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Effect of drying method on physical and chemical quality, hotness and volatile flavour characteristics of dried chilli

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Abstract: The effects of drying methods, such as sun drying at 37°C, hot air drying at 60°C and freeze drying, on the quality of dried Chee fah chilli (*Capsicum annuum Linn. var. acuminatum Fingarh.*) were investigated. The quality parameters were moisture content, colour (L*, a*, b* values), ascorbic acid content, capsaicin content, volatile flavour and sensorial description. The freeze-dried (FD) sample gave more bright-red colour and contained higher ascorbic acid content than the sun-dried (SD) and hot air-dried (HD) samples ($P<0.05$). Meanwhile, moisture content (11%) and capsaicin content (1 ppm) were not significantly different among the three drying methods ($P>0.05$). Types and concentrations of volatile flavour compounds were monitored using headspace solid phase microextraction (HS-SPME) with a gas chromatography-mass spectrometry (GC-MS). The groups of volatile flavour compounds were acids, alcohols, ketones, aldehydes, esters, furan and hydrocarbons. This was in agreement with the panelists who described the pungent odour as the most abundant one. In addition, the unique flavour attributes in the FD, HD and SD samples were green, sweet and alcohol-linked, respectively.

Keywords: Drying chilli, quality, ascorbic acid, capsaicin, volatile flavour

Introduction

Dried chilli is a spice product and the one most widely used as condiments for flavouring and colouring in Asian cuisines (Jitbunjerdkul and Kijroongrojana, 2007; Toontom *et al.*, 2010). The quality of dried chilli is assessed by a number of different parameters such as colour, hotness, ascorbic acid content and volatile flavour compounds (Henderson, 1992; Ruth *et al.*, 2003; Jiang and Kubota, 2004, Kim *et al*., 2006; Wang, *et al.*, 2009; Yaldiz *et al.*, 2010). Traditionally, dried chilli is obtained by sun drying (SD) (Oztekin *et al.*, 1999; Condori *et al*., 2001). It takes about 7-20 days (depending on the weather conditions) to reduce the moisture content to 10-15% (Hossain, 2003; Oberoi *et al*., 2005). Since dried chilli is susceptible to fungal proliferation, this process creates favorable conditions for mycotoxins contamination (Bircan, 2005). To prevent fungal proliferation, different drying methods have been employed in the processing of dried chilli.

Currently, hot air drying (HD) is popular for drying chilli due to a relatively short drying time, uniform heating and more hygienic characteristics. The temperature ranges from 45 to 70°C (approximately 10% of moisture content), and this reduces drying time to less than 20 hrs. This temperature range gives maximum colour values and minimizes the loss of volatile oils and discolouration (Mínguez-Mosquera *et al.*, 1994; Díaz-Maroto *et al*., 2003; Ibrahim *et al*., 1997; Berke and Shieh, 2001). However, freeze drying (FD) is the best method of water removal as it gives a final product of the highest quality without heat compared to other methods of food drying (Genin and René, 1995; Irzyniec *et al*., 1995). It has been found that this is the most suitable drying method for maintaining the colour quality of dried chilli (Park and Kim, 2007). However, the flavour formation may not meet the requirement of the consumers. Therefore, this present work will focus on the effects of drying methods on the quality, hotness and volatile flavour characteristic of dried chilli.

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Materials and Method

Raw materials

Chee fah chilli (*Capsicum annuum Linn. var. acuminatum Fingerh*.) was purchased from a local market in Songkhla province. The colour and degree of maturity of the samples were selected in accordance to Thai Agricultural Commodity and Food Standards (TACFS 1502-2004) that represent the stages of maturity. The chilli was washed and removed the system. The whole pod of chilli was blanched using hot water at 90°C for 3 min (Gupta *et al*., 2002), and then cooled in cold water and drained on a perforated tray before drying. The chilli was cut into approximately 2 cm lengths. It was then dried using three drying methods: hot air drying (HD); freeze drying (FD); and sun drying (SD). The fresh Chee fah chilli without drying was used as a control.

SD was conducted by spreading blanched-cut chilli on a net in a single layer and exposed directly to sunlight (approximately 37°C). The thermometer was placed on an empty tray besides a net of chilli. This method was dried for 8 hr per day. A temperature of 60°C was used for the HD. The blanched-cut chilli was placed on perforated tray which has an area of approximately 0.2 m^2. Freeze-drying chilli was performed at -50°C, 5 Pa in a freeze dryer. All the dried chilli samples were taken when the moisture content obtained was approximately 10-13% (this followed the Thai Industrial Standards Institute: TISI 456-1983). The final product was stored at room temperature in a dedicator and subjected to analysis within a week of collection.

Measurement of physical and chemical qualities

Determination of moisture content and water activity (a_w)

The AOAC method (A.O.A.C, 2000) was used for determining the moisture content using a hot air oven at a temperature of 105°C. Water activity was measured using a water activity meter (Novasina, Thermostanter) calibrated as a standard sample with a known value (Range 0.11-0.99). The experimental data was obtained using 3 replications.

Colour measurements

All samples were cut lengthwise and spread out to evaluate for colour using a Hunter Lab Colourflex colourimeter. Instrumental colour data was provided using the CIE system in terms of L* (lightness), a*(redness and greenness) and b*(yellowness and blueness).

Determination of pH

Five grams of Chee fah chilli ground samples was diluted with 10 ml of distilled water. It was measured for the pH value at ambient temperature with a pH meter (Satorious, USA) which was calibrated with pH 4.0 and 7.0 (A.O.A.C., 2000).

Determination of total acidity

Chee fah chilli ground samples were diluted with 10 ml of distilled water and titrated with 5 N NaOH using a few drops of 1% phenolphthalein solution as an indicator. The sample was transferred as a measured quantity (10 g) into 10 ml of distilled water. The result was calculated as the percentage of citric acid (adapted from Ranganna, 1986).

