Color, Capsaicin and Volatile Components of Baked Thai Green Chili (*Capsicum annuum* Linn. var. *Jak Ka Pat*)

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Abstract

Thai green chili (*Capsicum annuum* Linn.) was baked at temperatures of 180, 210 or 250°C for 5 to 30 min. The products were assessed for color, capsaicin content and flavor volatile components. Baking temperature and time beyond 10 min significantly altered the color parameters (L, $-a^*$, b^*) of product especially greenness. Capsaicin content was decreased significantly on baking. Flavor volatile components including hydrocarbons, esters and alcohols were found largely in fresh green chili, whereas other volatile classes such as aldehydes, ketones, sulfur-containing compounds, furans and pyrazine presented in the lesser extent. On cooking, some compounds were lost, while others were generated.

Keywords: baked Thai green chili, color characteristics, capsaicin content, flavor volatile components

1. Introduction

Green chili paste ('*Nam Prig Noom*') which is popular throughout Thailand is a traditional northern Thai dip with a unique flavor. The main ingredient includes baked green chili, baked shallot and blanched garlic. The most popular Thai green chili used for production chili paste is a variety of *Capsicum annuum* Linn., known in Thai as *Jak Ka Pat*. Apart from hot flavor, the important sensorial attributes of the green chili paste are color, appearance and its aroma, which baked green chili provides most of these perceptions. As a consequence, the baking time and temperature of chili are the essential factors in determining its consumer acceptability. Too high baking temperature and short baking time give rise to hard texture and the skin still attaches to the fruit, being unable to remove, but for longer baking time will impair the taste due to excessive browning and drying. On the other hand too low baking condition with longer time brings about too much moisture loss in turn of losing product weight. Therefore, an optimal condition for baking green chili is a prime justification for the implementation of desirable *'Nam Prig Noom'*.

The initial purpose of baking or grilling of green chili is to soften the texture, release intracellular components of the plant tissue and inactivate enzymes. These could lead to color change due to browning reaction and losing of capsaicin which would lessen the pungent taste. The pungent compounds of *Capsicum* species are capsaicinoids including capsaicin and dihydrocapsaicin which are responsible for more than 90% of the pungency (Kosuge & Furata, 1970). Capsaicinoids are alkaloids that are important in the pharmaceutical industry for their neurological effectiveness (Hayman & Kam, 2008). Sukrasno and Yeoman (1993) found that capsaicin and dihydrocapsaicin contents in hot pepper fruits (*C. annuum* L. var. *Acuminatum*) were different at three maturity stages (slight green, green and red). Moreover, Sanatombi and Sharma (2008) also compared the capsaicin contents in six chili varieties including *C. annuum* L. (var. *Meiteimorok* and *Haomorok*), *Capsicum frutescens* L. (var. *Uchithi* and *Mashingkha*)

and *Capsicum chinense* Jacq. (var. *Umorok* and *Chiengpi*). They found that variety *Umorok* had the highest capsaicin content (~ 2.06%), while the variety *Haomorok* had the least capsaicin content (~ 0.17%).

Several interesting reactions exist during baking of chili to contribute volatile components of the products. To our knowledge, the volatile profile of baked green chili has not been investigated. However, some aromatic constituents of fresh and heated fruits of *Capsicum* spp. were reported (Mateo et al., 1997). Buttery et al. (1969) identified about 60 compounds in green bell peppers (*C. annuum* var. *grossum*, Sendt), among which were 2-isobutyl-3-methoxypyrazine, (*E,E*)-2,6-nonadienal, (*E,E*)-decadienal. Van Ruth and Roozen (1994) and Van Ruth et al. (1995) identified Strecker aldehydes such as acetaldehyde, 2-methylpropanal, 2-methylbutanal and 3-methylbutanal in dried bell peppers and noted that these aldehydes could be used as an indicator of Maillard reaction. They also found dimethyl sulfide and 6-methyl-5-hepten-2-one in dried bell peppers.

Up to present, little literatures have been revealed about flavor or volatile components of baked Thai green chili (var. *Jak Ka Pat*) for formulating *'Nam Prig Noom'* which is the most popular chili paste and has great impact on the northern Thai economy. Therefore, this study was intended to find out the effects of baking times and temperatures on color, hot and volatile flavor components of processed green chili. This knowledge is indispensable for implementation high standard *'Nam Prig Noom'* with well balance of all quality attributes such as color, texture and flavor characteristics.

2. Materials and Methods

2.1 Preparation of Baked Chili

Thai green chili (var. *Jak Ka Pat*) was purchased from a commercial orchard in Chiang Mai province of Thailand. Samples (300 g) were baked at three temperatures of 180, 210 and 250ºC, for 5, 10, 20 and 30 min. After baking the samples were packed under vacuum atmosphere and stored at -20ºC until use. Unheated green chili was used as the control for experimental comparison.

2.2 Color Measurement

A colorimeter (Minolta Chroma Meter: CR-300, Japan) was used to measure the color of fresh and baked chilies. Analytical data were expressed as Hunter *L* (brightness), *a** (greenness/redness) and *b** (yellowness/blueness) values.

