Total Sugar and Scopoletin Contents

Total polyphenol contents were determined by Folin-Denis method [6] and the total sugar contents were measured by phenol-sulfuric acid method [7]. Scopoletin was analyzed with HPLC.

E. Volatile Flavor Analysis by Electric Nose

Volatile flavors from mugworts were analyzed with z-NOSE^{TM} equipped with surface acoustic wave sensor based on the GC system. The column was DB-624 capillary column and the programmed temperature was from 30℃ to 120℃ at a rate of 3℃ /sec.

TABLE I
CHANGES OF PH, TOTAL SOLUBLE SOLIDS AND HUNTER'S COLOR VALUE BY FERMENTATION OF MUGWORTS

SAMPLE	pH	TOTAL SOLUBLE SOLIDS(° BRIX)	HUNTER'S COLOR VALUE		
			L	A	B
ACM	6.4±0.1^{C}	23.0±0.0^{BC}	44.63±2.55^{B}	1.50±0.02^{B}	7.99±0.63^{B}
AFM	4.6±0.2^{A}	18.6±0.1^{A}	39.91±1.83^{A}	2.19±0.21^{C}	6.91±0.95^{A}
ICM	6.0±0.0^{C}	22.4±0.1^{B}	46.81±0.85^{C}	0.51±0.01^{A}	10.44±0.42^{D}
IFM	5.1±0.3^{B}	24.0±0.0^{C}	44.60±0.59^{B}	2.34±0.16^{C}	9.78±10.53^{C}

TABLE II
CHANGES OF AMINO ACID COMPOSITIONS BY FERMENTATION OF MUGWORTS
(UNIT : MG/100 G)

AMINO ACID	ACM	AFM	ICM	IFM
Essential amino acid(EAA)				
Leucine	918.6	1,054.1	541.5	557.6
Valine	669.6	804.6	405.3	437.1
Lysine	582.5	697.0	410.1	459.2
Phenylalanine	562.9	651.0	340.4	329.1
Threonine	536.7	637.2	326.8	304.7
Isoleucine	512.2	582.8	310.6	344.0
Methionine	124.4	164.4	85.2	81.0
∑EAA	3,782.5	4,426.7	2,334.7	2,431.7
Non-essential amino acid(NEAA)				
Glutamic acid	1,278.7	1,632.3	914.3	944.6
Aspartic acid	1,084.6	1,418.6	892.7	899.6
Proline	610.3	867.0	548.6	647.1
Alanine	662.2	832.1	416.0	513.0
Glycine	629.9	695.5	343.3	383.2
Serine	493.1	581.7	326.0	303.0
Arginine	502.1	533.0	141.1	121.8
Tyrosine	104.9	301.5	57.2	144.1
Histidine	86.3	211.6	54.6	46.8
Cysteine	ND	ND	ND	ND
∑NEAA	5,452.1	7,073.3	3,693.8	4,003.2
Total amino acid(TAA)	9,359.0	11,664.4	6,113.7	6,515.9
EAA/TAA(%)	38.5	39.4	39.6	38.6

ND : NOT DETECTED

III. DATA AND RESULTS

A. pH, Total Soluble Solid Contents and Hunter's Color Value

There were remarkable decreases in the pH from 6.0~6.4 to 4.6~5.1 and small changes in the total soluble solids after fermentation. The L (lightness) and b (yellowness) values in Hunter's color system were shown to be decreased, whilst the a (redness) value was increased by fermentation (Table I).

B. Amino Acid and Fatty Acid Composition

The HPLC analysis demonstrated that total amino acids were increased in quantity and the essential amino acids were contained higher in *A. asiaticae* Nakai than in *A. capillaries* Thumberg, specially with high contents of glutamic and aspartic acid (Table II). Free amino acid like vitamins or lactic acid could be produced and increased during the fermentation by microorganisms so that the nutritional value would be higher [8].