Determination of ascorbic acid

Ten grams of Chee fah chilli ground sample were diluted with distilled water, filtered by a vacuum process, centrifuged with 15,000 rpms for 30 min and the supernatant was removed to use as a determination. Five milliliters of extracted sample was added to 2,6-dichlorophenol-indophenol solution. Standard solutions of ascorbic acid were prepared using 2% metaphosphoric acid. Stock solutions contained 1 mg/ml ascorbic acid. A pipette was used to measure the requisite volume of standard ascorbic acid solutions of 1, 2, 2.5, 3, 4 and 5 ml. These were made up to 5 ml with the requisite amount of 2% metaphosphoric acid. Ten milliliters of 2,6-dichlorophenol-indophenol solution was added using a rapid delivery pipette, then mixed and taken for the determination within 15-20 s. The instrument was set to 100% transmission using a blank consisting of 5 ml of 2% metaphosphoric acid solution and 10 ml of water. Light-absorption was measurement at 518 nm. The absorbance was plotted against concentration (adapted from Ranganna, 1986).

Determination of capsaicin content

Extraction of capsaicin from fresh and dried chilli

Ten grams of the ground sample was placed in a 250 ml flask with 100 ml of acetone. The sample was stirred for one hour at room temperature. It was filtered by vacuum and the volume of the supernatant was reduced to approximately 5 ml by removing acetone using gas nitrogen. The final solution was filtered through a 0.45 mm filter before injection to HPLC.

High performance liquid chromatography analysis

Ten microliters of extracted sample was injected for analysis by using high performance liquid chromatography (HPLC) equipped with a Luna C18 column (5µ, 250 × 4.6 cm) and a UV detector at 284 nm. The mobile phase used a mixture of methanol and water (80:20 v/v) and a flow rate of 1.5 ml/min

(Betts, 1999).

The capsaicin in each sample was identified and quantified by comparing it with capsaicin standard compounds (≥95.0%, from *Capsaicum* sp., Sigma, USA). Standard curves were prepared using serial dilutions of 0.1525, 0.3125, 0.625, 1.25, 2.5, 5, 10 and 20 mg/l capsaicin concentrations. The pungency level in Scoville heat units (SHU) was calculated by using the amount of capsaicin (%dry weight) x 150,000 (Govindarajan, 1986).

Volatile flavour compounds analysis

Solid phase micro extraction

Three grams of ground sample ware adsorbed onto a Solid Phase Micro extraction (SPME; Supelco Inc., Bellefonte, PA) holder for GC analysis using the MS detector. Each SPME sampler consisted of a length of fused silica fiber absorption fibers coated with divinylbenzene, carboxen and polydimethylsiloxane (DVB/CAR/PDMS) 50/30 µm as a solid adsorbent.

The sample was taken for sampling in a glass vial of 20 ml capacity and capped with a Teflon-lined septum and crimped. The vial was incubated at 40°C for 20 min in the heating block chamber before the introduction of fiber into the headspace vial. The volatile flavour was adsorbed at 40°C for 20 min and subsequently thermally desorbed at 220°C for 5 min in a GC injection port,. The desorption time was optimized to ensuring there would be no carry-over effect to the next sampling.

Gas chromatography–mass spectrometry

Volatile flavour compounds were identified using Gas Chromatography–Mass Spectrometry (GC-MS) using an Agilent 6890 plus GC/HP 5973 MSD (Agilent, USA). The carrier gas was helium at a flow rate of 1.5 ml/ min with a split ratio of 1:1 at 220°C. The separation of volatile flavour compounds was achieved on a fused silica capillary column (25 m x 0.32 mm i.d.) coated with crosslinked polyethylene glycol modified with nitroterephthalic acid as a stationary phase (20 M) at a film thickness of 0.50 µm (HP-FFAP; J&W Scientific, Folsom, CA). The oven was programmed as follows: 45°C for 2 min, ramped to 130°C at 3°C/min and held for 1 min; ramped to 220°C for 3 min at 20°C/min; and then ramped to 230°C for 1 min at the same rate. The mass selective detector capillary direct-interface temperature was 280°C. Acquisition was performed in the electronic impact (EI) mode. The mass range used was 20-550 a.m.u. and the acquisition rate was 4.33 scan/sec. The identification was tentatively based on a comparison of the mass spectra of unknown compounds with those in the Wiley 275.L mass spectral database (Hewlett-Packard Co.) (Toontom, 2008).

Sensory lexicons development

Sensory screening was conducted using fresh and all the dried chilli. Five panels were recruited to describe the hotness and volatile odour attributes. They participated in two round table discussion sessions for orientation and development of terms. The panels were used to assess 2 concentration levels of 0.3 and 23 mg/L db of capsaicin content in chilli samples and a list of tentative terms for the attributes of hotness.

The panels were asked to describe the perceived sensations in terms of quality, intensity and time. The panels wore nose-clips during the course of the evaluations to help them focus on the perceived oral qualities by blocking the retronasal transfer of odourants (adaptation from Cliff and Hymann, 1992). For the development of terms for volatile odour, the chilli sample solutions were presented in covered glass flasks to mask interfering colours and to control the transfer of odourants (Toontom, 2008). The group leader undertook to summarize, resolve any confusion, and bring the group to consensus on the final terms to be used.

Following the group discussions, the panels participated in one practice session with the hot spices dealing with predominantly burning, tingling and numbing sensations. The development of terms for hotness and volatile odour was done separately. The panels were required to rinse their mouths with double distilled water and wait for 5 min between samples (Lawless *et al*., 2000; Allison *et al.*, 1999). For the perception volatile odour, panels were allowed to sniff the odour for 5 s and evaluate rapidly. The panels were required to clear the nasal passages with tissue paper (adapted from Cometto-Muñiz *et al.*, 2000).