2.3 Determination of Capsaicin Content

Extraction of capsaicin content from treated samples was followed the procedure as described by Mariod et al. (2009). Ten grams of fresh and baked chilies were continuously extracted by sonication (model CP2600D; Crest Ultrasonics, Thailand) for 1 h with 50 mL of 80% methanol (RCI Lab-Scan, Thailand) at room temperature, subsequently filtered through a 0.45 μm osmonics/MSI*cameo*glass/nylon syringe filter (Fisher Scientific; Los Angeles, CA). The filtrate was used for HPLC analysis performed on an Agilent 1100 Series HPLC system (Waldbronn, Germany) with a degasser, quaternary pump and a diode array detector. The chromatographic column was used Mightysil RP-18,GP 250-4.6 (5 μm), mobile phase was methanol (RCI Lab-Scan, Thailand) mixed with deionized water (RCI Lab-Scan, Thailand) and acetonitrile (RCI Lab-Scan, Thailand) at the ratio of 60:30:10, flow rate 1.0 ml/min and an injection volume of 20 μl. Absorbance measurement were read at λ_{max} 210 nm. Standard of capsaicin was purchased from Sigma/Aldrich (Steinheim, Germany). To validate the procedure, an average recovery of 81.75 ± 5.87% was found. The chromatograms of baked chilies are shown in Figure 1.
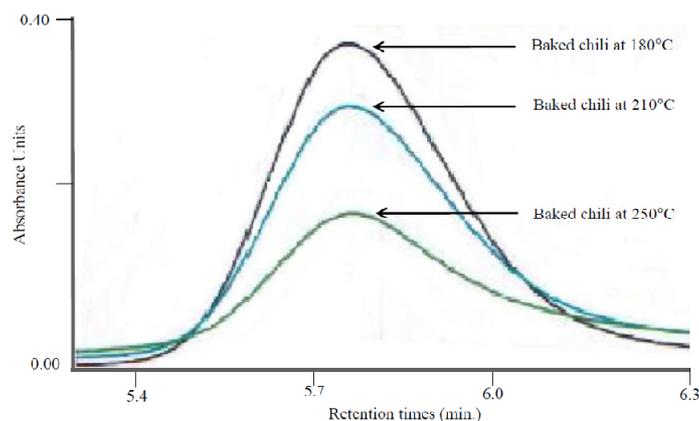

Figure 1. Chromatograms of capsaicin (retention time ~ 5.75 min) in baked chili at 180, 210 and 250°C for 30 min

2.4 Determination of Volatile Compounds

Five grams of chopped sample were transferred into a 40 ml screw-capped amber glass vials (Supelco, Bellefonte, PA, USA). The headspace was extracted at 35°C for 45 min by solid phase microextraction (SPME) fiber, using a 50/30 μm divinylbenzene (DVB)/carboxen on polydimethylsiloxane (PDMS) fiber (Supelco; Bellefonte, USA). Extract compounds were then analyzed by Gas chromatography-mass spectrometry (GC-MS: HP5972 MSD with HP5890 GC; Agilent, CA) using a VF-5MS column (60 m × 0.25 μm ID, 0.25 μm in film thickness). The volatile compounds were desorbed from the SPME fiber by heating at 250°C for 3 min, using initial oven temperature 40°C (2 min) rising to 250°C at 4°C/min. 1,2-Dichlorobenzene as an internal standard (1 μl of a solution in methanol, 130 ng/ml) was injected into GC-MS prior to the injection of samples. Carrier gas was helium at 21 psi., and the mass spectrometer scanned from m/z 400 to m/z 29 at a scan rate of 2.05 scans/s. Compounds were identified by comparing their mass spectra with spectra in NIST standard reference databases (NIST/EPA/NIH Mass Spectral Library, 2005) and by comparing their linear retention indices with those of reference compounds or literature values where available (Adams, 2007). The approximate relative concentrations of the volatile compounds were calculated by relating the GC-MS peak area of the compound of interest to the area of the internal standard, using a response factor of 1. The chromatogram of total volatile compounds in fresh chili is shown in Figure 2.
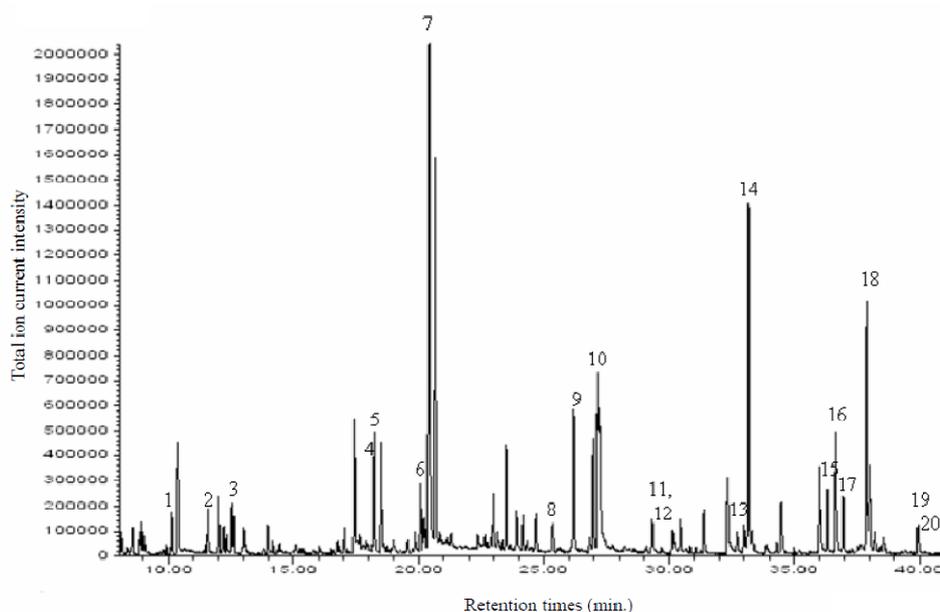

