IDENTIFICATION OF LIPID-DERIVED VOLATILE COMPOUNDS OF COMMERCIAL BROILER AND KORAT CROSSBRED CHICKEN DURING FROZEN STORAGE

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Abstract – Solid phase microextraction (SPME) using a DVB/CAR/PDMS fiber combined with gas chromatography/mass spectrometry (GC/MS) was used to evaluate the lipid oxidation products of cooked chicken breasts and thighs of commercial broiler and Korat crossbred chickens. Volatile aldehydes were the key compounds of cooked meat of both breeds. The increasing of octanal, nonanal, and decanal during long-term frozen storage might indicate the faster oxidation in breast of commercial broiler, leading to off-notes and undesirable flavor. The level of hexanal in commercial broiler appeared to decrease, while that in breast and thigh of Korat crossbred chicken was comparable over 8 months of frozen storage. This study revealed that the greater extent of lipid oxidation in broiler meat would imply a shorter shelf-life than Korat crossbred chicken during frozen storage.

Keywords – Cooked chicken meats, HS-SPME, Lipid oxidation products

I. INTRODUCTION

Chicken meat has become one of the most popular muscle foods being consumed worldwide due to its health benefits, as it contains high protein content, less fat and cholesterol [1]. Moreover, chicken meat was also rich in glutamic acid which is related to the umami taste [2]. Thus, chicken meat can fulfill the demand of consumers as a way of nutritional and sensory characteristics. Among chicken breeds, crossbreeding between native breeds and commercial broiler could result in breeds with outstanding growth performance with unique meat quality. Although raw meat has little aroma and only blood-like taste, thermal processing intensified the aromatic notes and characteristic flavors induced by complex reaction between non-volatile components of lean and fatty tissues present in meat [3]. Maillard reaction and lipid degradation markedly affect the desirable flavor of end products, whereas lipid oxidation leads to quality deterioration, resulting in off-flavor in chicken meat during storage [4]. Major classes of volatile compounds identified in chicken including hydrocarbons, aldehydes, ketones, sulfur-containing compounds and heterocyclic compounds such as furans, pyrroles, pyrazines, thiazoles and pyridines, but occurrence of these compounds depends upon the method of cooking [5].

In order to analyze volatile compounds, headspace-solid phase microextraction (HS-SPME) in combination with gas chromatography-mass spectrometry (GC-MS) is a well-established and accepted method for monitoring food quality. HS-SPME is a solvent-free, rapid, inexpensive, and portable analytical technique enable to extract and pre-concentrate volatile and semi-volatile compounds in the headspace of samples without interfering of organic solvent [6]. Goodridge *et al*. [7] reported that SPME and GC-MS could be used to identify and quantify the oxidation product, hexanal, of freeze-dried chicken myofibril for monitoring its shelf-life. Moreover, this technique was also used to detect sulfides, alcohols and free fatty acids (C2 to C5), which were the volatile spoilage markers of chicken breast [8].

Several factors influenced the cooked meat flavor including age, breed, sex, nutritional status, post-mortem aging, and method of cooking [1]. Generally, commercial broiler strains have a faster growth rate than native crossbred chickens, which may contribute to differences in qualities of meat, especially flavors after cooking and stability during frozen storage. Therefore, the objective of the present study was to compare the key volatile compounds of the 2 chicken breeds, commercial broiler and Korat crossbred chicken, during frozen storage.

II. MATERIALS AND METHODS

Sample preparation

Korat crossbred chickens were raised at Suranaree University of Technology Farm for 10 weeks. Commercial broilers aged 5 weeks were obtained from a local farmer. Both groups of bird were slaughtered in a commercial slaughter house using the same protocol. Whole chickens were cleaned, dewatered, and packed individually in a plastic bag made from nylon linear low density polyethylene. Samples were sealed without applying vacuum and stored in a -18 °C air-blast freezer. At 0, 4, and 8 month intervals, samples were thawed, and breast and thigh were obtained from the carcass. They were cooked without skin in boiling water with water-to-chicken of 2:1 (w/w) for 30 min. After cooling for 10 min, cooked samples were ground and 1 g of ground samples was added in 20 mL headspace vial with addition of 3 mL of DI water, 30 µL of 1 mg/L cyclohexanol (internal standard), and 10 µL of 7.2% BHA in 70% ethanol. Four replicates of four birds for each breed were analyzed.