A Completely Randomized Design (CRD) was planned for this experiment, with three replications. Data was subjected to analysis of variance (ANOVA). Duncan's New Multiple Range Test (DMRT) was used to test the significant difference between each pairs of means. The Statistical software, SPSS for Window V 11.0 was used for testing mean differences (Steel and Torrie, 1980). A 95% confident interval ($P<0.05$) was set throughout the data analysis to identify significant differences. Principal Component Analysis (PCA) was applied to observe any relationships among the capsaicin contents. The physical and chemical qualities of fresh and dried chilli using different drying methods were assessed by XLSTAT software (www.XLSTAT.com).

Results and Discussion

Effect of drying on physical and chemical qualities

The physical and chemical qualities of all the chilli dried with different drying methods were compared to the fresh chilli. The initial average moisture content and water activity of fresh chilli were 85.15% and 0.99, respectively. The average moisture contents of all dried chilli were 11% wb and water activities varied between 0.51 and 0.68 (Figure 1). The moisture content of chilli is very important because it is strongly correlated with the stability of ascorbic acid and pigment as well as any hygiene problems (Kim *et al*., 1982). Carbonell *et al.* (1986), Lee *et al.* (1992), and Kanner *et al*. (1977) all reported that the moisture content of dried chilli ranged from 10 to 14% which could retard colour loss. Moisture content lower than 8% could accelerate pigment destruction. Wall and Bosland (1993) reported that final moisture content at 8% is ideal. Moisture content above 11% allows mould to grow and moisture content below 4% causes an excessive colour loss. However, chilli generally needs to be dried to a moisture content of below 13% in order to prevent potential aflatoxin production (Pitt and Hocking, 1997). This is also recommended for Thai dried chilli as regulated by the Thai Industrial Standards Institute (TISI 456-1983).

The pH and total acidity of dried chilli were significantly different among the samples (P≤0.05). The pH value of all dried chilli varied between 3.21 and 4.84, while the total acidity was found to be in a range from 0.15 to 0.59% (Figure 2). The SD sample was lower in pH and higher in total acidity values than the FD and HD samples. Fresh chilli had the highest pH and was least in total acidity values. Citric acid is the main organic acid present in chilli (Koh, 2005). However, variations of pH and total acidity are possible due to variations caused by contamination from microorganisms. Microorganisms, mainly lactic acid bacteria, produce organic acids, which then increase in total acidity content and decrease in pH value. Generally, sun dried chilli becomes more contaminated with microorganisms than in the other drying processes (Mangaraj *et al.*, 2001). Hence, these variations in pH and total acidity can be used to indicate the safety of food.

The effect of different drying methods on the colour qualities of chilli is shown in Figure 3. Lightness (L*), redness (a*) and yellowness (b*) were significantly different among the samples (P≤0.05). It was shown that the L* values of all dried chilli ranged from 31.45 to 37.41. The a* values ranged from 10.83 to 29.56 and the b* values ranged from 4.61 to 25.72. Compared with the fresh chilli (L*= 38.34 and a*= 34.31), the FD method was more similar in L* and a* values than the other drying methods (P>0.05). This result showed that the FD method significantly improved the lightness and redness of dried chilli compared to the other drying methods (P≤0.05). This can be explained by the low temperature within a product due to the poor internal heat transfer in the dry layer of a product during the FD method.

The minimal colour deterioration during the FD method is an indication of the appropriateness of this method to preserve nutraceutical foods (Ratti, 2001). On the other hand, non-enzymatic browning was another cause of chilli colour degradation in the HD sample. This was because the temperature and time provided in this method was used to achieve the required moisture level in the dried chilli. It may

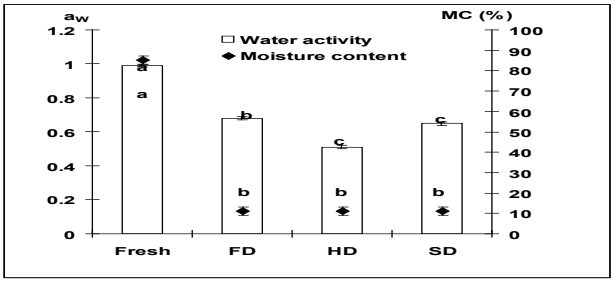

Figure 1. Water activity and moisture content of fresh and dried chilli using different drying methods.
Different letters in each parameter are significantly different (P≤0.05).

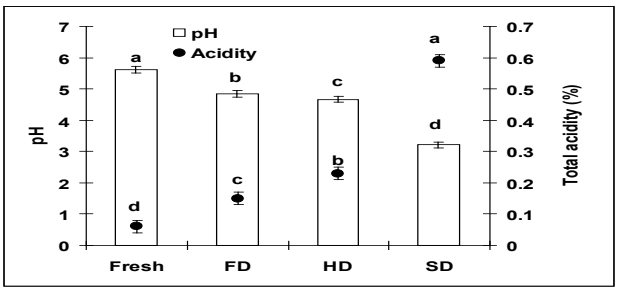

Figure 2. pH and acidity values of fresh and dried chilli with using different drying methods.
Different letters in each parameter are significantly different (P≤0.05).

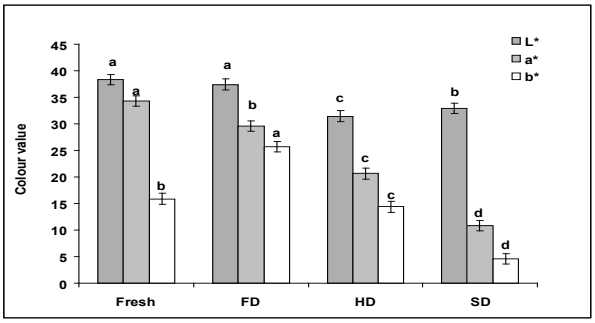

Figure 3. Colour qualities of fresh and dried chilli with using different drying methods.
Different letters in each parameter are significantly different (P≤0.05).