C. Total Polyphenol, Total Sugar and Scopoletin Contents

Polyphenol compounds are widely distributed in most plants and well known as its high antioxidative activity via free radical scavenging action [6]. The changes of total polyphenol contents in mugworts were not affected by fermentation. The total sugar contents were dramatically decreased, suggesting that they are utilized by microorganism during fermentation. Scopoletin (6-methoxy flavonoids), which is known as one of the most important index components in mugworts, were highly abundant in *A. capillaries* Thumberg, however, it was not detected in *A. asiaticae* Nakai.

D. Flavor Image Pattern by Electric Nose Based On SAW sensor and Vapor Print TMEquations

Fermented mugworts have slightly acidic flavor. To validate the changes of the scent, volatile flavor characteristics were analyzed by electric nose. The numbers of the main volatile flavor compounds in *A. asiaticae* Nakai has been increased from 11 peaks to 17 peaks via the fermentation. Similar result was shown in *A. capillaries* Thumberg from 12 to 19 peaks. The GC chromatogram by Electric Nose showed that the intensity of several peaks were increased much more than before and seven additional flavor peaks were newly produced after fermentation. The peaks in the chromatogram cannot be identified here, but the flavor differences of two mugworts were clearly distinguished from the image patterns of VaporPrint^{TM} like the fingerprints of human. These results demonstrate that the fermentation enables the two mugworts to have subtle flavor differences, which means that the kinds and the combinations of the flavor compounds in mugworts are entirely different which cannot be discriminated by human nose [3].

TABLE III
CHANGES OF TOTAL POLYPHENOL, TOTALSUGAR AND SCOPOLETIN CONTENTS BY FERMENTATION OF MUGWORTS (UNIT : MG/G)

SAMPLE	TOTAL POLYPHENOL	TOTAL SUGAR	SCOPOLETIN
ACM	24.12±2.84a)	1.58±0.39b	ND
AFM	23.64±1.92a	0.34±0.06a	ND
ICM	69.40±0.94c	2.70±0.06c	5.36±0.71a
IFM	62.71±1.53b	1.14±0.12b	6.24±0.04b

ND : NOT DETECTED.

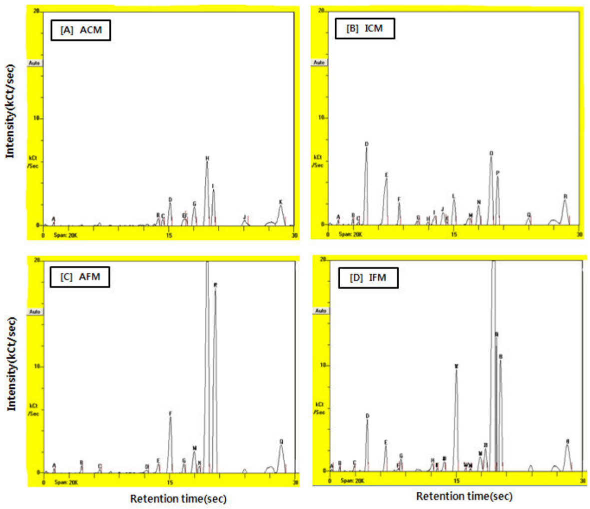

Fig. 1 GC chromatograms of volatile flavor components from mugworts by Electronic Nose based on SAW sensor

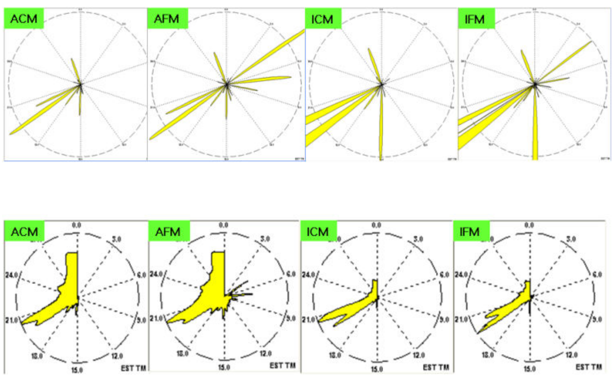

Fig. 2 Polar derivative patterns of mugworts using VaporPrint™ image analysis

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