SPME-GC-MS

The sample vial was incubated at 60 °C for 10 min at the agitator speed of 500 rpm. The SPME fiber (50/30 µm DVB/CAR/PDMS, Stableflex; Supelco, Bellefonte, PA, USA) was exposed into headspace of the sample vial, and extracted for 30 min. Then, the volatile compounds were desorbed in the hot splitless injection port of GC-MS at 250 °C for 5 min with 3 min GC valve delay.

GC-MS system consisted of a 450-GC/320-MS (Bruker Daltonics Inc, Fremont, USA) equipped with hot split/splitless injector. Separations were performed on a polar capillary column (DB-Wax, 60 m x 0.25 mm i.d.; 0.25 µm film; Agilent Technologies, USA). The oven temperature was programmed from 28 to 160 °C at a rate of 3 °C/min and ramp from 160 to 230 at a rate of 4 °C/min with the same initial and final hold times of 10 min. Helium was used as carrier gas at a constant rate of 0.8 mL/min. The MSD conditions were as follows: capillary direct interface temperature, 250 °C; ionization energy, 70 eV; mass range, 25-400 amu; electron multiplier voltage (Autotune + 200 V).

Identification of volatile compounds

Volatile compounds were identified by matching mass spectrometry data with the National Institute of Standards and Technology mass spectral database (NIST 2.0d). Tentative identification was based on matching retention indices of unknowns against those of authentic standards. GC retention indices were calculated against a homologous series of n-alkanes C6 through C30 analyzed under the same chromatographic conditions [9].

Statistical analysis

Volatile compounds of both chicken breeds were statistically analyzed using SPSS 17.0 (SPSS Inc., Chicago, IL, USA). Independent sample t-test ($p < 0.05$) was performed to detect significant differences among volatile compounds of beast and thigh meats in the same month. One-way analysis of variance (ANOVA) was performed to detect differences ($p < 0.05$) and Duncan's test was used to discriminate mean scores of individual volatile compound during storage time within the same part of meat.

III. RESULT AND DISCUSSION

The main groups of compounds found in both chicken breeds were aldehydes, alcohols, ketones, aliphatic hydrocarbons. Hexanal followed by heptanal, octanal, 2,3-octanedione, nonanal, and 1-octen-3-ol found in cooked breast and thigh of broiler were the major volatile compounds throughout 8 months storage (Table 1). In addition to those compounds, hexanol was also predominant in Korat crossbred chicken (Table 2), these compounds were also identified as the flavors of cooked commercial broiler and Korean native chickens [10].

Carbonyl compounds developed in cooked chicken meats might be formed by peroxidation of unsaturated acyl lipids and these compounds contributed to the chicken-like and meaty odors [11]. Moreover, Mottram [3] also reported that several hundreds of volatile compounds contributed to the aroma of cooked meat though lipid oxidation including aliphatic hydrocarbons, aldehydes, alcohols, ketones, and esters, which are in agreement to the present study. Aldehydes, especially hexanal, primary oxidation products of linoleic acid, found in thigh of broiler and Korat crossbred chicken have been reported to be a key odorant for chicken flavor [12]. Moreover, semi-quantification of volatile compounds in cooked broiler thigh showed higher relative peak areas than breast counterpart (Table 1). Higher fat contents in thigh meat might contribute to higher levels and numbers of volatile compounds [1]. Therefore, desirable and undesirable flavors can be resulted in meat due to lipid oxidation,

depends upon the rate of oxidative changes including sensory characteristics [12].

Table 1 Volatile compounds of cooked breast and thigh of commercial broiler during frozen storage at -18 °C