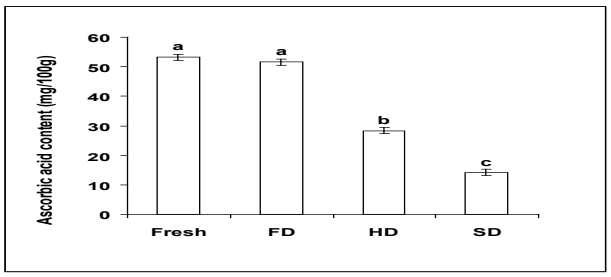

Figure 4. Ascorbic acid content of fresh and dried chilli with using different drying methods.
Different letters are significantly different (P≤0.05).

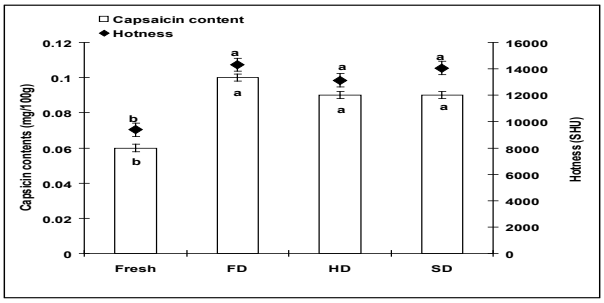

Figure 5. Capsaicin content of fresh and dried chilli using different drying methods.
Different letters are significantly different (P≤0.05).

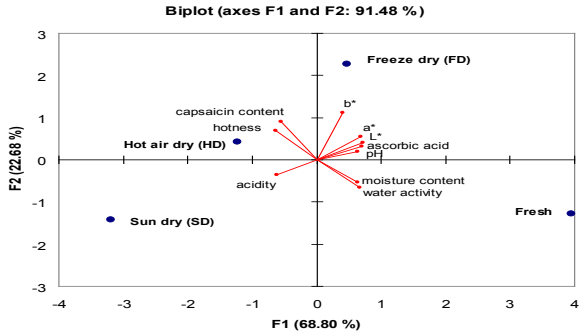

Figure 6. PCA bi-plot of physical and chemical qualities of fresh and dried chilli using different drying methods

be also related to the concentrations of sugar and amino acid in the chilli. It has been reported that non-enzymatic browning in dried chilli is due to a maillard reaction between reducing sugar and amino acid in pericarp (Lee *et al*., 1991). It is expected that the browning reactions would be minimized by the low temperature used in the FD method. Hence the FD sample showed less colour deterioration than the HD sample. However, the higher colour degradation in the SD sample was due to pigment oxidation and decomposition. These were due to the higher exposure to oxygen when an intensive vaporization takes place on the surface of this chilli (Topuz and Ozdemir, 2004).

The ascorbic acid contents of all of dried chilli significantly different among the samples (P≤0.05). The ascorbic acid contents of all dried chilli varied between 14.21 and 51.55 mg/100g (Figure 4), whereas, the ascorbic acid content of fresh chilli was 53.19 mg/100g. However, the FD sample was higher in ascorbic acid content than the HD and SD samples (P≤0.05). The ascorbic acid of red chilli decreased during drying. Howard et al. (1994) reported that 75% of ascorbic acid in red chilli was lost during drying, with the final content of ascorbic acid being in a range from 12.0 to 44.4 mg/100 g. Vega-Gálvez *et al*. (2008) reported that temperature in the HD method had a detrimental effect on the retention of ascorbic acid. This was because heated air inherently exposes the products to oxidation, thus reducing their ascorbic acid content. Ascorbic acid was oxidized by the light and high temperature during drying leading to the formation of L-dehydroascorbic acid and a wide variety of carbonyl and other unsaturated compounds (Gregory, 1996; BeMiller and Whistler, 1996). According to the Food Composition Table (RDA, 2001), the ascorbic acid content of dried chilli is about 26 mg/100 g (Kim *et al*., 2006). This is a lower content than in our results, except for the SD sample. This meant that ascorbic acid had been destroyed less in our drying methods and high ascorbic acid was contained in all the dried chilli, especially in the FD sample.

Effect of drying on capsaicin content

From Figure 5, it can be seen that all drying methods did not affect the capsaicin content. Furthermore, the capsaicin content and hotness of dried chilli from all the drying methods were higher than in the fresh chilli sample (P≤0.05). The lower capsaicin content in fresh chilli may due to the peroxidase enzyme by catalytic activity. Whereas, dried chilli samples were treated by blanching before drying for inactivating that enzyme. The similar result was reported by Schweiggert *et al*. (2006) and Topuz *et al*. (2011). The capsaicin content of all dried chilli varied between 0.09 and 0.1 mg/100g (P>0.05). The hotness of all the dried chilli varied between 13,141 and 14,314 SHU (P>0.05). Yaldiz *et al*. (2010) also reported that the capsaicin content of chilli (*Capsicum frutescens*) varied between 0.50 and 4.20%. This was due to temperature, time and drying methods. Topuz and Ozdemir (2004) reported that sun-dried Turkish paprika chilli, which was processed for 5-7 days, lost 24.6% of the capsaicin content (approximately 12-14% moisture content). Oven-dried Turkish paprika chilli, which was dehydrated at 70^{0}C for 90 min, lost 21.5% of the capsaicin content. On the other hand, thermally-treating chilli at 210^{0}C was reported to increase the capsaicin content (6.1-924.9%). This was caused by the dehydration of the food matrix and improved extractability of capsaicin by cell

Table 1. Volatile flavour compounds in Fresh and dried chilli using different drying methods