Figure 2. Chromatogram of total volatile compounds in fresh chili

1) hexanal, 2) 4-methyl-1-pentanol, 3) allyl methyl sulfide, 4. 2-pentyl furan, 5) Ethyl ester, 6) limonene, 7) 1,2-dichlorobenzene, 8) camphor, 9) 2-methoxy-3-isobutylpyrazine, 10) methyl salicylate, 11) hexyl 3-methylbutanoate, 12) propyl 2-methylbutanoate, 13) 8-methylnonanoic acid, 14) 2-methyltridecane, 15) pentadecane, 16) 2-methyltetradecane, 17) α-himachalene, 18) γ-himachalene, 19) 2-methylpentadecane, 20) hexadeane

2.5 Statistical Analysis

The experimental design for all treatment conditions were Completely Randomized Design (CRD) and comparison of mean difference using Duncan's Multiple Range Test. The computing program employed was SPSS® version 14.0. Every treatment was performed in triplication.

3. Results and Discussion

3.1 Effects of Baking Temperatures and Times on Color Qualities

Figure 3a illustrates the combined effects of baking temperatures and times on L value (lightness) of the products. As expected the samples became darker (lower L values) as heating time increased, with the highest rate of changing for the samples baked at 250°C. Although the trends of lower L values were samples baked at higher

temperature, but statistical analysis did not show significant differences ($P > 0.05$) for those baked at 5 min. In overall low baking temperature (180ºC) brought about lightest product color, as indicated by higher L values, but this temperature might not be adequate to soften the fruit and to facilitate further peeling process. Whereas, at highest temperature (250ºC) showed much greater change of color. Thus an intermediate baking temperature (210ºC) with time 20 min was chosen as an appropriate process condition for producing chili paste ("*Nam Prig Noom*").
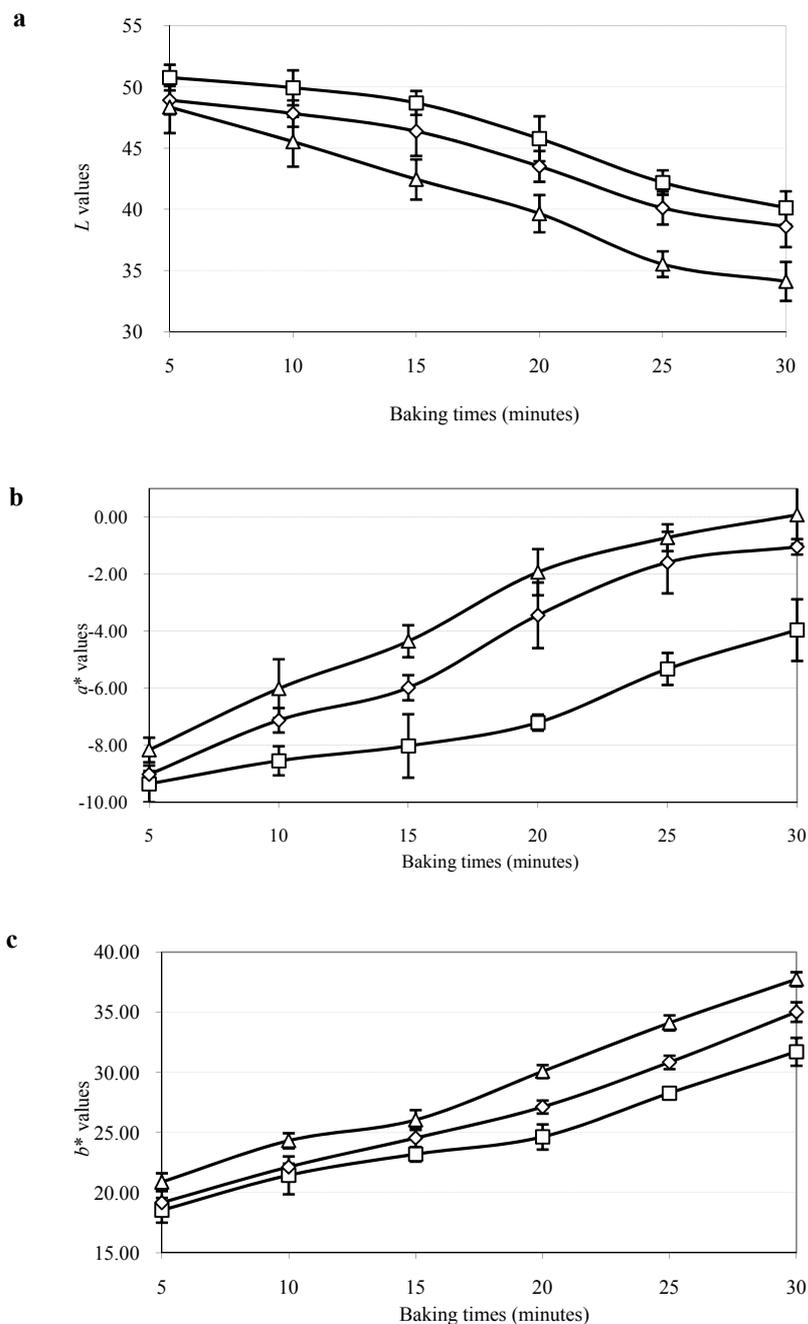

Figure 3. Stability of color parameters in chili baked at 180°C (—□—), 210°C (—◇—) and 250°C (—△—) for 5-30 min, a) L value, b) a^* value and c) b^* value.