RI*	Compound	Relative peak area					
		Breast			Thigh		
		0 m	4 m	8 m	0 m	4 m	8 m
936	2-Propanol	1.03± 0.47^{bA}	0.14± 0.03^{aA}	0.53± 0.20^{abA}	0.95±0. 08^{bA}	0.56± 0.19^{aB}	0.57± 0.24^{aA}
1079	Hexanal	30.89± 18.54^{bA}	7.26± 0.88^{aA}	11.92± 5.31^{aB}	58.69± 11.67^{bB}	11.15± 6.12^{aA}	2.95± 1.02^{aA}
1087	Undecane	nd**	2.88± 1.43^{A}	nd	nd	7.04± 2.37^{B}	nd
1180	Dodecane	nd	3.11± 1.87^{A}	nd	nd	11.02± 5.17^{A}	nd
1185	Heptanal	1.04± 0.68^{aA}	0.10± 0.05^{aA}	0.96± 0.54^{a}	1.47± 0.97^{aA}	0.61± 0.07^{aB}	nd
1256	1-Pentanol	nd	0.09± 0.04^{A}	nd	nd	0.12± 0.06^{A}	nd
1287	Octanal	1.20± 0.80^{abA}	0.48± 0.03^{aA}	2.41± 1.38^{bA}	3.05± 0.42^{bB}	0.99± 0.41^{aA}	0.50± 0.31^{aA}
1300	Tridecane	nd	2.21± 1.34^{A}	nd	nd	6.78± 2.69^{B}	nd
1323	2,3-Octanedione	1.27± 1.06^{aA}	0.24± 0.06^{aA}	1.12± 0.55^{aB}	6.15± 1.68^{bB}	0.56± 0.40^{aA}	0.15± 0.09^{aA}
1359	Hexanol	0.69± 0.87^{aA}	0.04± 0.00^{aA}	0.30± 0.46^{a}	0.81± 0.86^{aA}	0.08± 0.10^{aA}	nd
1394	Nonanal	1.86± 1.18^{aA}	1.12± 0.31^{aA}	4.73± 2.18^{bB}	4.00± 0.90^{bB}	1.62± 0.79^{aA}	1.10± 0.75^{aA}
1435	Ethyl octanoate	0.04± 0.02^{a}	nd	0.06± 0.07^{a}	nd	nd	nd
1454	1-Octen-3-ol	1.35± 1.07^{aA}	0.32± 0.05^{aA}	0.82± 0.25^{aB}	3.49± 0.61^{bB}	2.01± 1.95^{abA}	0.27± 0.14^{aA}
1461	1-Heptanol	0.15± 0.12^{aA}	0.04± 0.01^{aA}	0.11± 0.06^{a}	0.28± 0.05^{aA}	0.05± 0.03^{aA}	nd
1501	Decanal	0.03± 0.02^{aA}	0.05± 0.02^{aA}	0.23± 0.13^{b}	0.19± 0.07^{aB}	0.12± 0.09^{aA}	nd
1531	Benzaldehyde	0.40± 0.25^{aA}	0.18± 0.04^{aA}	0.42± 0.09^{aB}	0.29± 0.04^{abA}	0.34± 0.09^{bB}	0.16± 0.11^{aA}
1563	1-Octanol	0.28± 0.18^{aA}	0.08± 0.03^{aA}	0.32± 0.16^{aA}	0.45± 0.09^{bA}	0.12± 0.04^{aA}	0.07± 0.00^{aA}
1621	2-Octenol	0.10± 0.04^{aA}	0.02± 0.01^{aA}	0.05± 0.02^{a}	0.28± 0.00^{aA}	0.08± 0.08^{aA}	nd
2144	Hexadecanal	0.58± 0.41^{aA}	0.14± 0.08^{a}	0.60± 0.30^{a}	0.07± 0.04^{A}	nd	nd

* Retention index on DB-Wax column.
** Not detected.
$^{a-b}$ The different lowercase letters in the same row indicated differences during storage time within the same part of meat ($p < 0.05$).
$^{A-B}$ The different uppercase letters indicated differences between parts of meat at the same month of storage ($p < 0.05$).

The content of various aldehydes namely octanal, nonanal, and decanal, in broiler breast increased with frozen storage (Table 1), while that of Korat crossbred chicken showed higher amount of only nonanal (Table 2). These compounds were also found during refrigeration and reheating of boiled chicken and might contribute to the warmed-over flavor (WOF), which was characterized as off-flavor note [13].

As mentioned above, the commercial broiler breast underwent lipid oxidation easier than that of Korat crossbred chicken. This was evidenced by a lower rate of TBARS value increase of Korat crossbred chicken during frozen storage. (data not shown).

Table 2 Volatile compounds of cooked breast and thigh of Korat crossbred chicken during frozen storage at -18 °C