RT[A]	RI[B]	Volatile flavour compound	Attributes[C]	Peak area (%)			
				F	FD	HD	SD
		Acids					
2.78	**1081**	2-Methyl-butanoic acid	Cheesy	nd	1.63	nd	0.35
20.93	**1627**	2-Methyl-propanoic acid	Cheesy	nd	nd	nd	2.44
16.70	**1568**	Acetic acid	Pungent	0.02	4.72	2.37	10.71
24.80	**1662**	2-Methyl-butyric acid	Cheesy	nd	nd	0.54	nd
35.53	**2124**	Hexadecanoic acid	Waxy	0.08	nd	nd	nd
		Alcohols					
12.09	**1448**	Hexanol	Herbal	1.12	nd	nd	nd
10.14	**1396**	2-Octanol	Spicy	nd	0.20	nd	nd
20.26	**1621**	Linalool	Flowery	0.41	nd	0.03	nd
23.45	**1649**	5-Methyl-2-(1-methyl) cyclohexanol	Camphoraceous	nd	0.01	nd	nd
17.97	**1600**	2-Ethyl-1-hexanol	Citrus	nd	0.26	nd	nd
32.71	**1826**	Benzenemethanol	Sweet	0.59	nd	0.24	nd
32.70	**1825**	Phenylethyl alcohol	Fresh	nd	0.39	nd	nd
		Aldehydes					
2.83	**1095**	Hexanal	Leafy	0.03	nd	nd	nd
15.46	**1536**	2-Dodecen-1-al	Fatty	0.04	nd	nd	nd
17.26	**1583**	Furfural	Almond	nd	0.26	3.73	nd
19.25	**1612**	Benzaldehyde		nd	nd	0.04	nd
21.41	**1631**	5-Methylfurfural	Spicy	nd	nd	0.01	nd
23.43	**1649**	1,3-Cyclohexadiene-1-carboxaldehyde	Herbal	nd	nd	0.13	nd
23.62	**1651**	Benzeneacetaldehyde	Flora	nd	nd	0.04	nd
34.11	**1937**	Hexadecanal	Cardboard	0.51	nd	nd	nd
		Pyrazines					
17.26	**1583**	Tetramethylpyrazine	Nutty	nd	nd	nd	3.56
		Furans					
18.72	**1607**	2-Acetyl furan	Balsamic	nd	nd	0.22	nd
7.90	**1330**	2-Pentyl-furan	Green	0.42	nd	nd	nd
		Esters					
9.46	**1376**	n-Hexyl acetate	Herbal	0.07	nd	nd	nd
5.00	**1230**	Isoamylacetate	Banana	2.41	2.52	1.99	nd
19.95	**1618**	2-Furanmethanol-acetate	Horseradish	nd	0.04	nd	nd
28.34	**1693**	2-Hydroxybenzoic acid methyl ester	Wintergreen	0.16	0.36	0.10	nd
		Pyrroles					
5.48	**1248**	1-Methyl-1H-pyrrole	Herbal	nd	nd	nd	1.27
33.62	**1889**	2-Acetylpyrrole	Licorice	nd	0.47	0.28	nd

Table 1. (continuous)

RT[A]	RI[B]	Volatile flavour compound	Attributes[C]	Peak area (%)			
				F	FD	HD	SD
		Ketones					
10.24	**1399**	3-Hydroxy-2-butanone	Butter	0.16	nd	0.17	1.00
35.96	**2198**	2,3-Dihydro-3,5-dihydroxy-6-methyl-4(4H)-pyranone	Caramel	nd	0.71	0.23	0.89
32.99	**1845**	Beta-ionone	Violet	0.11	0.09	nd	nd
23.03	**1646**	Dihydro-2(3H)-furanone	Creamy	nd	nd	nd	1.43
		Sulphur compounds					
20.02	**1619**	2,3-Butanediol	Onion	nd	nd	nd	7.40
30.35	**1739**	Trans-anethole	Aniseed	0.11	nd	nd	nd
		Phenols					
31.62	**1778**	2-Methoxy-phenol	Smoky	0.04	nd	nd	nd
33.99	**1923**	Phenol	Acrid, Tar	0.02	nd	nd	nd
32.64	**1821**	2,6-bis(1,1-dimethylethyl)-4-methylphenol	Camphor	0.04	0.19	nd	nd
35.53	**2124**	4-Vinyl-2-methoxy-phenol	Clove	0.19	nd	nd	nd
		Hydrocabon compounds					
3.27	**1132**	Dodecane	Woody	nd	0.17	0.92	nd
4.05	**1190**	Undecane	Herbal	nd	nd	0.21	nd
4.06	**1191**	5-Ethyl-undecane	Herbal	nd	0.33	nd	nd
12.26	**1453**	2-Methyl-tridecane	Mild waxy	nd	nd	nd	1.78
10.22	**1399**	Tridecane	Mild waxy	nd	0.79	0.09	nd
14.01	**1499**	Tetradecane	Mild waxy	0.14	4.27	0.34	nd
18.55	**1605**	Alpha.-Gurjunene	Woody	nd	nd	0.41	nd
21.08	**1628**	Beta-Caryophyllene	Spicy	nd	2.01	1.13	nd
26.93	**1681**	Naphthalene	Pungent	0.02	0.36	0.31	nd
21.73	**1634**	Hexadecane	Mild waxy	nd	0.11	nd	nd
29.84	**1723**	Cyclobutylbenzene	Sweet	0.05	nd	nd	nd
3.61	**1157**	5-Methyl-undecane	Herbal	nd	2.60	0.06	0.34
30.85	**1754**	1-Methoxy-4-(1-propenyl)-benzene	Aniseed	nd	nd	0.03	nd
33.38	**1872**	1,6-Dimethyl-naphthalene	Woody	nd	0.04	nd	nd

Note: ART refers to retention time (min); BRI refers to retention index that was based on a series of alkane (C10-C24), CReference:http://www.thegoodscentscompany.com/ rawmatex.html, http://www.flavournet.org/flavournet.html., nd refers to not detected.

disruption during the thermal process (Harrison and Harris, 1985; Lee and Howard, 1999; Schweiggert, Schieber, *et al.*, 2006).