The $a*$ values are a measure of the greenness of baked chilies. Figure 3b shows that $-a*$ values significantly ($P{\leq}0.05$) reduced according to the increases of baking temperatures and times, comparison with fresh chili (control sample). However, for baking time 5 min, the greenness of baked chilies at three temperatures were statistically similar ($P{>}0.05$), while for baking times greater than 10 min the three baking temperatures caused significant sharp differences ($P{\leq}0.05$) in the $a*$ values. In general, the lowest baking temperature retained more greenness in the product. Ahmed et al. (2002) studied color degradation of green chili puree heated at temperatures between 50 and 90ºC for times up to 20 min and found that the $-a*$ values of samples gradually decreased with an increase heating time. These effects were more pronounced at higher temperature. The change of greenness might be due to the degradation of chlorophyll to pheophytin (Fennema & Tannenbaum, 1996). Ismail and Revathi (2006) blanched green chili puree with temperature 90, 95 and 100ºC for 10 min and found similar results.

The $b*$ value is a measure of yellowness of the product. Figure 3c shows $b*$ values significant increase ($P{\leq}0.05$) with increasing of baking temperatures and times. Three different baking temperatures brought about higher average rate of increase in $b*$ values (slope ~ 0.56) (Figure 3c) than the average rate of decrease in $-a*$ values (slope ~ 0.44) (Figure 3b) suggesting that the yellowness of the products developed faster than the reduction of greenness. This might be due to the stimulation of Maillard reaction faster than the degradation of chlorophyll to Mg-free derivatives (Fennema & Tannenbaum, 1996).

3.2 Effects of Baking Temperatures and Times on Stability of Capsaicin Content

Table 1 shows that the quantity of capsaicin which was the major component contributing to pungent flavor of baked chilies significantly reduced ($P \leq 0.05$) with the increase of baking times for every baking temperature. As comparison to fresh chili, the capsaicin in all baked samples decreased significantly ($P{\leq}0.05$), especially, sharp decrease of capsaicin in the set of highest temperature could be observed. At lower temperature short time (180-210°C for 5-10 min) the effects were milder. As the baking time increased beyond 20 min for sets of 180 and 210°C, significant decreases ($P{\leq}0.05$) of capsaicin were observed with only 64% and 53% remaining compared to the fresh sample. Thus, chili baked with high temperature would loss considerable amount of pungent flavor than those baked with low temperature and the average of those baked at longest time for 30 min showed a 42-67% loss. Suresh et al. (2007) compared cooking methods of dry red pepper powder by pressure cooking for 10 min and by atmospheric boiling for 10 and 20 min, and found that around 18% and 36% of the capsaicin were lost from the samples for atmospheric boiling and pressure cooking respectively. Besides the treatment conditions, hot flavor of chili also depends on the initial concentration of capsaicin in the chili which could vary according to the change of seasons. For instance, summer season enhances high capsaicin content in the fruit, while rainy season causes lower capsaicin. Varieties and stages of maturity also have great influence on its quantity. Therefore, these different factors also contribute to inconsistent product qualities (Kanner et al., 2006; Sanatombi & Sharma, 2008).

Table 1. Effects of baking temperatures and baking times on stability of capsaicin in fresh and baked green chilies

Samples	Baking temperatures (ºC)	Baking times (min.)	Capsaicin contents (ppm)
Fresh chili			283.9 ± 15.9^{a}
Baked chili	180	5	273.8 ± 7.2^{b}
		10	261.1 ± 8.2^{b}
		20	196.8 ± 1.7^{e}
		30	164.8 ± 7.6^{f}
	210	5	269.4 ± 2.7^{b}
		10	250.4 ± 6.1^{c}
		20	166.8 ± 1.7^{f}
		30	136.1 ± 4.9^{h}
	250	5	235.9 ± 9.1^{d}
		10	194.6 ± 6.6^{e}
		20	149.7 ± 7.1^{g}
		30	93.6 ± 5.4^{i}

Means followed by the same letters in the column are not significantly different ($P > 0.05$).

An average recovery of capsaicin content is $81.75 \pm 5.87\%$.

Table 2. Concentrations of selected volatile compounds in fresh and processed chilies baked at 180, 210 and 250ºC for 20 min