RI*	Compound	Relative peak area					
		Breast			Thigh		
		0 m	4 m	8 m	0 m	4 m	8 m
938	2-Propanol	1.54± 0.17^{bA}	0.63± 0.16^{aB}	1.01± 0.40^{aA}	1.36± 0.43^{bA}	0.23± 0.05^{aA}	1.00± 0.38^{bA}
1080	Hexanal	38.25± 5.74^{bB}	16.38± 4.38^{aA}	29.44± 4.33^{abB}	9.04± 10.10^{aA}	13.26± 2.31^{bA}	9.67± 5.21^{aA}
1088	Undecane	nd	0.76± 0.72^{A}	nd	nd	5.72± 2.92^{B}	nd
1180	Dodecane	nd	0.72± 0.69^{A}	nd	nd	6.68± 3.80^{B}	nd
1181	Heptanal	2.89± 1.14^{b}	0.39± 0.34^{aA}	1.23± 0.70^{aA}	nd	0.61± 0.45^{aA}	0.45 ±0.07^{aA}
1259	1-Pentanol	nd	0.17± 0.02^{A}	nd	nd	1.14± 002^{A}	nd
1287	Octanal	2.55± 2.83^{aA}	0.79± 0.25^{aA}	2.63± 0.87^{aB}	1.45± 1.39^{aA}	1.16± 0.52^{aA}	1.08± 0.70^{aA}
1288	Tridecane	nd	0.86± 0.31^{A}	nd	nd	3.92± 2.31^{B}	nd
1323	2,3-Octanedione	5.25± 3.72^{bA}	0.32± 0.15^{aA}	2.82± 1.60^{abA}	8.55± 4.99^{bA}	0.71± 0.32^{aA}	1.18± 0.79^{aA}
1359	Hexanol	25.31± 5.45^{bA}	0.10± 0.02^{aA}	nd	53.91± 13.36^{bB}	0.07± 0.02^{aA}	nd
1394	Nonanal	5.09± 4.45^{abA}	0.84± 0.46^{aA}	6.12± 1.04^{bB}	4.38± 3.98^{aA}	1.44± 0.49^{aA}	2.20± 1.12^{aA}
1437	Ethyl octanoate	0.10± 0.02^{B}	nd	nd	0.04± 0.04^{aA}	0.02± 0.01^{a}	nd
1454	1-Octen-3-ol	6.09± 1.53^{bA}	0.49± 0.22^{aA}	1.98± 0.83^{abB}	9.72± 1.88^{bB}	0.80± 0.18^{aA}	0.79± 0.37^{aA}
1461	1-Heptanol	1.14± 0.35^{bA}	0.05± 0.02^{aA}	nd	1.56± 0.38^{aA}	0.11± 0.04^{aA}	nd
1493	2-Ethyl-1-hexanol	nd	0.07± 0.05^{A}	nd	nd	0.03± 0.02^{A}	nd
1502	Decanal	0.56± 0.41^{aA}	0.06± 0.04^{aA}	nd	0.57± 0.41^{bA}	0.06± 0.02^{aA}	nd
1531	Benzaldehyde	0.57± 0.36^{bA}	0.12± 0.07^{aA}	0.48± 0.03^{abB}	0.32± 0.13^{aA}	0.22± 0.12^{aA}	0.24± 0.13^{aA}
1563	1-Octanol	1.80± 0.64^{bA}	0.09± 0.04^{aA}	0.35± 0.11^{aB}	2.28± 0.12^{bA}	0.11± 0.03^{aA}	0.12± 0.03^{aA}
1621	2-Octenol	0.70± 0.19^{bB}	0.03± 0.02^{aA}	nd	0.18± 0.06^{aA}	0.06± 0.03^{aA}	nd
2145	Hexadecanal	6.19± 2.68^{bB}	1.01± 0.59^{a}	2.37± 1.19^{aA}	1.47± 0.55^{aA}	nd	0.84± 0.29^{aA}

* Retention index on DB-Wax column.
** Not detected.
Lowercase and uppercase letters were the same as described in Table 1.

However, the number of volatile compounds in the headspace of thigh became fewer with storage time in both breeds, especially at 8 months (Tables 1 and 2). Chicken breast appeared to effectively bind to the volatile compounds during extended period of frozen storage (Table 2). Thigh showed lower shear

force value than breast muscle (data not shown). This would lead to a reduced binding affinity of thigh and higher extent of volatile compound release during frozen storage [14]. So, shelf-life of both breeds based on lipid-derived volatile compounds should be stored not more than 4 months due to the longer storage showed lower volatile compounds and might be loss of desirable flavor.

It should be mentioned that the number and amount of volatile compounds found in the headspace of breast and thigh of commercial broiler were lower than those of Korat crossbred chicken, especially the group of aldehydes as mention as the key volatile compounds earlier, throughout the frozen storage. This event might indicate the loss of key flavor compounds and further oxidation of those compounds [15].

IV. CONCLUSION

Formation of volatile compounds in cooked chicken meats is derived from lipid oxidation. The predominant volatile compound of both commercial broiler and Korat crossbred chickens was aldehydes, especially hexanal, during 8 months of frozen storage. Levels of most volatile compounds of Korat crossbred thigh were higher than commercial broiler chicken, particularly, at the end of frozen storage. This might imply that Korat crossbred chicken seemed flavorful than broiler chicken.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the Thailand research fund (TRF) for financial support.

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