PCA is normally used to illustrate the relationships among all qualities and the grouping of the samples is shown in Figure 6. The PCA is composed of two Principal Components (PC) that indicate 91.48% of the variability of the data. Capsaicin content and hotness are presented as having a highly positive correlation to the HD sample. On the other hand, colour qualities and ascorbic acid content are presented as having a positive correlation to the FD sample, but a negative correlation to the SD sample. From the PCA it can be seen that the HD sample showed the highest quality in terms of capsaicin content and hotness. On the other hand, the FD sample showed the highest quality in terms of colour and ascorbic acid content, whereas the SD sample showed the least in all qualities. This may be because the SD sample was very exposed to the air and also took a long time to dry (Daood *et al*., 1996; Mangaraj *et al.*, 2001).

Effect of drying on volatile flavour

The groups of volatile compounds were acid, alcohol, ketone, aldehyde, ester, pyrrole, furan and hydrocarbon as shown in Table 1. The effects of drying on volatile flavour chilli compounds could be distinguished as two groups, that is the compound decreased or disappeared or the compound increased or was formed. It was found that there are 2 compounds, namely 5-methyl-undecane and 2,3-dihydro-3,5-dihydroxy-6-methyl-4(4H)-pyranone that appeared in all the dried chilli, corresponding to herbal and caramel odours (Flavournet and human odour space, 2004; The good scents company, 2010). Acetic acid was mainly present in all samples and increased after drying, particularly in the SD sample. The volatile flavour compounds completely disappeared after drying. These were: cyclobutylbenzene (sweet odour); 4-vinyl-2-methoxy-phenol (clove-liked odour); phenol (acrid or tar-like odour); 2-methoxy-phenol (smoky odour); n-hexyl acetate (herbal odour); hexadecanal (cardboard-liked odour); 2-dodecen-1-al (woody odour); 2-pentyl-furan (green-liked odour); hexanal (leafy odour); hexanol (herbal odour) and hexadecanoic acid (waxy odour).

On the other hand, the volatile flavour compounds were found in the FD sample. These were: 1,6-dimethyl-naphthalene (woody odour); hexadecane (mild waxy odour); 5-ethyl-undecane (herbal odour); 2-furanmethanol-acetate (horseradish-like odour); phenylethyl alcohol (fresh odour); 2-ethyl-1-hexanol (citrus-like odour); 5-methyl-2-(1-methyl) cyclohexanol (camphoraceous-liked odour); 2-octanol (spicy odour); and 2-methyl-butanoic acid (cheesy odour). Some volatile flavour compounds were only found in HD sample. These were:

1-methoxy-4-(1-propenyl)-benzene (aniseed-like odour); alpha.-gurjunene (woody odour); undecane (herbal odour); 2-acetyl furan (balsamic-like odour); benzeneacetaldehyde (flora-like odour); 1;3-cyclohexadiene-1-carboxaldehyde (herbal odour); 5-methylfurfural (spicy odour); benzaldehyde (flora-like odour) and 2-methyl-butyric acid (cheesy odour).

On the other hand, the SD method decomposed highly volatile flavour compounds. The only ones found in SD sample were 2-methyl-tridecane (mild waxy odour); 2,3-butanediol (onion-like odour); dihydro-2(3H)-furanone (creamy odour); 1-methyl-1H-pyrrole (herbal odour); tetramethylpyrazine (nutty odour) and 2-methyl-propanoic acid (cheesy odour). The appearance of 2-methylpropionic and 2-methylbutyric acid may be due to Strecker degradation. Short chain fatty acids, namely, 2-methylpropionic and 2-methylbutyric acid, are probably formed upon further oxidation during drying (Luning *et al*., 1995). The formation of volatile flavour compounds, namely 2-acetyl pyrrole and furfural, were only detected in the FD and HD samples due to a Maillard reaction. This is in agreement with the work of Apriyantono and Ames (1993) who monitored the formation of Maillard reactions in a model system of xylose-lysine.

Sensory lexicons development

The hotness attributes of chilli were identified by five panelists. These consisted of overall burning, burning on the tip of the tongue, stinging, numbing and warming. A high concentration of the HD sample gave the highest overall burning, burning on the tip of the tongue and a stinging sensation, but less than in the fresh chilli. The FD sample gave medium overall burning and numbing of the tongue. On the other hand, the least overall burning sensation was present in the SD sample. A low concentration of all samples presented a little numbing. However, all samples gave lower perceived sensation in all hotness attributes and longer in the time assessed than the capsaicin solution samples.

The volatile flavour attributes of fresh and all dried chilli consisted of fresh chilli odour, green-like, sweet, alcohol-like odour, and heated chilli, with a pungent and stinging odour. The odour of fresh chilli and green-like odour was found in the FD and HD samples as well as the fresh chilli sample. A high concentration of the HD sample gave a green-like, sweet and heated chilli odour sensation. A high concentration of the FD sample gave a green-like and pungent odour sensation. Only the SD sample presented an alcohol-like odour, corresponding to the fermentation. However, the capsaicin gave an odourless result.

The sensory lexicons results that were developed agreed with the capsaicin and volatile flavour compound analysis results. The similarity of the volatile flavour attributes between the FD and HD samples may be the dominance of 2-acetyl furan and furfural. However, the acetic acid that was found in SD sample may have been induced by the fermentation of contaminated microorganisms during the long period of drying in the sun.

Conclusion

The FD sample gave more bright-red colour and contained 1.8 and 3.62 times higher ascorbic acid content than the HD and SD samples. The SD, HD and FD methods did not affect the capsaicin concentration in all the dried chilli. The groups of volatile flavour compounds, the acids, ketones, pyrroles, furans and aldehydes, dominated in the dried chilli volatile flavour attributes detected by the panelists. In addition, the unique volatile flavour attributes in the FD, HD and SD samples were green, sweet and alcohol-like. The FD and HD samples had similarities to the fresh chilli- and had green-like odours comparable to the fresh chilli sample.