Volatile compounds (ng/L)[A]	Fresh chili	Baking temperatures			LRI[B]
		180ºC	210ºC	250ºC	
Alcohol (4)					
Ethanol	1.21 ± 5.28[a]	nd[b]	nd[b]	nd[b]	< 600
1-Pentanol	1.17 ± 0.56[a]	nd[b]	nd[b]	nd[b]	765
4-Methyl-1-pentanol	2.07 ± 1.45[a]	nd[b]	nd[b]	nd[b]	836
Geraniol	1.14 ± 1.12[a]	0.05 ± 0.01[a]	nd[b]	0.08 ± 0.02[a]	1110
Aldehyde (6)					
3-Methylbutanal	1.32 ± 0.25[a]	0.43 ± 0.18[c]	0.70 ± 0.24[b]	nd[d]	654
2-Methyl butanal	0.84 ± 0.66[a]	nd[b]	nd[b]	nd[b]	663
Hexanal	3.66 ± 0.63[a]	0.11 ± 0.05[c]	0.29 ± 0.18[b]	0.09 ± 0.03[c]	797
2-Furfural	nd[b]	nd[b]	nd[b]	0.14 ± 0.08[a]	832
Benzaldehyde	nd[c]	0.06 ± 0.02[b]	4.74 ± 1.53[a]	0.08 ± 0.03[b]	965
E,E-2,4-nonadienal	nd[b]	nd[b]	nd[b]	0.04 ± 0.01[a]	988
Octanal	nd[b]	0.24 ± 0.11[a]	0.32 ± 0.29[a]	nd[b]	1001
Ketone (2)					
1-Penten-3-one	1.34 ± 0.82[a]	nd[b]	nd[b]	nd[b]	685
1-Octen-3-one	nd[c]	0.06 ± 0.02[b]	5.31 ± 2.88[a]	0.09 ± 0.03[b]	975
Ester (13)					
Ethyl acetate	2.27 ± 1.14[a]	nd[b]	nd[b]	nd[b]	606
Ethyl ester	8.63 ± 2.36[a]	nd[b]	nd[b]	nd[b]	993
Heptyl hexanoate	nd[c]	0.05 ± 0.04[b]	0.58 ± 0.13[a]	0.08 ± 0.02[b]	981
Isopentyl 2-methylbutanoate	nd[c]	0.12 ± 0.05[b]	2.42 ± 1.44[a]	nd[c]	1097
Hexyl 2-methylpropanoate	nd[d]	0.47 ± 0.12[a]	0.29 ± 0.09[b]	0.11 ± 0.07[c]	1105
Pentyl 2-methylbutanoate	0.09 ± 0.05[b]	0.04 ± 0.02[b]	0.14 ± 0.05[a]	nd[c]	1134
Pentyl 3-methylbutanoate	0.10 ± 0.02[a]	0.13 ± 0.06[a]	nd[b]	nd[b]	1141
Hexyl 2-methylbutanoate	nd[d]	1.33 ± 0.11[b]	3.57 ± 2.36[a]	0.46 ± 0.34[c]	1195
Methyl salicylate	7.63 ± 1.35[a]	0.40 ± 0.28[c]	1.31 ± 0.02[b]	0.16 ± 0.12[c]	1201
Hexyl 3-methylbutanoate	1.13±0.55[a]	nd[b]	nd[b]	nd[b]	1244
Propyl 2-methylbutanoate	1.04 ± 0.62[a]	0.25 ± 0.14[b]	0.21 ± 0.71 [b]	0.09 ± 0.02[c]	1249
7-Methyloctanoic acid ethyl ester	0.56 ± 0.21[a]	nd[b]	nd[b]	nd[b]	1257
8-Methylnonanoic acid ethyl ester	0.96 ± 0.35[a]	nd[b]	nd[b]	nd[b]	1356
Hydrocarbon (10)					
β-Pinene	nd[b]	nd[b]	0.14 ± 0.05[a]	0.28 ± 0.16[a]	987
Limonene	4.34 ± 1.12[a]	nd[b]	nd[b]	nd[b]	1030
cis-β-Ocimene	0.33 ± 0.95[b]	0.22 ± 0.11[b]	0.51 ± 0.21[b]	1.44 ± 0.58[a]	1044
2-Methyltridecane	10.4 ± 6.83[a]	12.86 ± 2.83[a]	15.37 ± 3.79[a]	3.23 ± 1.32[b]	1360
Pentadecane	2.38 ± 1.05[a]	0.97 ± 0.16[b]	2.33 ± 1.02[a]	0.18 ± 0.05[b]	1441
2-Methyltetradecane	3.17 ± 1.16[b]	3.16 ± 0.02[b]	8.37 ± 2.58[a]	3.38 ± 0.87[b]	1460
α-Himachalene	2.18 ± 0.87[a]	0.54 ± 0.74[b]	0.63 ± 0.05[b]	0.09 ± 0.01[c]	1469
γ-Himachalene	8.82 ± 2.64[a]	2.37 ± 0.55[b]	2.00 ± 0.23[b]	0.08 ± 0.01[c]	1500
2-Methylpentadecane	0.85 ± 0.37[b]	0.67 ± 0.42[b]	1.86 ± 0.81[a]	0.54 ± 0.24[b]	1559
Hexadecane	0.45 ± 0.54[bc]	nd[c]	1.31 ± 1.05[a]	0.47 ± 0.16[b]	1561
Miscellaneous (8)					
Dimethyl disulfide	0.77 ± 0.53[a]	0.25 ± 0.18[b]	0.42 ± 0.28[b]	nd[c]	740
Diallyl sulfide	0.84 ± 1.12[a]	nd[b]	nd[b]	nd[b]	859
Allyl methyl sulfide	3.55 ± 2.01[a]	nd[b]	nd[b]	nd[b]	895
2-Pentylfuran	5.32 ± 0.64[a]	nd[b]	nd[b]	nd[b]	990
2,5-Dihydrofuran	nd[c]	0.04 ± 0.01[b]	0.11 ± 0.03[a]	nd[c]	1008
Dihexylsulfide	nd[b]	0.06 ± 0.03[a]	nd[b]	nd[b]	1095
Camphor	1.42 ± 0.21[a]	nd[b]	nd[b]	nd[b]	1155
2-Methoxy-3-isobutylpyrazine	5.27 ± 1.42[a]	0.04 ± 0.01[b]	nd[c]	nd[c]	1176

[A] Approximate quantities (ng) in headspace for 5 g sample is estimated by comparison with 100 ng of 1,2-dichlorobenzene as an internal standard, mean values were data of 3-4 replications. [B] LRI is Linear retention index on a VF5-MS column. nd=not detected. Means followed by the same letters within each row are not significantly different ($P > 0.05$).

3.3 Effects of Baking Temperatures on Volatile Compounds

Besides the pungency component, Thai green chili also has its own distinctive aroma, characterized by the presence of various volatile constituents. In this study, approximately 72 volatiles were detected in Thai green chili (var. *Jak Ka Pat*). While Buttery et al. (1969) identified 60 volatile compounds in green Californian bell pepper using a vacuum Liken-Nickerson apparatus, and noted that 2-isobutyl-3-methoxypyrazine, (*E,Z*)-2,6-nonadienal and (*E,E*)-decadienal were the important aroma compounds in this fruit. Luning et al. (1994a, b) also detected 64 volatile compounds in fresh bell pepper at three ripening stages (green, turning and red) using dynamic headspace analysis. Moreover, Nijssen et al. (1996) found 125 volatile compounds in fresh and processed *Capsicum* fruits.

Selected volatiles found in this study were 10 hydrocarbons, 7 aldehydes, 13 esters, 4 alcohols and 8 others (Table 2). Amongst the quantified volatiles, hydrocarbons and esters were the largest groups. The most abundant compounds in fresh chili were 2-methyltridecane, γ-himachalene, pentadecane, methyl salicylate and ethyl ester which accounted for approximately 42% of the total volatiles.

Most of alcohols absented on baking except geraniol found remaining in baked chilies at 180 and 250°C. Geraniol is a monoterpenoid C-10 (branched) alcohol found widely as a chief constituent in essential oils including lemongrass oil and palmarosa oil (Reineccius, 1999). However, Chang et al. (1998) reported that the alcohol group of volatile compounds in longan fruit decreased extensively after drying at 70°C for 18 h. Apichartsrangkoon et al. (2009) pasteurized (90°C/3 min) and sterilized (121°C/4 min) pennywort juices, and found that acyclic alcohols were lost after heat treatments.

For some aldehydes and ketones, 3-methylbutanal, 2-methyl butanal, hexanal and 1-penten-3-one significantly reduced (*P*≤0.05) according to the severity of treatment condition. Akakabe et al. (2005) stated that 3-methylbutanal had a cheesy/malty odor. On the other hand, 2-furfural, benzaldehyde, *E,E*-2,4-nonadienal and octanal increased significantly (*P*≤0.05) on baking. Van Ruth et al. (1995) noted that hexanal liberated grassy odor of bell pepper, while octanal gave sweet, sickly/musty, grassy and rancid odors. Van Ruth and Roozen (1994) determined the volatiles of commercially dried bell peppers, and found some aldehyde compounds such as acetaldehyde, 2-methyl-propanal, 2-methylbutanal and 3-methylbutanal, which were products of Maillard reaction. After cooking 1-octen-3-one was significantly detected, which liberates mushroom odor (Van Ruth et al., 1995), whereas the other ketone, 1-penten-3-one was significantly lost on cooking (*P*≤0.05). Apichartsrangkoon et al. (2009) stated that flavor components such as aldehyde group could be lost or transformed during heating.

Under ester group, ethyl acetate, ethyl ester, hexyl 3-methylbutanoate, 7-methyloctanoic acid ethyl ester and 8-methylnonanoic acid ethyl ester disappeared on baking, along with significant loss (*P*≤0.05) of pentyl 2-methylbutanate, methyl salicylate and pentyl 3-methylbutanoate could be observed. Methyl salicylate is a predominant volatile in wintergreen plant and other natural plants (James & Price, 2004). Elmore et al. (2008) stated that 8-methyl-6-nonenoic acid ethyl ester was derived from, 8-methylnonanoic acid which, together with 7-methylcotanoic acid were the precursors of capsaicin, dihydrocapsaicin and nordihydrocapsaicin. They also reported several of methyl blanched ester in fresh and heated Thai green chilies which had an impact on aroma of the product. On the other hand, hexyl 2-methylpropanoate, heptyl hexanoate, iso-pentyl-2-methylbutanoate, hexyl 2-methylbutanoate and propyl-2-methyl-butanoate found on heating probably arising from the interaction between alcohol and organic acid in the fruit.

During baking the hydrocarbon group, limonene, pentadecane, α-himachalene, γ-himachalene, 2-methyltetradecane and 2-methylpentadecane significantly decreased (*P*≤0.05) especially for those treated at highest temperature (250ºC). Similarly, the hydrocarbon group of volatile compounds in processed sesame pastes was also decreased during roasting at 200°C for 20 min, steaming at 100°C for 20 min and microwaving at 2450 MHz for 15 min (Shahidi et al., 1997). For other compounds, *cis*-β-ocimene was a significant increase in baked chili at 250°C, while 2-methyltridacane significantly decreasing (*P*≤0.05) at highest heating temperature. Hydrocarbon such as β-pinene was generated on baking. Hirasa and Takemasa (1998) also identified β-ocimene and β-pinene in pepper.

Some sulfur-containing compounds, furans and pyrazines in miscellaneous group either disappeared or significantly decreased (*P*≤0.05) after cooking such as allyl methyl sulfide, dimethyldisulfide, diallyl sulfide, 2-pentylfuran, and 2-methoxy-3-isobutylpyrazine. Van Ruth and Roozen (1994) found dimethyl sulfide in dried bell pepper which was a product of the hydrolysis of *S*-methyl-methionine in Maillard reaction. Buttery et al. (1969) stated that 2-isobutyl-3-methoxypyrazine regarded as an important constituent of chili aroma. Among these volatiles, pyrazine and other alkyl-methoxypyrazines were the main characteristic compounds of the genus *Capsicum* (Whitfield & Last, 1991). Mazida et al. (2005) found the aroma compounds in different species of fresh peppers including 2,3-butanedione (caramel), 1-penten-3-one (pungent/spicy), hexanal (grassy/herbal), 3-carene

(red pepper/rubbery), β-ocimen (rancid), octanal (fruity), *trans*-2-hexenal (sweet) and 2-isobutyl-3-methoxypyrazine (green pepper). Chitwood et al. (1983) stated that *trans*-3-hexenol, 2-*sec*-butyl-3-metho-xypyrazine and 2-isobutyl-3-methoxypyrazine were frequently used as green descriptors for sensory evaluation of *C. annuum* cultivar. Keller et al. (1981) found that volatile compounds of red Jalapeňo pepper extracts presented floral aroma (3-carene). In addition, *trans*-2-hexenal and *trans*-hexenol, which have an almond, fruity and spicy odors, were found increasing during maturation.