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References

A.O.A.C. 2000. Official Methods of Analysis. Association of Official Analytical Chemists. 17th edn. U.S.A: Gaithersburg.

Allison, A. M., Chambers I. V. E., Milliken, G. A. and Chamber, D. H. 1999. Effect of interstimulus rinsing and time on measurements of capsaicin heat in Tomato salsa. Journal of Sensory Studies 14: 401-414.

Apriyantono, A. and Ames J. M. 1993. Xylose-lysine model systems: the effect of pH on the volatile reaction products. Journal of the Science of Food and Agriculture 61: 477-484.

BeMiller, J. N. and Whistler, R. L. 1996. Carbohydrate. In Fenema, O.R. (Ed.). Food Chemistry, p. 216-217. New York: Marcel Dekker, Inc.

Berke, T.G. and Shieh, S.C. 2001. Capsicum, chillies, paprikas, bird's eye chilli. In Peter, K. V. (Ed.). Handbook of herbs and spices, p. 111-121. Washington:

CRC press.

Betts, T. A. 1999. Pungency quantification of hot pepper sauces using HPLC. Journal of Chemical Education 76: 240-244.

Bircan, C. 2005. The determination of aflatoxins in spices by immunoaffinity column extraction using HPLC. International Journal of Food Science and Technology 40: 929-934.

Carbonell, J. V., Piñaga, F, Yusá, V. and Peña, J. L. The dehydration of paprika with ambient and heated air and the kinetics of colour degradation during storage. Journal of Food Engineering 5: 179-193

Cliff, M. and Heymann, H. 1992. Descriptive analysis of oral pungency. Journal of Sensory Studies 7: 279-290.

Cometto-Muñiz, J. E., Cain, W. S. and Abraham, M. H. 2005. Molecular restrictions for human eye irritation by chemical vapors. Toxicology and Applied Pharmacology 207: 232-243.

Condori, M., Echazu, R. and Saravia, L. 2001. Solar drying of sweet pepper and garlic using the tunnel greenhouse drier. Renewable Energy 22: 447-460.

Daood, H. G., Vjnkler, M., Markus, F., Hebshi, E. A. and Biacs, P. A. 1996. Antioxidant vitamin content of spice red pepper (paprika) as affected by technological and varietal factors. Food Chemistry 55: 365-372.

Dıaz-Maroto, M. C., Perez-Coello, M. S., Vinas, M. A. G. And Cabezudo, M. D. 2003. Influence of drying on the flavour quality of spearmint (*Mentha spicata L.*). Journal of Agricultural and Food Chemistry 51: 1265-1269.

Genin, N. and René, F. 1995. Analyse du rôle de la transition vitreuse dans les procédés de conservation agroalimentaires. Journal of Food Engineering 26: 391-408.

Govindarajan, V. S. 1986. Capsicum: production, technology, chemistry and quality. III. Chemistry of the colour, aroma and pungency stimuli. Critical Reviews in Food Science and Nutrition 24: 245-355.

Gregory III, J. R. 1996.Vitamins. In Fennema, O.R. (Ed.). Food Chemistry, p. 531-617. New York: Marcel Dekker, Inc.

Hair, J. F., Anderson, R. E., Tatham, R. L. and Black, W. C. 2005. Multivariate data analysis. New Jersey: Prentice-Hall, Inc.

Harrison, M. K. and Harris, N. D. 1985. Effects of processing treatments on recovery of capsaicin in jalapeno peppers. Journal of Food Science 50: 1764-1765.

Henderson, D. E. 1992. Thermal decomposition of capsaicin, 1, Interactions with oleic acid at high temperatures. Journal of Agricultural and Food Chemistry 40: 2263-2268.

Hossain, M. A. 2003. Forced convection solar drying of chilli. Ph.D. thesis. Bangladesh Agricultural University. Mymensingh.

Howard, L. R., Smith, R. T., Wagner, A. B., Villalon, B. and Burns, E. E. 1994. Provitamin A and ascorbic acid content of fresh pepper cultivars (*Capsicum annuum*) and processed jalapeños. Journal of Food Science 59: 362-365.

Ibrahim, M. H., Daud, W. R. W. and Talib, M. Z. M. 1997. Drying characteristics of oil palm kernels. Drying Technology 15: 1103-1117.

Internet: Flavournet and human odour space. 2004. Flavour attributes. *Downloaded from http;//www.flavournet.org/flavournet.html on 4/5/2010.*

Internet: The good scents company. 2010. Flavour specialties information. Downloaded from *http://www.thegoodscentscompany.com/flavoursx.html on 4/5/2010.*

Irzyniec, Z. Klimezak, J. and Michalowski, S. 1995. Freeze-drying of the black currant juice. Drying Technology 13: 417-412.

Jiang, L. and Kubota, K. 2004. Differences in the volatile components and their odour characteristics of green and ripe fruits and dried pericarp of Japanese pepper (*Xanthoxylum piperitum DC*.) Journal of Agricultural and Food Chemistry 52: 4197-4203

Jitbunjerdkul, S. and Kijroongrojana, K. 2007. Formulation of Thai herbal Namprik. Songkanakarin Journal of Science and Technology 29(3): 837-846.

Kanner, J., Harel, S. Palevitch, D. and Ben-gera, I. 1977. Colour retention in sweet paprika powder as affected by moisture contents and ripening stage. Journal of Food Technology 12: 59-64.

Kim, D. Y., Rhee, C. O. and Shin, S. C. 1982. Changes in colour of red pepper during drying and milling. Journal of the Korean Chemical Society 25: 1-7.