It was interesting to note that some compounds were lost on heating, while others were generated. Apichartsrangkoon et al. (2009) revealed that interaction among flavor constitutes induced by thermal was an important factor for contributing product aroma which depended on their rates of formation. In addition, Su & Wiley (1998) and Wongfhun et al. (2010) also supported that a decrease of volatile compounds from the products could be caused by thermal degradation or by evaporation. On the other hand, the increase of baked chili flavor components might be a result of heat activation of flavor precursors or the release of flavor compounds bound to cell membranes (Apichartsrangkoon et al., 2009).

4. Conclusion

Color values (*L*, -*a** and *b**) of baked chili were changed through the baking process with the samples becoming darker, less greenness and more yellowness. Both baking time and temperature significantly affected color of the products. Capsaicin contents in three baking temperatures were significantly decreased during baking with those baked at longest time for 30 min showing a 42-67% loss. Volatile analysis showed that hydrocarbon and ester were the predominant classes. Most hydrocarbons reduced on baking, while some esters generated on heating. Compounds presented in fresh chili at relatively high concentrations included methyl salicylate, 2-methyltridecane, γ-himachalene, pentadecane and ethanol but most of them diminished on cooking.

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References

Adams, R. P. (2007). *Identification of essential oil components by gas chromatography/mass spectrometry*. Illinois, USA: Allured Publishing Corporation-Carol Stream.

Ahmed, J., Shivhare, U. S., & Debnath, S. (2002). Colour degradation and rheology of green chili puree during thermal processing. *International Journal of Food Science & Technology, 37*, 57-63. http://dx.doi.org/10.1046/j.1365-2621.2002.00532.x

Akakabe, Y., Matsui, K., & Kajiwara, T. (2005). Steriochemical correlation between 10-hydroperoxyoctadecadienoic acid and 1-octen-3-ol in *Lentinula edodes* and *Tricholoma matsutake* mushrooms. *Bioscience, Biotechnology, and Biochemistry, 69*(8), 1539-1544. http://dx.doi.org/10.1271/bbb.69.1539

Apichartsrangkoon, A., Wongfhun, P., & Gordon, M. C. (2009). Flavor characterization of sugar-added pennywort (*Centella asiatica* L.) juices treated with ultra-high pressure and thermal processes. *Journal of Food Science, 9*, 643-646. http://dx.doi.org/10.1111/j.1750-3841.2009.01358.x

Buttery, R. G., Seifert, R. M., Guadagni, D. G., & Ling, L. C. (1969). Characterization of some volatile constituents of bell pepper. *Journal of Agricultural and Food Chemistry, 17*, 1322-1327. http://dx.doi.org/10.1021/jf60166a061

Chang, C. Y., Chang, C. H., Yu, T. H., Lin, L. Y., & Yea, Y. H. (1998). The effect of drying treatment on the flavor and quality of longan fruit. *Developments in Food Science, 40*, 353-367. http://dx.doi.org/10.1016/S0167-4501(98)80059-9

Chitwood, R. L., Pangborn, R. M., & Jenning, W. (1983). GC/MS and sensory analysis of volatiles from three cultivars of capsicum. *Food Chemistry, 11*, 201-216. http://dx.doi.org/10.1016/0308-8146(83)90103-6

Elmore, J. S., Srisajjalertwaja, S., Dodson, A. T., Apichartsarangkoon, A., & Mottram, D. S. (2008). Novel esters in Thai green chili. *Proceedings of 12th Werman Flavour Research Symposium*, Interlaken, Switzerland.

Fennema, R. O., & Tannenbaum, R. S. (1996). Enzymes. In T. Richartson, & D. B. Hyslop (Eds), *Food Chemistry* (3rd ed., pp. 402-458). New York, USA: Marcel Dekker, Inc.

Hayman, M., & Kam, P. C. A. (2008). Capsaicin: A review of its pharmacology and clinical applications. *Current Anaesthesia & Critical Care, 19*, 338-343. http://dx.doi.org/10.1016/j.cacc.2008.07.003

Hirasa, K., & Takemasa, M. (1998). Spices and herbs: Basic concepts. In *Spice Science and Technology* (pp. 9-11). New York, USA: Marcel Dekker, Inc.

Ismail, N., & Revathi, R. (2006). Studies on the effects of blanching time, evaporation time, temperature and hydrocolloid on physical properties of chili (*Capsicum annuum* var. *kulai*) puree. *LWT-Food Science and Technology, 39*(1), 91-97. http://dx.doi.org/10.1016/j.lwt.2004.12.003

James, D. G., & Price, T. S. (2004). Field-testing of methyl salicylate for recruitment and retention of beneficial insects in grapes and hops. *Journal of Chemical Ecology, 30*(8), 1613-1628. http://dx.doi.org/10.1023/B:JOEC.0000042072.18151.6f

Kanner, J., Mendel, H., & Budowski, P. (2006). Carotene oxidizing factors in red pepper fruits (*Capsicum annuum* L.): peroxidase activity. *Journal of Food Science, 42*(6), 1549-1551. http://dx.doi.org/10.1111/j.1365-2621.1978.tb02399.x

Keller, U., Flath, R. A., Mon, R. A., & Teranishi, R. (1981). Quality of selected fruits and vegetables of North America: Volatiles from red pepper (*Capsicum* ssp). In R. Teranishi, & B. H. Barrera (Eds.), *ACS Symposium Series 170* (pp. 137-146). Washington DC, USA: American Chemical Society.

Kosuge, S., & Furata, M. (1970). Studies on the pungent principles of capsicum. Part XIV: Chemical constitution of the pungent principle. *Agricultural Biology and Chemistry, 34*, 248-256.

Luning, P. A., de Rijk, T., Harry, J., Wichers, H. J., & Roozen, J. P. (1994a). Gas chromatrography, mass spectrometry and sniffing port analyses of volatile compounds of fresh bell peppers (*Capsicum annuum*) at different ripening stages. *Journal of Agricultural and Food Chemistry, 42*, 977-983. http://dx.doi.org/10.1021/jf00040a027

Luning, P. A., Yuksel, D., & Roozen, J. P. (1994b). Sensory attributes of bell peppers (*Capsicum annuum*) correlated with composition of volatile compounds. In H. Maarse, & D. G. Van der Heji (eds.), *Proceedings of the 7th Weeurman Flavour Research Symposium* (pp. 241-248). Amsterdam, Natherland: Elsevier Science Publishers.

Mariod, A. A., Ibrahim, R. M., Ismail, M., & Ismail, N. (2009). Antioxidant activity and phenolic content of phenolic rich fractions obtained from black cumin (*Nigella sativa*) seedcake. *Food Chemistry, 116*, 306-312. http://dx.doi.org/10.1016/j.foodchem.2009.02.051

Mateo, J., Aguirrezábal, M., Domínguez, C., & Zumalacárregui, J. M. (1997). Volatile compounds in Spanish paprika. *Journal of Food Composition and Analysis, 10*(3), 225-232. http://dx.doi.org/10.1006/jfca.1997.0535

Mazida, M. M., Salleh, M. M., & Osman, O. (2005). Analysis of volatile aroma compounds of fresh chilli (*Capsicum annuum*) during stages of maturity using solid phase extraction (SPME). *Journal of Food Composition and Analysis, 18*, 427-437. http://dx.doi.org/10.1016/j.jfca.2004.02.001

Nijssen, L. M., Visscher, C. A., Maarse, H., Willemsens, L., & Boelens, M. (1996). *Volatile compounds in food-qualitative and quantitative data*. TNO Nutrition and Food Research Institute, Zeist, The Netherlands.

NIST/EPA/NIH Mass Spectral Library. (2005). *National Institute of Standards and Technology*. Gaithersburg, MD.

Reineccius, G. (1999). Flavour chemistry. In *Source book of flavours* (2nd ed., pp. 78-81). Maryland, USA: Aspen Publishers, Inc.

Sanatombi, K., & Sharma, G. J. (2008). Capsaicin content and pungency of different *Capsicum* spp. cultivars. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 36*(2), 89-90. http://notulaebotanicae.ro/nbha/article/view/345

Shahidi, F., Aishima, T., Abou-Gharbia, H. A., Youssef, M., & Shehata, A. A. Y. (1997). Effect of processing on flavour precursor amino acids and volatiles of sesame paste (Tehina). *Journal of the American Oil Chemists' Society, 74*, 667-678. http://dx.doi.org/10.1007/s11746-997-0199-5

Su, S. K., & Wiley, R. C. (1998). Changes in apple juice flavor compounds during processing. *Journal of Food Science, 63*, 688-691. http://dx.doi.org/10.1111/j.1365-2621.1998.tb15813.x

Sukrasno, N., & Yeoman, M. M. (1993). Phynylpropanoid metabolism during growth and development of *Capsicum frutescens* fruits. *Phytochemistry, 32*, 839-844. http://dx.doi.org/10.1016/0031-9422(93)85217-F

Suresh, D., Manjunatha, H., & Srinivasan, K. (2007). Effect of heat processing of spices on the concentration of their bioactive principles: Turmeric (*Curcuma longa*), red pepper (*Capsicum annuum*) and black pepper (*Piper nigrum*). *Journal of Food Composition and Analysis, 20*, 346-351. http://dx.doi.org/10.1016/j.jfca.2006.10.002

Van Ruth, S. M., & Roozen, J. P. (1994). Gas chromatrography/sniffing port analysis and sensory evaluation of commercially dried bell peppers (*Capsicum annuum*) after rehydration. *Food Chemistry, 51*(2), 165-170. http://dx.doi.org/10.1016/0308-8146(94)90251-8,

Van Ruth, S. M., Roozen, J. P., & Cozijnsen, L. V. (1995). Volatile compounds of rehydrated French bean, bell peppers and leeks. Part 1. Flavour release in the mouth and in three month model systems. *Food Chemistry*, *53*, 15-22. http://dx.doi.org/10.1016/0308-8146(95)95780-A

Whitfield, F. B., & Last, J. H. (1991). Vegetable. In *Volatile compounds in food and beverages* (pp. 203-281). New York, USA: Dekker.

Wongfhun, P., Gordon, M. H., & Apichartsrangkoon, A. (2010). Flavour characterisation of fresh and processed pennywort (*Centella asiatica* L.) juices. *Food Chemistry, 119*, 69-74. http://dx.doi.org/10.1016/j.foodchem.2009.05.072