Kim, S., Lee, K. W., Park, J., Lee, H. J. and Hwang, I. K. 2006. Effect of drying in antioxidant activity and changes of ascorbic acid and colour by different drying and storage in Korean red pepper (*Capsicum annuum L.*). International Journal of Food Science and Technology 41: 90-95.

Koh, F. M. 2005. Physicochemical properties of pepper mash fermented in wood and plastic. Master of Science Thesis. Louisiana State University.

Lawless, H. T., Hartono, C. and Hernandez, S. 2000. Thresholds and suprathreshold intensity functions for capsaicin in oil and aqueous based carriers. Journal of Sensory Studies 15: 437-447.

Lee, Y. and Howard, L. 1999. Firmness and phytochemical losses in pasteurized yellow banana peppers (*Capsicum annuum*) as affected by calcium chloride and storage. Journal of Agricultural and Food Chemistry 47: 700-703.

Lee, D. S., Chung, S. K., Kim, H. K. and Yam, K. L. 1991. Nonenzymatic browning in dried red pepper products. Journal of Food Quality 14: 153-163.

Lee, D. S., Chung, S. K. and Yam, K. L.1992. Carotenoid loss in dried red pepper products. International Journal of Food Science and Technology 27: 179-185.

Luning P. A., Ebbenhorst-Seller, T., De Rijk, T. and Roozen, J. P. 1995. Effect of hot-air drying on flavour compounds of fresh bell peppers (*Capsicum annuum*). Journal of the Science of Food and Agriculture 68: 355-365.

Mangaraj, S., Singh, A., Samuel, D. V. K. and Singhal, O. P. 2001. Comparative performance evaluation of

different drying methods for chillies. Journal of the Science of Food and Agriculture 38: 296-299.

Mínguez-Mosquera, M. I., Jarén-Galán, M. and Garrido-Fernández, J. 1994. Carotenoid metabolism during the slow drying of pepper fruits of the agridulce variety. Journal of Agricultural and Food Chemistry 42: 2260-2264.

Oberoi, H. S., Ku, M. A., Kaur, J. and Baboo, B. 2005. Quality of red chilli variety as affected by different drying methods. Journal of Food Science and Technology 42: 384-387.

Oztekin, S., Bascetincelik, A., and Soysal, Y. 1999. Crop drying programme in Turkey. Renewable Energy 16: 789-794.

Park, J. H. and Kim, C. S. 2007. The stability of colour and antioxidant compounds in paprika (*Capsicum annuum L.*) powder during the drying and storing process. Journal of Food Science and Biotechnology 16: 187-192.

Pitt, J. I. and Hocking, A. D. 1997. Fungi and food spoilage. 2nd edn. Blackie Academic and Professional. London: Blackie Academic & Professional.

Pordestimo, L. O., Li, H., Lee, J. H. and Reddick, B. B. 2004. Effects of drying procedure, cultivar and harvest number on capsaicin level in dried Jalapeño peppers. American Society of Agricultural Engineers 20: 35-38.

Ranganna, S. 1986. Handbook of Analysis and Quality Control for Fruit and Vegetable Products. New Delhi: Tata McGraw-Hill.

Ratti, C. 2001. Hot air and freeze-drying of high-value foods: a review. Journal of Food Engineering 49: 311-319

RDA. 2001. Food Composition Table. 6th edn. Korea: National Rural Living Science Institute.

Ruth, S., Boscaini, E., Mayr, D., Pugh, J. and Posthumus, M. 2003. Evaluation of three gas chromatography and two direct mass spectrometry techniques for aroma analysis of dried red bell peppers. International Journal of Mass Spectrometry 223-224: 55-65.

Schweiggert, U., Schieber, A. and Carle, R. 2006. Effects of blanching and storage on capsaicinoid stability and peroxidase activity of hot chili peppers (*Capsicum frutescens L.*). Innovative Food Science and Emerging Technologies 7: 217-224.

Srinivasan, K., Sambaiah, K. and Chandrasekhara, N. 1992. Loss of active principles of common spices during domestic cooking. Food Chemistry 43: 271-274.

Toontom, N. 2008. Consumer acceptance of flavour characteristics and antioxidant activity of 'Tadang' chilli paste. Khon Kaen, Thailand: Khon Kaen University, MSc thesis.

Toontom, N., Meenune, M. and Posri W. 2010. Consumer preference on flavour profiles and antioxidant information of a Thai chili paste. British Food Journal 112(11): 1252-1265.

Topuz, A. and Ozdemir, F. 2004. Influence of gamma irradiation and storage on the capsaicinoids of sun-dried and dehydrated paprika. Food Chemistry 86: 509-515.

Topuz, A., Dincer, C., Özdemir, S. K., Feng, H., Kushad, M. 2011. Influence of different drying methods on carotenoids and capsaicinoids of paprika (*Cv*., *Jalapeno*). Food Chemistry, 129: 860-865.

Vega-Gálvez, A., Lemus-Mondaca, R., Bilbao-Sáinz, C., Fito, P. and Andrés, A. 2008. Effect of air drying temperature on the quality of rehydrated dried red bell pepper (*var. Lamuyo*). Journal of Food Engineering 85: 42-50.

Wall, M.M. and Bosland, P.W. 1993. The shelf-life of chillies and chilli containing products. In Charalambous, G., (Ed). Shelf Life Studies of Food and Beverages. p. 487-500. Amsterdam: Elsevier.

Wang, Y., Xia, Y., Wang, J., Luo, F. and Huang, Y. 2009. Capsaiciniods in chili pepper (*Capsicum annuum L.*) powder as affected by heating and storage methods. American Society of Agricultural Engineers 52: 2007-2010.

Yaldiz, G., Ozguven, M. and Sekeroglu. N. 2010. Variation in capsaicin contents of different *Capsicum* species and lines by varying drying parameters. Industrial Crops and Products 32: 434-438.